# Economic assessment of System Restart Ancillary Services in the NEM – Supplementary Sensitivity Analysis

## Australian Energy Market Commission

## 30 November 2016

# Contents

# Glossary

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|---|---|
| AEMC | Australian Energy Market Commission |
| AEMO | Australian Energy Market Operator |
| DAE | Deloitte Access Economics |
| NEM | National Electricity Market |
| NER | National Electricity Rules |
| SRAS | System Restart Ancillary Service |
| SRAS Plant | Equivalent to the terms SRAS or “restart service” as used in the Panel’s final determination |
| SRAS Source | Equivalent to the terms SRAS or “restart service” as used in the Panel’s final determination |
| VCR | Value of Customer Reliability |

# Executive Summary

As part of the Reliability Panel's review of the Standard applying to the National Electricity Market (NEM), Deloitte Access Economics was engaged to conduct an economic assessment to determine the theoretical optimal level of SRAS for each electrical sub-network in the NEM. The findings of this assessment, which were derived from a model (the 'initial model') built by Deloitte Access Economics, were submitted to the AEMC in July 2016 and have since been made publicly available.

In light of feedback from consultation carried out by the AEMC in late September 2016, Deloitte Access Economics has been re-engaged by the AEMC to test the sensitivity of the initial model's outputs for New South Wales by introducing the following changes and assumptions. These assumptions were provided to us by the AEMC in October 2016:

1. The restoration curves have been altered to reflect a slower ramp rate of restoration than was the case in our initial analysis. This was achieved by doubling the system restoration time;
2. Delayed system restoration by SRAS sources by a further 120 minutes on top of the 90 minute assumption embedded in our initial model; and
3. Factored in transmission reliability levels of 80% into the composite reliability used in our initial model to account for failures of the transmission network which contribute to system outages.

These assumptions are more conservative then those previously modelled in our July 2016 report. Note that due to the impact of longer restoration times on default blackout duration, the model was revised to value outstanding loads past twelve hours – this modification does not change the recommendations made in the July 2016 report (but the revised base case has been reflected in the dotted lines presented in the charts in Appendix A).

The AEMC requested that the sensitivity analysis be limited to New South Wales as the findings in our July 2016 report raised the most questions from stakeholders and other participants during consultation.

We have incorporated the AEMC's assumptions and conducted sensitivity analysis as requested by the AEMC. The results of this analysis for New South Wales show the optimal level of SRAS provision remains unchanged at two (2) SRAS sources. Note that these results were calculated based on actual cost data for each SRAS source provided by the AEMC on AEMO's behalf. This actual cost data is not presented in the figures and tables of this report for confidentiality reasons.

The AEMC also requested that a sensitivity analysis considering a flat value of customer reliability (VCR) be run for all the sub-networks of the NEM and that blackout probabilities estimated for each one of these sub-networks be revised with the inclusion of the state wide blackout that swept across South Australia on 28 September 2016.

The table below sets out the relative impact of each of the sensitivities (listed above) relative to the base case:

**Table 1 - Impact of each sensitivity on the probability weighted benefit relative to the base case**

| Number of SRAS sources >> | 1 | 2 | 3 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Slower SRAS ramp rates | -13.5% | 0.5% | 7.2% | 9.8% | 30.2% | 46.0% |
| 210 minute delay in restoration | -32.7% | -21.5% | -17.9% | -19.0% | -18.6% | -19.8% |
| 80% transmission reliability | -20.0% | 29.6% | 57.5% | 94.1% | 87.0% | 139.6% |
| Flat VCR | 33.2% | 36.7% | 24.1% | 29.0% | 8.3% | -0.5% |
| **All sensitivities combined** | **-34.3%** | **30.7%** | **78.3%** | **118.0%** | **133.1%** | **220.9%** |

Note that the percentages for each individual sensitivity are not additive (because of the way in which the sensitivities are applied in the model), and as the relative change of all sensitivities combined will not equal the sum of the individual sensitivities.

Nevertheless, the table does demonstrate that the 210 minute delay is the largest contributor to the differences relative to the base case for the NSW 1 scenario, but the transmission reliability is the largest contributor to the differences for the remaining scenarios.

# 1 Introduction

The following sections present the graphical and numeric results of our analysis. The report steps through each of the contributing components and details their impact on the marginal economic benefit of SRAS sources in New South Wales and the resulting estimated optimal number of SRAS sources.

Note that due to the confidentiality of the cost data for SRAS provision, an average cost of $3.56 million per SRAS source was used in our analysis and the tabular outputs in Sections 2 through 7 below are only for comparison purposes. The estimated optimal number of SRAS sources for New South Wales following the inclusion of the real cost assumption is presented at the end of each section.

The remainder of the report is structured as follows:

- Section 2 re-presents the relevant outcomes from the July 2016 report updated to include the economic cost of outstanding loads past the twelfth hour;
- Section 3 considers the impact on the New South Wales SRAS outcomes of the slower ramp rates in isolation;
- Section 4 considers the impact on the New South Wales SRAS outcomes of the longer (ie. 210 minute) delay in isolation;
- Section 5 considers the impact on the New South Wales SRAS outcomes of applying transmission reliability of 80% in isolation;
- Section 6 considers the impact on the New South Wales SRAS outcomes of the combination of the longer (ie. 210 minute) delay together with the transmission reliability of 80% and the slower SRAS source ramp rates;
- Section 7 considers the impact on the New South Wales SRAS outcomes of:
    - A flat VCR in isolation; and
    - The combination of all of the sensitivities, being the flat VCR, the slower ramp rate, the longer (ie. 210 minute) delay and the transmission reliability of 80%;
- Section 8 presents the revised restoration probabilities for all sub-networks following the inclusion of the South Australian system black event of 28 September 2016;
- Section 9 summarises the conclusions of this report;
- Appendix A sets out the SRAS outcomes in the other NEM sub-networks as a result of applying the flat VCR; and
- Appendix B sets out the restoration curve for NSW as a result of the slower ramp rates and the 210 minute delay in load restoration.

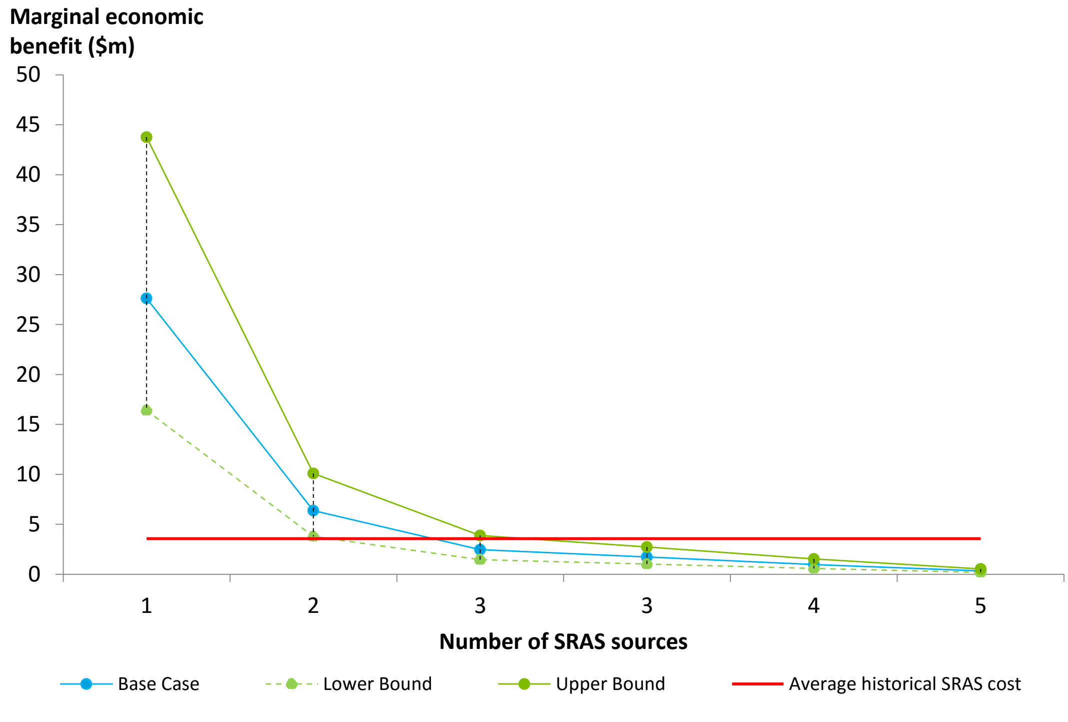
# 2 Marginal benefit of SRAS – updated July 2016 results

During the course of our analysis investigating slowed (Section 3) and delayed (Section 4) restoration curves, we extended the boundaries of the model to assign an economic value to outstanding loads past the twelfth hour. Because there is no published value of customer reliability (VCR) past 12 hours, we assume the VCR for New South Wales in the 12-24 hour bracket is the same as that in the 6-12 hour bracket (i.e. $17.97/kWh).

As a consequence of factoring in the full cost of the default blackout, which increases from $2.6 billion to $2.9 billion following the inclusion discussed previously, the probability weighted benefits have changed with the greatest impact showing on the benefit provided by the first two (2) sources. Note that this change does not impact the recommendations made in the July 2016 report.

The chart and table below re-present the updated output for New South Wales with the assumptions made in the July 2016 report and the increased default blackout cost. The base case results of the economic assessment suggest that the theoretical optimal level of SRAS in New South Wales is two (2) SRAS sources. Incorporating uncertainty into the analysis suggests that the appropriate level of SRAS is two (2) sources (using actual costs) for the sub-network. Note that the figure below is based on the average cost data for the SRAS sources

**Figure 1. Marginal benefit of SRAS in New South Wales – July 2016 results**




Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

**Table 2. Optimal level of SRAS in New South Wales – initial results ($m, FY15)**

| **Number of SRAS sources >>** | **1** | **2** | **3** | **3** | **4** | **5** |
|---|---|---|---|---|---|---|
| Probability weighted benefit | 27.62 | 6.37 | 2.45 | 1.72 | 0.96 | 0.33 |
| Marginal cost[1] | 3.56 | 3.56 | 3.56 | 3.56 | 3.56 | 3.56 |
| Net benefit (base case) | 24.06 | **2.80** | -1.11 | -1.85 | -2.60 | -3.23 |
| Net benefit - lower | 12.84 | **0.22** | -2.11 | -2.54 | -2.99 | -3.37 |
| Net benefit - upper | 40.19 | 6.52 | **0.32** | -0.85 | -2.04 | -3.04 |

Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

These results set out in the table and figure above form the base case for this report, against which each of the sensitivities are compared.

The next section of this report tests the model's sensitivity to a slowing of the SRAS sources' ramp rates and consequently of their load restoration capabilities. Each restoration is modelled to take twice as long as was modelled in our July 2016 model run.

[1] Estimate cost based on 2015 SRAS Tender Process Report, implied optimal level based on 2015 costs. This applies to all tables in this report where Marginal cost is presented

# 3 Marginal benefit of SRAS - slowing of SRAS ramp rates

Deloitte Access Economics was requested to test the sensitivity of the July 2016 model results by slowing the ramp rates of SRAS sources. To do so, the load restoration figures provided by the AEMC on AEMO's behalf were spread across double the time period. As a consequence of implementing this change, it was necessary to interpolate the restored load for a number of time-slots in the time period. The interpolation was performed by calculating the average of the immediately preceding and proceeding load values.

This approach for performing the slowing of the ramp rates is demonstrated in Table 3 below where the bold values in the last column are the interpolated restored load values:

**Table 3. Approach to delaying restoration**

| Initial timeline | Initial MW restored | New (slowed) timeline | New MW restored |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 5 | 120 | 5 | **60** |
| 10 | 145 | 10 | 120 |
| 15 | 170 | 15 | **132.5** |
| 20 | 185 | 20 | 145 |

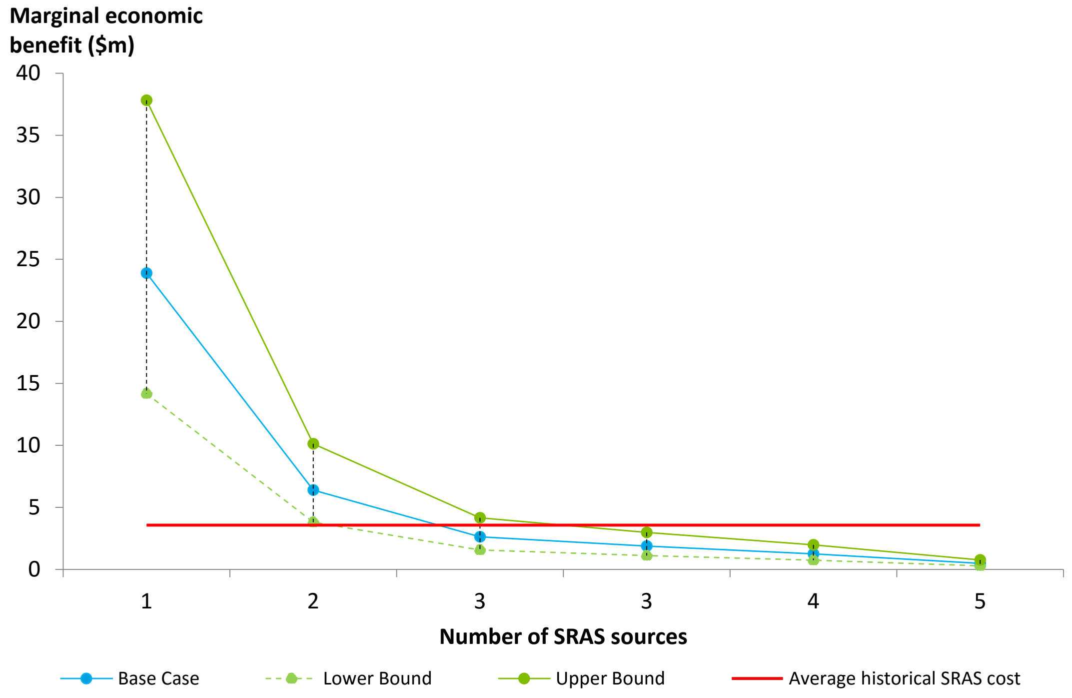
Source: AEMO and Deloitte Access Economics Analysis

We can see that the 5th minute load restored was initially 120MW. Under the slower ramp rate approach, the 120MW of load is now restored after 10 minutes. Similarly, the 10th minute load restored was initially 145MW. Under the slower ramp rate approach, the 145MW of load is now restored after 20 minutes.

Clearly the 5th and 15th minute load restored values under the slower ramp rate approach need to be interpolated. For the 5th minute load restored, the value is calculated as the average of the 0th minute load restored (0 MW) and the 10th minute load restored (120MW) – which is 60 MW. Similarly for the 15th minute load restored, the value is calculated as the average of the 10th minute load restored (120 MW) and the 20th minute load restored (145MW) – which is 132.5 MW.

Figure 2 below details the SRAS outcomes for New South Wales resulting only from the slower ramp rate. The material impact of the slower generator ramp rates is that the outstanding load values for each hour bracket increase.

**Figure 2: Optimal level of SRAS in New South Wales – slower ramp rates**




Source: AEMO and Deloitte Access Economics Analysis

The base case cost of the "default blackout" in New South Wales increases from $2.9 billion in the base-line model (Section 2), to $3.1 billion with the new restoration curves applied. This increase is minor (6%) compared to the 17% increase in the economic cost incurred if restoration is restored with the first SRAS source. The impact of these two changes is the reduction in the probability weighted benefit of procuring the first SRAS source in New South Wales.

Because the economic benefit of a combination "n" (where n>1) is calculated relative to the expected blackout cost of the "n-1" combination and the restoration curves are slowed by the same factor of time, there is little difference in the benefit provided by the five other combinations for New South Wales. The minor differences in benefit compared to the results in the base line case (Section 2) are a consequence of the averaging approach described at the start of this section.

Although the table below indicates that consideration could be given to including a third SRAS source, it must be emphasised the results in this table are based on the average cost data for the SRAS sources. When the real cost data is used instead (not presented in this report for confidentiality reasons), there is no net-benefit to having three (3) SRAS sources in NSW – the analysis reaffirms that two (2) SRAS sources is the optimal level of SRAS provision in New South Wales.

**Table 4. Optimal level of SRAS in New South Wales – slower ramp rates ($m, FY15)**

| **Number of SRAS sources >>** | **1** | **2** | **3** | **3** | **4** | **5** |
|---|---|---|---|---|---|---|
| Probability weighted benefit | 23.88 | 6.40 | 2.63 | 1.88 | 1.25 | 0.48 |
| Marginal cost | 3.56 | 3.56 | 3.56 | 3.56 | 3.56 | 3.56 |
| Net benefit (base case) | 20.32 | **2.83** | -0.93 | -1.68 | -2.31 | -3.08 |
| Net benefit - lower | 10.61 | **0.23** | -2.00 | -2.44 | -2.82 | -3.28 |
| Net benefit - upper | 34.26 | 6.57 | **0.60** | -0.58 | -1.58 | -2.80 |

Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

The table below sets out the relative change in the probabliltiy weighted benefits (including the upper and lower bounds) directly as a result of this scenario in isolation, when compared to the base case:

**Table 5. Impact on the probability weighted benefit relative to the base case**

| **Number of SRAS sources >>** | **1** | **2** | **3** | **3** | **4** | **5** |
|---|---|---|---|---|---|---|
| Probability weighted benefit | -13.5% | 0.5% | 7.2% | 9.8% | 30.2% | 46.0% |
| Upper bound | -13.5% | 0.5% | 7.2% | 9.8% | 30.2% | 46.0% |
| Lower bound | -13.5% | 0.5% | 7.2% | 9.8% | 30.2% | 46.0% |

Clearly the slower ramp rate reduces the benefit of the NSW 1 scenario, but increases the benefit of the remaining scenarios relative to the base case, for the reasons as noted in the paragraphs above.

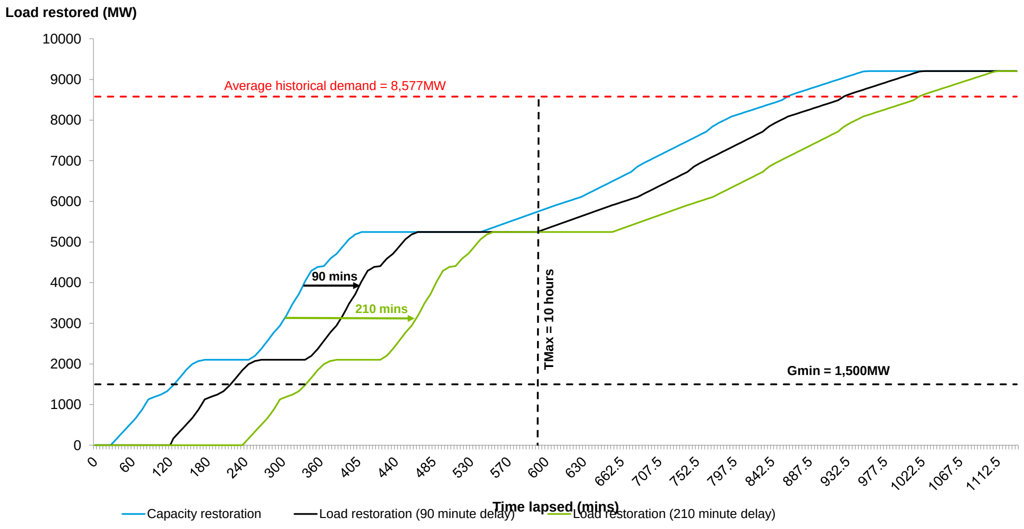
The next section of this report considers the restoration curves from our initial model (Section 2) and delays them by a further 120 minutes to test the model's sensitivity to an additional two (2) hour delay.

# 4 Marginal benefit of SRAS - 210 minute delay in restoration

In this section, we change the delay to be 210 minutes before restoration is commenced, which takes the 90 minute from our initial model and extends it by a further 120 minutes. This in turn means that the benefits of additional SRAS sources appear later during the blackout and the marginal benefit of additional SRAS therefore reduces compared to the baseline case shown in Section 2.

Figure 3 below is a representation of the delayed restoration, initially by 90 minutes and then by a further 120 minutes (to give the total delay of 210 minutes). The amount of the additional costs of the blackoutis proportional to the area between the 90 minute (black) and the 210 minute (green) curves in the chart below.

**Figure 3: Capacity restoration curve and supply – lagged by 90 and 210 minutes**

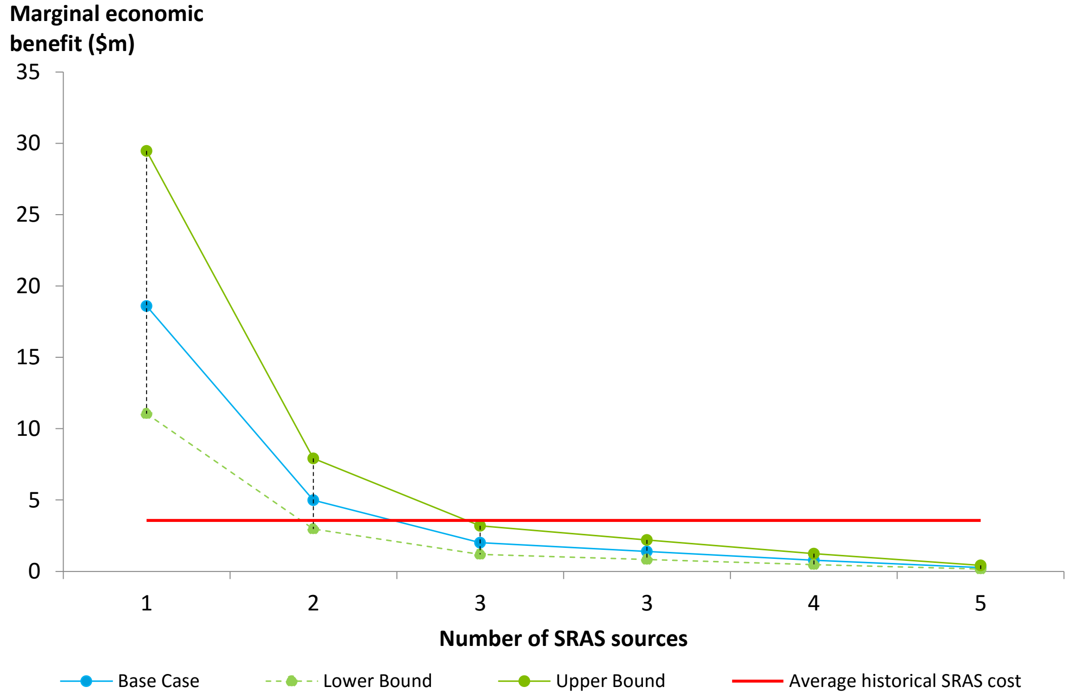



Source: AEMO and Deloitte Access Economics Analysis

As shown in Figure 4 below, the impact of the added delay on the modelled output is a reduction in certainty around the contracting of a second source for the provision of SRAS in New South Wales due to the marginal cost now exceeding the benefit provided by the two (2) SRAS sources combination at the lower bound.

Using the actual cost data (not presented in this report for confidentiality reasons) to determine the optimal level of SRAS provides the same outcome illustrated in the previous section. Under the base case, the optimal level of SRAS for New South Wales when delaying the restoration by 210 minutes is two (2) sources.

**Figure 4: Optimal level of SRAS in NSW – delayed restoration**




Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

**Table 6. Optimal level of SRAS in New South Wales – delayed restoration ($m, FY15)**

| Number of SRAS sources >> | 1 | 2 | 3 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Probability weighted benefit | 18.60 | 5.00 | 2.01 | 1.39 | 0.78 | 0.26 |
| Marginal cost | 3.56 | 3.56 | 3.56 | 3.56 | 3.56 | 3.56 |
| Net benefit (base case) | 15.04 | **1.43** | -1.55 | -2.17 | -2.78 | -3.30 |
| Net benefit - lower | **7.48** | -0.60 | -2.37 | -2.74 | -3.10 | -3.41 |
| Net benefit - upper | 25.90 | **4.35** | -0.38 | -1.36 | -2.32 | -3.15 |

Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

The results presented here are likely attributable to the time dependency of the VCR, which is investigated further in Section 7 of this report.

The table below sets out the relative change in the probabliltiy weighted benefits (including the upper and lower bounds) directly as a result of this scenario in isolation, when compared to the base case:

**Table 7. Impact on the probability weighted benefit relative to the base case**

| Number of SRAS sources >> | 1 | 2 | 3 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Probability weighted benefit | -32.7% | -21.5% | -17.9% | -19.0% | -18.6% | -19.8% |
| Upper bound | -32.7% | -21.5% | -17.9% | -19.0% | -18.6% | -19.8% |
| Lower bound | -32.7% | -21.5% | -17.9% | -19.0% | -18.6% | -19.8% |

Clearly the 210 minute delay in restoration reduces the benefit of all of the scenarios relative to the base case.

The next section of this report tests the model's sensitivity to the inclusion of a reliability factor of 80% to the composite reliability of each SRAS source.

# 5 Marginal benefit of SRAS - 80% transmission reliability

In this section, we factor transmission reliability into the composite reliability of each SRAS sources, which the AEMC has requested that we model as being 80% reliable.

As shown in Table 8 below, including a transmission reliability of 80% in the composite reliability of SRAS sources increases the weight of the blackout cost in the calculation of the marginal benefit and reduces the weight of the first SRAS source's economic benefit.

**Table 8. Restoration probabilities for New South Wales**

| SRAS sources | # sources | n sources work | n – 1 | n - 2 | n - 3 | n - 4 | n - 5 |
|---|---|---|---|---|---|---|---|
| NSW1 | 1 | 68.40% | 31.60% | 0.00% | 0.00% | 0.00% | 0.00% |
| NSW1 + NSW3 | 2 | 44.19% | 44.63% | 11.19% | 0.00% | 0.00% | 0.00% |
| NSW1 + NSW3 + NSW4 | 3 | 28.54% | 44.47% | 23.02% | 3.96% | 0.00% | 0.00% |
| NSW1 + NSW2 + NSW3 | 3 | 26.87% | 44.45% | 24.30% | 4.39% | 0.00% | 0.00% |
| NSW1 + NSW2 + NSW3 + NSW4 | 4 | 17.36% | 38.23% | 31.43% | 11.43% | 1.55% | 0.00% |
| NSW1 + NSW2 + NSW3 + NSW4 + NSW5 | 5 | 8.57% | 27.67% | 34.87% | 21.55% | 6.55% | 0.79% |

Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

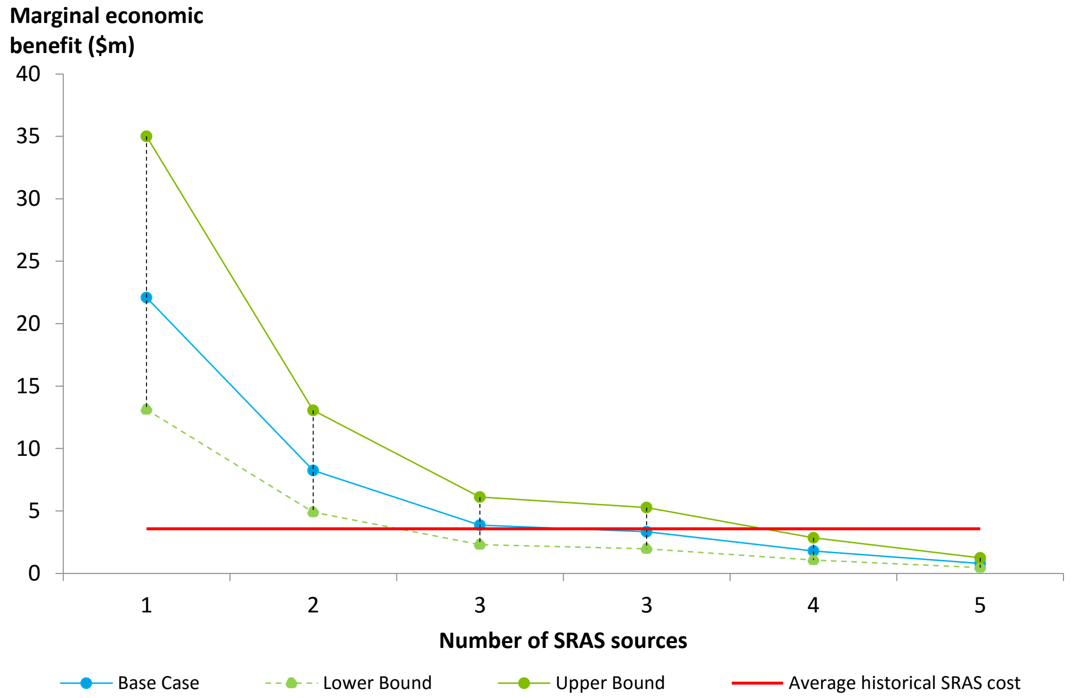
Adding a layer of transmission reliability has the effect of lowering all of the "n sources work" restoration probabilities. Including the 80% transmission reliability has also required us to recalculate the probabilities for all the combinations, therefore rebalancing their weights in the calculation of marginal benefits. The table below shows the SRAS outcomes when factoring in a transmission reliability of 80% using the average SRAS costs instead of the real cost:

**Table 9. Optimal level of SRAS in New South Wales – 80% reliability ($m, FY15)**

| Number of SRAS sources >> | 1 | 2 | 3 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Probability weighted benefit | 22.10 | 8.25 | 3.86 | 3.33 | 1.80 | 0.78 |
| Marginal cost | 3.56 | 3.56 | 3.56 | 3.56 | 3.56 | 3.56 |
| Net benefit (base case) | 18.54 | 4.69 | **0.30** | -0.23 | -1.76 | -2.78 |
| Net benefit - lower | 9.56 | **1.33** | -1.27 | -1.58 | -2.49 | -3.10 |
| Net benefit - upper | 31.44 | 9.50 | **2.55** | 1.71 | -0.71 | -2.32 |

Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

**Figure 5: Optimal level of SRAS in NSW – 80% reliability**




Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

The impact of the inclusion of the 80% transmission reliability ratio on the model output is illustrated in Figure 5 above. However, comparing the benefits to the actual costs of procurement with the inclusion of the 80% transmission reliability, the theoretically optimal level of SRAS provision is two (2) sources, one less than that illustrated in the figure and table above.

The table below sets out the relative change in the probability weighted benefits (including the upper and lower bounds) directly as a result of this scenario in isolation, when compared to the base case:

**Table 10. Impact on the probability weighted benefit relative to the base case**

| Number of SRAS sources >> | 1 | 2 | 3 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Probability weighted benefit | -20.0% | 29.6% | 57.5% | 94.1% | 87.0% | 139.6% |
| Upper bound | -20.0% | 29.6% | 57.5% | 94.1% | 87.0% | 139.6% |
| Lower bound | -20.0% | 29.6% | 57.5% | 94.1% | 87.0% | 139.6% |

Clearly the inclusion of the 80% transmission reliability reduces the benefit of the NSW 1 scenario, but increases the benefit of the remaining scenarios relative to the base case, for the reasons as noted in the paragraphs above.

The next section of the report tests the model's sensitivity to the inclusion of the three (3) sensitivities introduced thus far in the report.

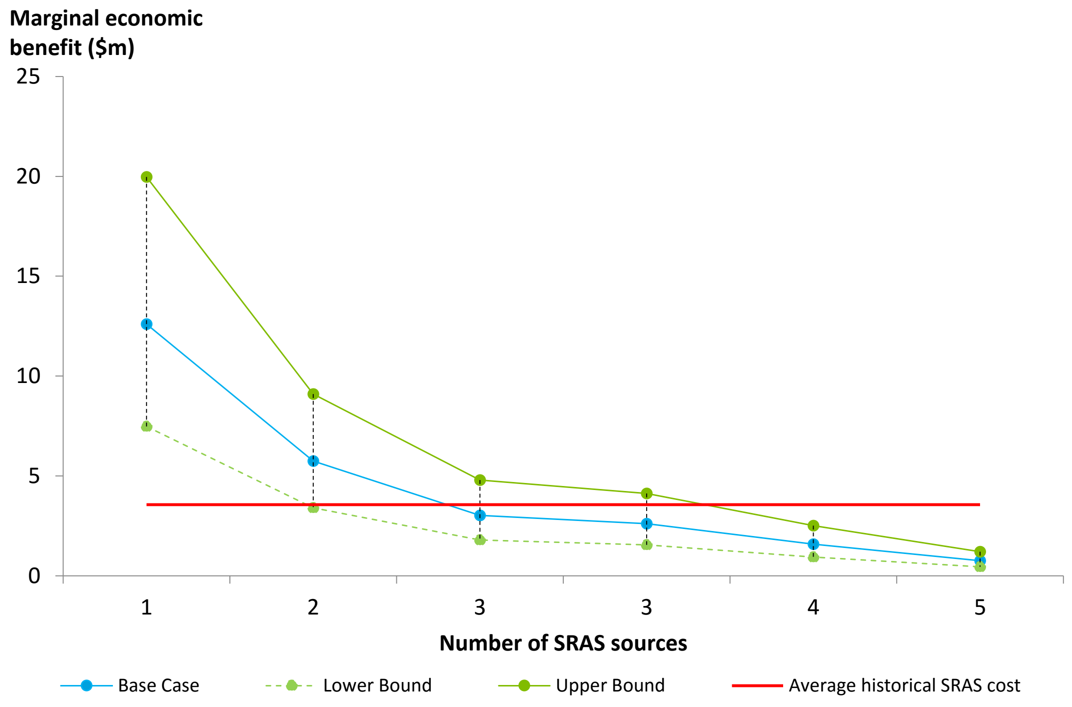
# 6 Marginal benefit of SRAS – slow ramp rates, delay in restoration and 80% transmission reliability

The sections above have introduced three sensitivities that have differing impacts on the optimal level of SRAS provision in New South Wales. Slowing the restoration curves only materially impacts the first combination of SRAS sources. Delaying the restoration curves by 210 minutes reduces the benefit of SRAS provision across all the combinations. In comparison, factoring in transmission reliability of 80% in the composite reliability of SRAS sources and using the average SRAS procurement costs rather than the real SRAS costs shifts the base case optimal level of SRAS provision to three (3) sources.

The three sensitivities impact the modelled SRAS outcomes in differing ways. This section considers the trio of sensitivities together and assesses their combined effect on the optimal number fo SRAS sources for New South Wales.

Using actual 2015 cost data in our analysis suggests the optimal level of SRAS for New South Wales is two sources (2) under the base case scenario, although using average cost data (as shown in the figure below) as set out in the figure below implies it is three.  We note that while we do not have the data from AEMO to support the scenario of SRAS sources 1, 2 and 5, adding SRAS source 5 could also be an economically viable option.

**Figure 6: Optimal level of SRAS in New South Wales – both sensitivities**




Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

It is important to note that the probability weighted benefit of the single source is the lowest out of all the sensitivities tested in this report thus far. This may be a consequence of the combined effects of the three sensitivities which on their own already drive down the benefit of the one (1) SRAS source scenario from the baseline case shown in Section 2.

**Table 11. Optimal level of SRAS in New South Wales – both sensitivities ($m, FY15)**

| Number of SRAS sources >> | 1 | 2 | 3 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Probability weighted benefit | 12.61 | 5.75 | 3.03 | 2.61 | 1.59 | 0.76 |
| Marginal cost | 3.56 | 3.56 | 3.56 | 3.56 | 3.56 | 3.56 |
| Net benefit (base case) | 9.05 | **2.18** | -0.53 | -0.95 | -1.97 | -2.80 |
| Net benefit - lower | **3.92** | -0.15 | -1.76 | -2.01 | -2.62 | -3.11 |
| Net benefit - upper | 16.41 | 5.54 | **1.23** | 0.57 | -1.04 | -2.35 |

Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

The table below sets out the relative change in the probabliltiy weighted benefits (including the upper and lower bounds) directly as a result of this scenario in isolation, when compared to the base case:

**Table 12. Impact on the probability weighted benefit relative to the base case**

| Number of SRAS sources >> | 1 | 2 | 3 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Probability weighted benefit | -54.4% | -9.7% | 23.6% | 52.0% | 65.2% | 133.1% |
| Upper bound | -54.4% | -9.7% | 23.6% | 52.0% | 65.2% | 133.1% |
| Lower bound | -54.4% | -9.7% | 23.6% | 52.0% | 65.2% | 133.1% |

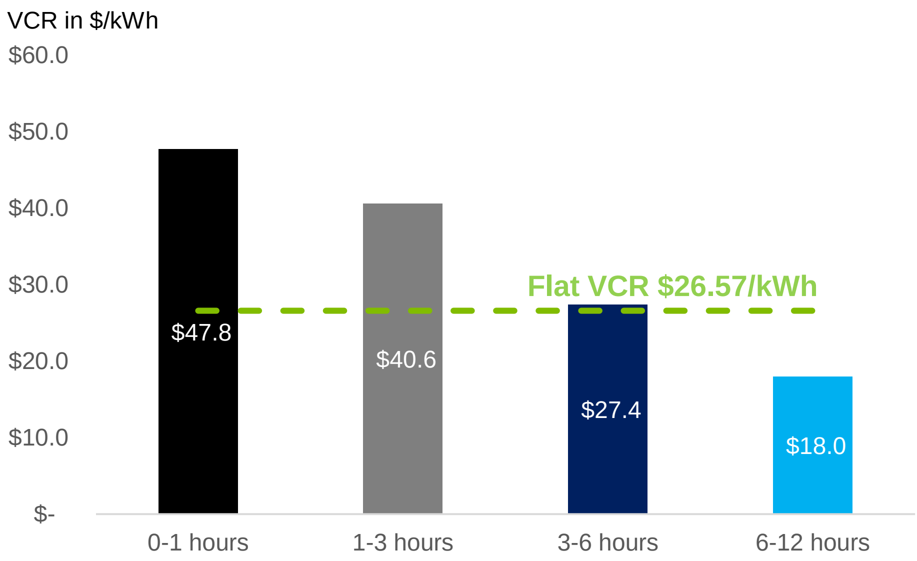
Clearly the combination of the slower ramp rates, the 210 minute delay in restoration and the 80% transmission reliability reduces the benefit of the NSW 1 and the NSW 2 scenarios, but increases the benefit of the remaining scenarios relative to the base case.

The next chapter of this report employs the same assumptions used in this section, but introduces the concept of a flat VCR for New South Wales.

# 7 Marginal benefit of SRAS - flat VCR

The reason for including this sensitivity is due to the existence of some contention on the way the value of the VCR changes for outages of different durations. The AEMC requested that we test the application of a flat VCR - this means that consumers would value electricity equally regardless how long the outage is, a departure from the existing VCR which declines over time for longer duration outages. Whilst a detailed analysis of the VCR is beyond the scope of this report, we have considered the impact of replacing the existing VCR structure with a flat VCR as depicted in the figure below (the flat VCR of $26.67/kWh is based on the time-weighted average of the current VCR values):

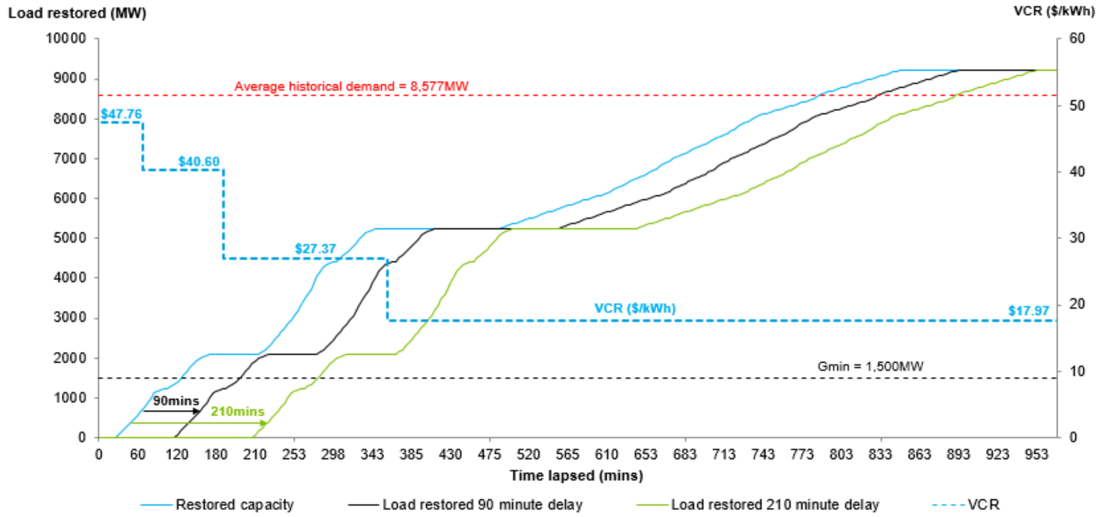
**Figure 7: New South Wales VCR**




Source: AEMO and Deloitte Access Economics Analysis

Our analysis relies on electricity restoration times to determine the economic benefit of SRAS. For each combination of SRAS sources, the outstanding load in MW in each hour bracket is multiplied by the corresponding value of customer reliability for that bracket and then weighted based on each SRAS combination's composite reliability. When a VCR that varies with time is used, the outstanding load in the first hour bracket (8,577MW) costs $533 million to society, the outstanding load in the third bracket (23,738MW) which is almost three times greater than that in the first hour bracket only costs $845 million to society, or 1.6 times as much. This relationship between VCR value and outstanding load is illustrated in Figure 8 below.

**Figure 8: NSW restoration curves and VCR**




Source: AEMO, Deloitte Access Economics Analysis

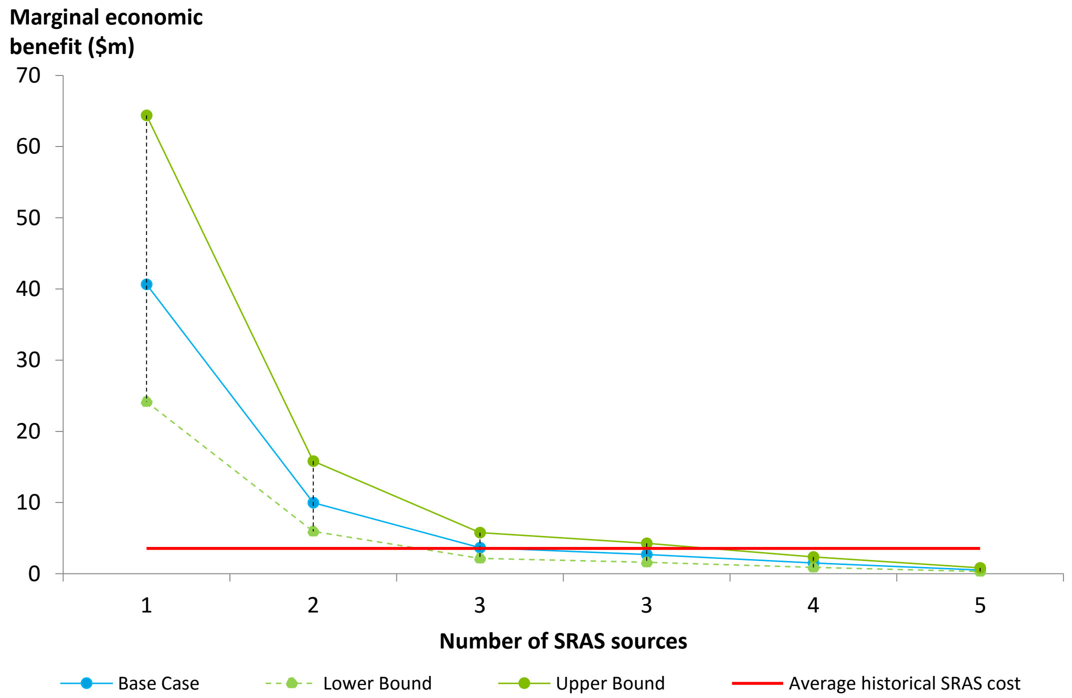
Based on the VCR figures used in our July 2016 report to the AEMC, a kilowatt-hour (kWh) of load restored in the later period of a major supply disruption is valued far less than a kWh of load restored in an earlier bracket. Figure 8 above shows that the VCR rapidly decreases and that 1kWh of outstanding load between SRAS combinations at the 420th minute is only valued at $17.97/kWh whereas an equal 1kWh gap between combinations at the 300th minute is valued at 27.37/kWh. Whether or not this should be the case requires a complex analysis of the NEM and is outside the scope of this sensitivity assessment.

The next two sub-sections of this report analyse the impacts of applying the flat VCR in isolation and then together with all three sensitivities outlined earlier in this report.

## 7.1 Flat VCR only

Flattening the VCR across all time periods means that customers (averaged across all sectors) value electricity at $26.57 per kWh at all stages of a major supply disruption. Figure 9 presents the impact of the flat VCR without delaying the restoration by more than 90 minutes or factoring in the transmission reliability of 80% in the SRAS composite reliability or the slower ramp rate.

**Figure 9: Optimal level of SRAS in NSW – flat VCR only**




Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

Similarly to the observation made in Section 2, the first two sources provide the largest benefit to society while the benefits of the other SRAS combinations remain small by virtue of their smaller probability weightings.

With this assumption (i.e. flat VCR only), the optimal level of SRAS is only two (2) when comparing the benefits shown in Table 13 to the actual 2015 costs of procurement of SRAS (not provided in this report for confidentiality reasons).

**Table 13. Optimal level of SRAS in NSW – flat VCR only ($m, FY15)**

| Number of SRAS sources >> | 1 | 2 | 3 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Probability weighted benefit | 36.80 | 8.70 | 3.04 | 2.21 | 1.04 | 0.33 |
| Marginal cost | 3.56 | 3.56 | 3.56 | 3.56 | 3.56 | 3.56 |
| Net benefit (base case) | 33.24 | **5.14** | -0.52 | -1.35 | -2.52 | -3.24 |
| Net benefit - lower | 18.29 | **1.60** | -1.76 | -2.25 | -2.94 | -3.37 |
| Net benefit - upper | 54.73 | 10.22 | **1.25** | -0.06 | -1.91 | -3.05 |

Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

The table below sets out the relative change in the probabliltiy weighted benefits (including the upper and lower bounds) directly as a result of this scenario in isolation, when compared to the base case:

**Table 14. Impact on the probability weighted benefit relative to the base case**

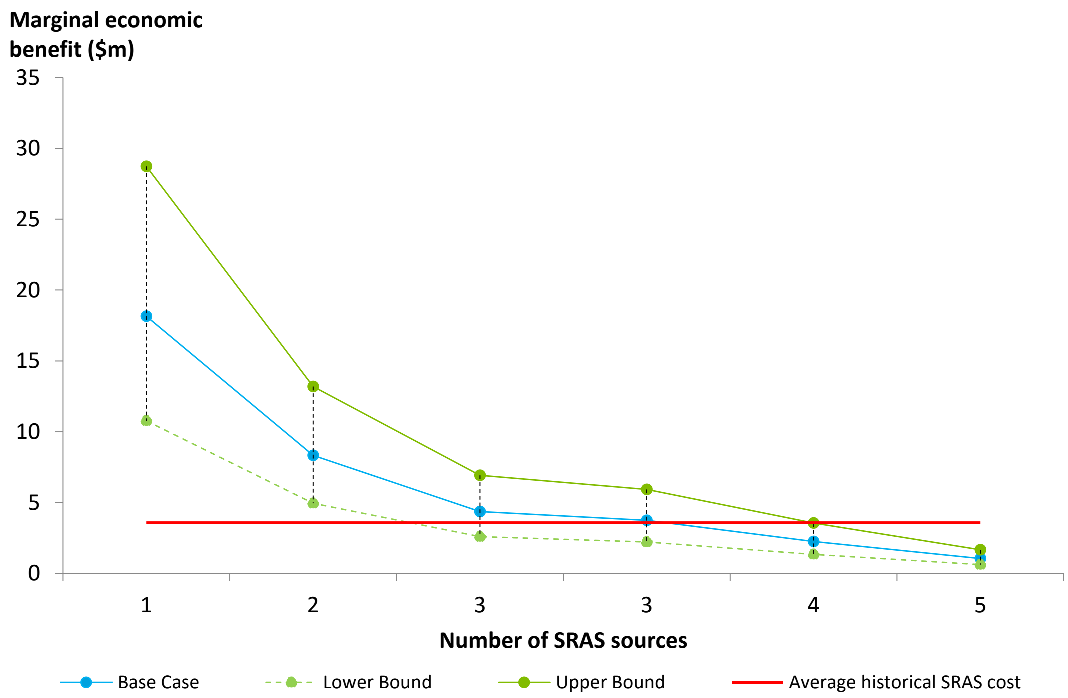
| Number of SRAS sources >> | 1 | 2 | 3 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Probability weighted benefit | 33.2% | 36.7% | 24.1% | 29.0% | 8.3% | -0.5% |
| Upper bound | 33.2% | 36.7% | 24.1% | 29.0% | 8.3% | -0.5% |
| Lower bound | 33.2% | 36.7% | 24.1% | 29.0% | 8.3% | -0.5% |

Clearly the flat VCR increases nearly all of the scenarios relative to the base case.

## 7.2 Flat VCR, slowed restoration curves, transmission reliability and delay sensitivities

Figure 10 shows the effect of applying a flat VCR, together with slower ramp rates, the 210 minute delay in restoration and the factoring in of transmission reliability of 80% in the composite reliability of SRAS sources.

**Figure 10: Optimal level of SRAS in NSW – all sensitivities combined**




Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

Compared to the flat VCR only case shown in the previous section, the combined effects of the flat VCR and the sensitivities discussed in Sections 3, 4 and 5 of this report reduce the benefit provided by the first SRAS source by close to $19 million meanwhile increasing the net benefit provided by the three (3), four (4) and five (5) SRAS source combinations slightly.

This is a consequence of the flattening of the curves as the weight of the probability of the one (1) SRAS combination starting succesfully is transferred to the other combinations (as discussed in Section 5).

Despite the upper bound getting closer to justifying its procurement with all the sensitivities combined (i.e. the benefit provided by the third combination is the highest of all the sentitivities tested), the third source remains uneconomical to contract in New South Wales when comparing the benefits to the actual procurement costs of SRAS (not provided in this report for confidentiality reasons).

The table below shows the SRAS outcomes for this combination of assumptions (the flat VCR, the slower ramp rates, the 210 minute delay in restoration and the factoring in of transmission reliability of 80%) using the average SRAS costs instead of the real cost:

**Table 15. Optimal level of SRAS in NSW – all sensitivities combined ($m, FY15)**

| Number of SRAS sources >> | 1 | 2 | 3 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Probability weighted benefit | 18.14 | 8.32 | 4.37 | 3.74 | 2.24 | 1.05 |
| Marginal cost | 3.56 | 3.56 | 3.56 | 3.56 | 3.56 | 3.56 |
| Net benefit (base case) | 14.58 | 4.76 | **0.81** | 0.18 | -1.32 | -2.51 |
| Net benefit - lower | 7.21 | **1.38** | -0.97 | -1.34 | -2.23 | -2.94 |
| Net benefit - upper | 25.18 | 9.62 | **3.36** | 2.36 | -0.01 | -1.90 |

Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

The table below sets out the relative change in the probabliltiy weighted benefits (including the upper and lower bounds) directly as a result of this scenario in isolation, when compared to the base case:

**Table 16. Impact on the probability weighted benefit relative to the base case**

| Number of SRAS sources >> | 1 | 2 | 3 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Probability weighted benefit | -34.3% | 30.7% | 78.3% | 118.0% | 133.1% | 220.9% |
| Upper bound | -34.3% | 30.7% | 78.3% | 118.0% | 133.1% | 220.9% |
| Lower bound | -34.3% | 30.7% | 78.3% | 118.0% | 133.1% | 220.9% |

Clearly the combination of the flat VCR, slower ramp rates, the 210 minute delay in restoration and the 80% transmission reliability reduces the benefit of the NSW 1 scenarios, but increases the benefit of the remaining scenarios relative to the base case.

# 8 Impact of the South Australian black system event on restoration probabilities

On 28 September 2016, as severe weather events swept through South Australia, the State suffered a major supply disruption which required the deployment of its two SRAS sources, a first in the history of the NEM.

We have been able to integrate this South Australian event into our analysis. The 1895MW loss of load in South Australia in September 2016 has been added to the model to become the 37th event in the dataset, an inclusion which has two effects.

The first is the impact it has on the regression for South Australia, which changes its base case probability of a major supply disruption in a given year from 5.45% to 7.67%.

The second is the resulting minor increase in the estimated base case and upper bound probabilities of major supply disruptions in Queensland and Tasmania. As discussed on page 76 (Appendix C) of the July 2016 report, tailored approaches were used for those two States.

Because of the lack of variation in the data for Tasmania and the lack of points for Queensland (both sub-networks) we couldn't effectively carry out an inverse Weibul distribution analysis of the load shedding events for those two States. To resolve that limitation, the outputs of the State Power law were escalated by the average variance between the lower and upper bound return periods for Victoria, New South Wales and South Australia.

The result of those calculations informed the upper bound of our analysis while the output of the State power law informed the lower bound. Similar to the approach used for the other three States, the base case probabilities for Tasmania and Queensland were obtained by calculating the inverse of their averaged lower and upper bound return periods. The following table sets out the resulting updated estimated probabilities of major supply disruptions and return periods:

**Table 17. Estimated Probabilities of major supply disruptions and return periods after inclusion of 28 September 2016 SA blackout event**

| | | Lower Bound | | Base Case | | Upper Bound | |
|---|---|---|---|---|---|---|---|
| Sub-network | Average Historical Demand (MW) | Probability (%) | Return Period (years) | Probability (%) | Return Period (years) | Probability (%) | Return Period (years) |
| TAS | 1,182 | 4.06% | 24.64 | 4.60% | 21.74 | 5.31% | 18.85 |
| SA | 1,587 | 7.04% | 14.20 | 7.67% | 13.04 | 8.42% | 11.87 |
| N.QLD | 2,144 | 2.97% | 33.63 | 3.37% | 29.67 | 3.89% | 25.72 |
| S.QLD | 3,456 | 2.07% | 48.39 | 2.34% | 42.70 | 2.70% | 37.00 |
| VIC | 5,784 | 2.63% | 38.06 | 2.98% | 33.54 | 3.45% | 29.02 |
| NSW | 8,577 | 2.23% | 44.74 | 2.64% | 37.94 | 3.21% | 31.14 |

Source: Deloitte Access Economics

Note that the shaded cells represent the probabilites that have changed since the South Australia Septemer 2016 blackout.

The table below sets out the old probabilities used in the July 2016 report, prior to the South Australia blackout occuring:

**Table 18. Estimated Probabilities of major supply disruptions and return periods before inclusion of 28 September 2016 SA blackout event**

| | | Lower Bound | | Base Case | | Upper Bound | |
|---|---|---|---|---|---|---|---|
| Sub-network | Average Historical Demand (MW) | Probability (%) | Return Period (years) | Probability (%) | Return Period (years) | Probability (%) | Return Period (years) |
| TAS | 1,182 | 4.06% | 24.64 | 4.56% | 21.92 | 5.21% | 19.20 |
| SA | 1,587 | 5.12% | 19.54 | 5.45% | 18.36 | 5.82% | 17.18 |
| N.QLD | 2,144 | 2.97% | 33.63 | 3.34% | 29.92 | 3.82% | 26.21 |
| S.QLD | 3,456 | 2.07% | 48.39 | 2.32% | 43.05 | 2.65% | 37.70 |
| VIC | 5,784 | 2.63% | 38.06 | 2.98% | 33.54 | 3.45% | 29.02 |
| NSW | 8,577 | 2.23% | 44.74 | 2.64% | 37.94 | 3.21% | 31.14 |

Source: Deloitte Access Economics

Appendix A sets out the updated SRAS outcomes for each NEM sub-network using both these updated restoration probabilities and the flat VCR considered in Section 7.1.

# 9 Conclusions

Our analysis shows the four sensitivities tested in isolation impact the benefits of SRAS combinations in New South Wales very differently and do not all contribute to increased net benefits across the spectrum of SRAS source combinations for New South Wales.

Reducing the ramp rates of the generators reduces the benefit provided by the first SRAS source by up to 17%, flattening the slope of the base case (and other uncertainties) benefit curve(s) accordingly.

Delaying the restoration by a further 120 minutes, cumulating to a 210 minute delay from the capacity restoration curves originally provided by AEMO reduces the net benefit provided by the first SRAS source by more than $9 million but has a negligible impact on the other SRAS combinations.

Factoring in transmission reliability of 80% into the composite reliability of SRAS sources re-balances the restoration probability for each SRAS combination, resulting in a decrease in the benefit provided by the first source whilst increasing the benefit provided by the other SRAS combinations. The table below sets out the relative impact of each of these sensitivities relative to the base case:

**Table 19 - Impact of each sensitivity on the probability weighted benefit relative to the base case**

| Number of SRAS sources >> | 1 | 2 | 3 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Slower SRAS ramp rates | -13.5% | 0.5% | 7.2% | 9.8% | 30.2% | 46.0% |
| 210 minute delay in restoration | -32.7% | -21.5% | -17.9% | -19.0% | -18.6% | -19.8% |
| 80% transmission reliability | -20.0% | 29.6% | 57.5% | 94.1% | 87.0% | 139.6% |
| Flat VCR | 33.2% | 36.7% | 24.1% | 29.0% | 8.3% | -0.5% |
| **All sensitivities combined** | **-34.3%** | **30.7%** | **78.3%** | **118.0%** | **133.1%** | **220.9%** |

Note that the percentages for each individual sensitivity are not additive (because of the way in which the sensativities are applied in the model), and as the relative change of all sensitivities combined will not equal the sum of the individual sensitivities.

Neverttheless, the table does demonstrate that the 210 minute delay is the largest contributor to the differences relative to the base case for the NSW 1 scenario, but the transmission reliability is the largest contributor to the differences for the remaining scenarios.

Combining all these sensitivities while levelling the VCR across the length of the default blackout shows the optimal level of SRAS for New South Wales remains unchanged from the July 2016 report at two (2) sources.

# Appendix A Model output of the other sub-networks with flat VCR

The AEMC requested Deloitte Access Economics run a model sensitivity of a 'flat' VCR on the other sub-networks within the NEM. We present our findings for the flat VCR sensitivity for the other NEM sub-networks in this appendix.

Specifically, this appendix details the change in probabilities of a major supply disruption in all sub-networks other than Victoria and New South Wales. These probabilities have a direct impact on the economic benefit values derived from the analysis as well as the model output for each sub-network following the application of the flat VCR. The table below sets out the flat VCR values used in each sub-network for the purpose of our analysis:

**Table 20. Estimated Probabilities of major supply disruptions and return periods before inclusion of 28 September 2016 South Australia blackout event**

| Sub-network | Flat VCR ($/kWh) |
|---|---|
| TAS | 20.15 |
| SA | 26.45 |
| N.QLD | 27.02 |
| S.QLD | 27.02 |
| VIC | 25.70 |
| NSW | 26.57 |

Source: Deloitte Access Economics

The modelled SRAS outcomes for each sub-network, using the update restoration probabilities as set out in Section 8 of this report and the flat VCR, are set out in this appendix.

## Victoria

**Figure 11: Optimal level of SRAS in Victoria – flat VCR**

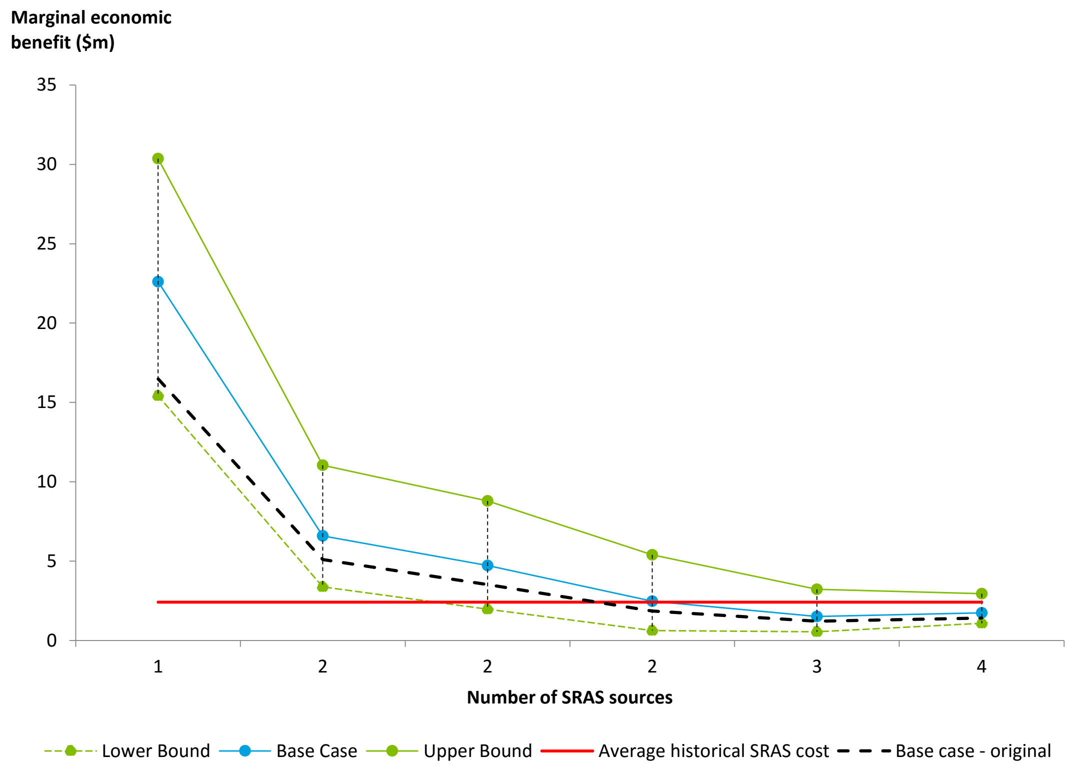



**Table 21. Optimal level of SRAS in Victoria – flat VCR ($m, FY15)**

| Number of SRAS sources >> | 1 | 2 | 2 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|
| Probability weighted benefit | 22.61 | 6.59 | 4.72 | 2.47 | 1.51 | 1.74 |
| Marginal cost | 2.42 | 2.42 | 2.42 | 2.42 | 2.42 | 2.42 |
| Net benefit (base case) | 19.57 | **3.83** | 1.05 | -2.17 | -3.13 | -1.93 |
| Net benefit - lower | 12.39 | **0.62** | -1.70 | -4.01 | -4.10 | -2.59 |
| Net benefit - upper | 27.33 | **8.28** | 5.13 | 0.76 | -1.42 | -0.72 |

Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

The optimal level of SRAS providers for Victoria is two (2) under both the case where the average SRAS cost and the flat VCR is used, and the case where the real 2015 cost of SRAS procurement is used instead of the average SRAS cost (the latter is not presented in this appendix for confidentiality reasons).

This outcome remains unchanged from our July 2016 report.

## North Queensland

**Figure 12: Optimal level of SRAS in North Queensland – flat VCR**

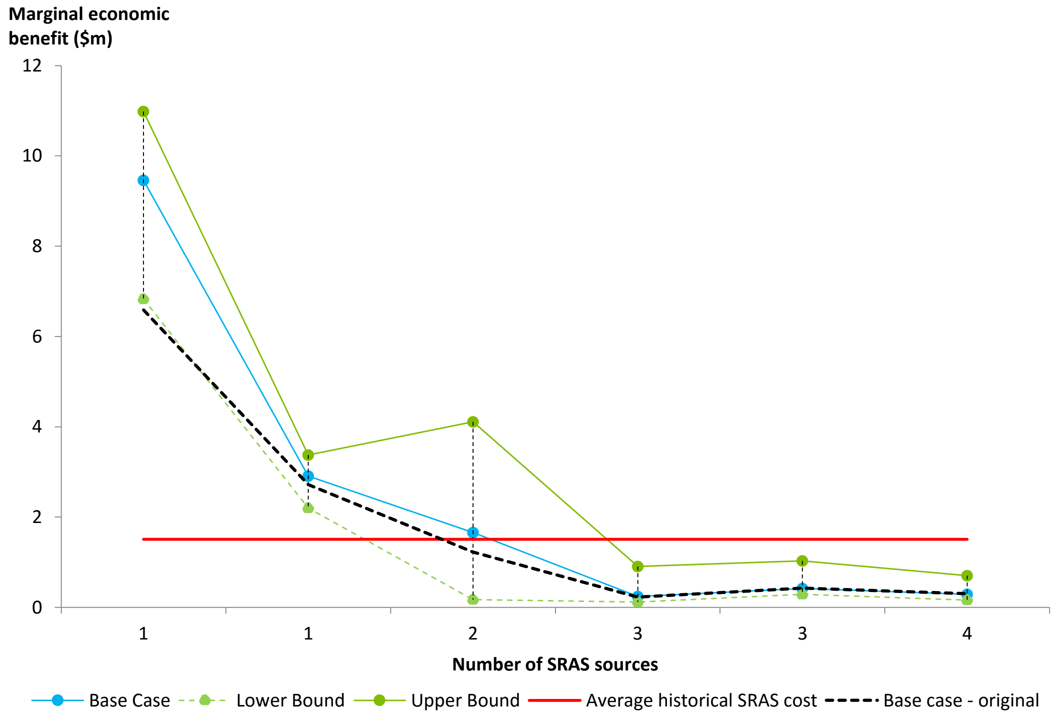



**Table 22. Optimal level of SRAS in North Queensland – flat VCR ($m, FY15)**

| Number of SRAS sources >> | 1 | 1 | 2 | 3 | 3 | 4 |
|---|---|---|---|---|---|---|
| Probability weighted benefit | 9.46 | 2.91 | 1.66 | 0.24 | 0.42 | 0.29 |
| Marginal cost | 1.51 | 1.51 | 1.51 | 1.51 | 1.51 | 1.51 |
| Net benefit (base case) | 7.95 | 1.40 | **0.15** | -1.26 | -1.09 | -1.21 |
| Net benefit - lower | **5.33** | 0.70 | -1.34 | -1.39 | -1.21 | -1.34 |
| Net benefit - upper | 9.48 | 1.87 | **2.60** | -0.60 | -0.47 | -0.80 |

Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

The optimal level of SRAS providers for North Queensland is two (2) under both the case where the average SRAS cost and the flat VCR is used, and the case where real 2015 cost of SRAS procurement is used instead of the average SRAS cost (the latter is not presented in this appendix for confidentiality reasons).

This outcome remains unchanged from our July 2016 report.

### South Queensland

**Figure 13: Optimal level of SRAS in South Queensland – flat VCR**

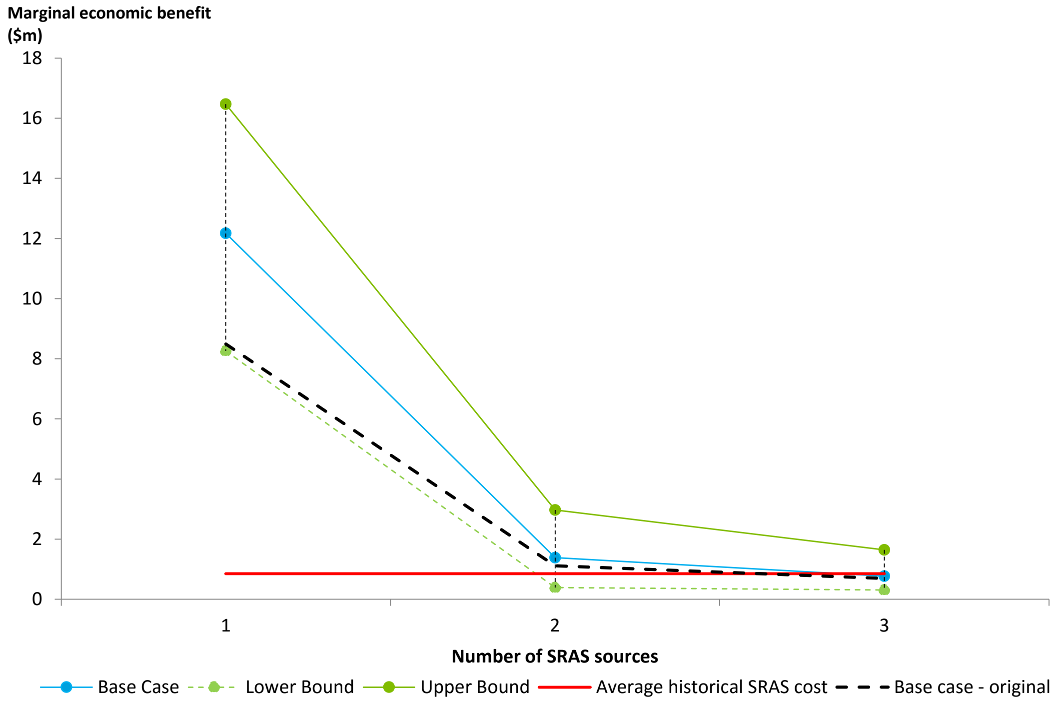



**Table 23. Optimal level of SRAS in South Queensland – flat VCR ($m, FY15)**

| Number of SRAS sources >> | 1 | 2 | 3 |
|---|---|---|---|
| Probability weighted benefit | 12.17 | 1.39 | 0.77 |
| Marginal cost | 0.85 | 0.85 | 0.85 |
| Net benefit (base case) | **11.32** | -0.38 | -1.99 |
| Net benefit - lower | **7.41** | -1.38 | -2.45 |
| Net benefit - upper | 15.62 | **1.20** | -1.12 |

Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

While the flat VCR pushes the theoretical optimal level of SRAS for South Queensland to two (2) under the case where the average SRAS cost is used, where the real 2015 cost of SRAS procurement is used, the optimal level of SRAS is one (1) (the latter is not presented in this appendix for confidentiality reasons).

This outcome remains unchanged from our July 2016 report.

## South Australia

**Figure 14: Optimal level of SRAS in South Australia – flat VCR**

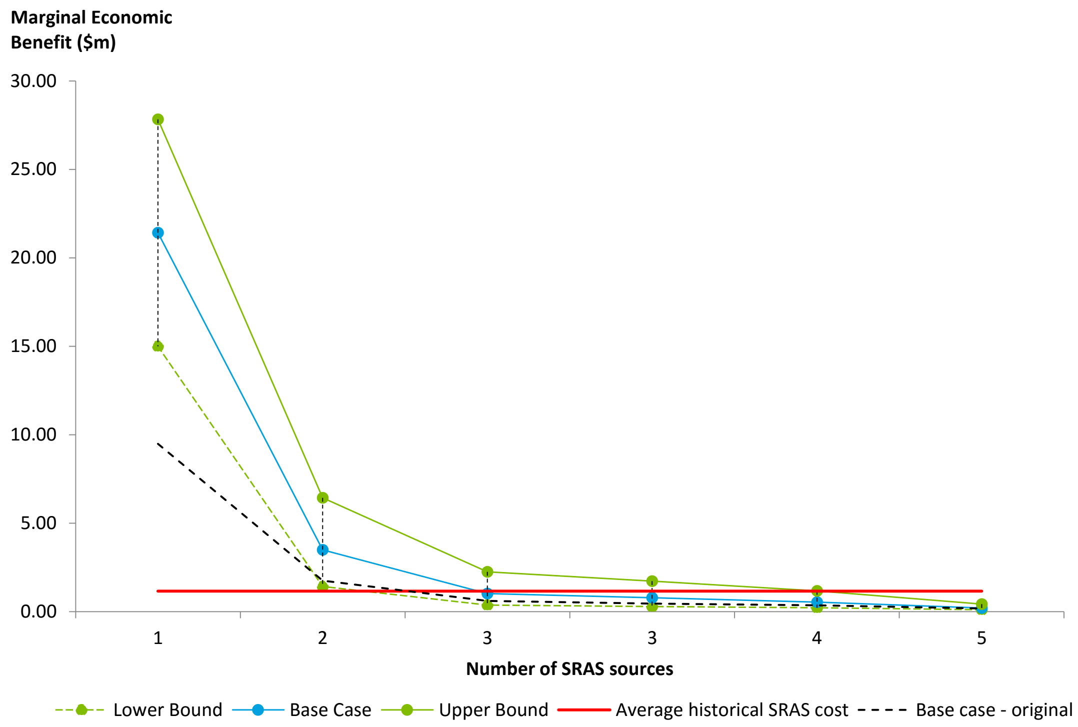



**Table 24. Optimal level of SRAS in South Australia – flat VCR ($m, FY15)**

| Number of SRAS sources >> | 1 | 2 | 3 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Probability weighted benefit | 21.42 | 3.49 | 1.03 | 0.79 | 0.54 | 0.22 |
| Marginal cost | 1.17 | 1.17 | 1.17 | 1.17 | 1.17 | 1.17 |
| Net benefit (base case) | 20.26 | **2.33** | -0.14 | -0.37 | -0.63 | -0.95 |
| Net benefit - lower | 13.84 | **0.26** | -0.79 | -0.87 | -0.94 | -1.05 |
| Net benefit - upper | 26.67 | 5.27 | **1.09** | 0.56 | 0.01 | -0.74 |

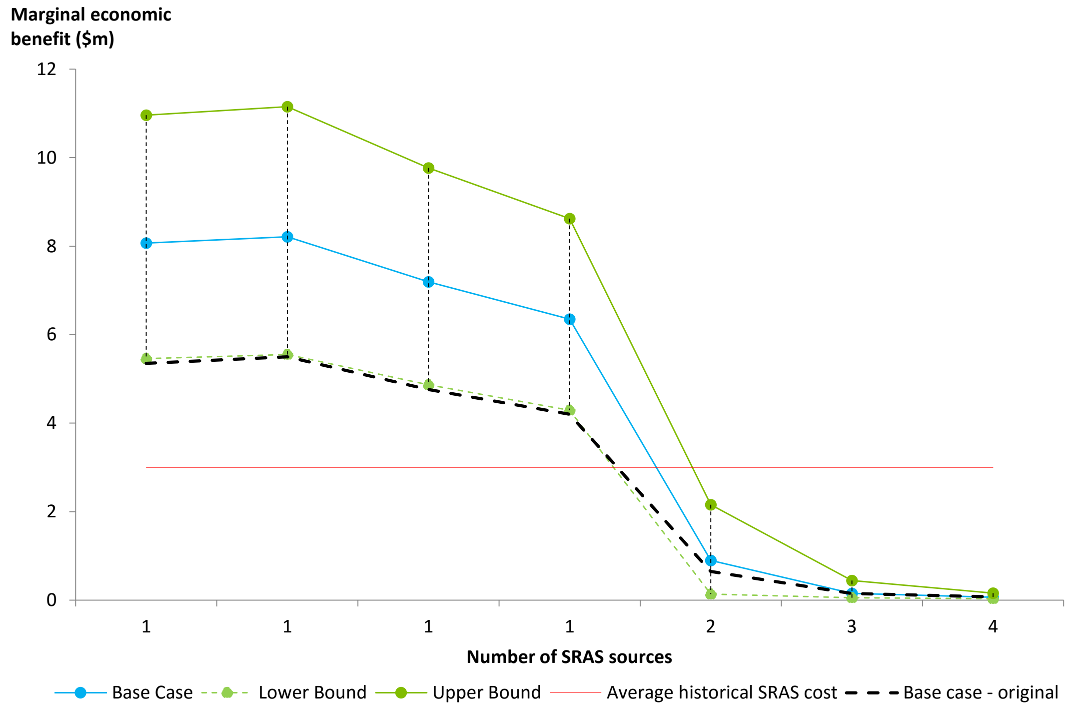
Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

The optimal level of SRAS providers for South Australia is two (2) under both the case where the average SRAS cost and the case where the real 2015 cost of SRAS procurement is used instead (the latter is not presented in this appendix for confidentiality reasons).

This outcome remains unchanged from our July 2016 report.

## Tasmania

### Figure 15: Optimal level of SRAS in Tasmania – flat VCR




### Table 25. Optimal level of SRAS in TAS – flat VCR ($m, FY15)

| Number of SRAS sources >> | 1 | 1 | 1 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|
| Probability weighted benefit | 8.07 | 8.21 | 7.19 | 6.35 | 0.90 | 0.15 | 0.07 |
| Marginal cost | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Net benefit (base case) | 4.83 | **5.08** | 4.19 | 3.35 | -2.34 | -2.85 | -2.93 |
| Net benefit - lower | 2.22 | **2.42** | 1.87 | 1.29 | -3.10 | -2.94 | -2.97 |
| Net benefit - upper | 7.72 | **8.02** | 6.77 | 5.62 | -1.08 | -2.55 | -2.84 |

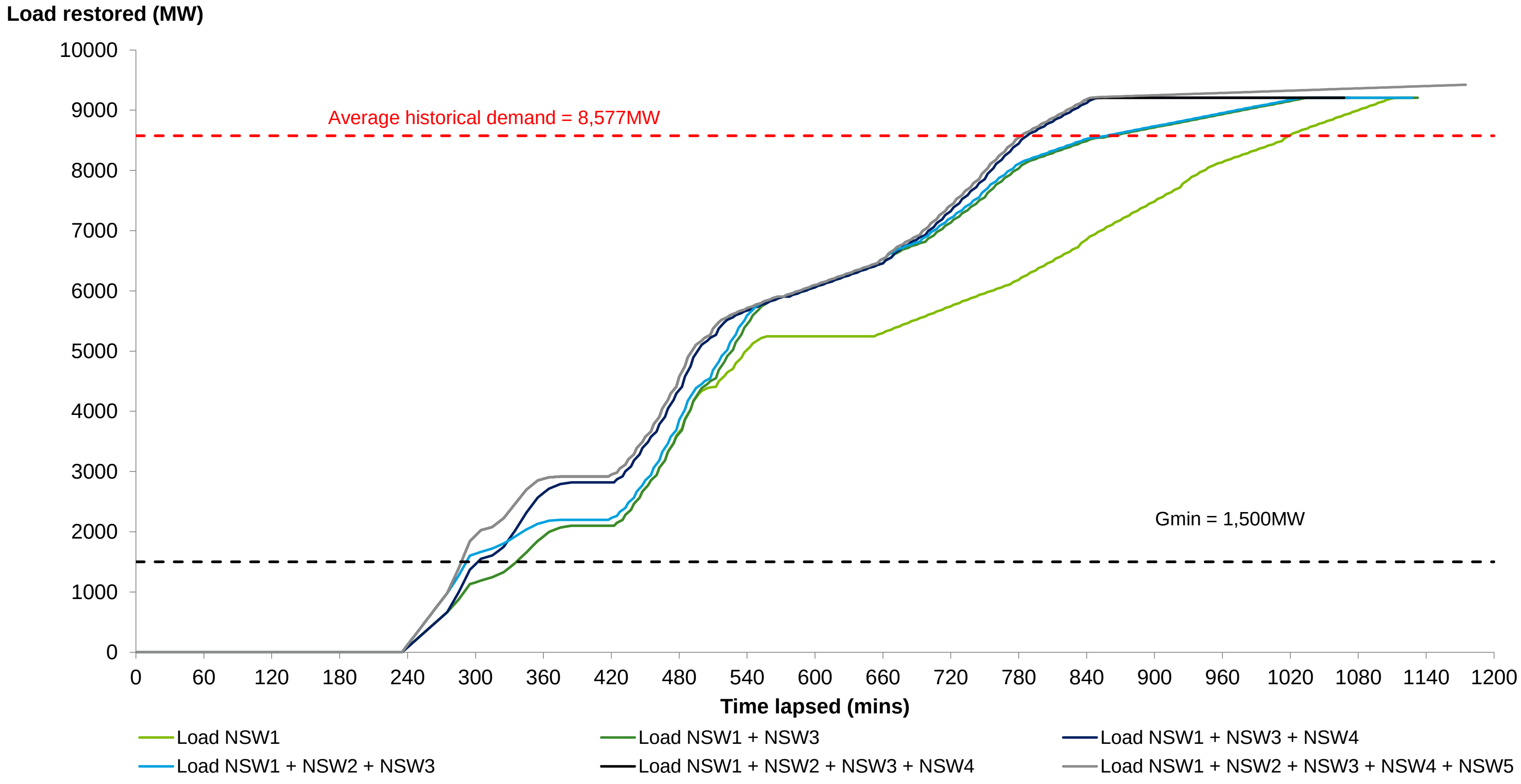
Source: Deloitte Access Economics, AEMO SRAS Tender Process Report

The optimal level of SRAS providers for Tasmania is one (1) under both the case where the average SRAS cost and the case where the real 2015 cost of SRAS procurement is used instead (the latter is not presented in this appendix for confidentiality reasons).

This outcome remains unchanged from our July 2016 report.

# Appendix B Restoration curve for NSW under the new set of assumptions

**Figure 16 NSW load restoration under new assumptions (slower ramp rate and 210 minute delay)[3]**




[3] The periods between additional load and generation being restored (i.e. horizontal sections of the curves) have not been doubled, explaining why these curves show New South Wales' average historical demand being restored sooner than double the time required in the July 2016 curve (plus 210 minutes).

# Limitation of our work

## General use restriction

This report is prepared solely for the use by the AEMC. This report is not intended to and should not be used or relied upon by anyone else and we accept no duty of care to any other person or entity. The report has been prepared for the purpose of conducting an economic assessment of SRAS in the NEM. You should not refer to or use our name or the advice for any other purpose.

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