STPIS reliability incentive rates 2015-2019

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Contents

Executive summary

This report investigates the value placed by electricity network customers in the Australian Capital Territory (ACT) on lost load and changes in reliability indices and develops incentive rates for the reliability component of the Service Target Performance Incentive Scheme (STPIS) to be applied to ActewAGL Distribution over the period 2015-16 to 2018-19 by the Australian Energy Regulator (AER).

The STPIS is a scheme applied by the AER that will make ActewAGL Distribution prices dependent on service performance from 1 July 2015.[1] The measures of service performance included in the scheme as it will apply to ActewAGL Distribution include:

- The average number of unplanned supply interruptions experienced by customers (USAIFI); and
- The average amount of customer time spent off supply due to unplanned supply interruptions (USAIDI).

The levels of financial rewards/penalties for unit variations in the performance measures are set by the AER in its 2015 final determination and are referred to as *incentive rates*. The STPIS guideline sets out formulae for calculating incentive rates, based on an estimate of the value of customer reliability (VCR), measured in units of lost load, and weights for converting this value into units of USAIDI and USAIFI.[2] The STPIS guideline also makes provision for ActewAGL Distribution to propose an alternative VCR (Clause 3.2.2(d)) and weights (Clause 3.2.2(f)(2)).

Over the past ten years, ActewAGL has funded two major studies into the value placed by its customers on changes in electricity supply reliability (measured as willingness to pay (WTP) or willingness to accept (WTA) compensation). In 2003, NERA and ACNielsen undertook a survey of both residential and non-residential customers (*the NERA study*).[3] In 2011, the Australian National University (ANU) undertook a survey of

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[1] The AER Stage 2 Framework and Approach paper of January 2014 confirmed that from 1 July 2015 the STPIS will apply to ActewAGL with revenue at risk.

[2] AER 2009, *Electricity distribution network service providers – Service target performance incentive scheme*, November, pp10-11.

[3] NERA and ACNielsen (2003). *Willingness to pay research study*. A report for ACTEW Corporation and ActewAGL. September.

residential customers (*the ANU study*).[4] These studies represent the best available evidence on which to set STPIS incentive rates for the ACT.

In this paper, value estimates from these studies are related to lost load and changes in reliability indices (USAIDI and USAIFI) for a large number of reliability changes (in order to avoid undue influence by a particular scenario). Historical data on the average frequency of interruptions and the distribution of duration over interruptions are used to define base reliability levels for each survey respondent. Reliability changes are generated by shifting the distributions of the frequency and duration of interruptions over respondents up or down by up to 10 per cent.

For each reliability change, average WTP, change in USAIDI, change in USAIFI, and lost load are recorded. Regression analysis is used to estimate linear relationships between WTP and lost load and between WTP and changes in reliability indices.

The potential application of the various value estimates derived from this analysis to STPIS is considered in the context of the potential for unintended incentives, the extent to which simulated reliability changes cover possible outcomes, potential bias, and comparison with the results of past studies.

Based on this assessment, ActewAGL Distribution proposes incentive rates be set using the average value of lost load from changes in the frequency of interruptions estimated in this paper; that is, an alternative VCR of $67,258 per MWh ($2014-15).

Table 1: Estimated value of lost load by sector based on changes in interruption frequency

	VCR ($/kWh 2014-15)	*Weighting*	*Contribution to sector-weighted VCR ($/kWh 2014-15)*
Residential	40.15	40.82%	16.39
Non-residential	85.96	59.18%	50.87
Total			67.26

Incentive rates based on this VCR estimate and calculated in accordance with clauses 3.2.2(h) and (i) of the STPIS guideline are set out in Table 2.

Table 2: Proposed incentive rates

	Urban	*Rural*
USAIFI	3.81%	0.47%
USAIDI	0.093%	0.011%

[4] McNair, B.J. and Ward, M.B. (2012). *Willingness to pay research project*. Final report for ActewAGL Distribution. March.

1 Introduction

1.1 Purpose of this report

This report investigates the value placed by electricity network customers in the Australian Capital Territory (ACT) on lost load and changes in reliability indices and develops incentive rates for the reliability component of the Service Target Performance Incentive Scheme (STPIS) to be applied to ActewAGL Distribution over the period 2015-16 to 2018-19 by the Australian Energy Regulator (AER).

1.2 Background

The STPIS is a scheme applied by the AER that will make ActewAGL Distribution prices dependent on service performance from 1 July 2015.[5] The measures of service performance included in the scheme as it will apply to ActewAGL Distribution include:

- The average number of unplanned supply interruptions experienced by customers (USAIFI); and
- The average amount of customer time spent off supply due to unplanned supply interruptions (USAIDI).

Financial rewards and penalties under the scheme will depend on performance relative to predetermined targets and will apply via an *S factor* in the formula for maximum allowable average revenue (MAAR) in annual pricing proposals. The levels of financial rewards/penalties for unit variations in the performance measures are set by the AER in its 2015 final determination and are referred to as *incentive rates*.

These incentive rates are intended to reflect the value placed by customers on changes in performance measures.[6] Setting incentive rates to reflect this value is consistent with the economic theory of performance-based regulation in that it attempts to induce optimal

[5] The AER Stage 2 Framework and Approach paper confirmed that from 1 July 2015 the STPIS will apply to ActewAGL with revenue at risk.

[6] National Electricity Rules 6.6.2(b)(3)(vi); also see AER 2013, *Submission to AEMO in relation to Value of Customer Reliability (VCR) Issues Paper*, 17 May, p3.

provision of quality by internalising the social cost-benefit analysis within the business's profit maximisation problem.[7]

The STPIS guideline sets out formulae for calculating incentive rates, based on an estimate of the value of customer reliability (VCR) in Victoria, measured in units of lost load, and weights for converting this value into units of USAIDI and USAIFI.[8] These weights are based on evidence from a study into willingness to pay (WTP) for changes in reliability in South Australia.[9] The STPIS guideline also makes provision for ActewAGL Distribution to propose an alternative VCR (Clause 3.2.2(d)) and weights (Clause 3.2.2(f)(2)).

ActewAGL Distribution has been an industry leader in undertaking high-quality research to understand the preferences of its customers with respect to the balance between cost and service levels. Over the past ten years, ActewAGL has funded two major studies that have investigated customer WTP and willingness to accept (WTA) compensation for changes in electricity supply reliability. In 2003, NERA and ACNielsen undertook a survey of both residential and non-residential customers (*the NERA study*).[10] In 2011, the Australian National University (ANU) undertook a survey of residential customers (*the ANU study*).[11] These studies used choice modelling techniques to estimate customer WTP to avoid (or WTA compensation for) a range of scenarios. The results of these studies provide a rich source of customer preference information that varies with the nature of interruptions and with customer characteristics. Both studies utilised well regarded researchers and internationally recognised experts in the field of non-market valuation, including Professors Ken Train, David Hensher, and Riccardo Scarpa.

These studies represent the best available evidence on which to set incentive rates for the ACT.

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[7] See, for example: Spence, M.A. (1975). Monopoly, Quality, and Regulation. *The Bell Journal of Economics* Vol. 6, No. 2, pp. 417-429; and Loeb, M. and Magat, W.A. (1979). A Decentralized Method for Utility Regulation. Journal of Law and Economics 22, 399-404.

[8] AER 2009, *Electricity distribution network service providers – Service target performance incentive scheme*, November, pp10-11.

[9] AER 2008, Explanatory statement and Discussion paper - *Proposed Electricity distribution network service providers service target performance incentive scheme*, April, p21.

[10] NERA and ACNielsen (2003). *Willingness to pay research study*. A report for ACTEW Corporation and ActewAGL. September.

[11] McNair, B.J. and Ward, M.B. (2012). *Willingness to pay research project*. Final report for ActewAGL Distribution. March.

This paper uses the results of those studies to:

- investigate the relationships between customer WTP and both lost load and changes in reliability indices (USAIDI and USAIFI); and
- develop proposed incentive rates for the STPIS to be applied to ActewAGL Distribution over the period 2015-16 to 2018-19.

1.3 Outline of this report

Section 2 of this report details the investigation of the relationships between ACT customers' WTP and lost load and between WTP and changes in reliability indices. It sets out the approach to the modelling, the estimated utility functions derived from the NERA and ANU studies, the method and assumptions for simulating reliability changes, and the calculation of the average value of lost load and average values of changes in reliability indices. Section 3 of the report uses the results from the investigation in Section 2 to formulate proposed incentive rates for the reliability component of STPIS.

2 Investigation of values

2.1 Approach

The NERA and ANU studies provide value estimates for a range of changes in the nature of supply reliability at the customer level. The studies use customers' stated choices between reliability scenarios to estimate utility functions defined in terms of the frequency and duration of interruptions with various characteristics, as well as cost, measured as the retail electricity bill or the change in bill. WTP for a given change in supply reliability is derived from these utility functions as the change in bill that keeps utility constant when interruptions change.

The objective of this paper is to identify how WTP estimates derived from these studies vary with two particular types of measures of reliability changes – unplanned lost load and changes in reliability indices, such as USAIDI and USAIFI. Ultimately, the goal is to estimate an average customer value per unit of lost load or per unit change in system-average reliability indices in the ACT. To do so, we need to identify a set of reliability changes and, for each change, measure customer value as well as the associated lost load and changes in reliability indices. We can then observe how these measures vary with estimated WTP.

The reliability changes used in this paper are defined at a survey respondent level so that the richness of the consumer utility functions estimated in the WTP studies can be retained in the analysis. This richness includes preference heterogeneity across respondents (in the residential data) and non-linear relationships between WTP and interruption duration. Lost load and reliability indices are not expected to be perfectly correlated with WTP estimates because they do not capture these effects (except, in the case of lost load, to the extent that preference heterogeneity is related to consumption). For example, the WTP studies suggest that most consumers would willing to pay more to avoid a one-hour interruption becoming a two-hour interruption than they would to avoid a four-hour interruption becoming a five-hour interruption, but both of these reliability changes would have the same impact on measures of lost load and reliability indices.

A large number of reliability changes are analysed in this paper in order to avoid undue influence by a particular scenario (see Appendix A for evidence of the dangers of using a small number of discrete reliability scenarios). Historical data on the average frequency of interruptions and the distribution of duration over interruptions are used to define base reliability levels for each respondent. Reliability changes are generated by shifting the distributions of the frequency and duration of interruptions over respondents up or down by up to 10 per cent. Historical data indicates that these changes are within the plausible range of system-average outcomes for a given year. Values for changes in *planned* interruptions are not investigated in this paper, since planned interruptions are not included in the STPIS.

The approach taken in this paper is illustrated in Figure 1, which shows that the following steps are taken to derive estimates of the value of lost load and the value of changes in reliability indices.

- For each sector (residential and non-residential):[12]
    - establish utility models for estimating the value (WTP) placed on changes in reliability;
    - establish functions for the lost load and the changes in reliability indices associated with changes in reliability;
    - define the changes in reliability to be used to assess value;
    - measure WTP, lost load and changes in reliability indices for each reliability change; and
    - use regression analysis on these data to estimate linear relationships between WTP and lost load and between WTP and reliability indices.
- Calculate the ACT average value of changes in reliability indices by averaging sector values weighted by customer numbers.
- Calculate the ACT average value of lost load by averaging sector values weighted by annual consumption.

This approach differs in some respects to those previously applied in Australian VCR studies (such as the recent assessment of VCR in NSW by Oakley Greenwood in 2012).[13] In this paper, values are assessed for a larger number of reliability change scenarios. The paper considers not only the effect of additional interruptions drawn from the existing distribution of duration over interruptions, but also changes in the distribution of duration itself. It considers the relationship not only between WTP and lost load, but also WTP and reliability indices.

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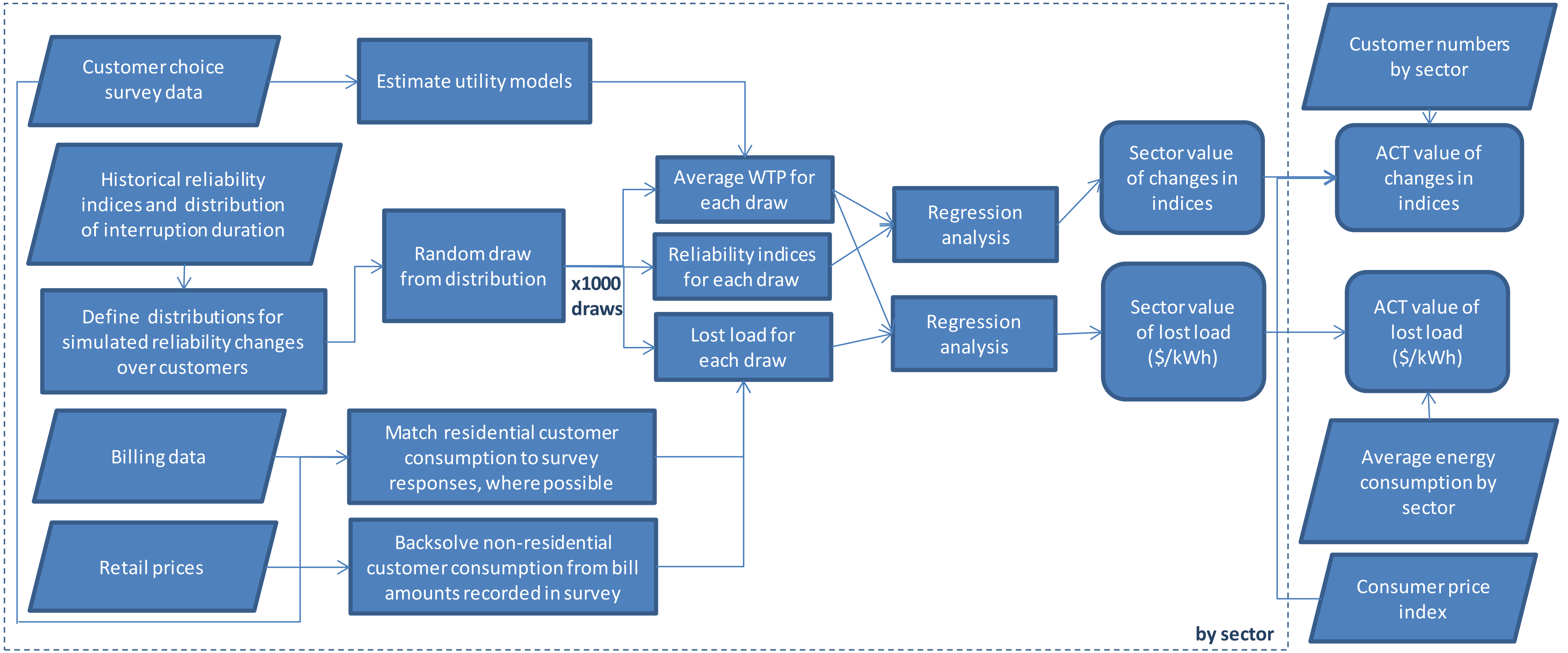
[12] Other studies have employed a further disaggregation of non-residential customers into small, medium and large business. The ActewAGL Distribution network does not service the type of large industrial customer that other Australian distributors service. Further, it is not practicable to disaggregate non-residential values in the ACT, since the NERA study provides a single WTP model for all non-residential customers.

[13] Oakley Greenwood (2012). *NSW Value of Customer Reliability*. Report to the Australian Energy Market Commission, May.

Values are not disaggregated by the feeder types defined in the STPIS guideline. The ACT network comprises mainly urban feeders, with a small number of short rural feeders. However, street addresses are not available for any respondents in the NERA study, so it is not possible to disaggregate values by feeder type for non-residential customers.

Figure 1: Approach to modeling value of lost load and value of changes in reliability indices



2.2 Models of customer preference

The first step towards incentive rates that reflect customer preferences is to examine the evidence on customer preferences; in particular, the value placed by customer on various changes in supply reliability.

2.2.1 Defining value

It is important to define at the outset the value being estimated. The correct measure of benefit (or cost) to consumers from a reliability improvement (or deterioration) is defined in the economics literature as the Hicksian compensating (or equivalent) variation. This value is the maximum amount that customers would be willing to pay (or the minimum amount they would be willing to accept) for a reliability improvement (or deterioration).[14]

2.2.2 Method for estimating value

The indivisible nature of energy network services means that consumers are rarely able to choose their preferred version of the service. Consumers are offered only one level of network reliability for a given property. It is therefore not possible to gather information on consumers' WTP by observing choices in a real market. *Ex post* examination of financial costs imposed by interruptions would provide an incomplete value estimate. Observing purchases of equipment, such as backup generators, may reveal preferences for a subset of customers placing a relatively high value on reliability, but this too would be an incomplete value estimate, since this equipment is not a perfect substitute for electricity network services and is unlikely to completely eliminate the effects of interruptions on these consumers. It is therefore necessary to turn to surveys as a means of gathering information on consumer WTP.

The three most common estimation methods in the context of electricity supply reliability, internationally, are choice modelling (or conjoint analysis), contingent valuation, and direct worth.[15] Choice modelling involves presenting survey respondents with sets of hypothetical scenarios describing the nature of supply interruptions and the cost to the respondent. Respondents indicate their preferred scenario in each set. These choices reveal respondents' willingness to pay (or accept compensation) for changes in a range of aspects of supply reliability. Examples of choice modelling include studies by Accent

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[14] See, for example, Randall, A. and Stoll, J. (1980). Consumer's Surplus in Commodity Space. The *American Economic Review*, 70(3), 449-455.

[15] Hofmann, M., Seljesth, H., Holst Volden, G., and Kjolle, G.H. (2010). *Study on Estimation of Costs due to Electricity Interruptions and Voltage Disturbances*, December, p79.

for Ofgem in the United Kingdom (UK)[16] and by the Electricity Authority in New Zealand.[17] Most types of contingent valuation surveys can be characterised as a specific case of choice modelling in which the focus is on a single scenario. Open-ended contingent valuation questions ask respondents to directly report WTP for a specific scenario. The direct worth method asks respondents to estimate the financial expenses they would incur due to hypothetical reliability scenarios.

Two main survey methods have been used in Australia. One is the choice modeling method described above, which has been used by NERA and ACNielsen[18] and the ANU[19] in the ACT, by KPMG in South Australia,[20] and by AEMO in the national VCR study currently being undertaken.[21] The other approach, which has been applied primarily in Victoria, uses a direct worth method that focuses on estimating the financial expenses that would result from deterioration in reliability. The application of this method to residential consumers was described in these studies as an 'economic principle of substitution' approach, but it has also been characterised as a 'preparatory action' method.[22] This approach was developed by Monash University's Centre for Electrical Power Engineering in 1997[23] and later updated by Charles River Associates in 2002[24]

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[16] For example, Accent 2008, *Expectations of DNOs and willingness to pay for improvements in service*, Report prepared for OFGEM, July.

[17] Electricity Authority (2012). *Investigation into the value of lost load in New Zealand* – Summary of findings.

[18] NERA and ACNielsen (2003). *Willingness to pay research study*. A report for ACTEW Corporation and ActewAGL. September.

[19] McNair, B.J. and Ward, M.B. (2012). *Balancing cost and standards of service: the stated preferences of Canberra households*. Energy Networks Conference, 2 May 2012, Brisbane, Australia.

[20] KPMG (2003). *Consumer preferences for electricity service standards*. Report to the Essential Services Commission of South Australia. September.

[21] AEMO (2013). *Value of Customer Reliability Statement of Approach*, November. Also see Scarpa, R. (2013). Methodology for the estimation of the value of customer reliability for AEMO, November.

[22] Hofmann, M., Seljesth, H., Holst Volden, G., and Kjolle, G.H. (2010). *Study on Estimation of Costs due to Electricity Interruptions and Voltage Disturbances*, December, p79.

[23] Khan, M.E. and Conlon, M.F. 1997, *Value of Lost Load*, Report for Victoria Power Exchange by the Centre for Electrical Power Engineering (CEPE), Department of Electrical and Computer Systems Engineering, Monash University.

[24] Charles River Associates 2002, *Assessment of the Value of Customer Reliability (VCR)*, Report for VENCorp, December.

and 2007[25] and Oakley Greenwood for the AEMO in 2011[26] and for AEMC in 2012[27] (the *Monash approach*).

The results derived from these two survey methods are similar in some ways. Both approaches measure value in terms of reliability events or scenarios and both can be converted to a value of lost load.[28] However, the value being measured by each approach differs, at least for residential consumers. Choice modelling holds a major advantage over the Monash approach in this regard – it is consistent with the economic concepts of compensating and equivalent variation.[29] By focusing on out-of-pocket expenses, the Monash approach is likely to omit non-financial costs associated with inconvenience to domestic consumers. It can also include values that should be excluded, such as the excess value of a restaurant meal over a home meal. These shortcomings were noted by AEMO in its March 2013 Issues Paper on VCR.[30]

The most significant challenges associated with using choice modelling to value non-market goods relate to contexts where respondents have little or no experience with the good or service in question and where respondents have no incentive to answer carefully and truthfully. In the electricity reliability context, respondents have generally experienced some form of supply interruption and ActewAGL Distribution's experience with surveys in the ACT confirms customers understand that price-reliability options could be enforced on the basis of survey findings, particularly if the survey has been commissioned by a utility or regulatory body. For these reasons, ActewAGL supports the use of choice modelling as a technique for estimating the value placed by customers on changes in reliability.[31]

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[25] Charles River Associates 2008, *Assessment of the Value of Customer Reliability (VCR)*, Report for VENCorp, August.

[26] Oakley Greenwood 2011, *Valuing Reliability in the National Electricity Market*, Final Report to the Australian Energy Market Operator, March.

[27] Oakley Greenwood 2012, *NSW Value of Customer Reliability*, Final Report to the Australian Energy Market Commission, May.

[28] The VCR studies have typically converted the scenario-based values to a VoLL in the consultant reports, whereas the choice modelling studies have not.

[29] Small, K.A. and Rosen, H.A. (1981). Applied Welfare Economics with Discrete Choice Models. *Econometrica*, 49(1), 105- 130.

[30] AEMO 2013, *Value of customer reliability*, Issues Paper, March, pp11-12.

[31] The direct worth method may be appropriate for industrial customers, but there are no large customers of this type in the ACT.

2.2.3 Studies used in this paper

Two choice modelling surveys have been conducted in the ACT in the past decade and are used as inputs to the calculation of values in this paper – the NERA study in 2003 and the ANU study in 2012. These surveys involved presenting respondents with several choice questions, where each choice question presented two or three scenarios at a specified cost and asked the respondent to indicate their preferred option. The scenarios were described by multiple attributes relating to the frequency, duration, and nature of supply interruptions. The levels assigned to attributes varied over scenarios and over questions to provide the variation necessary for statistical estimation of the value placed by respondents on marginal changes in each attribute.

In this paper, a model estimated on data from the ANU study is used to calculate residential consumers' WTP. A model from the NERA study is used to estimate non-residential customers' WTP, since this customer sector was not included in the more recent ANU study. WTP estimates from the ANU study were similar to estimates from the residential component of the NERA study, suggesting that, although a decade has passed since the NERA study, the result remain relevant.

The survey methods of the two studies are summarised in Table 3. An example of a choice question from the ANU study is presented in Figure 2 to illustrate the method.[32]

[32] Respondents were instructed that unplanned interruptions could occur at any time of day. In contrast, studies using the Monash approach asked respondents to consider unplanned interruptions occurring at the worst possible time.

Table 3: Summary of methods used in the NERA and ANU studies

	NERA study (non-residential component)	*ANU study*
Preparation and testing	Consultation with stakeholders, focus groups, cognitive testing interviews, and pilot survey	Consultation with stakeholders, focus groups, cognitive testing interviews, and pilot survey
Recruitment and survey methods	Computer-assisted telephone interview via random dialing from Electronic Business Pages. Questionnaires mailed to willing participants. Telephone interviews used to guide respondents through questionnaire.	Computer-assisted telephone interview via random dialing to obtain email addresses from willing participants. Recruitment to internet questionnaire via email.
Respondent incentive	$25 gift voucher	Cash prize draw – prizes totaling $4,000
Completed questionnaires	n=240	n=408
Sample stratification	Organisation size and industry type	Postcode and dwelling type
Survey period	27/02/2003 to 01/04/2003	19/09/2011 to 14/10/2011
Attributes (number and range of levels)	Number of times electricity is completely unavailable (seven levels: once every five years – once a fortnight) Length of time that electricity is completely unavailable each time that it goes out (eight levels: 30 minutes – 24 hours) Time of day that electricity is completely unavailable each time that it goes out (five levels) Prior notification that electricity will be unavailable (eight levels: no notification provided – one month) Response to phone inquiries in the event of electricity becoming unavailable (three levels) Total electricity bill for the year (13 levels: 90% of current bill – 150% of current bill)	Number of supply interruptions with written notice (four levels: once every four years – 8 times per year) Average duration of supply interruptions with written notice (four levels: 30 minutes – 5 hours) Number of supply interruptions without warning (four levels: once every four years – 8 times per year) Average duration of supply interruptions without warning (eight levels: 1 minute – 24 hours) Time taken to be put through to a human operator when making phone enquiries during a supply interruption without warning (five levels: 30 seconds – 20 minutes) Number of supply interruptions due to a disaster (two levels: once every 50 years, once every 20 years) Average duration of supply interruptions due to a disaster (two levels: 2 days, 7 days)

	NERA study (non-residential component)	*ANU study*
		Change in annual electricity bill (nineteen levels: -$600 – +$500)
Choice question format	Eight choice questions per respondent. Two unlabeled alternatives per choice question.	Eight choice questions per respondent. Three alternatives per choice question (status quo and two change alternatives).
Number of choice observations used in model estimation	n=1624	n=2104
Model estimation	Mixed logit model with non-random cost parameter	Mixed logit model with observed heterogeneity in non-random cost parameter
Peer reviewer	Prof. David Hensher	Prof. Riccardo Scarpa

Figure 2: Example of a choice question from the ANU study

	CURRENT PACKAGE	PACKAGE A	PACKAGE B
Supply interruptions with written notice (in normal business hours)			
Number of supply interruptions with written notice:	1 time per year	4 times per year	8 times per year
Average duration of supply interruptions with written notice:	1 hour	30 minutes	1 hour
Supply interruptions without warning			
Number of supply interruptions without warning:	1 time per year	Once every 4 years	1 time per year
Average duration of supply interruptions without warning:	2 hours	24 hours	1 hour
Time taken to be put through to a human operator when making phone enquiries in the event of a supply interruption without warning:	2 minutes	5 minutes	10 minutes
Supply interruptions due to a disaster			
Number of supply interruptions due to a disaster:	Once every 50 years	Once every 20 years	Once every 20 years
Average duration of supply interruptions due to a disaster:	2 days	2 days	7 days
The cost to your household			
Electricity bill for the year:	$0 more than your current bill	$200 less than your current bill	$300 less than your current bill
If these were the only options available to you, which option would you choose?	☐	☐	☐

The outputs from these studies are estimated customer utility functions. These functions can be used to calculate the amount of money (framed as an increase or decrease in electricity bills) that would keep customer utility unchanged when there is a change in supply reliability. This amount of money is referred to as the WTP (or WTA compensation) for the change in supply reliability. The remainder of this section of the paper sets out the estimated utility functions used in this paper for residential and non-residential customers in the ACT.

2.2.4 Residential customer preferences

The estimated residential customer utility function derived from the ANU study and used in this paper is set out in Table 4.

Table 4: Model of residential customer utility

	Coef.	t-stat
Non random parameters	[redacted]	
Alternative-specific constant: status quo		
Increase in annual electricity bill		
Number of supply interruptions with written notice per annum		
Average duration in hours of supply interruptions with written notice: 1 hour [a]		
Average duration in hours of supply interruptions with written notice: 2 hours [a]		
Average duration in hours of supply interruptions with written notice: 5 hours [a]		
Number of supply interruptions without warning per annum		
Ln (1 + average duration in hours of supply interruptions without written notice)		
Supply interruptions due to a disaster: 7 days off-supply once in 50 years [b]		
Supply interruptions due to a disaster: 2 days off-supply once in 20 years [b]		
Supply interruptions due to a disaster: 7 days off-supply once in 20 years [b]		
Time taken to be put through to a human operator when making phone enquiries in the event of a supply interruption without warning		
Hours off-supply per annum due to supply interruptions with written notice		
Hours off-supply per annum due to supply interruptions without warning		
Interactions with "Increase in bill"		
x equivalised household income < $50,000 pa [c]		
x equivalised household income between $50,000 and $80,000pa [c]		
x equivalised household income > $80,000 pa [c]		
x average energy consumption < 20 kWh/day [d]		
x average energy consumption 20-30 kWh/day [d]		
x average energy consumption < 20 kWh/day [d]		
x higher number of interruptions experienced [e]		
Random parameters: diagonal elements of Cholesky decomposition matrix (		
Total hours off-supply per annum		
Total number of interruptions per annum		

	Coef.	t-stat
Alternative-specific constant: alternatives to status quo	[redacted]	
Random parameters: below-diagonal elements of Cholesky decomposition matri		
Total number : total hours		
Total hours : constant		
Total number : constant		
Model fit		
Choice observations		
Log likelihood		
McFadden pseudo R^2		
AIC/N		

[a] Effects-coded variables taking value -1 when duration is 30 minutes.

[b] Effects-coded variables taking value -1 when two days off-supply once in 50 years.

[c] Effects-coded variables taking value -1 when income is not stated.

[d] Effects-coded variables taking value -1 when consumption data are unavailable.

[e] (1,-1) variable taking value 1 when the number of experienced interruptions is two or eight per annum and value -1 when once every two years

This model differs slightly in specification from the model in the ANU report to ActewAGL Distribution. The model in the ANU report used effects coded variables for the various levels of unplanned interruption duration presented in the survey. The coefficients on those variables indicated that utility decreases with interruption duration at a decreasing rate. However, the decrease over the point estimates was not monotonic, with the coefficient on the ‘1 hour’ level higher than the coefficient on the ’30 minutes’ level (although the difference is not statistically significant). The majority of unplanned interruptions in the ACT have a duration of an hour or less. The simulated reliability changes discussed in the next section will therefore focus largely on interruptions with durations in that range. As a result, outputs in terms of the point estimates of value of lost load or the value of changes in reliability indices will be sensitive to this coefficient ordering. To overcome this problem, the model in this paper specifies the duration of unplanned interruptions as a continuous variable in log form.[33]

Estimates of WTP are not calculated directly from the unconditional coefficient estimates in Table 4. Rather, estimates of average WTP for a change in supply reliability are calculated as an average of respondent-specific WTP estimates, where each of the 263 respondent-specific WTP estimates is calculated by averaging WTP estimates derived

[33] The model also uses different respondent characteristics to capture observed preference heterogeneity, which does not have a material effect on average WTP or the results in this paper. Overall model fit is slightly improved.

from 500 draws from the conditional distribution for each random parameter (see Appendix B and Appendix C for detailed calculations). The WTP estimate for each draw of a respondent-specific utility function is calculated as the sum of the changes in utility resulting from the reliability change divided by the marginal utility of income for the respondent, which is the fixed parameter on the cost variable (-0.00463) adjusted for observed respondent heterogeneity related to income, consumption and previous interruption experience.[34]

2.2.5 Non-residential customer preferences

The estimated non-residential customer utility function derived from the NERA study and used in this paper is set out in Table 5.

Table 5: Model of non-residential customer utility

	Coef	*t stat*
Random parameters		
Number of interruptions per year	[redacted]	
Ln(1+length in hours)		
Ln(1+number)ln(1+length)		
Mon-Fri after 8am		
Person answers		
Acct manager		
Non-random parameters		
Price as share of current bill		
Mon-Fri after 6pm		
Mon-Fri after midnight		
Weekdays		
1 day's notice		
2 day's notice		
5 day's notice		
7 day's notice		
Two week's notice		
One month's notice		

[34] For further detail on this approach see Greene, W. H., Hensher, D. A., Rose, J. M., 2005. *Using classical simulation based estimators to estimate individual willingness to pay values: A mixed logit case study of commuters*. In: Scarpa, R., Alberini, A. (Eds.), Applications of Simulation Methods in Environmental and Resource Economics. Springer, Dordrecht, The Netherlands, pp. 17-34.

	Coef	t stat
Emergency	[redacted]	
Standard deviations of random parameters		
Number of interruptions per year		
Ln(1+length in hours)		
Ln(1+number)ln(1+length)		
Mon-Fri after 8am		
Person answers		
Account manager		

Estimates of WTP for reliability changes are calculated using the unconditional coefficient estimates shown in Table 5. This approach differs slightly from the approach used for residential customers because it was not possible to re-estimate the non-residential choice model in order to obtain the conditional respondent-specific random parameter estimates.

The model from the NERA study did not interact frequency or duration of interruptions with the variable indicating whether notice of interruptions was provided. As a result, the WTP values derived from this model for changes in frequency and duration of interruptions are not specific to either planned or unplanned interruptions. They could be considered a weighted average of values over planned and unplanned interruptions and may therefore represent conservative estimates of the true WTP to avoid *unplanned* interruptions.

2.3 Simulating changes in reliability

In order to estimate the effect on consumer welfare associated with lost load or changes in reliability indices, it is necessary to identify a change in reliability or set of changes in reliability that will be used in the calculation. For example, the Oakley Greenwood study of VCR for AEMC measured the consumer value placed on an additional interruption at six different duration levels and weighted the results by the likelihood of interruptions of each duration occurring based on historical interruption data.[35]

Rather than focussing on a small number of specific reliability change scenarios, we simulate a large number of changes in the distribution of interruption frequency and duration across customers, using historical interruption data for the ACT to inform the distributions. This approach achieves a better coverage of plausible reliability changes and is less susceptible to undue influence from a particular scenario. Evidence of the

[35] Oakley Greenwood 2012, *NSW Value of Customer Reliability*, May, p95-96.

potential impact of arbitrary selection of a small number of reliability scenarios is provided in Appendix A.

Two reliability simulation approaches are used – one that varies only the distribution of the *frequency* of unplanned interruptions over respondents (the *frequency simulation*), and another that varies the distributions of both frequency and duration of unplanned interruptions over respondents (the *full simulation*).[36] Previous VCR reports for NSW and Victoria have focused on the costs of additional interruptions and do not explicitly value the costs of increasing the duration of the existing number of interruptions.

In the full simulation approach, we simulate, for each respondent, the frequency and duration of unplanned interruptions at time t_0 and time t_1 (before and after the reliability change). The frequency and duration of *planned* interruptions is simulated for residential respondents at time t_0 and held constant at t_1, since residential preference heterogeneity is related in the utility model to total (planned and unplanned) interruptions and time off supply. In the frequency simulation approach, the t_1 duration of unplanned interruptions is set equal to the t_0 duration. The complete set of distributions over respondents used to generate reliability scenarios are set out in Table 6.

Table 6: Distributions for simulation of reliability changes

Parameter	***t_0 level***	***t_1 level***
Frequency of planned interruptions (per annum)	Asymmetric triangular distribution min=0, max=0.6756, mode=0	= t_0 level
Duration of planned interruptions (hours)	Assigned to the levels used in the survey based on U(0, 12.7)	= t_0 level
Frequency of unplanned interruptions (per annum)	Asymmetric triangular distribution min=0, max=1.9680, mode=0	Asymmetric triangular distribution min=0, max~U(1.7712, 2.1648), mode=0
Duration of unplanned interruptions (hours)	Log normal distribution μ=-0.34 σ=0.64	*In the frequency simulation:* = t_0 level *In the full simulation:* Log normal distribution μ~U(-0.445,-0.15) σ=0.64

[36] The choice modelling studies captured the preferences expressed by customers towards changes in reliability via the main effects of frequency and duration as well as via total time off supply (the interaction between frequency and duration).

The t_0 distributions for frequency of planned and unplanned interruptions have been constructed so that the distribution means are equal to the average PSAIFI and USAIFI observed in the ACT over the past five years. The distribution of interruptions over individual customers is approximated by asymmetric triangular distributions, which provide a reasonable fit to the historical distributions while avoiding unrealistic values that can result from the tail of a lognormal distribution. The t_1 distribution for frequency of unplanned interruptions is randomly generated so that the mean (and range) lies within the range ±10 per cent of the t_0 distribution. Historical data indicates that this range is within the plausible range of system-average outcomes for a given year.

The t_0 distributions for duration of planned and unplanned interruptions have been constructed to fit the distribution observed in the ACT over the past five years. The distributions of planned and unplanned interruptions were best captured by uniform and log normal distributions, respectively. The means of these distributions are consistent with average PCAIDI and UCAIDI in the ACT over the past five years. In the full simulation approach, the t_1 distribution for duration of unplanned interruptions is randomly generated (by varying the location parameter, μ) so that the mean lies within the range ±10 per cent of the t_0 distribution mean. Historical data indicates that this range is within the plausible range of system-average outcomes for a given year.

To illustrate, Figure 3 shows the historical distribution of the duration of unplanned interruptions and the t_0 distribution used in the simulation of reliability changes.

Figure 3: The distribution of unplanned interruption duration – actual and fitted

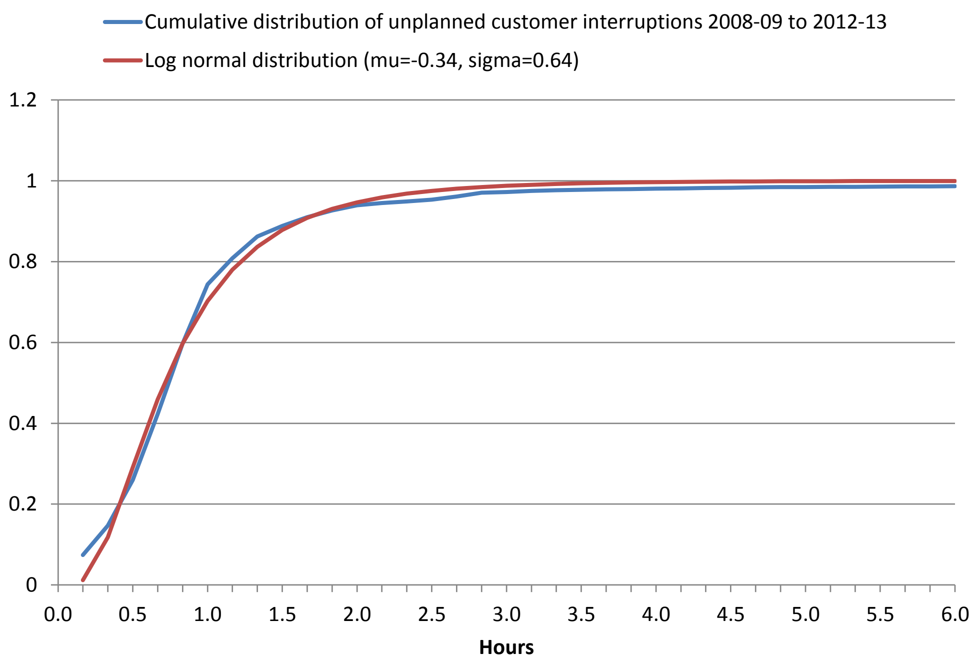
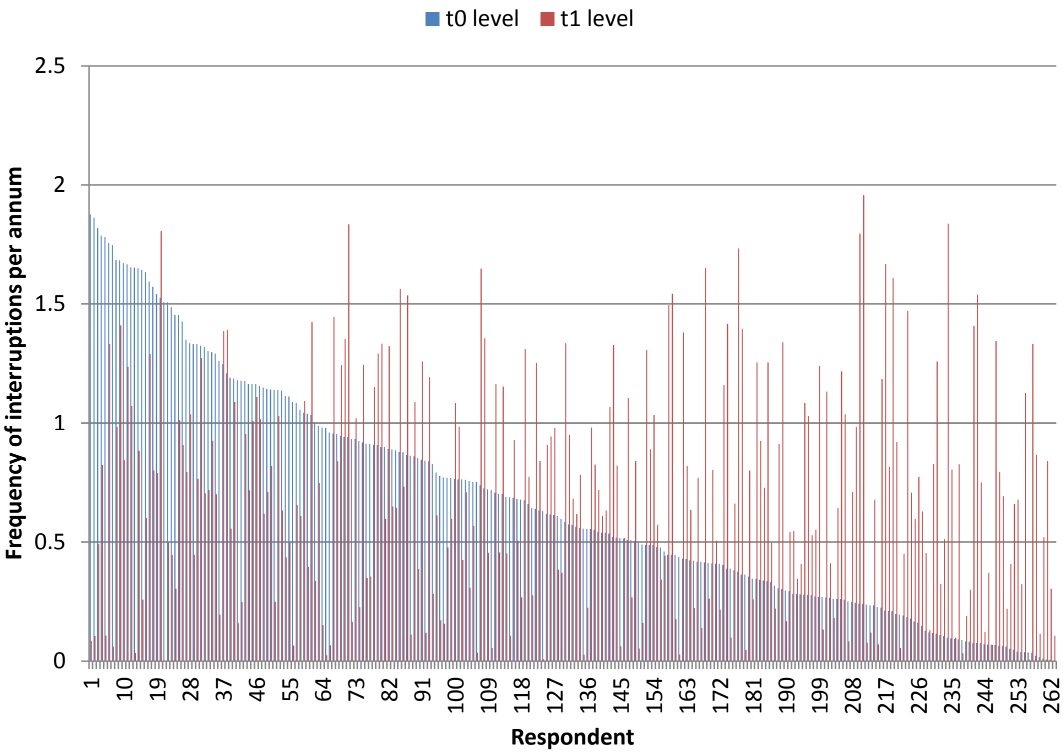


Figure 4 provides an example of one reliability change in which the average frequency of unplanned interruptions increases by around seven per cent. It highlights that the t_1 level is independent of the t_0 level for each respondent, so that each simulated reliability change involves some respondents experiencing an increase in frequency and others a decrease in frequency.

Figure 4: Example of simulated t_0 and t_1 frequency of interruptions with respondents ordered by t_0 frequency



Some 1000 reliability changes were simulated for each sector (residential and non-residential).

2.4 Relating willingness to pay to lost load and changes in reliability indices

2.4.1 Data and regression analysis

For each reliability change, the following were recorded:

- average WTP;
- change in USAIDI;
- change in USAIFI; and
- lost load.

Average WTP was calculated as described in Section 2.2. USAIDI was calculated as the sum over all respondents of the expected time off supply per year in minutes divided by the number of respondents. USAIFI was calculated as the sum over all respondents of the expected number of interruptions per year divided by the number of respondents.

Lost load was calculated as follows. Annual consumption for residential respondents was assumed to be equal to each respondent's actual consumption in 2011 (the year in which the survey took place), where respondents chose to provide their street address and were successfully matched to billing records (98 respondents). Where this data was unavailable, average consumption across all residential network customers was assumed. This process resulted in average consumption across the 263 respondents of 23.55 kWh/day (or around 8,600 kWh per annum).

Annual consumption for non-residential respondents was estimated by backsolving consumption from annual bill amounts reported in the survey using regulated retail tariffs in force at the time of the survey (2002-03). This process resulted in average consumption across the 203 respondents of 45,026 kWh per annum.

Constant usage across time was assumed, so that lost load was simply measured as average hourly consumption multiplied by the change in time off supply (measured in hours). The assumption of uniform load over all hours of the year is consistent with the way in which VCR ($/MWh) is converted to incentive rates ($/USAIDI and $/USAIFI) in Appendix B of the STPIS guideline. It is also consistent with the instruction to respondents in the ANU study that unplanned interruptions could occur at any time of day and with the wide range of times of day used to describe interruptions in the NERA study.

Descriptive statistics for these four variables generated by the simulations are provided in Table 7. They show that the variation in the distribution of interruption duration included in the full simulations (as distinct from the frequency simulations) leads to greater variation in SAIDI, lost load and, particularly, WTP.

Table 7: Descriptive statistics

	Minimum	*Maximum*	*Standard deviation*
Residential, frequency simulation			
WTP/WTA ($2011)	-7.608	7.498	2.598
ΔUSAIDI	-8.729	9.494	3.149
ΔUSAIFI	-0.136	0.167	0.053
Lost load (kWh)	-0.149	0.191	0.054

	Minimum	Maximum	Standard deviation
Residential, full simulation			
WTP/WTA ($2011)	-26.606	21.459	7.856
ΔUSAIDI	-11.864	13.312	4.393
ΔUSAIFI	-0.179	0.170	0.056
Lost load	-0.217	0.246	0.074
Non-residential, frequency simulation			
WTP/WTA ($2003)	-69.802	56.091	20.729
ΔUSAIDI	-9.662	11.617	3.651
ΔUSAIFI	-0.166	0.194	0.061
Lost load (kWh)	-0.827	0.995	0.313
Non-residential, full simulation			
WTP/WTA ($2003)	-173.609	191.796	65.083
ΔUSAIDI	-13.882	16.241	4.796
ΔUSAIFI	-0.198	0.172	0.058
Lost load (kWh)	-1.188	1.390	0.411

By way of example, Figure 5 illustrates the WTP/WTA and lost load outputs from the frequency simulation approach for residential customers. As expected there is a strong negative relationship between the two measures. The measures are not perfectly (negatively) correlated primarily because preference and consumption heterogeneity are not closely related (that is, it matters which respondents receive the worst reliability outcomes).[37] An average value of lost load for the residential sector is calculated by fitting a line through these points, subject to the constraint that the line must pass through the origin (0, 0). The slope of that line represents the average value of lost load.

The same process is repeated for the non-residential sector. Similarly, average values of changes in USAIDI and USAIFI for each sector are calculated by regressing changes in the indices against average WTP/WTA across all simulated reliability changes (with the intercept set to zero). Both indices are included in the same regression, since both apply concurrently in STPIS. The incentive rate for USAIFI should represent the value placed on a change in USAIFI with USAIDI held constant. The coefficients from the regressions have this interpretation. The coefficient estimates resulting from all eight of these regressions are set out in Table 8.

[37] It also matters which interruption durations are more frequent, since preferences are non-linear over interruption duration, whereas lost load is linear.

Figure 5: Average WTP and unplanned lost load from the frequency simulation for residential customers

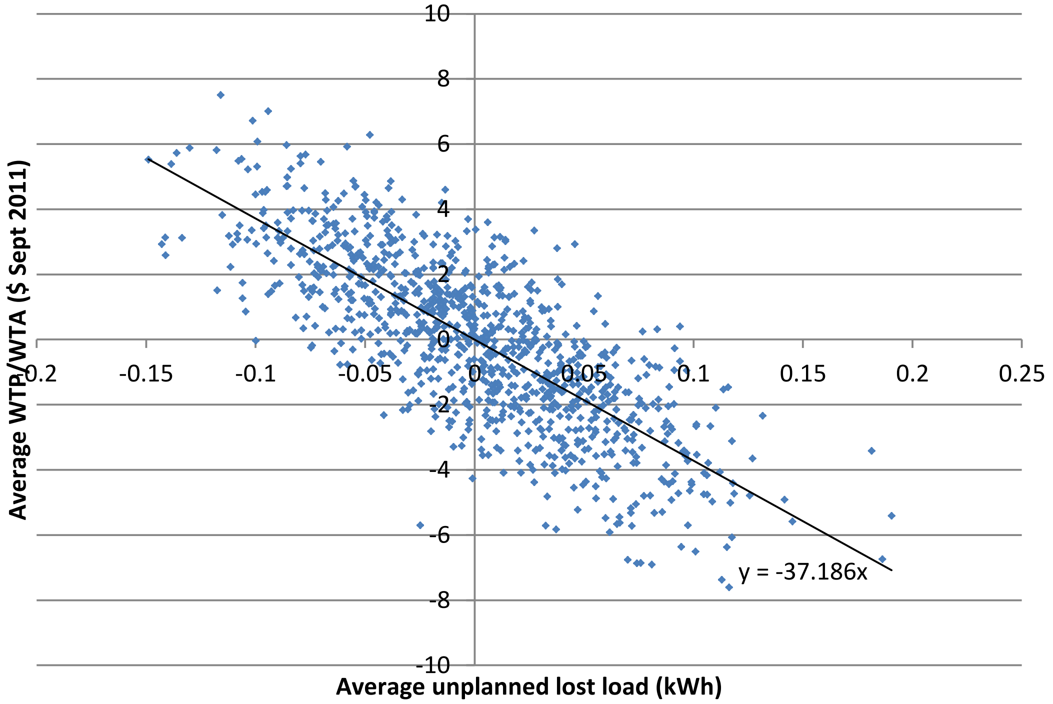


Table 8: Estimated coefficients from regression analysis

Data (dependent variable)	*Explanatory variable*		
	ΔUSAIDI	*ΔUSAIFI*	*Lost load (kWh)*
Residential, frequency simulation (WTP/WTA $2011)	-0.1143	-37.4401	-37.1864
Residential, full simulation (WTP/WTA $2011)	-1.9347	58.4714	-84.2776
Non-residential, frequency simulation (WTP/WTA $2003)	-2.0014	-228.4506	-62.7011
Non-residential, full simulation (WTP/WTA $2003)	-14.7940	418.0415	-138.2470

2.4.2 Indexation

Values are indexed to 2014-15 dollars using the consumer price index values set out in Table 9. Non-residential results are indexed from the June 2003 quarter, while residential results are indexed from the September 2011 quarter to reflect the timing of the respective surveys. An alternative approach for non-residential consumers would be to increase WTP estimates in line with electricity retail bill increases since 2003, since WTP was modelled by NERA as a proportion of bills. This approach is not adopted, since it is expected that bill amounts are correlated with WTP in the cross-sectional data, not because of a causal relationship, but because both variables are positively influenced by consumption. Further, adjusting VCR in line with CPI is consistent with the approach taken in the STPIS guideline (see clause 3.2.2(b)).

Table 9: Consumer price index

Time period	*Consumer price index, weighted average of eight capital cities (ABS 640101)*
June quarter 2003	78.6
September quarter 2011	99.8
Average of four quarters of 2014-15[a]	107.8

[a] CPI growth of 2.5 per cent per annum is forecast beyond the most recent actual (December 2013).

2.4.3 Sector weighting

Values of changes in indices are weighted by customer numbers in each sector. Values of lost load are weighted by energy consumption in each sector. The weightings were based on data from 2012-13 (the most recent complete financial year) as shown in Table 10.

Table 10: Customer numbers and consumption by sector in 2012-13

	Residential	*Non-residential*
Number of customers	152,919 (91.3%)	14,604 (8.7%)
Annual consumption (MWh)	1,184,349 (40.8%)	1,716,871 (59.2%)

The network total values resulting from this aggregation are set out in Table 11.

Table 11: Sector-weighted value estimates ($2014-15)

	ΔUSAIDI	ΔUSAIFI	Lost load
Frequency simulation			
Value of changes in indices ($ per unit change per customer)	-0.35	-64.20	
Value of lost load ($/kWh)			-67.26
Full simulation			
Value of changes in indices ($ per unit change per customer)	-3.67	107.59	
Value of lost load ($/kWh)			-149.30

3 Application to STPIS

This section uses the results of the investigation in Section 2 to form a proposal in relation to incentive rates for the reliability component of STPIS.

3.1 Discussion of value estimates

3.1.1 Values for changes in reliability indices

It is important to understand the interpretation of the values of changes in indices set out in Table 8 and Table 11. The value of changes in USAIDI represents the average WTP per customer for a unit change (one minute per annum) in USAIDI, with USAIFI held constant. An increase in USAIDI with USAIFI held constant implies an increase in UCAIDI, since UCAIDI = USAIDI / USAIFI. We would expect that an increase in both USAIDI and UCAIDI would make consumers worse off. Consistent with this expectation, the value of changes in USAIDI is negative in all four simulations.

The interpretation of the value of changes in USAIFI is more complex. It represents the average WTP for a unit change (one interruption per annum) in USAIFI, with USAIDI held constant. An increase in USAIFI with USAIDI held constant implies a *decrease* in UCAIDI. Consumers may or may not be worse off when USAIFI increases and UCAIDI decreases, depending on the relative values placed on changes in interruption frequency and duration. Estimated values for USAIFI are negative in the frequency simulations, but positive in the full simulations.

These positive values are supported by closer inspection of the choice models. The estimated utility functions suggest that customers prefer a given amount of time off supply to be divided into more interruptions of equal length, rather than less. For example, on average, customers appear to prefer two one-hour interruptions per year to one two-hour interruption per year. However, it is important to recognise that survey respondents may have made their choices on the assumption that all interruptions would be the same length. Therefore, it cannot be directly inferred from the choice data whether customers would prefer one two-hour interruption to two interruptions lasting 119 minutes and one minute. In reality, while there may exist some reliability scenarios in which customers are better off when USAIFI increases, with USAIDI held constant, there are clearly reliability scenarios in which this would not be the case.

Applying a positive USAIFI incentive rate would lead to perverse incentives, since the occurrence of additional very short interruptions could improve financial outcomes for

ActewAGL Distribution under STPIS.[38] It is therefore reasonable to rule out the use of values of changes in reliability indices from the full simulation approach to set STPIS incentive rates directly.

Using values of changes in reliability indices from the frequency simulation to set incentive rate weights is also considered problematic, since the simulation focuses solely on changes in time off supply that result from changes in interruption frequency, with no consideration of changes in time off supply that result from changes in interruption duration. As a result, this approach may not fully capture the relativity between values for USAIDI and USAIFI.

For these reasons, values of reliability indices estimated in this paper will not be used to propose incentive rates or an alternative to the AER's default weighting between STPIS incentives for USAIDI and USAIFI for the 2014-2019 regulatory control period. Further research would be warranted to understand how customer preferences in relation to the frequency of interruptions with total time off supply held constant can best be reflected in incentive rates.

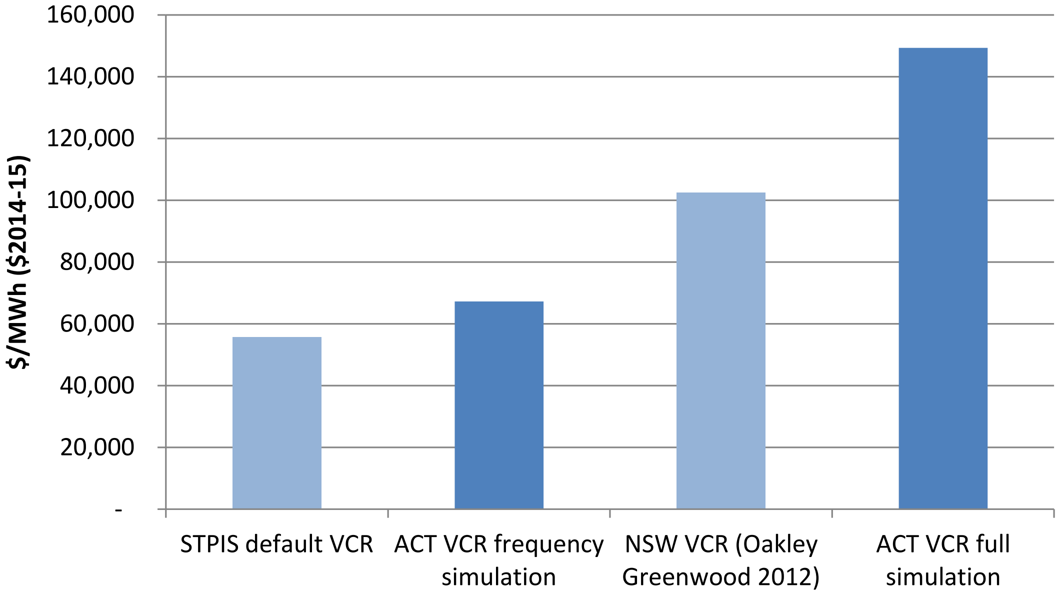
3.1.2 Value of lost load

The question then becomes whether to propose an alternative VCR for STPIS based on the value of lost load from the full simulation, the frequency simulation, or a combination of both.

Table 12 shows the magnitude of the values of lost load (or VCR estimates) estimated in this paper, relative to the default VCR set out in clause 3.2.2(b)(2) of the STPIS guideline (which was based on Victorian studies) and the VCR estimated for NSW by Oakley Greenwood in 2012. The evidence in this paper indicates that the value of lost load in the ACT is higher than the current default VCR in the STPIS. The estimate derived from the frequency simulation lies between the Victorian and NSW estimates, which were estimated using the Monash approach (as discussed in section 2.2). The estimate from the full simulation is considerably higher than previous Australian VCR estimates.

[38] This perverse incentive may also arise under schemes based on SAIFI and CAIDI parameters (as distinct from SAIFI and SAIDI parameters), such as the s-factor scheme applied by the Essential Services Commission of Victoria (ESC) prior to 2006.

Table 12: Comparison of VCR estimates ($2014-15)



Although the estimate from the full simulation is based on a more complete coverage of potential reliability changes (than the estimate from the frequency simulation), there is a risk that the magnitude of the estimate may be driven in part by the combination of:

a) respondents employing decision heuristics that utilise interruption duration independently of interruption frequency (so that average interruption duration enters the utility function); and
b) reliability change scenarios that utilise interruption frequency levels at the low end of the range used in the surveys (so that the estimated welfare effect of changes in average duration are spread over less consumption).

The estimate from the frequency simulation may tend to underestimate the value of lost load, since the evidence suggests that customers are more averse to lost load resulting from changes in duration than resulting from changes in frequency. However, on balance, the risk of significant deviation from the true value is judged to be lower for this estimate. Its use in STPIS would be an appropriate precautionary step in the right direction at this time, since a higher VCR estimate would create a level of inconsistency with the default VCR under the current STPIS. A less conservative approach to the use of the ACT-specific data may prove to be warranted if further studies continue to confirm VCR estimates that are significantly higher than the default VCR in the current STPIS.

3.2 Proposed STPIS incentive rates

ActewAGL Distribution's proposed approach to setting STPIS reliability incentive rates is to use the VCR estimate from the frequency simulation approach of $67,258 per MWh (in 2014-15 dollar terms).

Incentive rates based on this VCR estimate are calculated in accordance with clauses 3.2.2(h) and (i) of the STPIS guideline. The values for the various inputs required for those calculations are set out in Table 13 along with references to the source of the values.

The calculations set out in clauses 3.2.2(h) and (i) of the STPIS guideline require average annual energy consumption by feeder type. ActewAGL Distribution does not possess data on consumption by feeder type. In the absence of this data, ActewAGL Distribution has disaggregated the total forecast by feeder type on the assumption that average consumption per customer is constant across feeder types. ActewAGL Distribution's recently revised feeder classification (with 20 rural feeders) has been used in this calculation for consistency with future reporting.

Table 13: Assumptions for incentive rate calculations

Item		*Amount*	*Source*
Average of smoothed revenue requirement ($2014-15 '000s)		166,990	ActewAGL Distribution proposal Chapter 12
Feeder type	*Urban*	*Short rural*	
VCR ($2014-15 / MWh)	67,258	67,258	This paper
Weighting	0.97	0.92	STPIS guideline, p11
Average annual energy consumption (MWh)	2,464,134	300,332	ActewAGL Distribution proposal Chapter 5
Average USAIDI target	33.46	43.45	ActewAGL Distribution proposal Chapter 16
Average USAIFI target	0.840	1.116	ActewAGL Distribution proposal Chapter 16

ActewAGL Distribution's proposed incentive rates are set out in Table 14, with calculations provided in Appendix D.

Table 14: Proposed incentive rates

	Urban	*Rural*
USAIFI	3.82%	0.47%
USAIDI	0.093%	0.011%

Appendix A: VCR estimation with a small number of reliability scenarios

As part of the investigation of values, ActewAGL Distribution also applied an approach similar to that used in past VCR studies to convert WTP amounts measured in dollars per event/scenario to a VCR measured in dollars per unit of lost load (for example, Oakley Greenwood 2012. *NSW Value of Customer Reliability*. Report to the Australian Energy Market Commission, May).

Table 15 shows the calculation of the residential VCR based on six specific reliability changes. These reliability changes represent increases in the frequency of interruptions and are therefore analogous to the frequency simulation in the body of this report. WTP and consumption are calculated in accordance with the approach described in the body of this report. The probability weighting placed on each of the six scenarios is drawn from the actual distribution of duration over customer interruptions over the period 2008-2013, using the midpoints between duration levels to define the range over which probability was calculated (for example, the probability for the 4-hour interruption scenario is based on the actual number of interruptions of duration between 3 and 6 hours). This set of calculations results in an estimated VCR for residential customers of around $61/kWh (which is higher than the equivalent estimate in the body of the report using the frequency simulation).

Table 15: Residential VCR based on six selected changes in interruption frequency

Duration of additional interruption (hours)	*Average WTP to avoid ($)[a] ($2011)*	*Average annual energy consumption (kWh pa)*	*Interruption duration VCR ($/kWh)*	*Probability of an interruption*	*Duration weighted contribution to sectoral VCR ($/kWh)*
0.50	[redacted]	8601	82.37	0.51	42.02
1.00	[redacted]	8601	44.43	0.32	14.43
1.50	[redacted]	8601	32.04	0.08	2.67
2.00	[redacted]	8601	25.88	0.05	1.40
4.00	[redacted]	8601	16.61	0.01	0.24
8.00	[redacted]	8601	11.91	0.01	0.16
				1.00	60.92

[a] Assumes the annual frequency and duration of planned interruptions are 0.225 and 4 hours, the annual frequency of unplanned interruptions increases from 0.656 to 1.656, and the duration of unplanned interruptions is given in the left-hand column.

Table 16 shows the same calculation based on a different set of six duration levels. It results in an estimated VCR of around $82/kWh. This figure is considerably higher than the $61/kWh estimate obtained above and serves to highlight the dangers of using a small number of reliability changes to convert WTP to dollars per unit of lost load.

Table 16: Residential VCR based on an alternative set of six changes in interruption frequency

Duration of additional interruption (hours)	Average WTP to avoid ($) ($2011)	Average annual energy consumption (kWh pa)	Interruption duration VCR ($/kWh)	Probability of an interruption	Duration weighted contribution to sectoral VCR ($/kWh)
0.17	[redacted]	8601	231.73	0.15	34.07
0.50	[redacted]	8601	82.37	0.28	22.72
0.83	[redacted]	8601	52.31	0.39	20.15
1.50	[redacted]	8601	32.04	0.13	4.21
2.50	[redacted]	8601	22.09	0.04	0.80
4.00	[redacted]	8601	16.61	0.02	0.41
				1.00	82.35

[a] Assumes the annual frequency and duration of planned interruptions are 0.225 and 4 hours, the annual frequency of unplanned interruptions increases from 0.656 to 1.656, and the duration of unplanned interruptions is given in the left-hand column.

Table 17 shows another calculation of residential VCR based on six changes in interruption *duration*. It results in a VCR estimate that is higher again. This result is consistent with the finding in the body of the paper that value estimates from the full simulation are greater than value estimates from the frequency simulation. As noted in the body of the paper, there is a risk that the magnitude of this estimate may be driven in part by the combination of:

a) respondents employing decision heuristics that utilise interruption duration independently of interruption frequency (so that average interruption duration enters the utility function); and
b) reliability change scenarios that utilise interruption frequency levels at the low end of the range used in the surveys (so that the estimated welfare effect of changes in average duration are spread over less consumption).

Table 17: Residential VCR based on six selected changes in interruption duration

Initial interruption duration (hours)	*Average WTP to avoid 30 minute increase in duration ($) ($2011)[a]*	*Average annual energy consumption (kWh pa)*	*Interruption duration VCR ($/kWh)*	*Probability of an interruption*	*Duration weighted contribution to sectoral VCR ($/kWh)*
0.17	[redacted]	8601	141.00	0.15	20.73
0.50	[redacted]	8601	114.66	0.28	31.62
0.83	[redacted]	8601	96.88	0.39	37.32
1.50	[redacted]	8601	74.43	0.13	9.78
2.50	[redacted]	8601	55.76	0.04	2.01
4.00	[redacted]	8601	41.15	0.02	1.01
				1.00	102.47

[a] Assumes the annual frequency and duration of planned interruptions are 0.225 and 4 hours, the annual frequency of unplanned interruptions is 0.656, and the duration of unplanned interruptions increases by 30 minutes from the level given in the left-hand column.

For completeness, the equivalent three tables for non-residential customers are provided in Table 18, Table 19, and Table 20. The results (and comparisons with the results in the body of the paper) follow the same pattern observed in the residential calculations.

Table 18: Non-residential VCR based on six selected changes in interruption frequency

Duration of additional interruption (hours)	*Average WTP to avoid ($) ($2003)*	*Average annual energy consumption (kWh pa)*	*Interruption duration VCR ($/kWh)*	*Probability of an interruption*	*Duration weighted contribution to sectoral VCR ($/kWh)*
0.50	[redacted]	45026	104.60	0.51	53.37
1.00	[redacted]	45026	64.71	0.32	21.02
1.50	[redacted]	45026	49.56	0.08	4.13
2.00	[redacted]	45026	41.10	0.05	2.22
4.00	[redacted]	45026	26.06	0.01	0.37
8.00	[redacted]	45026	16.20	0.01	0.22
				1.00	81.32

Table 19: Non-residential VCR based on an alternative set of six changes in interruption frequency

Duration of additional interruption (hours)	Average WTP to avoid ($) ($2003)	Average annual energy consumption (kWh pa)	Interruption duration VCR ($/kWh)	Probability of an interruption	Duration weighted contribution to sectoral VCR ($/kWh)
0.17	[redacted]	45026	248.77	0.15	36.58
0.50	[redacted]	45026	104.60	0.28	28.85
0.83	[redacted]	45026	73.15	0.39	28.17
1.50	[redacted]	45026	49.56	0.13	6.51
2.50	[redacted]	45026	35.54	0.04	1.28
4.00	[redacted]	45026	26.06	0.02	0.64
				1.00	102.04

Table 20: Non-residential VCR based on six selected changes in interruption duration

Initial interruption duration (hours)	Average WTP to avoid 30 minute increase in duration ($) ($2003)	Average annual energy consumption (kWh pa)	Interruption duration VCR ($/kWh)	Probability of an interruption	Duration weighted contribution to sectoral VCR ($/kWh)
0.17	[redacted]	45026	216.01	0.15	31.76
0.50	[redacted]	45026	174.23	0.28	48.05
0.83	[redacted]	45026	146.05	0.39	56.25
1.50	[redacted]	45026	110.42	0.13	14.51
2.50	[redacted]	45026	80.87	0.04	2.92
4.00	[redacted]	45026	57.72	0.02	1.41
				1.00	154.91

Appendix B: Residential VCR model

Attachment F1 Appendix B VCR residential (confidential).xlsm

Appendix C: Non-residential VCR model

Attachment F1 Appendix C VCR nonresidential (confidential).xlsm

Appendix D: VCR aggregation and incentive rate calculations

Attachment F1 Appendix D VCR aggregation and incentive rates.xls