E EGR Consulting - Review of ROAM Consulting's MPC Modelling

Review of ROAM's RSSR and EWER Modelling

Prepared for

AEMC

by

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Executive Summary

1. Questions have been raised with regard to the accuracy and reliability of two closely related studies performed by ROAM for the AEMC, in relation to the setting of a Market Price Cap (MPC) for the NEM :

    - The "Reliability Standards and Settings Review" (RSSR) study, a revised version of which was published by the AEMC on 15th January 2010; and
    - The "Extreme Weather Events Review" (EWER), which has not yet been published, although initial results from that work were supplied to the AEMC on 30th November 2009, and revised on 16th February 2010.

2. Questions have been raised with regard to the accuracy and reliability of both of these studies because ROAM has reported two errors in its modelling, or more exactly in its processing of model result, each of which has resulted in a significant downward revision of the MPC recommendation. First the RSSR recommendation fell from $20,000/MWh to $16,000/MWh. Then the EWER recommendation fell from $27,500/MWh to $16,000/MWh.

3. In view of these two revisions, some parties have raised questions regarding the reliability and accuracy of the final report, particularly questioning the conclusion that, with the corrected methodology, the market price caps recommended under the EWER assumptions are now no different from those recommended under the RSSR assumptions. Accordingly, the AEMC has requested EGR Consulting Ltd to undertake a review of both studies with a view to providing assurance to the market, and the Reliability Panel, that the results now being reported by ROAM can be relied upon.

4. We have reviewed ROAM's methodology, and its implementation of key aspects of that methodology most likely to affect the MPC calculation. In discussion with ROAM, we have also investigated the errors reported by ROAM, and the way in which they have been addressed. While absolute guarantees can not be given, we conclude that ROAM's methodology and implementation seem basically sound. In particular, ROAM has provided detailed explanations of the previous errors, and their rectification, and we are satisfied with the explanations given.

5. But we have also undertaken a high level top-down analysis of the situation ROAM was asked to model. And our main conclusion, from that analysis, is that the apparently coincidental results should actually have been expected, on a fundamental theoretical basis. This follows from the fact that market investors were assumed to believe that extreme weather events actually would be more probable, thus increasing investment until the same levels of reliability, and profitability, were achieved.

6. Thus we are inclined to suggest that the fact that, after extensive iteration and analysis, these two studies have come up with the same MPC recommendation, actually suggests that the underlying analysis has been done correctly.

7. We also comment on sensitivities, relating to the assumptions under which we understand ROAM were asked to conduct their analysis. In our view, estimating the MPC without accounting for the impact of the Cumulative Price Threshold, in combination with what seems to us to be relatively low rate of return requirement for the risk involved, suggests that ROAM's MPC estimate should be treated as a conservative lower bound.

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1. Introduction

1. On 23 December 2009, ROAM Consulting provided a report to the (Australian Electricity Market Commission) AEMC in relation to the "Reliability Standards and Settings Review" (RSSR) which was published by the AEMC[1]. A revised version of this report was supplied, and published by the AEMC on 15th January 2010, and a public forum was held to discuss the results of the RSSR on 12th February 2010.

2. In parallel, ROAM Consulting was asked to do some further work with regard to the "Extreme Weather Events Review" (EWER), for which substantially greater probabilities were to be assumed for extreme weather events leading to high electricity loads, and hence high prices. ROAM have provided a further draft report to the AEMC on that topic.[2] That report has not yet been published, but initial results from that work were supplied to the AEMC on 30th November 2009, with a revision being supplied on 16th February 2010.

3. Questions have now been raised with regard to the accuracy and reliability of both of these studies because:

   - ROAM reported that, due to an error in one of the spreadsheet models, the RSSR market price cap, which had initially been reported at $20,000/MWh for 2013-14 should really have only been $16,000/MWh. The change for 2012-13 was less, from $17,500 to $16,000, while the change over the entire study period was from $22,500 to $20,000. This change was reported on 7th January 2010 and reflected in the ROAM's revised advice to the AEMC Reliability Panel on 15th January 2010.

   - Following the discovery of this error, ROAM subsequently advised that a different error was discovered in the methodology used to implement certain aspects of the EWER study, and this, in combination with correction of the above error resulted in a revision of the market price cap recommended by that study from $27,500/MWh to $16,000/MWh.[3]

   - In view of these two revisions, some parties have raised questions regarding the reliability and accuracy of the final report, particularly questioning the conclusion that, with the corrected methodology, the market price caps recommended under the

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1 http://www.aemc.gov.au/Market-Reviews/Open/Review-of-the-Reliability-Standard-and-Settings.html

2 *Levels of the MPC that are consistent with the value of customer reliability,* ROAM Consulting, 16th February 2010.

3 The USE mis-calculation on its own, seems to have accounted for the difference between $27,500 MPC in the EWER report and the $22,500 MPC in the RSSR report.

EWER assumptions are now no different from those recommended under the RSSR assumptions.

4. Accordingly, the AEMC has requested EGR Consulting Ltd to undertake a review of both studies with a view to providing assurance to the market, and the Reliability Panel, that the results now being reported by ROAM can be relied upon.

5. It should be understood that a quick review of the nature requested here cannot claim to have identified or investigated all possible sources of error. In particular the studies involve the use of an extensive, and detailed, simulation model, and also of a collection of quite large spreadsheet models. Thus a complete audit of the whole modelling system, and verification of results, would be a very large undertaking, and lies beyond the scope of our present review.

6. The main thrust of our investigation has actually focussed on assessing the plausibility of the results, and particularly the coincidence between the calculated market price cap values, in light of general theoretical considerations which we outline below.[4]

7. Our main conclusion is that the apparently coincidental results should not really be of any great surprise, given the assumptions and methodology employed, and also that the results are not very different from what we would have expected, on a fundamental theoretical basis. Thus we are inclined to suggest that the fact that, after extensive iteration and analysis, these two studies have come up with the same MPC recommendation, actually suggests that the underlying analysis has been done correctly.

8. We have no reason to think that there would have been any substantial error in the underlying simulation analysis, which we understand has been extensively calibrated against other models, and used for other studies[5]. But the reasoning below also suggests that the nature of the iterative calibration process employed in this study is such that, even if there had been any errors, they would only have affected the ultimate conclusions if they occurred in one of three areas, namely:

   i) The calculation of cost recovery requirements and revenue, given simulated running hours, for OCGT peaking plant;

   ii) The post-processing employed to determine a weighted average Unserved Energy (USE) measure from the underlying simulation results; or

   iii) The calculations determining the trade-off between cost and revenue.

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[4] Actually, the recommendations are not exactly the same, because the RSSR report recommends an MPC gradually rising from $16,000 to $20,000, with USE being held close to the 0.002% standard throughout. But this rise is actually not much more than the assumed inflation rate, so the recommendation can be characterized as a more-or-less constant MPC, in real terms. Conversely, the EWER study recommends an MPC of $16,000, with USE gradually increasing over the study period. But that is also consistent, because, in real terms, the MPC is actually declining over time.

[5] For example the IES model "Prophet", and ROAM's 2-4-C, have been benchmarked against each other by AEMO since 2006, for Minimum Reserve Level studies, and again since mid 2009, for revised MRL studies. These benchmark studies have shown that for equivalent input data, the outcomes are equivalent.

9. With respect to (i), ROAM has used cost data supplied by ACIL Tasman, and discounted revenue using a WACC-based methodology which we understand to have been specified by ACIL Tasman. We consider that data, and methodology, to be beyond the scope of the present review.

10. The errors previously identified by ROAM lie in areas (ii) and (iii), and we have investigated those errors, and the way in which they have been addressed. In discussion with ROAM, we have also developed a reasonable understanding of the way in which the spreadsheet calculations have been undertaken, and examined those areas identified above in which we believe an error would be likely to have had a substantial impact on the market price cap calculated.

11. While absolute guarantees can not be given, we conclude that ROAM's methodology and implementation seem basically sound. In particular, ROAM has provided detailed explanations of the previous errors, and their rectification, and we are satisfied with the explanations given.

12. Thus we commence our report by summarising ROAM's methodology, ROAM's self-reported errors, and ROAM's rectification of those errors. But we then move on to explain our understanding of the theory, and what that theory implies about the kinds of results that should be expected from studies of this nature. We conclude by noting the way in which some of the key assumptions which ROAM was asked to make by the AEMC may have affected the results and about the likely sensitivity of the results to those assumptions.

2. ROAM's Methodology

13. The goal of both of these studies has been to set a Market Price Cap (MPC), and a related Cumulative Price Threshold (CPT), for the Australian National Electricity Market (NEM). Thus, updating a study undertaken by CRA in December 2007[6], the basic goal is to set the MPC so that prices rise high enough to incentivise enough generation capacity to be built to reduce Un-Served Energy (USE) to an acceptable level, currently 0.002% of load, as determined by the Reliability Panel.

14. Thus the main drivers are, on the one hand, the cost of providing peaking capacity to avoid USE, and, on the other hand, a simulation of the operation of the market to determine the probability of USE, given any proposed capacity entry. In this instance, ROAM has used its 2-4-C simulation model to perform the simulation, and assessed the economics of capacity entry from data supplied by ACIL Tasman.

15. As we understand it, the process was:

   - First, build up a capacity expansion plan, based on current commitments, the renewables investment required to meet the RET, etc.

   - Second, determine how much extra capacity would be required to meet projected loads, as presented by the median projected LDC for expected economic growth,

[6] *Comprehensive Reliability Review*, CRA International, Dec 2007, http://www.aemc.gov.au/Market-Reviews/Completed/Comprehensive-Reliability-Review.html

assuming the peak availability factors (eg for wind) specified by the AEMC Reliability Panel.

- Next, simulate operation of the system assuming all existing plant, and similar new plant, bids in a manner similar to the past, and that wind and generation unit availability are as inferred from historical data[7].

- Then, having incorporated planned capacity expansions of various types, iterate on the amount of OCGT installed until the observed reliability in the simulations is close to the Reliability Panel's 0.002% USE criterion.

- Finally, assuming that new entrant OCGT plant built to meet the peak requirements only operates at times when other capacity is fully utilised, and the MPC is reached, determine what MPC is required to make that plant profitable.[8]

16. This methodology seems basically sound, and aligns with similar studies performed in Australia and elsewhere. As ROAM itself notes, it is quite sensitive to several key assumptions which are discussed later. But, as discussed in the next section, ROAM has also reported two errors which arose during earlier phases of this analysis, and one issue which remains unresolved.

3. Errors and Issues raised by ROAM

3.1. Mis-calculation of Break-even Point

ROAM Statement

17. ROAM assessed the profitability of the extreme peak generators at eight MPC levels between the current MPC ($10,000/MWh) and a perceived maximum ($40,000/MWh). As all dispatch periods were priced at the MPC, a straight line relationship exists between the nominated MPC and the profitability of the generator.

18. To calculate this, ROAM originally used an overly complex formula to break the straight line relationship into six straight line relationships, being the six segments between the eight MPC price levels. The calculation proceeded as follows:

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[7] The historical availability of wind (c. 30%) at any time is much higher than the "reliable wind capacity" assumed by the Reliability Panel (c. 0-8%). Conversely, the observed availability of peaking thermal generation is much lower (72%) than might be expected given international best practice as will be assumed for a new plant (97%).

[8] This calculation assumed a 97% reliability for a new OCGT plant built specifically for the purposes of "last resort" peaking.

ROAM Original MPC Calculation

IF ($Profitability_{MPC1}$ > 0) THEN
    $MPC = MPC_1 - Profitability_{MPC1} / (Profitability_{MPC2} - Profitability_{MPC1}) \times (MPC_2 - MPC_1)$
ELSEIF ($Profitability_{MPC2}$ > 0) THEN
    $MPC = MPC_2 - Profitability_{MPC2} / (Profitability_{MPC3} - Profitability_{MPC2}) \times (MPC_3 - MPC_2)$
ELSEIF ($Profitability_{MPC3}$ > 0) THEN
    $MPC = MPC_3 - Profitability_{MPC3} / (Profitability_{MPC4} - Profitability_{MPC3}) \times (MPC_4 - MPC_3)$
ELSEIF ($Profitability_{MPC4}$ > 0) THEN
    $MPC = MPC_4 - Profitability_{MPC4} / (Profitability_{MPC5} - Profitability_{MPC4}) \times (MPC_5 - MPC_4)$
ELSEIF ($Profitability_{MPC5}$ > 0) THEN
    $MPC = MPC_5 - Profitability_{MPC5} / (Profitability_{MPC6} - Profitability_{MPC5}) \times (MPC_6 - MPC_5)$
ELSEIF ($Profitability_{MPC6}$ > 0) THEN
    $MPC = MPC_6 - Profitability_{MPC6} / (Profitability_{MPC7} - Profitability_{MPC6}) \times (MPC_7 - MPC_6)$
ELSEIF ($Profitability_{MPC7}$ > 0) THEN
    $MPC = MPC_7 - Profitability_{MPC7} / (Profitability_{MPC8} - Profitability_{MPC7}) \times (MPC_8 - MPC_7)$
ELSEIF ($Profitability_{MPC7} = Profitability_{MPC8}$) THEN
    MPC = N/A
ELSE
    $MPC = MPC_8 - Profitability_{MPC8} / (Profitability_{MPC8} - Profitability_{MPC7}) \times (MPC_8 - MPC_7)$
END IF

19. In Excel 2007, this formula was:

MPC Formula [Excel Implementation]

```
=IF('12500'!B2>0,12500-'12500'!B2/('15000'!B2-'12500'!B2)*(15000-12500),
  IF('15000'!B2>0,15000-'15000'!B2/('17500'!B2-'15000'!B2)*(17500-15000),
  IF('20000'!B2>0,20000-'20000'!B2/('22500'!B2-'20000'!B2)*(22500-20000),
  IF('22500'!B2>0,25000-'22500'!B2/('25000'!B2-'22500'!B2)*(25000-22500),
  IF('25000'!B2>0,25000-'25000'!B2/('30000'!B2-'25000'!B2)*(30000-25000),
  IF('30000'!B2>0,30000-'30000'!B2/('40000'!B2-'30000'!B2)*(40000-30000),
  IF('40000'!B2='30000'!B2,"",40000-'40000'!B2*(40000-30000)/('40000'!B2-
  '30000'!B2)))))))
```

20. The highlighted term was incorrect, and due to the complexity of the formula this error was not identified until ROAM had undertaken an internal review of the results after the publication of the original ROAM report on 23rd December 2009.

21. ROAM discovered the error during an internal review of the published results between 23rd December 2009 and 15th January 2010. An updated report (15th January 2010) was issued as soon as practical once the error was identified and corrected.

22. The relationship between MPC and USE is constructed using the X/Y scatter of the break-even MPC per iteration against the USE of that iteration. The impact of the break-even error was to increase the MPC for some of the points surrounding $20,000/MWh MPC, which affected the MPC versus USE relationship. Correcting this error reduced the break even MPC by approximately $2000/MWh for those affected points[9], shifting the MPC versus USE curve and reducing the net MPC required at 0.002% USE.

23. ROAM implemented an alternative calculation in order to simplify the original equation and correct the identified error. The equation uses the extremities of the MPC versus profitability straight line relationship, and interpolates/extrapolates the break-even point using this single relationship.

EGR Conclusion

24. The methodology adopted here was basically correct, and the error was purely numerical, not conceptual.[10] We conclude that this issue has now been resolved, now that the spreadsheet formula has been simplified.

3.2. Mis-calculation of USE

ROAM Statement

25. The USE Calculation tool for the first EWER report was based on a reworking of an earlier spreadsheet from NEMMCO, which estimated USE using forecast decile peak demand levels from 0% POE up to 100% POE. The error was later noticed and corrected by NEMMCO, but this correction was not carried through to ROAM's work. Essentially, it involves working with peak demand on a "POE" axis rather than on a "MW" axis.

26. As in the figure, the correct approach is to multiply the probability density function (PDF) by the USE and calculate the area under the resulting curve. The "0%" and "100%" POE values were estimated by extending the distance between "5%" and "90%" POE values by 10%.

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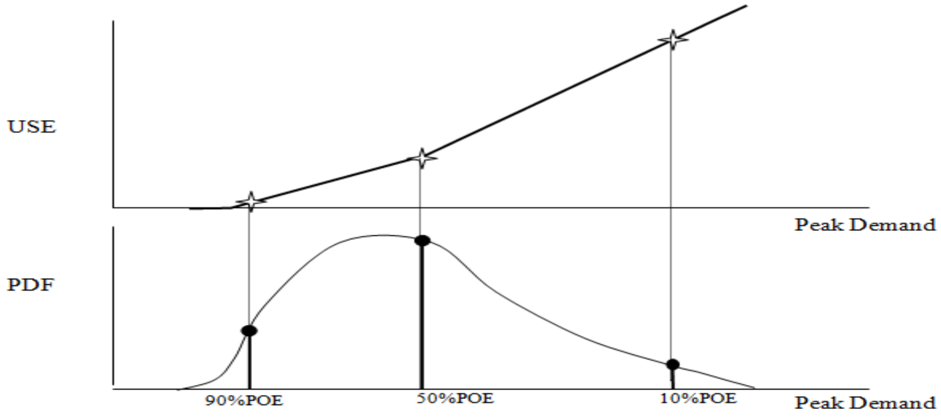
[9] From ROAM's revised report, we understand that the extent of the mis-estimation may have varied quite significantly from year to year.

[10] There was actually another numerical oversight, in that the reported Excel formula does not explicitly test for breakeven points in the range from 15000 to 17500. But the underlying profit curve is in fact linear in this range, so any breakeven point in that range would have been correctly identified by the next logical test in the IF statement.

Figure – NEMMCO method: inputs, including linear fit to USE



27. The PDF is a function *P* such that *P(x)**Δx describes[11] the likelihood of the peak demand (MW) for a given year being between x and *(x*+Δx). Assume that the peak demands corresponding to the 10%, 20%, etc POE values are x_{10},x_{20},etc. The probability of being within range x_{10} to x_{20} is therefore 10%, by definition, and the probability density[12] is $P(x_{10}) = \frac{10\%}{x_{10}-x_{20}}$.

28. To calculate the expected USE, the spreadsheet should calculate the integral:

$$< U > = \int P(x)U(x)dx$$

$$\approx \frac{\sum_{i=0\%,0.5\%,\ldots}^{99.5\%} \frac{1}{2}(U(x) + (U(x+0.5))}{200}$$

29. In simple language, we estimate USE at 201 points (x_0, $x_{0.5}$, ..., x_{100}) and calculate the average of values representing each of the 200 "bins" formed by these points to obtain the expected USE.

30. However, the original spreadsheet incorrectly approximates this integral as a sum-product:

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11 Precisely, P(px)*Δpx is approximately the probability of a peak demand between px and px+Δpx.

12 Hence, the wider the spacing for a given POE band, the lower the probability of observing any single megawatt value occur – but the total probability across the band, given by P(px10)*(px-10-px20), will be a constant 10%, regardless of how wide the band is.

$$< U > \approx \sum_{i=0,5,10,50,90,100} R(x_i).U(x_i)$$

Where:

$$Q(x_0) = \frac{\left(\frac{5}{x_0 - x_5}\right)}{2}$$

$$Q(x_5) = \frac{\left(\frac{5}{x_0 - x_5} + \frac{5}{x_5 - x_{10}}\right)}{2}$$

$$Q(x_{10}) = \frac{\left(\frac{5}{x_5 - x_{10}} + \frac{40}{x_{10} - x_{50}}\right)}{2}$$

$$Q(x_{50}) = \frac{\left(\frac{40}{x_{10} - x_{50}} + \frac{40}{x_{50} - x_{90}}\right)}{2}$$

$$Q(x_{90}) = \frac{\left(\frac{40}{x_{50} - x_{90}} + \frac{10}{x_{90} - x_{100}}\right)}{2}$$

$$Q(x_{100}) = \frac{\left(\frac{10}{x_{90} - x_{100}}\right)}{2}$$

$$Q = Q(x_0) + Q(x_5) + Q(x_{10}) + Q(x_{50}) + Q(x_{90}) + Q(x_{100})$$

$$R(x_i) = Q(x_i)/Q$$

31. As an example, for Queensland in 2010-11, the input data is $x_5 = 10535$, $x_{10} = 10430$, $x_{50} = 9914$, $x_{90} = 9600$. Extrapolating the MW values gives $x_0 = 1.1x_5 - 0.1x_{90} = 10535 + (10535\text{-}9600)/10 = 10629$ and $x_{100} = 1.1x_{90} - 0.1x_5 = 9600\text{-}(10535\text{-}9600)/10 = 9506$. Then $Q(x_0) = 0.0267$, $Q(x_5) = 0.0505$, $Q(x_{10}) = 0.0625$, $Q(x_{50}) = 0.1025$, $Q(x_{90}) = 0.1172$, $Q(x_{100}) = 0.0535$. Following this, $Q = 0.4128$ and $R(x_0) = 0.0648$, $R(x_5) = 0.1223$, $R(x_{10}) = 0.1514$, $R(x_{50}) = 0.2482$, $R(x_{90}) = 0.2838$, and $R(x_{100}) = 0.1295$. The R values sum to 1.

32. Using the linear extrapolation of USE in MW terms,

$$U(x_0) - U(x_{10}) + (1.1x_5 - x_{10} - 0.1x_{90})/(x_5 - x_{10}).(U(x_5) - U(x_{10}))$$

$$U(x_{100}) = U(x_{50}) + (1.1x_{90} - x_{50} - 0.1x_5)/(x_{90} - x_{50}).(U(x_{90}) - U(x_{50}))$$

33. Substituting, we find coefficients for the U(x_5), U(x_{10}) and U(x_{50}) values. The coefficient for x_5 turns out to be

$$R_0\left(\frac{1.1x_5 - x_{10} - 0.1x_{90}}{x_5 - x_{10}}\right) + R_5$$

which in this case is 0.0648 * 1.890 + 0.1223 = 0.2446. Assuming $U(x_{50})=U(x_{90})$, the coefficients for x_{10} and x_{50} turn out to be 0.0939 and 0.6615. These weightings are not dependent on USE at all.

34. These weightings (0.2446, 0.0939, 0.6615) were indicative of the ones that were used incorrectly for the draft report.

35. The weightings in the corrected method are dependent on USE; for Queensland in 2010-11, the simulated M5 USE was 1.26 GWh, M10 USE was 0.69 GWh and M50 USE was 0.09 GWh. The correct method gives an expected USE of 0.33 GWh here; the incorrect method gives an expected USE of 0.43 GWh. For all the scenarios studied, the incorrect method gave a higher estimated expected USE because of the significantly higher coefficient on u(x_5).

36. In the correct case, the expected USE is simply the sum of the USE corresponding to each POE band, multiplied by the probability of each band (0. 5% in this case, if 200 bins are used), as would be expected. In fact, in this approximation, there is no need to consider probability density functions at all. In the incorrect calculation used by the spreadsheet, the probability distribution function is used like a discrete probability function.

37. ROAM discovered this error upon an internal review and corrected the error, such that calculations are now performed by a full numerical integration.

38. The first draft report was submitted on 30th November 2009. The error was discovered during an internal seminar on expected USE estimation methodology on 10th December 2009. This was conveyed verbally to AEMC but the report was not revised as the need for a revision was not discussed with AEMC at that time. ROAM consultants then spent some further time developing an alternative corrected methodology which was used in the next draft report sent on 16th February 2010.

39. The weightings used to estimate expected USE produced an overestimate. Thus, the values in Table A.4 of the November draft report would overestimate expected USE. However the methodology was then redeveloped from first principles and is now much simpler to understand, as above.

EGR Conclusion

40. The methodology adopted here was basically correct, but a conceptual error occurred in its detailed implementation. The critical point to note is that the incorrect methodology over-estimated expected USE. It might be thought that this would also cause the method to over-estimate the hours for which OCGT ran, causing the analyst to calculate a lower MPC.

41. But this is not the case, because the error affected the expected USE calculation, without changing the OCGT running hours in the underlying simulation results. Then, when ROAM applied its iterative approach to match reported USE to the required standard of 0.0002% of load, the actual USE, in the underlying simulation results was significantly

less than 0.002%. So, of course, the OCGT running hours in the underlying simulation results were also proportionately lower.[13]

42. Under-estimation of OCGT running hours implies a higher MPC requirement, and the size of the effects reported by ROAM seem broadly plausible, given that the relationship between USE and OCGT running hours is non-linear.[14] Some further analysis would be required to verify that the magnitude of the USE estimation errors exactly matched the reported results, particularly since there are a number of periods and cases involved. And there would be significant "noise" in the calculation, because there will not be a perfect match to the USE standard in any particular year.

43. Subject to that caveat, though, we consider that the reported MPC mis-estimation is most likely due to the errors identified by ROAM. And we consider that the method now employed by ROAM for the expected USE calculation is quite accurate enough for the purpose.

3.3. Weighting of LDCs

ROAM Statement

44. From the time that the error in the RSSR calculation was identified, further investigation was carried out by ROAM to convert the MPC estimation for the Extreme Weather Report into a similar framework to that of the RSSR report by recalculating the MPC on an iteration by iteration basis. This lead to a general reduction in the calculated MPC for the EWER report, delivering MPC estimates consistent with the RSSR report.

45. ROAM then applied their corrected set of weightings to the calculation of MPC. But, using the corrected approach, the impact of changes in weightings was observed to be relatively independent of the weighting of the demand forecasts, and also relatively independent the introduction of a 5% PoE demand forecast.

46. The result was that the calculated MPC was also similar, if not identical, when the new weightings proposed by the AEMC were applied. Still, the effect of adding the 5% PoE and changing the weighting factors, has been carefully assessed and will be fully described in the final report to be delivered to AEMC.

EGR Conclusion

47. For theoretical reasons outlined in the next section, we consider that the weightings applied to the various LDCs should actually make no difference to the MPC calculation. We understand that ROAM came to a similar conclusion, by comparing its own results for various cases. We understand that ROAM does have the simulation results ready to

[13] See discussion in the Appendix for the exact relationship between USE and "last resort" OCGT running hours, there approximated by LOLP.

[14] From the Appendix it may be seen that OCGT running hours (LOLP) basically form the base of a triangle, the area of which determines USE. So LOLP should change in proportion to the square root of USE, thus implying a less than proportional change to MPC.

perform a re-calculation, if desired, but we do not consider that re-calculation is actually necessary.

4. Interpretation of Results

4.1. Theoretical Perspective

48. In reviewing these studies it seems to us that the critical issue is whether the results can be relied upon as a guide to setting the MPC. Apart from “bottom up” checks of the type reported above, a “top down” check seems appropriate with respect to two key questions:

    - Do the results align with “common sense” application of theory; and
    - How sensitive might they be to key assumptions?

49. There is, in fact, a very simple theory applying to the calculation of the price level required to sustain any plant operating in the market. All plant must recover its capital (plus O&M) costs, on average, over its lifetime. So, if the price at which a plant will operate is known, then the number of hours for which that plant must operate, per annum, is easily calculated. Conversely, if the number of hours for which a plant must operate, per annum, is known, the price which must apply during those hours, to ensure capital cost recovery, is easily calculated.

50. By assumption, in these studies there is some OCGT plant which runs only when USE would otherwise be unavoidable, and the very last MW of that plant capacity effectively only runs when USE is actually occurring. Thus the number of hours for which that plant runs, and over which it must recover its capital cost, is the number of hours during which USE is expected to occur, on average, per annum. This is generally referred to as the “Loss of Load Probability”, or LOLP, time the number of hours in the year.

51. This theory is developed a little further in an Appendix. Calculations there show, for example, that if the Annual Cost Recovery Requirement is $70,000 per MW (as appears to be the case here), then LOLP would need to be 0.051%, implying USE for approximately 4.5 hours pa, in order to justify ROAM’s recommended MPC of $16,000. In other words, if ROAM’s calculations are correct, we should expect to see peaking OCGT’s operating for about 4.5 hours pa in their simulation results. We have discussed this implication with ROAM, who confirm that this is, in fact, broadly true in their simulation results.

52. This theory has another important implication, though. Imagine, for a moment, that the AEMC were to specify its reliability standard in terms of a LOLP criterion of, say, 4.5 hours pa. Then suppose ROAM were asked to perform a study to determine an MPC matching that LOLP criterion. It could follow exactly the same methodology outlined above, iteratively adjusting OCGT entry until it found a capacity plan that exactly met the LOLP criterion. And it could then determine the price at which the last OCGT MW just covered its capital cost. But we know, by construction, that the last OCGT MW will be simulated as operating for 4.5 hours pa, and will need an MPC of $16,000, if its capital cost is $70,000 per MW.

53. Importantly, the same conclusion will be reached, no matter what LDC was assumed. And that conclusion also applies to all “composite” LDCs, formed as weighted averages of P_5, P_{10}, and P_{50} LDCs for example, and no matter what weights are applied. Thus, if the calculations are all performed correctly, and the iteration followed through to provide a

careful matching to the LOLP criterion, we should always see the same conclusion emerging.

54. In reality, the Australian NEM applies a USE ratio criterion, not a LOLP criterion, but the implications are much the same. The Appendix derives a relationship between USE and LOLP, and concludes that, in principle, that ratio might vary in proportion to the square root of the total to peak load ratio. But that actually implies that the USE/LOLP ratio will not change if the assumed PDC are simply scaled up versions of another, or aggregates of scaled versions. And it will not change much even if that ratio does change a little. In other words the logic applying to a LOLP criterion applies equally to a USE ratio criterion, unless the total to peak load ratio varies significantly.

55. So, even with a USE ratio criterion, we should expect to see the same MPC conclusions emerging, no matter what LDCs, or LDC weightings, are assumed. And the "surprising" conclusion of ROAM's revised EWER study should really be seen as confirmation that the analysis is probably correct.

56. If that perspective is accepted, the appropriate role of simulation modelling is to provide a picture of what a recommended MPC is being assumed to imply in terms of market investment and operations. This may be seen as a useful sanity check, and provides a basis for assessing the likely impact of key factors discussed below, such as risk perceptions and the CPT. It may also provide a more realistic estimate of the profitability of actual OCGT plant which will have more than 1MW of capacity, and hence should be expected to run (partially loaded) rather more often than LOLP might indicate. But simulation does not really determine what the theoretical MPC level should be, in an environment in which those factors are actually ignored, as discussed below.

57. One important proviso, applies, though: The market participants must be assumed to believe that whatever (composite) LDC is modelled is an accurate representation of the range of situations likely to occur, as seen from the point in time at which they are assumed to commit investment.

58. To be clear then, what ROAM has modelled, and what we understand they were asked to model, is a situation in which extreme weather events are actually seen, and agreed by investors, to be more probable than in the RSSR study. The situation would be quite different if, for example, the intent was to model a situation in which a regulator considered it prudent to incentivise capacity investment sufficient to cover extreme events which it considered might occur with some probability greater than market investors would likely assign to them. In that case, it might be able to induce extra investment by setting a much higher MPC.[15] But that situation is not what has been modelled here..

59. Also, to be clear, what ROAM has modelled is a situation in which the prospective investor is assumed to believe that the <u>conditional</u> probabilities of the entire range of P_5, P_{10}, and P_{50} LDCs is still the same (ie 5%, 10%, and 50%, or as adjusted for the EWER study), when assessed at a commitment date, say 3 years ahead, as they are now.[16] This

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[15] But market participants would surely perceive a greater risk attached to such investment, so raising their required rate of return, as discussed below. Thus the regulator might not be able to induce what it considered to be "adequate" investment at all.

[16] This follows from the fact that the same capacity mix is assumed to apply across all three LDC scenarios.

seems quite plausible for assessing the 2013-14 MPC, but less plausible for dates in the more distant future. On the other hand, the above logic suggests that this approximation will make little or no difference to the results, and there seems little point in re-visiting it.

4.2. Sensitivities

60. The other relevant question seems to be how robust ROAMS conclusions might be with respect to some of the key assumptions made. As discussed below, three potentially significant sensitivities emerge from consideration of the final formula developed in our Appendix,.

61. Taken together, these sensitivities may suggest that ROAM's MPC estimate is a conservative lower bound. It should be stressed, though, that none of what follows is intended as a criticism of the ROAM study. As we understand it, ROAM have pursued their analysis under the assumptions provided to them, and in line with other similar studies on this topic. And many of our comments actually echo comments made by ROAM in its report. Thus these comments are provided as a contribution to debate about policy settings in the broader context within which this study has been undertaken, rather than a critique of the study itself.

Plant Availability

62. As our simplified MPC formula shows, the profitability of peaking plant, and hence the MPC, will be sensitive to the assumption regarding (non)availability, since the less capable a plant is of actually generating at peak time the higher the MPC will have to be to make this operation profitable.

63. In this regard, the assumption of a 97% availability factor, while bench marked against international best practice, seems quite optimistic when set beside a 72% availability factor observed for a plant of a similar type to date in Australia. Increasing the forced outage rate from 3% to 28% would imply that the effective capital cost for producing each MW actually produced during MPC periods would increase by one third, suggesting an equivalent change to the MPC setting.

64. On the other hand, historical data presumably applies to older plant, which could be purchased or retained at a price considerably lower than that assumed for new "international best practice" plant, so the price per "effective MW" is unlikely to be higher, and this apparent discrepancy is not of serious concern.

Cumulative Price Threshold

65. The CPT also plays a critical role, as it truncates the number of periods for which a peaking generator can receive prices at the MPC level. A higher CPT ratio will allow a generator the possibility of collecting high MPC prices over a longer period, thus requiring a lower MPC to make the generator profitable. But we understand that the MPC recommendations in these reports have been derived assuming that the CPT has no effect at all.

66. In reality we understand that ROAM's simulations indicate that, with a CPT multiple of 15, the CPT will truncate earnings in 50% of the MPC hours simulated, thus implying a 50% reduction in the expected revenue. One implication seems to be that, if the CPT effect had been accounted for, the recommended MPC would have increased. Conversely, participants may not actually invest at the assumed rate, if the MPC is set at only $16,000,

and the MPC ratio remains at 15. We would recommend further study on the trade-off between setting a higher CPT and maintaining a lower MPC.

Risk and Return Requirements

67. The rate of MPC will be basically linear in the assumed capital cost of entry, and hence highly sensitive to both the technology cost, and the assumed rate of return requirement for peaking plant. ROAM has used capital cost estimates, and methodology, provided by ACIL Tasman, the assessment of which is beyond the scope of our review. But we note that the rate of return actually required by investors in this sort of plant will depend significantly on the risks they face.

68. The CPT discussion above implicitly raises the more general issue of risk perceptions, and aversion. It seems to us that investing in plant intended to run for only 4.5 hours per year, on average, is an inherently risky business. ROAM's simulations highlight the risk that an OCGT may find itself subject to significant variability with respect to the number of hours for which it is actually called upon to run. And their discussion of the CPT underlines the risk that a significant part of the potential earnings assumed to make OCGT investment profitable will not, in fact, be available to the OCGT investor.

69. To this must be added the risk of unexpected or "lumpy" market developments undercutting the economics of OCGT plant, once committed. Increasing load, increasing peakiness, and increasing wind penetration may all make increasing OCGT investment desirable. But developments need not necessarily proceed in a "monotone increasing" fashion. It may well be that market prospects for OCGT capacity in some regions could be threatened, over many years, by the likelihood of an interconnector development, for example.

70. We have presented an analysis of this issue in another context, and consider that risk perceptions are likely to be quite a critical factor in determining the attractiveness of entry, and thus the price that has to be offered to induce entry.[17] We understand that a real WACC of 6.82% has been used here, as recommended by ACIL Tasman, and OCGT profitability assessed using a matching formula, also specified by ACIL Tasman.

71. We understand that this is an established approach, but query whether a WACC of around 7% is really adequate for a plant which is supposed to be run for only a very few hours each year, and may find itself subject to significant variability with respect to the number of hours which it is actually called upon to run, and/or receives payment for.

72. We appreciate that it is common for risk to be accounted for by applying a discount rate "appropriate for the plant type under consideration". And perhaps this has been done here. But, in our view, this is not really an adequate approach to modeling risk, because the risk has nothing directly to do with "the plant type under consideration". It has much more to do with the planned utilisation factor, and there is a great deal of difference, in risk terms, between an OCGT operating at a 5% utilisation factor, and one operating at a 0.05% utilisation factor, as assumed here

[17] E. G. Read, M Thomas and D Chattopadhyay "The Impact of Risk on Capacity Investment in Electricity Markets" keynote presentation, *IAEE Proceedings*, Wellington, 2007

73. We are not in a position to comment on the actual behaviour of investors in the Australian market, or the actual WACC requirements. But, given the risks involved, we would have thought that quite a high rate of return would be required to induce investment in "last resort" peaking plant, at least on a merchant basis. Thus it seems clear to us that risk aversion implies the likelihood that the MPC should be set higher than has been calculated here.

74. We note, though, that setting a very high MPC, of itself, creates another form of risk, by removing a plausible anchor point for participant bidding, and thus increasing the likelihood of a breakdown in the kind of bidding behaviour which is assumed to make this regime workable.[18]

5. APPENDIX: LOLP, USE and MCP

LOLP vs USE

75. As in ROAM's "Expected USE Estimation Methodology", assume the LDC for a reference year can be approximated in a linear fashion:

$$y = a - bx$$

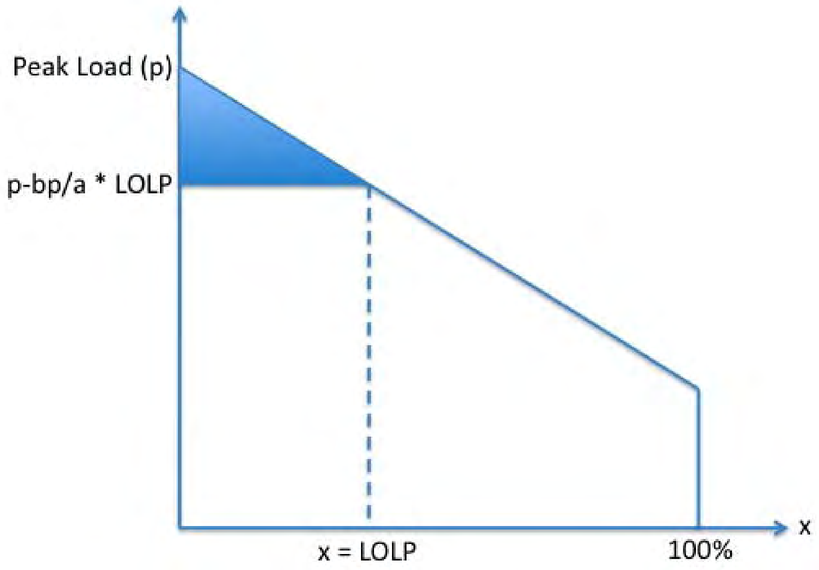
Where: y is load, a is peak load and x is a percentage of total time, leaving b to define the slope of the line.

76. If this LDC scales up in proportion to peak load, it follows that a year with a peak demand, p, has an LDC that can be described by:

$$y = p - \frac{bp}{a}x$$

77. Thus USE can be measured as the shaded area in the triangle below:

[18] In the limit, an "infinite MCP", as in the (uncapped) New Zealand market, is believed by some to discourage, rather than encourage, high offers from participants, because there is no "sanctioned" price that can be offered..



78. Calculating the area of the triangle:

$$USE = \frac{base \times height}{2} = \frac{LOLP \times \frac{bp}{a} LOLP}{2} = \frac{bp \times LOLP^2}{2a}$$

79. Rearranging, we get:

$$LOLP = \sqrt{\frac{2aUSE}{bp}}$$

80. Substituting USE=0.002% of total GWh, gives:

$$LOLP = \sqrt{\frac{2aUSE}{bp}} = c\sqrt{\frac{TotalGWh}{PeakMW}}$$

Where c is a constant summarising the remaining parameters, including the required USE ratio (in this case 0.002%).

81. From this formula we can conclude that:

- For a given USE target, LOLP will be identical across all LDC scenarios with the same ratio of total energy to peak demand. Scaling a linear LDC by a constant preserves this ratio.

- A given LOLP implies a unique MPC setting, so all scaled linear LDCs no matter how weighted will predict the same MPC setting.

- If the LDC becomes "peakier", LOLP will be reduced and will require a higher MPC to achieve the same USE target. If the LDC becomes less peaky, LOLP will be increased and MPC may be lower for the same USE target.

- If the LDC is non-linear, or load growth is biased towards peak or base load this simplified result will not be strictly valid, although the intuition behind it could be developed to handle variations.

LOLP vs Cost Recovery Requirement

82. The following formula describes the calculation of the annual capital recovery requirement (ACRR) per MW:

$$ACRR(RADR)/MW = \frac{WACC(RADR)\%}{1-\left(\frac{1}{1+WACC(RADR)\%}\right)^{LIFE}} \times Cost/MW$$

Where WACC% represents the weighted average cost of capital which depends on a risk adjusted discount rate (RADR), and LIFE represents the expected life of the plant.

83. The annualised capital cost above is used by ROAM and assumes 100% reliability, but in practice the capital cost per MW needs to be scaled to account for the impact of outages:

$$ACRR_R/MW = \frac{ACC}{1-FOR}$$

Where $ACRR_R$/MW is the effective cost of capacity for a technology with a forced outage rate, FOR.

84. The costs for OCGT in 2013-2014 as presented in the ROAM study translate to an annualised capital cost of $69,084/MW before adjusting for reliability, or $71,220 after adjusting for a FOR of 3% as prescribed by ROAM.[19]

85. On average this capital cost must be covered by the MPC in times of USE, and leaving aside issues surrounding truncation due to the CPT we have:

$$ACCR_R = 8760 \times LOLP \times MPC$$

86. If the MPC is set at $16,000/MWh:

$$71220 = 8760 \times LOLP \times 16000 \text{ or}$$

$$LOLP = 0.051\%$$

87. This LOLP is equivalent to the plant operating an average of 4.5 hours, or 9 half hour periods per annum, without interruption from the CPT. If, on average, USE only occurs 6

[19] This would be $95,950/MW using a FOR of 28% as is currently observed for OCGT plant

half hours per annum, then the MPC would have to be closer to $24,000/MWh to provide cost recovery to investors.

MPC vs LOLP and USE

88. Alternatively we can describe MPC as a function of LOLP, this time considering the CPT, the effect of which is incorporated by a CPT Threshold Factor (CPTTF) which measures the fraction of revenue lost due to the CPT:

$$MPC = \frac{ACRR(RADR)}{8760 \times LOLP \times (1 - FOR) \times (1 - CPTTF)}$$

89. The higher the CPTTF, the greater the fraction of revenue will be lost, and the higher MPC would have to be to compensate.

90. We can also derive a formula for MPC by substituting for LOLP:

$$MPC = \frac{ACRR(RADR)}{8760 \times (1 - FOR) \times (1 - CPTTF)} \times \frac{1}{c} \sqrt{\frac{PeakMW}{TotalGWh}}$$