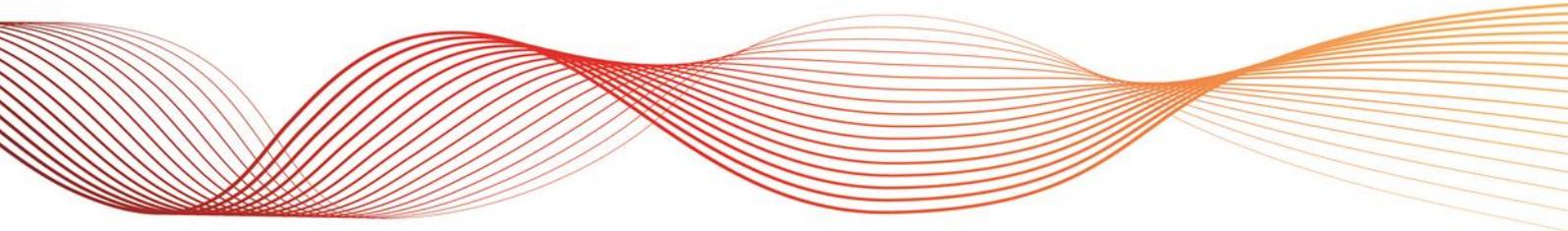




# VALUE OF CUSTOMER RELIABILITY REVIEW

FINAL REPORT

Published: **September 2014**





# IMPORTANT NOTICE

## Purpose

The purpose of this publication is to provide information about the outcomes of AEMO's 2013–14 Value of Customer Reliability (VCR) review.

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## EXECUTIVE SUMMARY

The Australian Energy Market Operator (AEMO) has completed a National Electricity Market (NEM) wide review of the value of customer reliability (VCR), providing national level VCRs for the first time. The study was requested by the Standing Council on Energy and Resources, now the Council of Australian Government (COAG) Energy Council, and is the largest-ever of this scope.

The VCR represents, in dollars per kilowatt hour (kWh), the willingness of customers to pay for the reliable supply of electricity. The VCR assists electricity planners, asset owners, and regulators to strike a balance between delivering secure and reliable electricity supplies and maintaining reasonable costs for customers.

AEMO's review commenced in March 2013 and sought to improve understanding of customer reliability expectations by producing VCRs to a greater degree of granularity, reflecting customers of different sizes, locations, and patterns of consumption across the NEM.

This report sets out the final results from the VCR review, updating the state-level VCRs derived from the results of AEMO's Victorian VCR study completed in 2007–08.

### Key findings

AEMO's assessment of the survey findings includes the following:

- Residential VCR values are similar across all NEM states.
- The most important outage characteristics affecting residential VCR values are length of outage and whether the outage occurred at the time of the NEM daily peak.
- Residential VCR values have not substantially changed since the 2007–08 values. However, survey feedback indicates that residential customers are concerned about the rise in electricity prices since 2007–08, which has resulted in an increased customer focus on implementing energy efficiency measures.
- Business VCR values on average continue to be higher than the residential values, consistent with other Australian and international studies.
- Business VCR values for the commercial and agricultural sectors are notably lower than the 2007–08 values. Drivers include increased electricity costs since 2007–08 and the implementation of energy efficiency savings by businesses in these sectors.
- Larger businesses tend to have a lower VCR value than smaller businesses, reflecting the likelihood that larger businesses are better equipped to mitigate against the impact of power outages.
- The survey indicates the majority of residential and business customers are satisfied with their current level of reliability and consider it to be of a high standard.
- The VCR values are broadly consistent with international and Australian VCR studies, where a similar survey methodology and approach has been used.

### VCR review approach

AEMO consulted widely with industry stakeholders to develop an appropriate methodology and approach to derive a new set of VCR values. Following this consultation, AEMO adopted a survey-based choice modelling and contingent valuation approach to derive the VCR values. Due to their unique load characteristics, customers directly connected to the transmission network (direct connect customers) were surveyed separately to residential and business customers using a direct cost measurement approach.

AEMO also engaged international econometric modelling expert Professor Riccardo Scarpa to undertake VCR survey design and development, and review AEMO's interpretation of the survey results.

### Survey results

Between November 2013 and July 2014, AEMO surveyed approximately 3,000 residential, business and direct connect customers across all NEM states. Customers were surveyed on their preferences regarding different types



of power outages, reflecting a range of attributes including time of day, duration, frequency, severity, and season. Where survey results and supporting outage profile information were robust, AEMO produced VCR values at a granular level.

Using this approach, AEMO derived VCR values for residential customers by NEM state and for business customers by industry sector and size of customer. For residential customers, further granularity of VCR values by state sub-regions, at central business district, urban, and rural level, was explored. However, survey results did not support statistically significant variations in customer preferences. The granularity of the business customer results is largely consistent with AEMO’s objective to derive VCR values reflective of different customer sizes, and consumption patterns.

Overall, AEMO found the NEM-wide residential VCR value to be \$25.95 per kilowatt-hour (kWh), with limited variation across the average state-level values. Aggregated VCR values for the agricultural, commercial, and industrial business sectors across the NEM range from \$44.06 per kWh to \$47.67 per kWh.

Results for direct connect customers were separately derived using responses received directly from the direct measurement survey. Due to large variations in direct costs each customer provided via this process, and in order to protect commercial confidentialities, indicative direct connect VCR values have been produced. Based on the survey responses, AEMO found the indicative NEM-wide VCR value for direct connect customers to be \$6.05 per kWh.

The aggregated NEM-wide VCR value, reflecting residential, business, and direct connect customers, is \$33.46 per kWh. These results are summarised in Table 1.

**Table 1 NEM-level VCR results (\$/kWh)**

Customer class	Residential	Agriculture	Commercial	Industrial	Direct connect customers	Aggregate NEM wide value
VCR	25.95	47.67	44.72	44.06	6.05	33.46

### Next steps

AEMO will apply the VCR survey results in undertaking Victorian and national transmission planning as part of its economic planning approach. AEMO recognises the VCR values may also be applied in other regulatory, market, and policy contexts within the NEM. To assist stakeholders with these current and potential applications, AEMO will publish a VCR Application Guide in October 2014 for consultation.

AEMO will also conduct a VCR workshop from 9.30 am to 12.30 pm on 23 October 2014 via video conference from its Melbourne, Sydney, and Brisbane offices to discuss the VCR survey results and feedback on the draft VCR Application Guide. Please email AEMO at [support.hub@aemo.com.au](mailto:support.hub@aemo.com.au) for further details about the forum or to register your attendance.



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# 1. INTRODUCTION

## 1.1 Purpose

This document sets out the results of Australian Energy Market Operator's (AEMO's) 2013–2014 review of the Value of Customer Reliability (VCR) (VCR review).

This VCR review has been carried out by AEMO at the request of the former Standing Council on Energy and Resources (SCER), now the Council of Australian Governments' (COAG) Energy Council.

## 1.2 Background

### Value of Customer Reliability

The VCR represents, in dollar terms, the estimated aggregated value that customers place on the reliable supply of electricity. The actual value will vary by the type of customer and the characteristics of the outages being considered. The VCR at different points on the grid would then vary based on the mix of customer types at that point. As customers cannot directly specify the value they place on reliability, the VCR plays an important role in determining the efficient level of investment in, and efficient operation and use of, electricity services required by customers in the National Electricity Market (NEM).

### AEMO's VCR review

AEMO operates the wholesale and retail electricity and gas markets across eastern and south-eastern Australia, oversees the system operations and security of the NEM power system and Victorian Gas Declared Transmission System, and is responsible for national transmission planning.

AEMO commenced the VCR review in 2013 following the SCER's 2009 Review of Extreme Weather Events. The SCER tasked AEMO with delivering national-level VCRs.<sup>1,2</sup>

A VCR review was timely as:

- A comprehensive national survey had not been undertaken, and a detailed VCR survey had not been undertaken in Victoria since VENCORP's (now AEMO's) 2007 survey.
- There was a need to develop more granular VCRs for use in planning and revenue setting.

The review aims to improve understanding of the level of reliability that customers expect by producing VCRs at a more granular level for the nature of the outage, different customer and business categories than has previously been available. This will support improved decision-making across the electricity industry and assist in achieving the National Electricity Objective (NEO).<sup>3</sup>

### VCR approach and application

On 11 March 2013, AEMO published a VCR Issues Paper<sup>4</sup> seeking stakeholder input on how best to determine the VCR, and under which circumstances NEM planners, system and network operators, regulators, and policy makers should apply the values.

After engaging with stakeholders on the submissions received, AEMO published a VCR Directions Paper setting out its proposal on how best to measure the VCR.<sup>5</sup> The Directions Paper proposed to calculate a range of VCRs

<sup>1</sup> SCER also directed the Australian Energy Market Commission (AEMC) to carry out a review of National Electricity Network Reliability Framework and Methodology, for which the VCR values are a relevant consideration.

<sup>2</sup> The Productivity Commission identified that reliability standards in the NEM should be based on the value customers place on reliability in its Inquiry Report on Electricity Network Regulatory Frameworks, April 2013 (r.14.1), <http://www.pc.gov.au/projects/inquiry/electricity/report>.

<sup>3</sup> Defined in Section 7 of the National Electricity Law as: "to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to – (a) price, quality, safety, reliability and security of supply of electricity; and (b) the reliability, safety and security of the national electricity system".

<sup>4</sup> The VCR Issues Paper is available at: <http://www.aemo.com.au/Consultations/National-Electricity-Market/Value-of-Customer-Reliability-Issues-Paper>. Published 11 March 2013.

<sup>5</sup> The VCR Directions Paper is available at: <http://www.aemo.com.au/Consultations/National-Electricity-Market/Open/Value-of-Customer-Reliability-Directions-Paper>. Published on 31 May 2013.

for each transmission connection point in the NEM, measuring the value customers place on different outage attributes, including time and duration. The Directions Paper proposed that a choice survey-based modelling approach be used to measure VCR with contingent evaluation questions included to estimate non-financial losses.

In the Directions Paper, AEMO acknowledged it could not specify all of the contexts in which the VCR should be applied in the NEM. While the primary aim of the review is to develop a suite of VCRs focused on delivering better network investment decisions, the VCRs calculated through the review will also benefit other NEM processes by providing confidence that the value customers place on reliability is reflected in the outcomes delivered by those processes.

In November 2013 AEMO published a Statement of Approach for the VCR review, building on the stakeholder feedback and issues raised over the review process, including consultation with the Australian Bureau of Statistics (ABS).<sup>6</sup>

The Statement of Approach set out AEMO's intention to:

- Deliver VCRs nationally for four different customer categories (including different sector types).
- Enable VCRs to be produced at the transmission node level in the NEM.
- Develop VCRs that incorporate a number of attributes to account for uncertainty. This includes attributes such as outage duration, severity and time of day.
- Conduct a survey based on choice modelling and contingent valuation approaches to obtain VCRs for residential and business customers.
- Approach customers directly connected to the transmission network (direct connect customers) separately as part of the VCR review due to the unique impact of outages on them.
- Engage Professor Riccardo Scarpa, an international academic consultant from the University of Waikato in New Zealand, to undertake survey design and development, and review AEMO's interpretation of the survey results.

The Statement of Approach was complemented by a methodology paper provided by Professor Riccardo Scarpa,<sup>7</sup> setting out the underlying survey design and methodology for calculating VCR values based on a choice modelling technique.

## Pilot survey and Updated Statement of Approach

Following publication of its Statement of Approach, AEMO commissioned a market research firm to undertake pilot residential and business surveys in November and December 2013. The key objectives of the pilot study were to:

- Test the survey instrument (a web-based survey using choice modelling techniques).
- Verify the ability of the survey to deliver estimated VCR coefficients and other statistics at required levels of accuracy.
- Identify any practical issues relating to survey recruitment and execution.

The pilot survey achieved these objectives and was valuable for informing revisions to the sampling plan and survey approach ahead of the main survey. The residential pilot survey largely performed as expected, however, the business survey did not deliver useful responses and highlighted a need to amend the survey design and implementation approach for the next phase of the project.

In January 2014, AEMO held a stakeholder workshop to discuss issues arising from the pilot surveys. Following this feedback, AEMO published an Updated Statement of Approach detailing the changes made to the survey approach in light of the outcomes from the pilot study.<sup>8</sup> In the Updated Statement of Approach, AEMO reiterated its intention to publish a matrix of VCR estimates (in \$/kWh) for significant outage variables reflecting geographic (state/sub-region), customer category and demographic dimensions, noting that the emerging results may be less granular than previously anticipated, based on the scale of the sample achieved.

<sup>6</sup> Statement of Approach and Methodology Paper for the VCR review is available at: <http://www.aemo.com.au/Consultations/National-Electricity-Market/Open/Value-of-Customer-Reliability-Statement-of-Approach>.

<sup>7</sup> The methodology paper is available at: <http://www.aemo.com.au/Consultations/National-Electricity-Market/Open/Value-of-Customer-Reliability-Statement-of-Approach>.

<sup>8</sup> The Updated Statement of Approach is available at: <http://www.aemo.com.au/Electricity/Planning/Value-of-Customer-Reliability-review>. Published on 7 March 2014.



## Main survey

In March 2014, AEMO commenced implementation of the main residential and business customer surveys in line with the approach set out in the Updated Statement of Approach.

A range of recruitment methods was employed to engage residential and business customers in the survey process. To assist the customer recruitment process AEMO engaged a number of market research service providers with a presence across all NEM regions. Response rates for both residential and business surveys were lower than anticipated, with quotas taking additional time to be filled.

AEMO also directly approached a range of directly-connected business customers to separately participate in the VCR review. These customers were interviewed on a one-on-one basis, providing separate direct feedback on the impact of a range of outage scenarios on their business operations.

### 1.2.1 Finalisation of the VCR results

Recruitment for all customer types was closed at the end of July 2014 with the results modelled and customer feedback analysed over August and September 2014.

As part of this process AEMO has sought independent review of its work, particularly in relation to the modelling assumptions. AEMO commissioned Dr Bill Kaye-Blake of PricewaterhouseCoopers in New Zealand to support this review process.

The study results are set out in Chapter 3. AEMO also intends to publish an Application Guide for stakeholder consultation, setting out AEMO's views on how the updated VCR values should be interpreted and applied. The Application Guide will be published in advance of the stakeholder workshop in late October 2014.

AEMO's application of the VCR survey results to its Victorian and national transmission planning functions is set out in Chapter 5 of this report.

## 2. SURVEY APPROACH, DESIGN AND IMPLEMENTATION

This chapter provides an overview of the VCR survey approach, methodology and implementation.

### 2.1 Survey approach

#### 2.1.1 Residential and business customers

After considering various approaches to measure VCR and undertaking stakeholder consultation,<sup>9</sup> AEMO selected a choice modelling and contingent valuation approach to measuring VCR values for residential and business customers. This combination was the preferred approach for the following reasons:

- Choice modelling asks participants to choose between specific options across both reliability and cost dimensions. Thus, participants are not required to undertake much hypothetical reasoning and are better able to reveal true customer willingness to pay for (WTP), or willingness to accept (WTA), different levels of reliability.
- Choice modelling seeks to understand the utility placed on specific outage attributes by customers, enabling more granular VCR values to be derived.
- This approach is considered more appropriate than a Direct Cost Approach or Economic Principle of Substitution Approach as customers place their own financial value on their non-financial costs.
- A literature review showed that choice modelling is the predominant approach to modelling VCR values internationally.<sup>10</sup>
- Stakeholder submissions to AEMO supported the use of a choice modelling and contingent valuation approach to measure VCR values across the NEM.

#### 2.1.2 Direct connect customers

In the VCR Statement of Approach, AEMO recognised that large direct connect customers should be surveyed separately for the VCR review. The potential impacts of outages on large direct connect customers differ significantly from other large customers and therefore the value they place on electricity will reflect this. Following the publication of the VCR Statement of Approach, AEMO undertook a further literature review and stakeholder consultation to develop a survey approach for large direct connect customers.

In the Updated Statement of Approach, AEMO concluded that a direct measurement survey approach would be used to survey large direct connect customers. Under this approach, participants would be provided with a hypothetical outage scenario and asked a detailed set of questions to capture all direct and indirect costs of the outage scenario. The direct measurement approach was considered preferable for direct connect customers because:

- Direct connect customers in the NEM are comprised of large mining and industrial loads that are better equipped to calculate the losses incurred due to electricity outages than other business customers.
- Often there are no choices or substitutes that would affect their outage preferences.
- Their use of electricity, and hence the effects ensuing from its discontinuity of supply give rise to a much wider range of potential losses of production, and;
- Stakeholders supported a direct measurement approach to measure the VCR over a choice modelling or contingent evaluation approach.

<sup>9</sup> AEMO's VCR Issues Paper sought stakeholder feedback regarding the approach (or combination of approaches) most appropriate for measuring VCR that AEMO should consider employing for the Review.

<sup>10</sup> Scarpa Methodology Paper, page 12. Choice modelling surveys have been conducted by a range of organisations, including ActewAGL, SA Power Networks, the New Zealand Institute of Economic Research (NZIER) (for the New Zealand Electricity Authority) and London Economics (for the UK Office of Gas and Electricity Markets (OFGEM)).

## 2.2 Survey design

### 2.2.1 Residential and Business customers

A combination of choice modelling and contingent valuation techniques was used to derive VCRs for residential and business customers in the NEM.

#### Contingent valuation (WTP)

The contingent valuation questions asked participants for their willingness to pay to avoid experiencing basic outages. The basic outage, determined based on an assessment of available historical outages, was defined as follows:

“

*Please imagine that your most likely unexpected power outage is once every six months and with duration of one hour. It is likely to be on a weekday, in winter, off-peak and localised (i.e. only affecting your street).*

”

The survey then asked respondents to consider how much they would be willing to pay to avoid such an outage, in dollar or bill percentage amounts.

“

*Consider the possibility of avoiding this type of power loss during this outage by paying towards additional investment to 'bolster' the network or alternative power supplies.*

*Would you be willing to pay an increase of \$3/month in your electricity bill (over six months this is a total of \$18) to avoid this type of outage?*

”

In the pilot survey, the WTP questions were posed in a table format. A series of WTP amounts were displayed in rows (\$1, \$2, \$3, \$5, \$8, \$10 and \$12) and the degree of certainty for which a customer would be willing pay to avoid an outage were displayed in columns, ranging from “I would certainly pay it” in column 1 to “I would certainly not pay it” in column 5. By ticking the appropriate box, probability values could be assigned to each WTP value.

The format of the WTP questions was updated in the main survey to simplify the survey and reduce the likelihood of respondents defaulting to a \$0 WTP response (i.e. by selecting “I would certainly not pay it” for all WTP amounts displayed). One question gave respondents a WTP amount (a ‘bid’) and asked if they were willing to pay that amount to avoid an outage. A second question then presented respondents with a different bid, and they were again asked whether they were willing to pay the bid. The second bid was based on the answer to the first question. A ‘yes’ answer led to a higher bid; a ‘no’ led to lower bid. The combined answers to the two bids (no-no, no-yes, yes-no, yes-yes) produced data that was analysed to estimate respondents’ WTP.

#### Choice modelling (WTA)

The choice modelling section of the survey asked participants to consider a series of questions where they chose preferred outage scenarios defined by a set of attributes and compensation amounts for experiencing the outage. Participants were presented with the following scenario:

“

*We ask you to consider accepting a rebate or discount on your electricity bill to compensate you for experiencing specific types of unexpected power outages. Imagine the following scenario: power outages are inevitable but new regulation requires your electricity provider to compensate you with a rebate for the inconvenience caused to you by specific unexpected power outages.*

”

Participants were asked a series of eight questions. For each question, participants were presented with three outage scenarios and associated compensation amounts to the experience the outage. They were then asked which scenario they would most prefer, weighing the trade-off between reduced reliability and compensation. Each outage scenario was defined by the following outage attributes:

1. severity (localised or widespread)
2. duration (1 hour, 3 hours, 6 hours or 12 hours)
3. frequency (2 times a year or 3 times a year)
4. season (summer or winter)
5. day of the week (weekday or weekend)
6. peak (7-10 am and 3-6 pm) or off peak (all other times)
7. monthly bill decrease accepted for incurring the outage scenario described (nil., \$3 a month, \$7 a month or \$15 a month for the residential survey, and 1 per cent, 2 per cent and 3 per cent of monthly business participants' average bill for the business survey).

Outage attributes 1, 2 and 6 were outlined by AEMO in the VCR Directions Paper as characteristics likely to affect the value placed by customers on reliability.<sup>11</sup> Outage attributes 3 to 5 were included due to the strong evidence found in previous VCR studies that they affected the value placed on reliability.<sup>12</sup> The inclusion of a monetary attribute, the monthly bill decrease, enables monetary values to be calculated for each attribute.<sup>13</sup>

Based on participant responses to these questions, it is possible to gain insight into the outage attributes which are important to customers and statistically estimate the monetary value which is placed on experiencing outages of a specific attribute. These values when combined with consumption and history data can be used to derive the value of unserved energy for an outage of particular characteristic.

### Combining choice modelling and contingent valuation results

The choice modelling (WTA) results were combined with contingent valuation (WTP) results to produce the VCR estimates. The VCR depends on the nature of the outage and in particular on its determinants of value. These values were defined comparatively in the choice modelling exercise. To assign them a dollar value, the contingent valuation questions produced a baseline value for a “typical” outage. Once the value of this “typical” outage was established, it was possible to use the choice modelling results to derive the value of other outages that had different characteristics (e.g. duration, time of the year, time of the week, severity, etc.). In practice, the VCR of a specific outage will depend on the basic outage value, plus or minus the values of any difference between the specific outage and basic, baseline outage.

In respect of all outage scenarios and attributes tested, AEMO has sought to develop incremental VCR values only where statistically robust results have been delivered.<sup>14</sup>

### Rare but long outage

The residential and business customer survey asked participants about their willingness to pay to avoid high impact low probability events. The following scenarios were presented to participants:

<sup>11</sup> AEMO, VCR Directions Paper, p.11-12.

<sup>12</sup> AEMO, VCR Methodology Paper p.5

<sup>13</sup> New Zealand Electricity Authority, *Investigation into the Value of Lost Load in New Zealand – report on methodology and key findings*, July 2013, p.15.

<sup>14</sup> This is discussed in section 3.2.2 and 3.3.2 of this report.

- a one in ten year power outage lasting one day
- a one in forty year power outage lasting one week, and
- a one in ten year power outage lasting four hours. This power outage would occur at peak time during a summer peak wave where daily temperatures remain above 35 degrees.

The extreme weather outage contingent valuation questions were added to the main survey following stakeholder feedback on the pilot survey.

### Consumer demographics and behaviour questions

The residential and business surveys both contained additional questions intended to assist in contextualising a participant's survey response and the value which they placed on the reliable supply of electricity. This included:

- customer demographic questions
- locational details including State and postcode
- average bill and consumption information
- National Metering Identification (NMI) number (for business customers only)<sup>15</sup>
- back-up supply
- energy efficiency investments and conservation behaviours

The information collected from these questions was later used to help verify and identify drivers for change in the VCR values over time and across studies.

#### 2.2.2 Direct measurement survey for direct connect customers

A direct cost approach to measuring the VCR seeks to have participants estimate the economic cost of an outage or the cost of the steps taken by customers to mitigate the risk of an outage, or its impacts.<sup>16</sup> The direct measurement survey asked large direct connect customers to:

- Describe the core business processes that occur at their main or largest site where electricity supply is most critical
  - Of the business processes identified, outline which are critically reliant on a continuous supply of electricity for the efficient operation of those processes
  - Note whether the cost impacts of a loss of power supply vary over time of year/week/day
- Identify what would be the worst possible month(s), day(s) and hour(s) for a loss of power supply to occur at their main or largest site.
- Identify and quantify the types of direct costs their business operations would incur at their main or largest site (i.e. lost production, damage to plant or equipment, overtime labour costs) if it experienced two localised ten-minute unplanned outages over a twelve-month period (the base case). The unplanned outages would occur during a weekday between 7-10 am or 3-6 pm.
  - Note the incremental direct costs if these outages were extended beyond 10 minutes by an hour, six hours, twelve hours or seven days.
  - Note the incremental direct costs if these outages increased to four times a year, six times a year or ten times a year.
  - Identify and quantify any cost savings that would occur if the base case outage scenario occurred.
  - Identify and quantify any indirect costs which the business would incur if the base case outage occurred.
- Provide any supporting information about their approximate electricity consumption and electricity supply costs.

In the development of the direct measurement survey, AEMO consulted with a range of directly connected customers and representative bodies.

<sup>15</sup> This was optional for residential customers.

<sup>16</sup> Oakley Greenwood, *Valuing Reliability in the National Electricity Market – Final report*, March 2011, p. 5.



## 2.3 Pilot survey implementation

The pilot residential and business surveys were carried out over November and December 2013, with 742 residential and 148 business customer responses received. The objectives of the pilot surveys were to:

- Test the survey instrument (a web-based survey using choice modelling and contingent valuation techniques).
- Verify the ability of the survey to deliver estimated VCR coefficients and other statistics at required levels of accuracy.
- Identify other practical issues associated with survey recruitment and implementation.

The pilot survey achieved its objectives and informed revisions to the sampling plan and survey approach ahead of recruitment for the wider customer survey process. The residential pilot survey largely performed as expected, however the business survey did not deliver useful responses and highlighted a need to amend the survey design and implementation approach for the next phase of the project. Based on the performance of the pilot surveys, aspects of the survey design, implementation and recruitment were adapted for the main phase of recruitment. The key changes made were:

- The sample size of the residential survey would be reduced to approximately 1,500 responses as the pilot responses showed a statistically significant relationship for the majority of the tested outage variables.
- Residential VCRs would be produced at a coarser level of granularity given challenges associated with obtaining the robust data necessary to produce more granular results.
- Recruitment for the business survey to be more targeted at specific industries to obtain statistically robust results across key industry sector reflecting Australian Bureau of Statistics (ABS) sector classifications. Customers recruited for an industry in one location would be considered representative of that industry in another location. Approximately 500–750 completed business survey responses would likely be required to obtain statistically robust results along industry lines.
- Business customer recruitment would be aided by clear criteria to ensuring recruitment of representatives in the business that can understand and discuss what the opportunity cost to their business may be of being without power over a short or long period.
- AEMO would employ a range of facilitated focus groups and computer-aided personal interview (CAPI) approaches to survey business customers.
- Direct connect customers would be surveyed using the direct measurement survey approach. This approach would likely be more appropriate than choice modelling given the larger directly connect customers' ability to directly calculate the losses incurred due to an outage.

## 2.4 Residential survey implementation

Customer recruitment to participate in the main residential survey commenced in March 2014. Surveys were administered online, with market research firms engaged to undertake telephone based recruitment of residential customers across the NEM to participate in the survey. A prize incentive was offered to increase the rate of participation.

The sample plan sought to recruit a total of 649 completed survey responses from all five NEM jurisdictions over two recruitment phases. To obtain a representative sample of the residential population, residential customers within each NEM region were recruited in accordance with CBD, rural and urban sub-regional groupings.<sup>17</sup>

During the recruitment period, AEMO engaged Professor Scarpa to undertake an interim assessment of the residential results available at the time. This enabled the statistical robustness of the results to be assessed over the same period, and allowed recruitment to be targeted to specific NEM sub-regions where divergences in customer preferences were emerging. The interim assessment identified a need to focus recruitment on residential customers in Tasmania to ensure statistically robust results could be obtained (which was subsequently delivered).

Recruitment for the residential survey closed in June 2014. A total of 674 residential customer responses was obtained from across the NEM regions and sub-regional groupings. These responses are set out in Appendix D.

<sup>17</sup> CBD, rural and urban groupings were determined on the basis of post code.

The results of the main residential survey have been combined with those from the pilot residential survey to produce VCRs for residential customers across the NEM.

## 2.5 Business survey implementation

Following the pilot study, changes were made to business customer recruitment and survey implementation. While the survey was accessed online, business customers were recruited to attend facilitated focus group sessions, hosted in CBD, urban and regional centres. Business participants completed the business survey at their focus group session. Representatives from AEMO and the market research firm attended the focus groups to answer queries and facilitate sessions.

The sample plan sought to recruit between 500-700 business customer responses over two recruitment phases. A representative spread of businesses were sampled across agricultural, commercial and industrial sectors reflective of ABS groupings. The sample for each group consisted of a representative spread of small, medium and large consumption customers.

Table 2 below sets out the ABS industry groupings for each industry sector.

**Table 2 Business sector breakdown by ABS industry groupings**

SECTOR	INDUSTRY GROUPINGS	ABS DIVISION
<b>Agriculture</b>	Agriculture, Forestry and Fishing	A
<b>Commercial</b>	Electricity, Gas, Water Supply & Communication Services	D, J
	Commercial Services and Education	L, N, K, P, Q, P, J, M, R, S
	Accommodation, Cafes and Restaurants	H
	Wholesale and Retail Trade	F,G
	Health and Community Services	Q
	Construction	E
	Transport and Storage	I
<b>Industrial</b>	Mining	B
	Manufacturing	C

The recruitment of business customers to participate in the survey was managed via telephone. It was important that recruiters ensured that businesses sent an appropriate business representative, one who was familiar with the electricity needs and costs of the business, to attend the survey with a copy of a recent electricity bill. The market research firm paid honorariums to business customers for completing the survey.

The Energy Users' Association of Australia (EUAA) and regional development centres located in NEM regions also provided assistance in the recruitment of business customers to participate in the VCR survey.

Business survey recruitment was closed at the end of July 2014. A total of 1,499 business customer responses was obtained from across the industry groupings and are set out in Appendix D. Only the results of the main business survey have been used to produce VCRs for business customers by sector across the NEM due to the low quality of pilot business survey responses.

## 2.6 Observations from survey implementation

The following observations were made following residential and business survey implementation:

- It was difficult to engage and recruit customers. This was in part due to:
  - The nature of the survey content and subject matter.
  - Limited financial incentives for respondents.
  - The nature of it being an online based survey (where certain locations/demographics were found to be more challenging to recruit).

- Difficulties associated with ensuring the ‘right’ person was filling in the survey — ideally this would be the bill payer for residential customers and a well-informed officer for a business customer, familiar with the business and its electricity requirements.
- The majority of residential and business participants were not familiar with AEMO and its functions. This may have contributed to slower than expected rates of recruitment.
- By its nature, the survey was more challenging to respondents than a usual “perception” survey as it sought to quantify non-economic losses under hypothetical scenarios. Changes were made during the pilot to improve the flow of the scripted recruitment material and the survey text. These changes appeared to significantly improve response rates.
- Multiple market research firms were required to recruit a representative spread of customers across the NEM. While the firms have specialist skills in customer recruitment, they typically have a stronger presence or speciality in a particular region or industry. Although an integral part of delivering the results, these services did add significantly to the overall cost of the project.
- The use of telephone-based recruitment combined with pre-survey information materials was generally effective in ensuring that responses were obtained from the most relevant household members and business representatives.
- The quality of business customer responses from focus groups was generally high and ensured that accurate NMI data and billing was obtained. Representatives from both AEMO and the market recruitment firm were available to assist business customers in finding information on their electricity bill and address queries about the survey questions. However, this method of recruitment is time and resource intensive.
- In contrast, the use of online panels allowed for responses to be collected quickly for both residential and business surveys. However, the quality of responses was generally of a lower standard compared to those received from customers recruited by telephone and provided in a focus group. For example, some online panel responses did not provide accurate NMI and billing responses. Neither AEMO nor market recruitment firm staff were on hand to assist participants with any queries in completing the survey.
- A further disadvantage of online panels was its limited ability to screen participants on their eligibility to undertake the survey. Online panel participants were still provided with the same pre-survey materials as participants recruited via telephone. However, some online panel responses could not be included as they were not provided by the energy decision makers in the household or business.
- The use of incentives did not bolster recruitment rates as greatly as anticipated. In particular, the use of honorariums to incentivise business customers appeared to be ineffective in recruiting larger businesses. The majority of business customer responses were from small and medium sized businesses.
- “Functional literacy” was a common issue. Many respondents had difficulties interpreting their electricity bill and grasping the underlying technical and financial concepts covered in the survey. This was evident from the customer feedback received during the focus group sessions and on the survey feedback itself. As the survey was conducted online using tablets supplied to respondents there were additional challenges in certain sub-regions and demographics, relating to internet access and the use of technology.

## 2.7 Direct connect customer implementation

### 2.7.1 Main survey approach

To implement the direct measurement survey, AEMO established a list of direct connect customers reflecting a range of energy intensive sectors across the NEM. Direct connect customers were invited to participate in the study on a one-on-one basis with AEMO representatives. As the survey asked participants to provide details of the direct costs of an outage on their business operations, it was important to ensure the most relevant person(s) from the business answered the survey questions, and to emphasise the confidentiality of survey responses.

Industry groups Grid Australia and the EUAA assisted AEMO in contacting direct connect customers to participate in the survey.

Of the 30 direct connect customers contacted, 13 responses were received. These responses have been used as a basis to estimate VCR values for direct connect customers and better understand how outages impact such businesses and are managed.



## 2.7.2 Key observations of implementing the direct connect survey

The following observations were made following implementation of the direct connect survey:

- A number of direct connect customers were unwilling to participate in the survey because they did not want to provide information about the direct costs they would incur during an outage.
- Responding to the survey was a significant resource commitment for some businesses because the survey required input from staff across divisions.

## 3. VCR SURVEY RESULTS

This chapter sets out the detailed results of the VCR review, outlining the assumptions made, data used and methods and techniques employed to verify and validate the VCR values.

The rest of the chapter is organised as follows:

- Each major division in the survey research is presented in its own section: Residential (3.2), Business (3.3) and Direct connect (3.4)
- Within each of those sections, the headline results and key points are presented first. Then, the detailed description of calculations follows. Details include valuation results from the surveys, and the methods used to calculate load amounts, which are combined to create load-weighted averages.
- Section 3.5 describes the method for combining all results into the final aggregate NEM and stage VCR values.
- Section 3.6 reviews the work done to assess the validity and robustness of the estimates.

Residential customer VCR values are discussed first, followed by business customers and direct connect customers. Appendix A provides an overview of all VCR values for all customer types derived from the review.

VCR values from previous VCR studies are provided in Appendix G. While comparisons can provide interesting context, it is important to note that the different studies have each been conducted using their own specific approaches.

### 3.1 Development of residential and business VCR values

The residential and business surveys used both choice modelling and contingent valuation techniques to derive VCR values for residential and business customers in the NEM.

- The contingent valuation exercise determined what customers would be willing to pay to avoid a baseline outage. This outage was described in the survey as occurring once every six months, happening on a weekday in winter, at an off-peak time and in a localised area.
- The choice modelling exercise presented respondents with different types of outages by adjusting one or more of the outage attributes defined in the baseline case, for example, moving from a non-peak to a peak time.
- Statistical modelling for the choice modelling exercise found how the different attributes of an outage affected the value of each specific outage. Technically, it estimated how a change in an attribute changed the probability that respondents would accept a specific outage.
- The impact of a change on an attribute was found by estimating the model parameter for that attribute. Choice modelling was used to estimate the relative value of different types of outages with respect to the baseline outage.
- One of the attributes in the choice model was compensation in dollars, expressed as a decrease in the monthly bill. The conversion of other model parameters into dollar values was a simple calculation: the other parameters are divided by the dollar value parameter and multiplied by -1.<sup>18</sup> For example, to calculate the value of a peak outage relative to a non-peak outage, the 'peak time' parameter is divided by the 'bill compensation' parameter, and the result multiplied by -1.
- The contingent valuation and choice modelling results were combined to yield a \$/month value for each type of outage.
- The per-outage values were combined with additional data, the probability of each type of outage electricity consumption data. The result was the VCR values in \$/kWh.

<sup>18</sup> Bateman, I. J., et al, (2002), *Economic valuation with stated preference techniques: a manual*. Cheltenham, U.K.: Edward Elgar.

In developing the VCR values set out in this chapter, only outage variables with a high degree of statistical significance at a 99% level were considered. This means that there is less than a 1% chance that the relationship found between the survey responses and the outage attributes is random.

Academic literature about the statistical principles behind the contingent valuation and choice modelling survey techniques can be found in Appendix B.4.

## 3.2 Residential survey results

NEM-wide and state-level VCR values for residential customers are set out below in Table 3.

**Table 3 Aggregate residential VCR results (\$/kWh)**

State	NEM	NSW	VIC	QLD	SA	TAS
<b>Residential VCR</b>	25.95	26.53	24.76	25.42	26.88	28.58

### Observations

- The NEM-wide residential VCR value of \$25.95/kWh is higher than previous Australian studies. Inflation may play a part in this increase.
- Controlling for differences in electricity consumption levels, the study showed limited variations in values emerging across the NEM regions. Any differences are most likely due to statistical uncertainty from the sampling, but could also be explained by these underlying factors:
  - Victoria was on the low end of the residential VCR range, likely due to high residential gas usage.<sup>19</sup>
  - Tasmania was the highest, likely due to its relatively lower base level of reliability compared to other NEM regions and its high winter heating requirements.
  - Queensland had the second-lowest VCR value, likely due to lower heating requirements as a result of its mild winters compared to the southern states.
- AEMO's assessment of VCR survey results found there were either no statistical differences or minimal dollar differences in different geographic areas within States (CBD, urban and rural).
- The residential VCR values are of a similar magnitude to previous domestic studies.<sup>20</sup>
- The value of base case outage was 'low' – residential customers are unlikely to be greatly affected by such an outage.
- The most important outage characteristics to affect the residential VCR values were outage duration and daily peak time. The impact of other variables on the VCR was not sufficiently statistically significant to include in the estimates.

### 3.2.1 Sample characteristics

A total of 1,416 residential customers was surveyed across the pilot and main surveys. This sample has enabled NEM-wide and state level VCR values to be developed. As part of the survey, participants were asked questions about their demographic data and energy consumption behaviours. This information, combined with comments provided by survey participants, gives some insight into consumers' behaviour and what motivates them.

Residential customers were sampled from CBD, rural and urban areas across each of the NEM regions. Customers recruited were required to be over the age of 18 and the bill payer in the household. The resulting datasets indicate how different demographics value reliability in different ways.

**Table 4 Residential survey numbers**

State	NSW	VIC	QLD	SA	TAS	Total
<b>Number surveyed</b>	304	283	288	246	295	1,416

<sup>19</sup> Australian Energy Regulator (AER), 20 December 2013, *State of the Energy Market 2013*, p. 90. Available: <http://www.aer.gov.au/node/23147>.

<sup>20</sup> See Appendix G for results of previous domestic studies.

### 3.2.2 Detailed results and assumptions

#### Contingent Valuation (WTP)

The contingent valuation results were based on a pooled pilot and main survey sample. Respondents were asked to consider a baseline outage, which was uniformly defined for all respondents regardless of location.

**Table 5 Residential WTP results (\$/month)**

State	NSW	VIC	QLD	SA	TAS
WTP residential sample	2.32	1.24	1.69	2.05	1.64

- Responses to the contingent valuation questions indicated a large number of respondents (69.82%) had no willingness to pay to avoid the base case outage. This implies that the current level of reliability for electricity is perceived as satisfactory. It might, however, also include a component of strategic response from those who feared that a statement of a positive WTP would lead to a higher bill amount.
- The difference across regions (CBD, urban and rural) in terms of WTP was not found to be statistically significant.
- A non-parametric modelling (straight-line average) approach was used to produce the WTP results. Non-parametric modelling links results directly to the data, rather than estimating model parameters from the data and is intended to result in a more conservative and more statistically robust estimate of the sample's WTP. See Appendix B.4 for further details.
- Use of parametric modelling however would require complex modelling to be undertaken due to the nature of the data collected. While the modelling may yield more statistically powerful results they would be difficult to interpret and apply. Parametric modelling also requires supplemental assumptions, such as the type of statistical distribution to use in modelling.
- The WTP results were considered acceptable by the peer reviewers. The results also reflect survey participant feedback that suggested many customers are satisfied with their base level of reliability and are not willing to pay more to avoid a basic outage.

#### Choice Modelling (WTA)

The sample of completed responses for the residential choice modelling survey produced 10,832 choices.

#### Modelling process

- Multinomial logit models (MNL) were used to fit the choice modelling data. These are statistical models appropriate for representing the utility-maximising decision process of an individual or segment in a particular context. They model the probability that a respondent gives a particular answer, based on the nature of the outage described. See Appendix B.4 for further details.
- In this survey, model estimates were derived from an estimated probability function representing the likelihood of a preference for a particular outage scenario in response to the proposed compensation.
- WTA compensation estimates were developed for each NEM region.
  - The residential sample was divided along state lines. Five separate MNL models were run for New South Wales, Victoria, Queensland, South Australia and Tasmania to estimate respondent outage and compensation preferences for each.
  - An alternative modelling technique using interaction effects models was not used in developing WTA estimates, as this model would be larger and more complex than running a series of separate models.<sup>21</sup>
  - Interaction effect models are useful and generally more appropriate for identifying statistical differences between sample segments<sup>22</sup> than producing dollar estimates. Such models were used to determine the level of granularity of VCRs to be produced for this study sample.

<sup>21</sup> The main issue with interaction effects models is that it is hard to differentiate whether statistical differences within a sample are due to inherent attribute preferences or due to experimental error. These models make use of the entire residential sample which can hide experimental errors that are difficult to tease out when different sample segments are brought together. This issue is reduced when the sample is separated, for example by State, as attribute preferences and error variances can be more easily isolated and modelled.

- Only variables with a minimum 99% significance were included in the development of the VCR \$/kWh values. This was to ensure strong statistical robustness of results and minimise the likelihood of false inferences that could have a sizable impact on the final VCR values.

## WTA results

Table 6 below sets out the outage variables which the MNL models identified as being 99% statistically significant. Only the outage attribute values that are statistically significant to this level of confidence have been included in the derivation of \$/kWh values. Key observations across all outage variables tested are outlined below.

**Table 6 Statistically significant residential outage variable by state (%)**

Outage Variables	NSW	VIC	QLD	SA	TAS
Severity	✓ (99%)	✓ (90%)	X	X	✓ (95%)
Duration 3 hours	✓ (99%)	✓ (99%)	✓ (99%)	✓ (99%)	✓ (99%)
Duration 6 hours	✓ (99%)	✓ (99%)	✓ (99%)	✓ (99%)	✓ (99%)
Duration 12 hours	✓ (99%)	✓ (99%)	✓ (99%)	✓ (99%)	✓ (99%)
Peak time	✓ (99%)	✓ (99%)	✓ (99%)	✓ (99%)	✓ (99%)
Summer	X	✓ (90%)	X	X	✓ (99%)
Frequency 2 times per year	X	X	X	X	✓ (95%)
Frequency 3 times per year	✓ (99%)	✓ (95%)	✓ (99%)	✓ (99%)	✓ (99%)
Weekend	X	X	✓ (95%)	X	✓ (95%)

- Consistently, the most valued outage variable across all regions is duration, especially so in Tasmania and Queensland, but not significantly lower in other regions.
- Weekend outages were valued at 95% statistically significant in Tasmania and Queensland but not across the other regions, and not at the 99% statistically significant level to which other results have been delivered. Therefore the weekend variable was not included in the final VCR values.
- In the surveys, the severity attribute was described in qualitative terms (e.g. a few blocks) making it difficult to source underlying outage history data to support the weighting of this variable in the resulting VCR values. The additional value that the severity attribute contributed to the VCR was also low across all NEM regions. Further, New South Wales was the only state where severity was 99% significant. Therefore, this outage variable was not included.
- In order to produce VCRs on a per outage basis, the outage frequency variables were also disregarded. This significantly reduced the complexity of calculation and underlying outage history required to support the results. Producing VCRs on a single-event basis also allows the results to be more readily applied in network planning.
- The VCR survey results indicate there is diversity of preferences regarding the season in which an outage occurs. For New South Wales, Queensland and South Australia, customers did not indicate a preference for either summer or winter outages; the season of the outage had no significant impact on model results. Customers in Victoria demonstrated a weak preference for summer outages, but the results did not reach the 99% level of statistical significance. The only state with a statistically significant preference regarding the season of outage was Tasmania. Its survey results showed that respondents prefer to experience an outage in summer rather than winter. Since season was a significant factor in VCR for only one state, the summer attribute for Tasmania was not included in calculating its residential VCR. This treatment allows results from Tasmania to be treated consistently with other states. Further detail on the treatment of the summer outage attribute can be found in Appendix B.4.
- It is recommended for future reviews that the issue of seasonality be explored further, in particular with Tasmania. Future work could include presenting respondents with different base cases, some in summer and some in winter, or additional questions to determine the drivers of seasonal preferences. The impacts of these

<sup>22</sup> For example, interaction effects models could be run to show differences in outage preferences from one state to another.

differences on VCR could then be estimated.

### Statistical differences – regional segmentation

At the start of this review, and as addressed in the earlier Issues Paper and Discussion Paper, it was considered that VCR values may differ within and across locations, i.e. state and sub-regions.<sup>23</sup> Using the pooled residential sample and interaction effect models, this hypothesis was tested.

#### Across NEM states

Interaction effects models were used to examine whether differences in customer preferences existed at a NEM region level compared to the pooled NEM sample. The results showed, at a 99% level of statistical significance, a difference between the value of avoiding winter outages in Tasmania compared to the pooled NEM sample. Similarly, for South Australia, the interaction models suggest some difference between the value of avoidance of summer outages and the pooled NEM sample but this finding was at a lower level of statistical significance. This likely reflects those regions' respective reliance on winter heating and summer air conditioning.

#### Across sub-regions

Across the NEM, there were minimal differences in preferences found between CBD, rural and urban respondents. CBD residents had a slightly higher willingness to accept larger compensation amounts for short duration outages than compared to those in rural and urban areas who shared similarly lower values.

**Table 7 Significant regional attribute interactions**

Outage Variable	Coefficient estimate	Statistical significance	Standard error
Urban outage duration 6 hours	0.37792	99%	0.09697
Rural outage duration 6 hours	0.33053	99%	0.10701

Given the negligible differences across regions, there is limited benefit in further disaggregation of residential VCRs into CBD, urban and rural sub-classes.

AEMO notes that in respect of application of the VCR values, there are some practical issues in supporting a transition from sub-region specific VCRs in that there is no clear cut definition of regional borders in the NEM.<sup>24</sup>

### Outage history

Historical outage data was used to support the development of VCR values based on the approach used in the study.

The residential peak outage attributes were combined together to create six outage scenarios considering daily, weekly and seasonal peak periods:

- Offpeak, weekday, winter
- Peak, weekday, winter
- Offpeak, weekend, winter
- Offpeak, weekday, summer
- Peak, weekday, summer
- Offpeak, weekend, summer

The residential duration attributes of DUR3, DUR6, DUR12, together with the base case, defined four duration outage scenarios:

<sup>23</sup> AEMO, 11 March 2013, *VCR Issues Paper*, page.10. Available: <http://www.aemo.com.au/Consultations/National-Electricity-Market/Value-of-Customer-Reliability-Issues-Paper>; AEMO, 31 May 2013, *VCR Directions Paper*, pages. 9-11. Available: <http://www.aemo.com.au/Consultations/National-Electricity-Market/Open/Value-of-Customer-Reliability-Directions-Paper>.

<sup>24</sup> For the purpose of this study, AEMO assigned respondents manually to a region using Local Government Area (LGA) postcode definitions and Google Maps. This is a highly resource-intensive exercise and is not recommended for future studies.

- Outages lasting 0-1 hour (base case)
- Outages lasting 1-3 hours
- Outages lasting 3-6 hours
- Outages lasting 6-12 hours

A VCR value for each one of the 24 outage scenarios was calculated for each state using the survey results. To derive aggregate residential state level VCR values, the 24 outage scenario-VCRs were weighted by their probability of occurrence based on a compilation of state specific outage history along the three peak and four duration variables. These “probability factors” are set out below:

**Table 8 Residential peak, weekday and summer outage probabilities by state**

State	Daily Peak	Weekday	Summer
NEM	0.30	0.30	0.53
NSW	0.32	0.31	0.50
VIC	0.30	0.28	0.48
QLD	0.24	0.22	0.63
SA	0.32	0.36	0.64
TAS	0.18	0.40	0.29

**Table 9 Residential outage duration probabilities by state<sup>25</sup>**

State	0-1	1-3	3-6	6-12
NEM	0.36	0.38	0.15	0.11
NSW	0.33	0.33	0.18	0.16
VIC	0.33	0.43	0.15	0.09
QLD	0.45	0.38	0.10	0.07
SA	0.27	0.42	0.21	0.10
TAS	0.41	0.39	0.12	0.08

Outage probabilities were derived using 2012 Australian Energy Regulator (AER) regulatory information notice (RIN) data.<sup>26</sup> The AER requires transmission network service providers (TNSPs) and distribution network service providers (DNSPs) to provide this data annually basis as a part of its economic benchmarking processes.

While it may be possible to base the outage scenarios on the participants’ actual historical experience with outages, the AER RIN data is a more credible and public data source. In addition, given the generally high level of electricity reliability in the NEM, it may be difficult for electricity customers to accurately recall their last outage experience.

Customer interruption to supply outage data provided by DNSPs in the RIN’s was used to produce the probability factors as approximately 95% of outages in the NEM occur at distribution network level.<sup>27</sup> This DNSP RIN includes customer loss of supply caused by outages at the transmission network level, capturing the effect that transmission outages have on customer supply.

To produce the outage probability values, the AER RIN data was collated across distribution networks by state and filtered on the following basis:

- Outages must be unplanned
- Outages must be greater or equal to five minutes in duration

<sup>25</sup> Rows sum up to 100%.

<sup>26</sup> The RIN is a regulatory instrument through which the AER obtains financial and operational data from network businesses.

<sup>27</sup> AER, 20 December 2013, *State of the Energy Market 2013*, p. 80. Available: <http://www.aer.gov.au/node/23147>.

- Outages must be greater or equal to 50 customers impacted

Each outage line entry in the AER RIN data was identified as occurring either on-peak/off-peak, on a weekday/weekend, and in the summer/winter time. The “Effect on System Average Interruption Duration Index (SAIDI)/ System Average Interruption Frequency Index (SAIFI)”<sup>28</sup> values were then summed along the three peak and four duration variables and divided by the feeder total SAIDI/SAIFI value to obtain feeder-specific outage probabilities.

Since the “Effect on SAIDI/SAIFI” values are produced along feeder lines, AER RIN data on customer connection feeder volumes was used to weight the feeder-specific outage probabilities to produce probabilities across all feeder types by state.

## Demand Profile

NEM-wide average hourly demand and peak factors were used to approximate unserved energy during a power outage.

AER RIN outage and customer data was also used to determine the NEM hourly consumption figure. A NEM-wide consumption average was used to highlight the dollar differences in respondent preferences between different states.

The peak factors were developed using data from AEMO’s Market Settlement and Transfer Solutions (MSATS) systems. They reflect higher consumption during weekdays and day time hours.

**Table 10 NEM demand and peak factors by outage scenario**

	Offpeak Weekday Winter	Peak Weekday Winter	Offpeak Weekend Winter	Offpeak Weekday Summer	Peak Weekday Summer	Offpeak Weekend Summer
<b>NEM average</b>	0.78	0.78	0.78	0.78	0.78	0.78
<b>NEM peak factor</b>	1.1	1.4	1.1	1.1	1.4	1.1

## Load weighting

The NEM residential \$/kWh result was derived by load weighting the state level \$/kWh results. Load weights were determined using 2012 Energy Supply Association of Australia (ESAA) State residential consumption data.

**Table 11 Residential load weighting by state**

ESAA Consumption and Connection Data	NEM	NSW	VIC	QLD	SA	TAS
<b>Residential consumption (TWh)</b>	50.03	20.10	12.06	11.74	4.14	1.99
<b>No. of Residential Connections</b>	8,197,932	3,116,809	2,312,250	1,806,860	732,350	229,663
<b>Load weight (%)</b>	<b>1.00</b>	<b>0.40</b>	<b>0.24</b>	<b>0.23</b>	<b>0.08</b>	<b>0.04</b>

## 3.3 Business survey results

A range of businesses were surveyed from across 11 industry groups (see Chapter 2 for industry table). These groups are consistent with ABS sector classifications and broadly reflective of business consumption across the NEM. Table 12 below sets out the business customer VCR values (in \$/kWh).

**Table 12 Business VCR values (\$/kWh)**

Sector	Agriculture	Commercial	Industrial
<b>Sector average</b>	<b>47.67</b>	<b>44.72</b>	<b>44.06</b>
<b>Small size</b>	54.87	57.13	69.66

<sup>28</sup> SAIDI and SAIFI are measures of distribution network reliability and are measured as part of the AER Distribution Service Target Performance Incentive Scheme (STPIS).

Sector	Agriculture	Commercial	Industrial
Medium size	51.81	57.28	64.44
Large size	46.41	42.13	39.13

## Observations

The business sector VCRs are higher than the residential values, which is broadly consistent with results from other domestic and international studies. Larger businesses tend to have a lower VCR value. This is again consistent with other studies. It may be explained by larger companies having back-up systems in place to mitigate the impact of outages. Also, smaller users of power may have businesses in which energy is a smaller input or cost, which leads to a higher value per kWh from these businesses.

Customers in the agriculture and industrial sectors tend to have flatter demand profiles with no additional impact at system peaks.

For customers in the commercial sector, and to some extent the industrial sector, weekend outages have a lower impact than weekday outages.

Compared to the 2008 Victorian study:

- Sector-specific results are lower for agricultural and commercial sectors, dropping from between \$90-110/kWh to \$44-47/kWh.
- Results for industrial customers have risen slightly.

### 3.3.1 Sample characteristics

Business customers were recruited from across a range of industries, with a business customer in one state treated as representative of a similar operation in another state. The survey assessed users of different sizes across the NEM with a mix of small, medium and large users recruited to participate across a range of ABS industry classifications. The business VCR values were grouped by industry or type of consumption across the NEM rather than state level. The industry results have been aggregated to reflect ABS sector classifications of agriculture, commercial and industrial sectors (consistent with the previous 2008 study).

**Table 13 Business survey numbers**

Sector	Agriculture	Commercial	Industrial	Total
Business survey numbers	91	1,234	174	1,499

The comments revealed that the larger commercial businesses were generally better able to articulate the link between reliability and business losses. The commercial category is the most diverse category with a wide range of business operations with varying consumption patterns, for example, flat, medium or high peaks. The agricultural customer sample was comprised of a mix of standard agricultural and rural commercial businesses.

### 3.3.2 Detailed results and assumptions

#### Contingent valuation (WTP)

Similar to the residential survey, business survey respondents were asked for their willingness to pay to avoid a basic outage, which was uniformly defined for all respondents regardless of location. The WTP dollar amounts that businesses were asked to consider were based on a percentage of their monthly electricity bill.

- The WTP to avoid the baseline outage over all the businesses that completed the contingent valuation survey was 5.5% of their monthly bill.
- There was variation in the WTP business results across businesses of different consumption sizes and sectors.

**Table 14 Mean business sector WTP (% of bill)**

Sector	Agriculture	Commercial	Industrial
Mean WTP	7.2	5.0	6.3

- For the same reason as the residential survey, a non-parametric modelling approach was taken to produce the mean business WTP values.
- Only the main survey dataset was used to derive the business WTP values as the business pilot study yielded poor quality results.
- Similar to the main residential survey, the WTP question was posed in a sequential format asking respondents to either accept or reject payments.

### Choice modelling (WTA)

Similar to the residential survey, MNL models were used to fit the choice modelling data. The sample of completed responses for the business choice modelling survey produced 13,824 choices.

As with the residential survey, only variables with a minimum 99% significance were considered in the computation of the VCR values to ensure the statistical robustness of results.

Table 15 below sets out those outage variables tested that were found to be 99% statistically significant.

**Table 15 Statistically significant business outage variable by sector (%)**

Outage Variables	Agriculture	Commercial	Industrial
Severity	X	✓ (99%)	X
Duration 3 hours	✓ (99%)	✓ (99%)	✓ (99%)
Duration 6 hours	✓ (99%)	✓ (99%)	✓ (99%)
Duration 12 hours	✓ (99%)	✓ (99%)	✓ (99%)
Peak time	X	✓ (99%)	✓ (99%)
Summer	X	X	X
Frequency 2 times per year	X	✓ (99%)	X
Frequency 3 times per year	✓ (90%)	✓ (99%)	✓ (95%)
Weekday	X	✓ (99%)	✓ (99%)

- Most outage attributes tested were found to have a statistically significant relationship with business customers sampled, indicating these attributes are important to customers. Appendix B.3 illustrates raw \$/month modelled estimates on a per outage basis.
- Duration was the most valued outage attribute for all sectors.
- Off-peak and weekend timing of outages was preferred significantly by industrial and commercial businesses, while agricultural businesses were generally indifferent.
- For customers in the commercial and industrial sectors, a weekday outage estimate rather than a weekend outage estimate was included in the VCR results. See Appendix B.4 for further detail.
- Season did not appear to be a significant factor of the business customers sampled.
- Similar to the residential survey, the severity and frequency variables were removed from consideration due to their qualitative nature and to assist in producing the VCR values on a single-event basis.

### Statistical differences – consumption class segmentation

- Given the high degree of variability of the business sample with respect to consumption and bill amounts, the business sample was further divided into consumption classes in order to produce more robust VCR value

estimates. Interaction effect models supported the division of the business sample into small, medium and large sub-classes, showing statistically significant differences across these consumption sub divisions.

- The definitions of small, medium and large consumption classes are set out in Table 16 below.

**Table 16 Business consumption class segmentation by state (MWh pa)**

Consumption size	NSW	VIC	QLD	SA	TAS
Small	< 40 MWh pa	< 150 MWh pa			
Medium	40–100 MWh pa	40–100 MWh pa	40–100 MWh pa	40–160 MWh pa	
Large	> 100 MWh pa	> 100 MWh pa	> 100 MWh pa	> 160 MWh pa	> 150 MWh pa

- These consumption class definitions reflect recent changes in the Consumer Administration and Transfer Solution (CATS) Procedures and are consistent with customer classifications in AEMO’s MSATS system data.
- Interaction effects models suggest a significantly higher outage attribute value for 12 hours duration for commercial and industrial large and medium-sized customers.
- To develop industry-specific VCRs across the consumption classes, the small, medium and large results within each industry were load weighted using population demand data extracted from AEMO’s metering databases. Further detail on the consumption class load weighting methodology is in load weighting section below.

### Outage history

- Historical outage data was used to calculate single business VCRs values across various outage types.
- A similar approach to the residential survey was taken in defining 24 outage scenarios across three peak time outage attributes (seasonal, daily peak time and weekday) and four duration outage scenarios (including the base case).
- To derive sector-specific business VCR values, a VCR for each of the twenty-four outage scenarios was derived using the survey results and weighted by their probability of occurrence based on a compilation of sector-specific outage history along the three peak and four outage duration variables. These probability factors are set out in tables 17 and 18 below.

**Table 17 Business peak, weekday and summer outage probabilities by sector**

State	Daily Peak	Weekday	Summer
NEM	0.30	0.30	0.53
Agriculture (NEM rural)	0.31	0.31	0.57
Industrial (NEM CBD)	0.21	0.25	0.37
Commercial (NEM CBD/urban)	0.25	0.27	0.45

**Table 18 Business outage duration probabilities by sector <sup>29</sup>**

Sector	0-1 hours	1-3 hours	3-6 hours	6-12 hours
NEM	0.36	0.38	0.15	0.11
Agriculture (NEM rural)	0.35	0.38	0.15	0.12
Industrial (NEM CBD)	0.37	0.26	0.20	0.17
Commercial (NEM CBD/urban)	0.38	0.32	0.16	0.14

<sup>29</sup> Rows sum up to 100%.

Similar to the residential survey, outage probabilities were derived using 2012 AER RIN distribution outage data. A similar filtering criteria was used to obtain a subset of outage data of a minimum duration, customer impact and characteristic. Sector-based outage profiles were based on feeder-specific data.

- The agriculture outage factors were based on NEM rural feeder data.
- The industrial outage factors were based on NEM CBD feeder data. Industrial businesses tend to invest in achieving high levels of reliability and therefore CBD level of reliability was assumed.
- The commercial outage factors were developed from a combination of NEM CBD and urban feeder data. Commercial businesses as defined in this study are non-rural services and hence are located in CBD and urban areas.

### Demand Profile

Business sector and size-based demand profiles were developed using a combination of information provided by survey respondents and AEMO MSATS system data. Business respondents were required to provide NMIs that were used to query respondent demand history and compare with responses provided. Inconsistencies were either corrected or responses were culled if either sources of demand information were inconsistent with bill information provided. Once a clean dataset was established that had reasonable bill and demand information, the average hourly demand information in kilowatt-hours was averaged for each sector-consumption size subgroup.

**Table 19 Average Hourly Demand by sector and consumption class (kWh)**

Industry	Small	Medium	Large	Average
Agriculture	1.45	7.98	39.04	11.75
Commercial	1.18	8.01	144.09	17.35
Industrial	1.70	8.89	274.98	102.54
NEM	1.23	8.14	168.96	26.36

### Peak Factors

Peak factors were applied to average demand figures to estimate unserved energy during peak periods. Agricultural and Industrial sector customers generally had a flatter consumption profile than that of commercial sector businesses. Commercial businesses tended to have higher electricity usage during weekdays and during day time hours.

**Table 20 Business sector peak demand factors by outage scenario**

Sector	Outage Scenarios					
	Offpeak Weekday Winter	Peak Weekday Winter	Offpeak Weekend Winter	Offpeak Weekday Summer	Peak Weekday Summer	Offpeak Weekend Summer
Agriculture	1	1	1	1	1	1
Commercial	1.1	1.4	0.8	1.1	1.4	0.8
Industrial	1.1	1.1	0.8	1.1	1.1	0.8

### Average Electricity Bills

One difficulty with survey business respondents was their wide range of monthly bill amounts. The range of monthly bills makes using absolute dollar amounts for questions and models problematic. The computer-aided survey used set percentages to calculate values for each respondent, based on the monthly bill amount entered into the survey. This approach ensured that survey questions were congruent with the monthly electricity bill of each business respondent. The same approach was taken for the contingent valuation questions, where the WTP amounts were expressed as a percentage of the respondent's average monthly bill.

As a consequence, average bill information is required to convert the percentage bill responses to absolute dollar figures. Using bill information provided by respondents and demand data in AEMO's MSATS system data to verify the accuracy of the responses, the following average monthly bill amounts were obtained for each business customer class.

**Table 21 Average Monthly Bill Amounts by business sector and consumption class (\$)**

Industry	Small	Medium	Large	Average
Agriculture	306.08	1,592.50	6,974.41	2,142.76
Commercial	240.52	1,637.75	21,682.53	2,699.82
Industrial	376.79	1,822.29	34,226.76	12,938.57
NEM	253.74	1,664.16	23,580.10	3,788.57

Note it was not necessary to translate percentage bill responses to absolute dollar figures for residential customers given their narrower bill range.

### Load weighting

To obtain industry and NEM-wide VCR figures, the nine industry-size VCRs were load weighted. MSATS data was used to load weight the small, medium and large VCR values to the three sector-based VCRs. Bureau of Resources and Energy Economics (BREE) consumption data was used to load weight the industries to determine a NEM-wide VCR value. These are set out in Table 22 below.

**Table 22 Load weighting by business sector and consumption class (%)**

Industry	Agriculture	Commercial	Industrial
Small	11.0	11.0	11.0
Medium	6.2	6.2	6.2
Large	82.8	82.8	82.8
total	100.0	100.0	100.0

## 3.4 Direct connect survey results

The energy consumed by direct connect customers' accounts for approximately 20% of total NEM demand. Direct connect customer load comprises a range of industry sectors, including metals (production and processing), wood pulp and paper, mining, water (pumping and desalination), oil refining and liquefied natural gas (LNG). The direct connect customer survey sought to obtain responses from customers directly connected to the transmission network about the costs incurred due to a supply interruption.

Table 23 below sets out the direct connect VCR values (in \$/kWh)

**Table 23 Direct connect sector VCR results (\$/kWh)**

	Metals	Wood, pulp and paper	Mining	Weighted Average
Sector-based VCRs	5.29	1.44	14.96	6.05

## Observations

Responses were indicative of the varied range of direct connect site operations across the NEM and few consistent trends or observations can be made across the responses.

- Direct connect customers rarely experienced outages, with some responses indicating that they had not experienced an outage for several years. This is consistent with the high level of reliability that transmission networks provide.
- Most direct connect customers ran continuous 24-hour business operations. Given the continuous nature of most direct connect business operations, the majority of responses indicated the impact of an outage would not vary over any month, day or time.
- For many direct connect customers the direct costs associated with an outage were a function of lost production. However, for some direct connect customers, extended outages could be catastrophic and result in irreversible equipment damage. For example, see section 3.4.2 below and the discussion on the metals sector.
- A short outage duration can often lead to periods of lost production longer than the outage itself, depending on the time taken to bring machinery back online.
- Some direct connect customers indicated that they had negotiated directly with the local TNSP to ensure that their required levels of supply reliability were able to be met.
- Few direct connect customer responses indicated there were incremental direct costs associated with an increase in outage frequency. The incremental costs of an increase in the frequency of costs may have been difficult to estimate given the typically low occurrence of outages on transmission networks. However, some customers did provide feedback that a substantial increase in outage frequency could threaten the commercial viability of their operations.
- No attempt was made by the customers sampled to quantify the indirect costs associated with outages. However, responses detailed several types of indirect costs which may arise from an outage. These included indirect costs associated with breaching environmental standards or health and safety regulations and impacts to reputational risk.
- Back-up generation was used by some direct connect customers. In the majority of these cases, it was used to back up essential equipment only and not to maintain operations.
- Levels of insurance to mitigate the risk of supply failures varied amongst direct connect customers. Larger businesses which operated direct connect sites would often engage in “self-insurance” through on-site supply options. Other direct connect customers either did not have supply failure insurance arrangements in place or were only insured against supply failures resulting from extreme events (i.e. force majeure).

### 3.4.1 Sample characteristics

Direct connect customers were recruited and surveyed separately using a direct questionnaire approach (rather than choice modelling). These customers were asked to directly quantify the costs associated with outages of various durations. AEMO wrote to all 30 direct connect customers in the NEM and received 13 responses. The 13 responses received represented 30% of overall direct connect consumption in the NEM. Business operations at the direct connect site ranged from mines to paper and timber mills and included smelters and refineries.

### 3.4.2 Detailed results and assumptions

#### Direct costs

The 13 direct connect customer responses indicated the expected costs associated with a 10-minute outage and the incremental costs incurred if the outage extended by varying durations. These costs were converted into dollars per kilowatt hour values using consumption data for those businesses in AEMO’s system databases. These results have been combined by load weighting the responses into three industry groupings – metals, wood, pulp and paper, and mining. Table 24 below sets out the results of the direct connect customer survey.

**Table 24 Direct connect sector VCR results by outage duration (\$/kWh)**

	Metals	Wood, pulp and paper	Mining
10 minute outage	3.76	10.35	37.99
1 hour outage	0.67	1.51	19.50
6 hour outage	15.56	0.32	4.79
12 hour outage	7.96	0.23	4.21

In calculating the dollars per kilowatt hour VCR values, the following assumptions were made:

- Where responses provided a range of costs associated with an outage, the mid-point of the costs was assumed.
- Where potential plant or equipment damage costs associated with an outage were provided, these were incorporated by weighting the damage costs by the probability of plant or equipment damage occurring.

The initial high 10 minute outage VCRs for wood, pulp and paper, and mining sectors indicates that an outage of 10 minutes is likely to result in a halt in production at site operations of a duration which exceeds the interruption to supply. This is due to plant shut down and restoration procedures, which will often exceed 10 minutes. Responses indicated that often an hour or more of production would be lost. VCRs in both sectors were lower for longer outages as lost production time better matched the lost outage time.

In comparison, the metals sector recorded VCR values that did not scale directly with either time or lost electricity consumption. This reflects the nature of metals production and processing. While short duration outages tend to be tolerable for the sector<sup>30</sup>, long duration outages will often lead to permanent plant damage as high plant temperatures, exceeding hundreds of degrees Celsius, must be maintained to ensure metals remain liquid while being processed.

Direct connect customers were also surveyed about the incremental costs associated with an increase in the annual frequency of base case outages (defined as two 10-minute interruptions to supply occurring on a weekday between 7-10 am or 3-6 pm). The majority of direct connect customers indicated that there would be no incremental costs associated with an increase in the frequency of base case outages.

### Outage History and Load Weighting

Sector-based VCRs for direct connect customers were obtained by weighting the duration outage specific VCRs by the probability of outages occurring. Due to the inherently high levels of reliability provided by transmission networks, loss of supply is rare. Thus, there is a very small set of historical transmission outage data available compared to historical distribution outage data, making it difficult to source transmission outage data to use as the basis for probability weighting.

Given the lack of available transmission outage data, the probability weighting of the VCR survey results was based on AEMO's review of significant power system events (2005-2010) undertaken for the AEMC's extreme weather events review.<sup>31</sup> AEMO considers this provides a reasonable dataset of transmission outages which reflect a proportionate spread of the type of outages occurring on the transmission network.

## 3.5 Calculation of aggregate NEM and state VCRs

Table 25 below sets out NEM and State VCRs derived from the survey results.

**Table 25 Aggregate NEM and state level VCR results (\$/kWh)**

Location	NEM	NSW*	VIC	QLD	SA	TAS
VCR excluding direct connects	39.00	38.35	39.50	39.71	38.09	39.43

<sup>30</sup> Direct connect metals production and processing plants are actively involved in short-term load tripping schemes and demand side participation in the NEM wholesale market.

<sup>31</sup> Available at the AEMC's website at: <http://www.aemc.gov.au/Markets-Reviews-Advice/Review-of-the-Effectiveness-of-NEM-Security-and-Re.aspx>.

Location	NEM	NSW*	VIC	QLD	SA	TAS
VCR including direct connects	33.46	34.15	32.62	34.91	34.06	25.62

To calculate the NEM and state VCRs the following approach was used:

- For the NEM and each state, the aggregate VCR was determined by load-weighting the residential, agricultural, commercial, industrial and if applicable, direct connect VCRs. BREE consumption data was used to determine the appropriate load weighting.
- Two sets of NEM and state VCRs were produced that either included or excluded consideration of direct connect customers.
  - Inclusion of direct connects: AEMO's large industrial customer study results were used to differentiate non-direct connect and direct connect industrial load. Load weights were calculated accordingly on the basis of this division of industrial load.
  - Exclusion of direct connects: Direct connect load was subtracted from the total industrial load and the customer classes were re-weighted accordingly.
- A single aggregate direct connect VCR was used in favour of sector specific direct connect VCRs as states tend to comprise a range of direct connect customers. Further as direct connect values are indicative there would be limited additional value gained in the use of more disaggregated VCR numbers.

**Table 26 Weighting by customer class and state (%)**

Load Weight (%)	NEM	NSW	VIC	QLD	SA	TAS
Agriculture	0.9	0.8	1.0	0.7	1.8	0.6
Industrial - DC	16.8	13.0	20.6	14.3	12.5	41.4
Industrial - Non DC	16.8	18.1	9.4	23.0	14.2	15.6
Commercial	40.6	38.1	48.4	40.5	39.2	23.7
Residential	24.9	29.9	20.6	21.6	32.3	18.7

### 3.6 Confidence intervals for VCR estimates

AEMO has produced standard error and confidence interval information to help stakeholders appreciate the degree of sensitivity surrounding the VCR results modelled in this review.

Since statistical regression models were used to fit the choice modelling responses, this enabled standard errors and confidence intervals to be produced for each outage attribute (WTA \$/month value).

Appendix B.3 sets out these detailed values alongside the residential and business choice modelling results.

In order to produce confidence intervals for the overall \$/kwh VCR results, additional probabilistic modelling (likely involving a Monte Carlo simulation) would have to be undertaken. Such a simulation would estimate probabilistically the net impact of the combined uncertainties from both the survey results and supporting data to determine rough confidence intervals. Due to the lack of information on the standard errors and confidence intervals associated with the supporting data (such as AER's RIN data, BREE data, and demand data), AEMO did not undertake this analysis.

On the basis of the choice modelling results alone, the approximate confidence interval for a VCR produced in this study is +/-30%, which is an acceptable range for a survey of this nature.

## 4. VALIDATION AND ROBUSTNESS OF RESULTS

This chapter sets out the process AEMO has undertaken to validate and better understand the drivers behind emerging results. This involved analysis of sample demographics, survey feedback, previous domestic and international VCR studies, comparison with ABS economic indicators (input-output tables), and independent peer review.

### 4.1 Sample demographics

To ensure the sample was representative of customers across the NEM, the residential and business VCR surveys surveyed a large number and diverse set of customers across geographies and industry types. This VCR review is the largest of its type conducted in Australia to date. As illustrated in Table 27 below, the sample size also compares well with other similar international studies.

**Table 27 Survey numbers of previous Australian and international VCR studies**

VCR study	AEMO NEM study (2014)	UK (2013)	NZ (2013)	AEMC NSW study (2012)	VENCorp Victoria study (2008)	VENCorp Victoria study (2002)	Monash Victoria study (1997)
<b>Total sample size</b>	2,915	2,224	3,203	2,188	821	656	397

AEMO took the following steps to ensure the sample collected was sufficient to produce statistically robust results, the following steps were taken by AEMO:

- Results from the pilot study enabled refinement of the experimental design, therefore reducing the overall sample size requirement. The pilot study provided useful information about the population and its preferences, eliminating the number of outage scenarios to be tested in the main survey.
- A targeted approach was taken to sampling in order to achieve as balanced a sample as possible. For example, towards the end of the residential recruitment process, resources were targeted to obtain additional responses from Tasmania, rural areas, and other areas where the sample was found to be lacking. Periodic statistical analysis conducted by our academic consultant helped to refine the sampling requirements as recruitment progressed.
- A large sample was required to enable poor quality responses to be removed, while still retaining an overall robust dataset. From discussions with authorities who have carried out similar studies, we understand this to be a common experience.

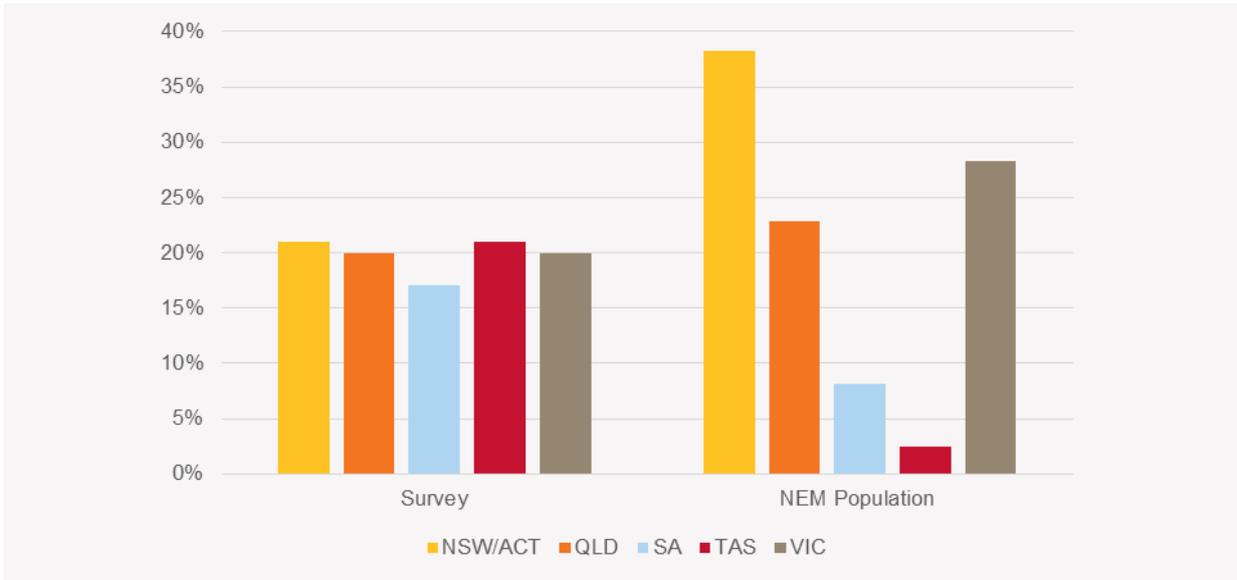
#### 4.1.1 Reflective sample composition

Customer recruitment was targeted on the basis of sample plans prepared by AEMO, with the assistance of Professor Scarpa to ensure a statistically robust and representative group of customers was surveyed. Where possible, market research firms targeted and adjusted their recruitment efforts to meet AEMO’s sample plan. Generic incentives were provided to reduce aspects of selection bias and encourage higher response rates. An analysis of how AEMO’s survey sample compares with the ABS population data is set out below.

#### Residential

Residential recruitment sought to ensure the residential customer sample was statistically significant across geographical regions. A certain number of responses were required in each state, considering both state population size and diversity of customers. A higher proportion of responses were collected in South Australia and Tasmania to account for the greater diversity of climate zones and customer preferences compared to other states with larger populations but more homogenous preferences. This is shown through a comparison of the survey sample with ABS population data, illustrated in Figure 1 below.

**Figure 1 Residential survey by state compared to the NEM population**



Analysis of the residential sample along other population attributes, such as gender, income and household characteristics was also examined.

- An analysis of income of responding households showed that the majority of respondents earn less than \$1,800/week with most respondents earning between \$901-\$1,800/ week (29%). Those earning over \$150,000/year (or \$3000/week) comprised only 4% of respondents.
- In terms of gender split, the number of residential customers surveyed across the states captured more female than male (56% to 43%).
- In terms of age, there was an over-representation of respondents in the 46-65 years age group between (52%), and an under-representation of under 30 (6%) compared to the general population. This is to be expected, partly because the surveys targeted bill payers who are typically more likely to be in a higher age bracket.
- Respondents tended to own their house outright or own with a mortgage rather than rent.

Altogether, these statistics demonstrate that AEMO’s residential sample captures the diversity of the Australian population along different demographics. Additional graphs comparing AEMO’s sample with ABS population data are in Appendix E.

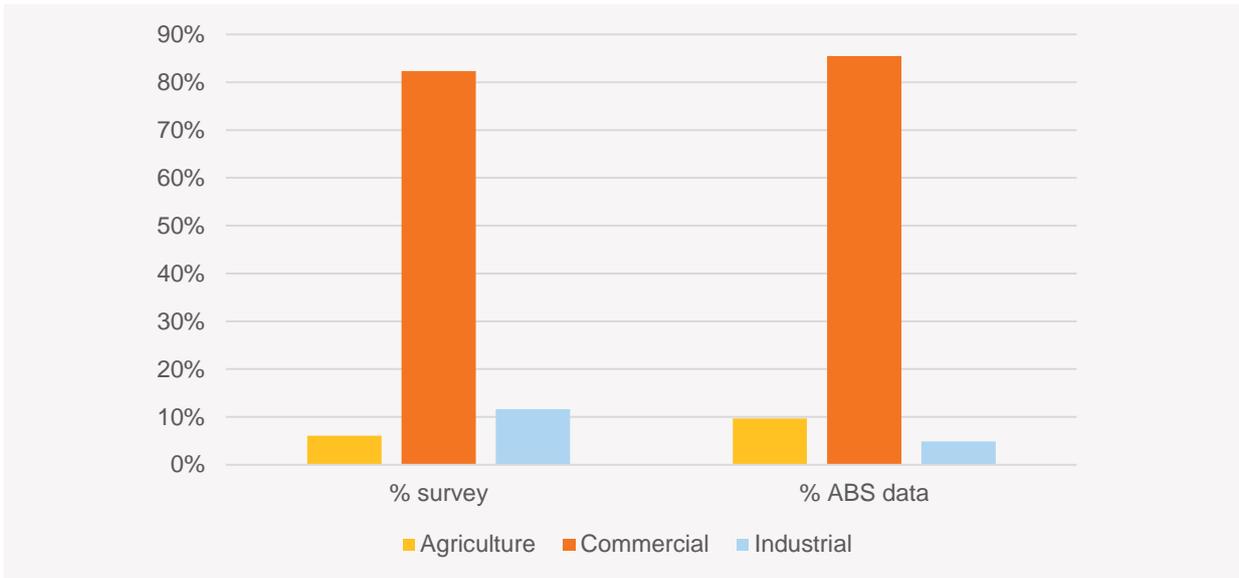
**Business**

To produce the business VCRs along the three sectors types, AEMO sought to target its recruitment approach to a defined set of 11 ABS industries strongly represented in these sectors in the NEM. These industries were primarily selected based on their energy use. They reflect ABS sector classifications for ease of recruitment and comparison with ABS population data.

The business focus groups and online panels captured a diverse spread of industries and consumption sizes within each sector. Customers surveyed for each industry were treated as representative for that industry across other NEM regions.

The mix of surveyed businesses was found to strongly correlate with the industry mix in the Australian population as captured by the ABS. When aggregated to the sector level, the business sample composition was found to be highly reflective of the population. Figure 2 supports this conclusion.

**Figure 2** Number of businesses surveyed by sector compared to the ABS data



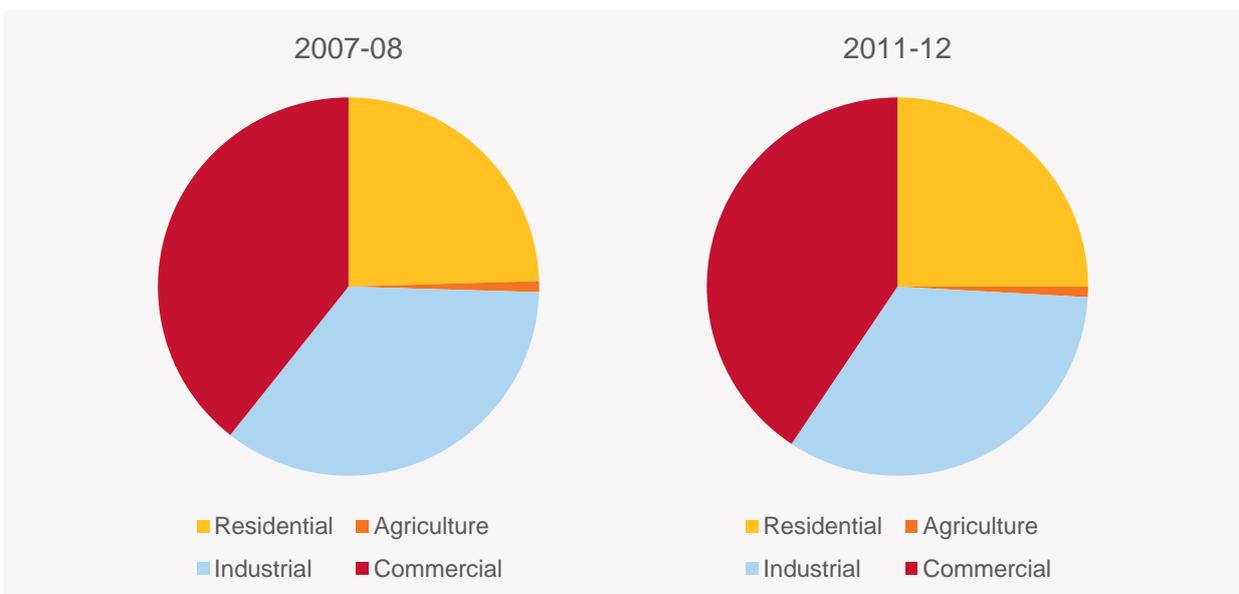
### 4.1.2 Load weighting

To assess whether change in the load proportion in the NEM may have been a factor in the change in the aggregate VCR values, AEMO compared 2008 and 2014 customer load composition.

The proportion of residential, agriculture, commercial and industrial customers in the NEM has stayed relatively constant between 2008 (when VENCORP’s last study was conducted) and 2014 for this current study. This suggests that any changes to the aggregate VCR value from 2008 and 2014 are primarily attributed to the changes in the residential and business sector VCR values themselves and not the relative composition of the NEM load.

In Figure 3 below, BREE data was used to compare the residential and business sector load composition in the NEM. Business consumption has grown from 163TWh in 2007-08 to 168TWh in 2011-12. The residential total grew from 53TWh to 55TWh. Total growth was almost 4%, which appears to be relatively even across customer classes.

**Figure 3** Change in NEM consumption by sector



### 4.1.3 Data sources

Where possible, publicly-available data sources were used to support the development of the VCR values in addition to the survey results. This approach allows the VCR values to be derived more readily and consistently by external parties.

- Australian Bureau of Statistics (ABS) – Census data was used for industry classification and sector mapping, demographic information, and input-output tables.
- Bureau of Resources and Energy Economics (BREE) – Industry consumption data was used to aggregate business VCR values.
- Australian Energy Regulator Economic Benchmarking Regulatory Information Notice (AER RIN) – Distribution outage and customer data was used to develop the outage history profiles underpinning the weighting of scenario-based VCRs to single value estimates.
- Market Settlement and Transfer Solutions (MSATS) – Metering data was used to verify bill and demand information supplied by business respondents. It was also used to weight consumption class VCR values into sector-based VCR values.
- Energy Supply Association of Australia (esaa). Annual supply reports provided residential consumption and connection volume figures to load weight state residential VCR figures to a single NEM residential figure.
- Reserve Bank of Australia (RBA). Australian inflation figures were used to compare AEMO's VCR results with values produced in the VENCORP 2008 study.

### 4.1.4 Data cleaning process

As noted, a large customer sample set was achieved. However, some responses were removed from the sample set in order to improve the quality of responses on which the results were modelled.

- Given variability in bill sizes and the electricity consumption of business customers, the survey sought preferences in terms of % bill and not in absolute dollar value. While this provided tighter statistical estimates, it meant the study relied on respondents providing accurate bill and demand information. As a result, a higher proportion of business customer responses were removed than compared to residential customer responses.
- AEMO checked responses by calculating electricity prices based on demand and bill information provided by respondents and reviewing demand profiles on MSATS using respondent provided NMIs.
- Responses were scrutinised to check:
  - Location (that responses were from NEM jurisdictions only)
  - Accurate billing data, customer type and industry details
  - Result duplication
  - Test responses
  - Incomplete responses (i.e. if key questions were left blank).
  - Survey comments (that responses were provided by a legitimate or relevant person and that the correct survey type was completed)

## 4.2 Survey feedback

As part of the survey, participants were able to provide qualitative feedback. Survey comments were initially used to verify that respondents were legitimately trying to complete the survey. Survey responses that were flagged as inappropriate were removed.

Overall, customer feedback was consistent with the modelled results and support emerging themes and conclusions.

### 4.2.1 Residential

Residential comments were diverse. Most residential customers commented that they are unwilling to pay more to avoid outages. These customers generally indicated their electricity bills are already high and that existing reliability levels are acceptable. Many customers expressed a desire to reduce their bills further by implementing

energy efficiency measures and investing in renewable energy. A smaller subset of the residential group expressed strongly that increased electricity reliability is very important to them.

Written feedback also indicated a lack of understanding about electricity prices and bills in general, and also the purpose of the VCR survey, further highlighting the issues experienced in the recruitment process.

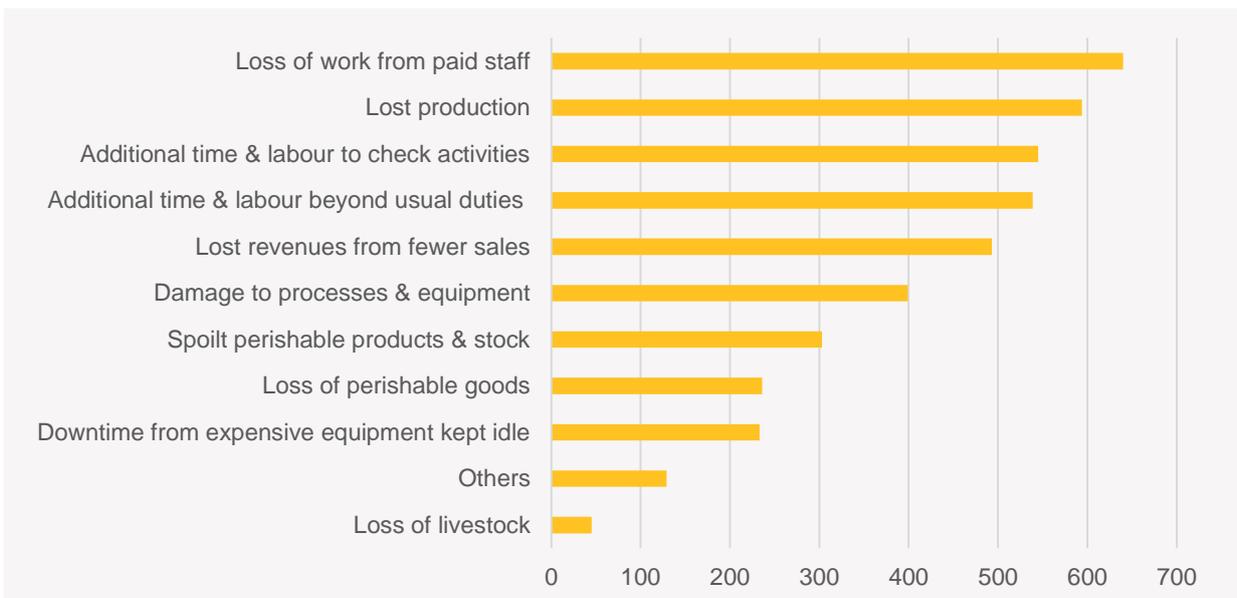
### 4.2.2 Business

Comments from business respondents indicated that many agriculture and commercial businesses are feeling bill pressure and are generally not willing to pay more to avoid power outages. Industrial businesses on the other hand appear to better appreciate the trade-offs between reliability investment and production loss.

- Agricultural businesses, particularly smaller family farms, indicated that energy costs have been “eating into their profits” and were becoming a significant financial pressure. One agricultural business even commented they had to reduce production due to increasing energy expenses.
- Commercial businesses also indicated that increasing electricity bills were contributing financial pressure to their businesses. Many commercial businesses were looking to invest in energy reduction measures to combat increasing electricity bills, rather than invest in greater network reliability.
- The comments from agricultural and commercial businesses are consistent with the lower VCR values seen in this study compared to the VENCORP 2008 study.
- The industrial business VCR result is similar to the VENCORP 2008 study highlighting that reliability of supply is still important for industrial businesses. Many industrial customers indicated the importance of electricity reliability for their businesses, evidenced by the fact they have in many cases invested in back-up electricity supply to keep key processes and equipment running during outages. These comments reflect that industrial businesses have long understood the importance of electricity reliability and why their reliability requirements have not changed markedly since 2008.

Qualitative survey responses appear to support AEMO’s choice modelling results. The survey asked participants to list activities that most affected their businesses during a power outage. The most common loss type indicated was the loss of work from paid staff. The third and fourth options, ‘Additional time and labour to check activities’ and ‘Additional time and labour beyond usual duties’, also relate to labour and time costs. Figure 4 summarises these responses in graphical form.

**Figure 4 Number of businesses impacted by loss type**



This graph highlights the fact that outage duration is the most important factor for businesses when considering the financial and intangible losses associated with power outages. A similar finding was found in the choice modelling, where the outage duration attribute was valued above other outage attributes.

### Direct connect customers

- Most direct connect customers could estimate the extent of production losses as the duration of plant shut down and restoration procedures that would occur during a planned outage.
- Some direct connect customers had difficulty estimating the direct costs associated with an outage because:
  - Lost production costs fluctuated based on changes in the price of goods (i.e. metal-based products) they produced or extracted.
  - Costs could increase significantly if there was damage to machinery or equipment caused by the outage.
- Some direct connect customers commented they received a very high level of reliability and would not be willing to accept an increase in network charges.

## 4.3 Domestic and international studies

AEMO has sought to contrast its results with other VCR type studies. Other studies (both domestic and international) were used for verification of VCR magnitude and relativity between customer classes. AEMO notes that results from previous studies should not be directly compared due to differences in survey design and methodology. Broadly speaking, the results compare well with other VCR studies and ABS industry indicators on the economic value produced for each unit of electricity used.

Specifically:

- The NEM-wide residential VCR value of \$25.95/kWh is similar to the previous VENCORP study when accounting for inflation.
- The updated agriculture and commercial VCR figures are comparable to ABS economic indicators (net Australian production and electricity usage per industry figures). The industrial VCR figure was close to the VENCORP value when inflation is taken into account.
- The relativity of AEMO's updated VCR values by industry sectors (agriculture, commercial and industrial) is comparable to other VCR studies.
- The nature of the survey design, the outage variables tested, and the way in which respondents are asked questions and how they participate, all lead to quite significant differences in findings of these reviews.
- One of the benefits of using the services of Professor Scarpa is that as an expert in the field of choice modelling, he has been involved in a number of these studies across a range of other energy markets. While these studies are not all directly comparable, a number of recent studies has been developed and informed based on his advice regarding choice modelling survey design.

## 4.4 Input-output tables

AEMO sought to validate the business results of its VCR review by comparing the VCRs modelled using ABS input-output (I-O) economic accounts. Comparing the survey results against VCRs modelled from macroeconomic indicators, provides a broad indication of the reasonableness of the VCR survey results.

I-O tables disaggregate and describe the gross domestic product account in terms of the supply of goods and services flowing between producers and their consumers. In doing so, these tables capture the relationships between domestic production and the cost of production inputs, such as electricity, at a given point in time. Using electricity usage and attributed production output by industry (ANZIC code), VCR values can be derived from the I-O tables.

AEMO recognises there are limitations in using VCRs derived from economic-based modelling to verify the VCR survey results. While both approaches can be used to derive VCRs, they are not the same measure. I-O modelling measures electricity consumption at market prices. In contrast, the survey approach measures a consumer's willingness to pay for electricity, including the excess of the market price to ensure a desired level of reliability. This may include intangibles costs or inconveniences that may not be readily captured by economic accounts or that some industries may be more flexible in making up production after an outage than others. While the VCR

values derived from the two approaches should be broadly similar of the same magnitude they will not likely be equal.

Three preliminary I-O models were developed to produce indicative VCR results. The modelling approaches, including price input assumptions, are described in detail below:

- **Net use of electricity and Australian production.** This approach measures, for each industry, the net use of energy and the production per industry sector to model the VCR. Under this approach, the VCR is explained as the input cost of electricity to the industry output. The more energy-intensive the industry, the higher the VCR value.
- **Weighted net use of electricity using price assumptions and Australian production.** This method is similar to the above approach but involves calculating an electricity input multiplier allocating electricity price assumptions per industry sector. This reflects how much electricity is consumed in the production of output by each represented sector under a specific price level. It is relevant to note that levels of production/output are affected differently during electricity supply interruptions depending on the duration of the electricity supply outage and the specific industrial sector. For example, depending on the duration, the operating machinery of some industries may not be affected by an interruption of one hour or less, whereas others would have to stop production and wait until the next day to restart operations, involving a significant impact on production levels. The latter case is expected to be willing to pay a higher cost for reliability. A weighted combination of labour cost and production has been considered in this case.
- **Weighted combination of labour costs and Australian production.** This approach measures the VCR as a function of the economic cost of labour combined with lost production. Under this approach, a combination of labour cost and production losses are identified for each industry and combined with weighting measures of the probability of an outage that incurs a closure of operations for one or more days.

Comparing the results, relatively small differences were found between AEMO's agriculture, commercial and large direct connected industrial survey results and the I-O derived results. These results are predicated on market price assumptions estimated for each industry, ranging from a wholesale energy price of approximately \$60 per MWh to the residential price of approximately \$150 per MWh.

This comparison provides an indication of the likely accuracy of AEMO's calculation of the business VCR values.

## 4.5 Independent review of survey results

To help ensure confidence in the VCR survey results, Pricewaterhouse Coopers (PwC) New Zealand was engaged to review and provide advice as follows:

- Qualitatively review the modelling undertaken to develop the residential and business customer VCR values, in particular the development of baseline WTP values.
- Provide advice and support in respect of treatment of direct connect customer responses.
- Technical peer review of AEMO reports prior to publication.

PwC was selected due to their extensive experience in econometric modelling and VCR studies.<sup>32</sup>

PwC's review found the modelling to be reasonable and the VCR survey results to be sensible. PwC considered that the VCR values may be on the lower range due to WTP being calculated using non-parametric estimates and the use of WTA attributes with only 99% statistical significance.

In relation to the business results, PwC considered the drop in commercial figures compared to the 2007-08 study to be unsurprising given the larger number of small businesses sampled, who are more flexible and can better cope with a supply interruption. Changes in technology, especially improved mobile computing and telephony, is likely to also contribute to businesses being more resilient and reducing the costs of short-term outages. PwC also noted that the agricultural VCR values in previous studies appeared to be high compared to other study results.

For the residential results, PwC noted the finding that there were few statistical differences across sub-regions in states was a positive observation of the survey.

<sup>32</sup> For example, the PwC review of VCR survey results included Dr. Bill Kaye-Blake, who is also an honorary associate professor at Lincoln University New Zealand and previously assisted the New Zealand Electricity Authority in its investigation into the Value of Lost Load in New Zealand

## 5. APPLICATION OF RESULTS AND NEXT STEPS

This chapter sets out the application of the VCR survey results, setting out:

- AEMO's application of the results in its role as Victorian and national transmission planner.
- Application of the results to distribution network planning in Victoria.
- The next steps following completion of the VCR review.

### 5.1 AEMO application of the VCR survey results

As highlighted at the start of the VCR review, AEMO intends to apply the new VCR values in its own transmission planning processes as part of its national and Victorian planning role.<sup>33</sup> The VCR survey results will ultimately allow more granular VCRs to be developed and applied in our network planning processes, to support investment decision-making that is more reflective of customer reliability preferences at a particular location in the grid.

AEMO recognises that a period of transition may be required to move from the current VCRs used in network planning, based on the 2007-08 VENCORP study, to VCRs of a more granular nature if locational load group composition data is not currently available. Accordingly, in the absence of load group composition data, AEMO will apply aggregate NEM and/or state level VCR values derived from the VCR survey results to its network planning processes.

#### 5.1.1 Application to Victorian transmission planning

In its role as Victorian transmission planner, AEMO conducts market modelling to determine any expected unserved energy<sup>34</sup> (USE) in Victoria due to:

- Intra-regional limitations to maintain security (security USE)
- Inter-regional limitations to maintain supply-demand balance (reliability USE).

Reliability USE is calculated at a regional level, whereas security USE is typically identified at the connection point level. Therefore, the granularity of the VCR to apply will depend on the type of USE identified: a state VCR for reliability USE and ideally a more granular locational VCR for security USE.

The following VCR values will be used for transmission planning in Victoria where reliability USE is identified, or where there is insufficient load group composition data to model at a more granular level:

- An aggregate state VCR value that includes direct connect load. The VCR is derived by load weighting, using BREE data, the residential, agriculture, commercial, non-direct connect industrial and direct connect VCR values produced in this review. This VCR value will be used to assess reliability costs and benefits for projects which supply both distribution and direct connect load.
- An aggregate state VCR value that excludes direct connect load. The VCR is derived by load weighting, using BREE data, the residential, agriculture, commercial and non-direct connect industrial VCR values produced in this review. This VCR value will be used to assess reliability costs and benefits for projects which supply distribution load only.
- The aggregate NEM direct connect customer VCR value. This VCR value will be used to assess reliability benefits for projects which supply directly connected load only.

<sup>33</sup> AEMO, VCR Statement of Approach, 12 November 2013, page.9. Available at: <http://www.aemo.com.au/Electricity/Planning/Value-of-Customer-Reliability-review>.

<sup>34</sup> Unserved energy is the amount of energy that cannot be supplied because there is insufficient generation to meet demand.

The aggregate VCR values that AEMO will apply for Victorian transmission planning are set out in Table 28 below.

**Table 28 Aggregate Victorian VCR results (\$/kWh)**

VICTORIAN PLANNING AGGREGATE VCERS	
Victorian VCR including direct connects	32.62
Victorian VCR excluding direct connects	39.50
Direct connect VCR	6.05

Where security USE is identified and load group composition data is available, the following locational VCR values will be derived:

- A locational VCR value that includes direct connect load. The VCR is derived by load weighting, using relevant DNSP data, the residential, agriculture, commercial, non-direct connect industrial and direct connect VCR values produced in this review. This VCR value will be used to assess costs/benefits for projects which supply both distribution and direct connect load.
- A locational VCR value that excludes direct connect load. The VCR is derived by load weighting, using relevant DNSP data, the residential, agriculture, commercial and non-direct connect industrial VCR values produced in this review. This VCR value will be used to assess costs/benefits for projects which supply distribution load only.

The DNSP data used by AEMO may contain other customer classes, such as public lighting, which fall outside the VCR customer classification. Where this occurs, the most relevant VCR customer class will be selected to derive the load weighted VCR value. If none of the VCR customer classes are appropriate, the aggregate Victorian VCR value which excludes direct connects will be applied to that DNSP customer load.

Development of these locational VCR values is discussed in AEMO's Application Guide (see below).

### 5.1.2 Application to national transmission planning

AEMO intends to apply the new aggregated state-level VCR values (both including and excluding direct connect customers) in its National transmission planning functions, including for Regulatory Investment Test (RIT-T) assessments and reviews of other TNSP investment plans

These VCR values are set out in Table 29 below. Please see section 3.5 of this report for further information for how these numbers have been calculated.

**Table 29 National planning VCR values (\$/kWh)**

	NSW*	VIC	QLD	SA	TAS
VCR (including direct connects)	34.15	32.62	34.91	34.06	25.62
VCR (excluding direct connects)	38.35	39.50	39.71	38.09	39.43

More granular VCR values can be derived for network planning purposes by weighting the VCR survey results by load composition, for example, at a connection point level. This is discussed in further detail in the VCR Application Guide.



### 5.1.3 Broader application of VCR survey results

AEMO recognises that VCR survey results may be utilised in revenue regulation, planning and operational purposes by TNSPs, DNSPs, regulators, policymakers, governmental bodies, and industry participants. To assist in applying the VCR survey results, and to facilitate a more consistent application of the values, AEMO is publishing a draft VCR Application Guide for consultation shortly following the release of this report.

AEMO intends that the Application Guide will assist in interpreting and applying the VCR survey results to:

- Derive locational VCR values.
- Transmission and distribution network planning, including in quantifying reliability benefits for the RIT-T and Regulatory Investment Test for Distribution (RIT-D) processes.
- Factoring in transmission losses when calculating USE.
- Undertake an annual adjustment of VCR survey results.

In addition, the Application guide also mentions potential applications of the VCR survey results to:

- Set transmission and distribution reliability standards.
- Set an efficient NEM reliability setting and standard.
- Set load shedding/restriction schedules.
- Set the price of non-market ancillary services (NMAS).

AEMO welcomes feedback on the Application Guide. Further details on the consultation procedure for submissions to the Application Guide will be set out at the time of its release.

## 5.2 Next steps

### 5.2.1 Stakeholder workshop and continued engagement

AEMO welcomes feedback from interested parties on the results detailed in this report. Please contact [support.hub@aemo.com.au](mailto:support.hub@aemo.com.au) with any queries.

A workshop has also been scheduled to discuss findings with industry stakeholders on 23 October 2014, to be hosted at AEMO's Sydney, Melbourne and Brisbane offices. Parties interested in attending this workshop should contact George Huang at [george.huang@aemo.com.au](mailto:george.huang@aemo.com.au).

### 5.2.2 Report to the COAG Energy Council

As the VCR review was requested to be undertaken by the COAG Energy Council, AEMO will write to the Council Secretariat setting out an overview of the results in its next update to the COAG Energy Council.