Investigation into the Value of Lost Load in New Zealand

Report on methodology and key findings

23 July 2013

Market Design

797427-1

Contents

Tables

Figures

Executive summary

What is the value of lost load?

The value of lost load (VOLL) is a measure of the economic value given to an amount of electricity that is prevented from being delivered to consumers (i.e. is 'unserved') as a result of a planned or unplanned outage of one or more components of the electricity supply chain.

The VOLL is therefore the economic cost attributed to such an outage.

In the Electricity Industry Participation Code (Code), the VOLL is referred to as "the value of expected unserved energy" and is:

- $20,000/megawatt-hour (MWh), or
- such other value as the Electricity Authority (Authority) may determine.

The summary key findings of the Authority's VOLL study

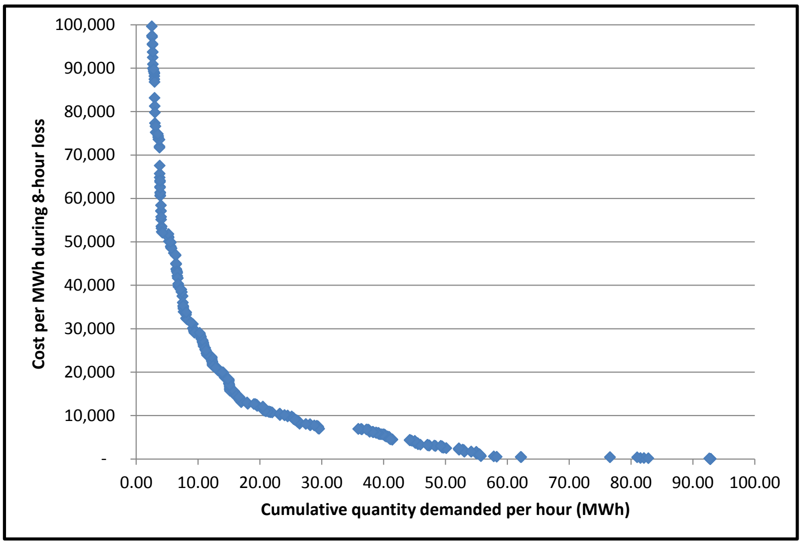
The Electricity Authority (Authority) has recently completed a study of the VOLL in New Zealand, which was commenced under the former Electricity Commission. The summary key findings of this study are:

1) a single VOLL figure is an inappropriate measure of the value that New Zealand electricity consumers place on unserved energy
2) a carefully designed survey-based approach to estimating the VOLL works.

Key finding 1: A single VOLL is inappropriate

At best the VOLL is a range of values that different kinds of electricity consumer consider to be the economic cost of power outages. These values can be treated as a distribution, with parameters to describe the average and the spread of values, as shown in Figure 1.[1]

Figure 1 'Demand' curve for unserved energy, for Auckland 2010 VOLL survey respondents, 8 hour power outage



Source: NZIER

[1] The demand curve in Figure 1 is limited to $100,000 on the y-axis and 80 MWh on the x-axis for presentation purposes, but there are data outside those ranges (although the graph shows nearly all of the survey sample).

Instead of representing the VOLL as a distribution of values, tables of VOLLs can be generated that are based on these values. An example of this approach is shown below, where regional VOLLs for Auckland, Christchurch and Taranaki have been calculated using data from the survey undertaken in Stage 2 of the VOLL study.

To put the residential values in these tables into context, if a household loses power for 8 hours on a winter evening, and that household's average electricity consumption over those 8 hours is 3 kilowatts (kW), the economic cost faced by that household from the outage is approximately:

- $288 if the household is in Auckland
- $356 if the household is in Christchurch
- $505 if the household is in Taranaki.[2]

Table 1 VOLL for Auckland respondents, 8 hour outage

By respondent type and average across samples

Respondent	VOLL
Residential	$11,980
Small non-residential	$56,815
Medium non-residential	$27,992
Large non-residential	$3,906
Average	**$14,900**

Source: NZIER

Note: The average is weighted by consumption, so it is not the mean of the other figures shown in the table.

Table 2 VOLL for Christchurch respondents, 8 hour outage

By respondent type and average across samples

Respondent	VOLL
Residential	$14,818
Small non-residential	$69,761
Medium non-residential	$46,686
Large non-residential	$10,940
Average	**$18,690**

Source: NZIER

Note: The average is weighted by consumption, so it is not the mean of the other figures shown in the table.

[2] Taking the example of the Auckland residential electricity consumer, $11,980/MWh is equivalent to $11.98/kWh, which is then multiplied by the consumer's (average) hourly usage (3 kWh) and the duration (8 hours) of the power outage, which gives a cost to the consumer of $287.52 ($11.98/kWh x 3kW x 8 hours).

Table 3 VOLL for Taranaki respondents, 8 hour outage

By respondent type and average across samples

Respondent	VOLL
Residential	$21,049
Small non-residential	$32,101
Medium non-residential	$9,906
Large non-residential	$7,383
Average	**$9,377**

Source: NZIER

Note: The average is weighted by consumption, so it is not the mean of the other figures shown in the table.

Key finding 2: A survey-based approach to estimating VOLL works

Estimating a VOLL is not straightforward because there is no market for electricity consumers to choose between purchasing different levels of security of electricity supply (i.e. choosing between purchasing different price/reliability packages). Consequently there are no readily identifiable prices for differing levels of electricity reliability.

The use of surveys is by far the most popular approach to estimating a VOLL. The VOLL study has confirmed that a survey method using a combination of the ‘choice modelling’ and ‘direct measurement’ survey approaches can be used to derive VOLL figures.

The VOLL study has been very beneficial in confirming (and in some instances extending) various guidelines for conducting VOLL research in this regard.

Purpose of this technical report

This technical report summarises the findings of Stage 2 and Stage 3 of the VOLL study, and describes the research approach used in each stage.

A companion document entitled ‘Investigation into the Value of Lost Load in New Zealand: Guideline for conducting a VOLL survey’ describes a suggested methodology for researching the VOLL in New Zealand.

1 Introduction and purpose of this report

The VOLL

1.1 The VOLL is a measure of the economic value given to an amount of electricity that is prevented from being delivered to consumers (i.e. is 'unserved') as a result of a planned or unplanned outage of one or more components of the electricity supply chain. The VOLL is therefore the economic cost attributed to such an outage. It is commonly expressed as a dollar amount for each MWh ($/MWh) of electricity (load) not delivered.

1.2 Currently, the VOLL is specified in the Code as being $20,000/MWh, or such other value as the Authority may determine.[3] The $20,000/MWh figure is generic – it does not, for instance, pertain to specific classes of electricity consumer, or to specific locations within New Zealand, or to particular times of the day or seasons of the year, or certain durations of power outage. If the Authority determines a different VOLL, the Authority must publish its determination.

Challenges associated with deriving a VOLL

1.3 Estimating a VOLL is not straightforward because there is no market for electricity consumers to choose between purchasing different levels of security of electricity supply (i.e. choosing between purchasing different price/reliability packages). Consequently there are no readily identifiable prices for differing levels of electricity reliability.

1.4 Therefore an approach needs to be adopted that captures not only the cost of lost production to a business from a power outage, but also the cost to a residential consumer from not having electricity with which, for example, to cook dinner or watch television on a winter's evening. That is, the approach to deriving the VOLL needs to be able to identify both tangible and intangible costs from a power outage.

1.5 In the absence of a market-determined VOLL, two approaches have predominantly been used to derive a VOLL:

(a) some form of survey-based approach (e.g. asking electricity consumers to choose between alternative reliability/price service packages, so as to understand their preferences in regard to electricity reliability; or asking them about the costs they face as a result of a power outage and how much they would be willing to pay, or alternatively how much compensation they would be willing to accept, to avoid a power outage)

(b) some form of model-based approach to value derivation (e.g. estimating a VOLL based on the economic value created per kilowatt-hour (kWh) or MWh of electricity consumed).[4]

1.6 Both of these general approaches to deriving a VOLL have shortcomings. A model-based approach tends to ignore indirect or intangible costs and relies heavily on a priori assumptions embedded in the model. Alternatively, surveys can suffer from poor response rates, thereby impacting the validity of the results. Consumers can find the cognitive effort required of them during the survey challenging (e.g. placing a dollar value on activities affected by a power outage for which the cost is indirect or intangible, such as the entertainment value of watching television).

Purpose of report

1.7 The purpose of this technical report is to summarise the findings of Stage 2 and Stage 3 of the VOLL study, and to describe the research approach used in each stage.

[3] Refer to clause 4 of schedule 12.2 of Part 12.

[4] Australian Energy Market Operator (2013) Value of Customer Reliability Issues Paper, p.11.

2 Background

Use of the VOLL under the Code

2.1 Under the Code, the VOLL is used as a default value as follows:

(a) under the benchmark (transmission) agreement,[5] when Transpower is assessing whether a transmission connection asset should be replaced or enhanced[6]

(b) in assessing increased services and reliability, or decreased services and reliability, under a transmission agreement[7]

(c) when Transpower applies the net benefits test specified in Part 12 of the Code when assessing whether to:

(i) remove or reconfigure shared connection assets[8]

(ii) permanently remove interconnection assets[9]

(d) when Transpower applies the net benefits test specified in the outage protocol to assess proposed planned outages, connection asset variations, and interconnection asset variations.[10]

The Authority's use of the VOLL outside the Code

2.2 The VOLL is also relevant to the Authority's continuing functions. In particular, the VOLL is relevant to the Authority's objective of promoting competition in, reliable supply by, and the efficient operation of, the electricity industry for the long-term benefit of consumers (section 15 of the Electricity Industry Act 2010 (Act)), and its function of undertaking industry and market monitoring (section 16(1)(g) of the Act).

2.3 In order to regulate the reliable supply of electricity and efficient operation of the industry (as provided for in section 32(1) of the Act), the Authority must understand the value that consumers place on the reliable supply of electricity to them, and the costs incurred by those consumers if their demand for electricity is not met due to a power outage.

The electricity industry's use of the VOLL outside the Code

2.4 Perhaps the most important use of the VOLL occurs outside the Code. The VOLL (whether it be the figure stated in Part 12 of the Code or some other figure) is a fundamental input to transmission investment decisions made in New Zealand.

2.5 The Authority has been advised that electricity distribution companies also use a VOLL (although not necessarily the VOLL specified in the Code) when determining the economic value of their

[5] The benchmark agreement referred to in the Code is intended to provide a basis for Transpower and designated transmission customers to negotiate transmission agreements. It becomes the default transmission agreement in the event that parties are unable to agree a transmission agreement.

[6] Refer to clause 40.2 of the benchmark agreement incorporated by reference into the Code.

[7] Refer to clauses 12.35 to 12.37, and 12.39 of the Code.

[8] Refer to clauses 12.41, 12.42 and 12.43 of the Code.

[9] Refer to clause 12.117 of the Code.

[10] Refer to the outage protocol incorporated by reference into the Code, which specifies the circumstances in which Transpower may temporarily remove any national grid assets from service or reduce their capacity. The outage protocol also specifies procedures and policies for Transpower to plan and carry out outages.

network investments. The Electricity Engineers' Association refers to the Authority's work on the VOLL in its 'Guide for Security of Supply' in New Zealand.[11]

2.6 The substantial cost of transmission and distribution network investments emphasises the need to estimate, as accurately as practicable, the economic value of network reliability.

Derivation of the current VOLL in New Zealand

2.7 The current VOLL in the Code dates from December 2004. It was based on work undertaken for the former Electricity Commission by Frontier Economics in 2004, and on studies by the New Zealand Centre for Advanced Engineering (CAENZ) in 1992 and 2004.

2.8 In addition to the above studies, selection of the current VOLL took into account a number of international studies on unserved energy, as well as submissions received through consultation. Submissions indicated a wide range of views on what the appropriate value should be. Industrial groups and retailers/distributors with urban customers favoured a higher value, while distributors with rural customers favoured a lower value. Although the majority of submitters supported a central value, a significant percentage of submitters either opposed a central value or believed that further research into the appropriateness of multiple VOLLs was required.

Derivation of the VOLL in overseas jurisdictions

2.9 Most countries have adopted a VOLL in some form as an input to the economic assessment of transmission investment.[12] Of the two different approaches predominantly used to derive a VOLL, by far the most popular approach has been the use of surveys.[13]

2.10 International VOLL figures vary substantially across countries. For instance, a 2000 study estimated Thailand's VOLL to be approximately $4,000/MWh at the time, while a 2005 study estimated Ireland's VOLL to be approximately $95,000/MWh at that time.[14]

2.11 International VOLL figures also vary substantially across different types of electricity consumers. For instance, in New South Wales, Australia the VOLL for residential electricity consumers is approximately $26,500/MWh, while the VOLL for businesses with electricity consumption of less than 160MWh per annum is $528,000/MWh (derived in 2012).[15] (To put the residential value into context, a Sydney household using approximately 4 kW of electricity on a winter evening is estimated to face an economic cost of a little over $100 (Australian) if it loses power for an hour.)

Purpose and structure of the Authority's VOLL study

2.12 As the initial work underpinning the VOLL was not based on a comprehensive study of New Zealand electricity consumers, and submissions during the consultation process regarding the VOLL provided such divergent views, the Electricity Commission initiated an investigation into the appropriateness (fitness-for-purpose) of the current VOLL of $20,000/MWh and its application (the VOLL study). This study is now nearing completion.

2.13 The objectives of the VOLL study have been to:

(a) evaluate the 'fitness-for-purpose' of the VOLL under the Code

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[11] Electricity Engineers' Association (2013) Guide for Security of Supply Discussion Draft - Jan 2013, p. 20.

[12] Concept Economics (2008) Investigation of the Value of Unserved Energy Stage 1 Report, pp. 20-21.

[13] Concept Economics (2008) Investigation of the Value of Unserved Energy Stage 1 Report, pp. 21.

[14] Australian Productivity Commission (2012) Electricity Network Regulatory Frameworks Draft Report, p.475. All numbers are in 2009 New Zealand dollars.

[15] Australian Energy Market Operator (2013) Value of Customer Reliability Issues Paper, p.11. All numbers are in 2012 New Zealand dollars.

(b) revise the VOLL if required, and/or

(c) revise the application of the VOLL under the Code.

2.14 The VOLL study has been divided into three stages:

(i) Stage 1 – planning, conceptual analysis and research into the concept of the VOLL and its application in New Zealand and internationally. This work was undertaken by Concept Economics (an Australian economic consultancy) and CAENZ

(ii) Stage 2 – research using a combination of mail-out surveys and face-to-face interviews, and analysis of the feedback. This work was undertaken by Strata Energy Consulting, the New Zealand Institute of Economic Research (NZIER) and UMR Research. Professor Riccardo Scarpa of Waikato University, an international expert in the topic, was engaged to undertake econometric modelling and to provide advice on challenges experienced during the analysis of the results of the mail-out surveys

(iii) Stage 3 – surveys of electricity consumers predominantly in Canterbury, Taranaki and Wellington using internet-based surveys, followed by consultation with stakeholders on the findings of the investigation into the VOLL. The intent of these further surveys was to validate and where possible improve upon the findings of the 2010 mail-out survey, building on the lessons learned from the 2010 survey. This work was undertaken by Strata Energy Consulting, NZIER and Lincoln University.

2.15 Appendix A contains further information on how the mail-out surveys and direct measurement survey (face-to-face interviews) were carried out in Stage 2 of the VOLL study, while Appendix D contains further information on how the internet-based surveys were undertaken in Stage 3 of the VOLL study.

3 The summary key conclusions of the VOLL study

A single VOLL is inappropriate

Stage 2 survey results

3.1 Analysis of the results from the mail-out and face-to-face surveys undertaken in Stage 2 of the VOLL study concluded that a single VOLL figure is an inappropriate measure of the value that New Zealand electricity consumers place on unserved energy, for the following reasons:

(a) *the VOLL varies considerably across and within consumer classifications*
organisations within the same industrial classification may have quite different tolerances to outage durations, and therefore significantly different VOLLs

(b) *the VOLL varies across regions*
the VOLL for a given region in New Zealand will be sensitive to the type and range of consumers within that region[16]

(c) *a consumer's VOLL is dependent on the duration of the power outage*
although the cost can be the same for both a 10 minute and an 8 hour outage, the amount of unserved energy (MWh) can be significantly different, meaning different $/MWh values for the different duration outages.

3.2 Appendix C summarises estimated VOLLs for three regions – Auckland, Christchurch and Taranaki – as well as for New Zealand. This highlights the diversity of VOLLs in New Zealand, supporting the conclusion that a single VOLL for the country is inappropriate.

Stage 3 survey results

3.3 Analysis of the results from the internet-based surveys undertaken in Stage 3 of the VOLL study also concluded there is considerable variability in the value placed on unserved energy, and hence that a point estimate of VOLL is inadequate to capture that variability. Instead of a single VOLL, there is in fact a range of values that are best represented by a distribution, with parameters to describe the average and the spread of these values.

3.4 The value that electricity consumers place on avoiding a power outage varies in complex yet predictable ways, not just by the number and length of outages, but by interactions between attributes of a power outage such as the length of outage and the season (summer/winter).

[16] Given the uneven distribution of population and industrial loads across the country, this issue is perhaps more likely to be relevant in New Zealand than many overseas jurisdictions.

A carefully designed survey-based approach to estimating VOLL works

3.5 A survey method using a combination of the choice modelling and direct measurement survey approaches can be used to derive VOLL figures. The VOLL study used each of these survey approaches to gather data for estimating the VOLL in New Zealand. This was consistent with the recommendations of the report prepared in Stage 1 of the VOLL study.[17]

3.6 The VOLL study has been very useful in confirming (and in some instances extending) various guidelines for conducting VOLL research. Key amongst these are the following:

(a) some form of survey is the best approach to gathering the information that the electricity industry needs on the VOLL

(b) using a choice modelling survey approach to estimate the VOLL for residential, small (and possibly medium) non-residential electricity consumers is desirable. In addition, the survey should contain some contingent valuation questions (which assess survey respondents' willingness to pay to avoid an interruption or willingness to accept compensation for an outage) so as to perform a 'sanity check' on the reasonableness of the VOLL figures obtained from the choice modelling data. Care must be taken to avoid potential biases in the contingent valuation questions (e.g. minimising bias or error from the way that respondents are asked to pay for continuity of service)

(c) using a direct measurement survey approach to estimate the VOLL for large (and possibly medium) non-residential electricity consumers is desirable and preferable to the choice modelling survey approach

(d) the survey administration method should be interviews, in order to get better quality information and higher response rates than other methods. Preferably the survey should use computer-assisted personal interview (CAPI) systems, with a telephone-assisted internet-based survey as a fall-back option

(e) limiting the number of attributes of the power outage (e.g. length of outage, frequency of outage, season when an outage occurs) to no more than four or five is desirable to assist survey respondents to evaluate stated choice questions, and to be able to test for interactions amongst attributes

(f) the price attribute (be it an electricity consumer's willingness to pay to avoid a power outage or willingness to accept compensation for a power outage) needs to be presented as an absolute dollar amount, again to assist survey respondents to evaluate the stated choice questions. This is a key reason for a computer-based survey approach, whereby the level of the price attribute is specific to the survey respondent's consumption[18]

(g) the range of prices included in the price attribute of a power outage is a key consideration in the survey design, and is affected by differences in respondents' use of electricity and the price variation needed for a survey. The price range on a survey can span two orders of magnitude, which leads to cognitive issues for the survey respondents

[17] Concept Economics (2008) Investigation of the Value of Unserved Energy Stage 1 Report.

[18] The questions given to electricity consumers participating in the Stage 3 survey included dollar amounts for the stated choice questions asking how much the survey respondent was prepared to pay to avoid a power outage. These dollar amounts were based on a 'pivot design', which pivots the amount the survey respondent is prepared to pay around the respondent's electricity consumption. In the Stage 3 survey, respondents were asked at the start of the survey to provide the amount of their last electricity bill, which the computer-assisted survey then used to generate dollar amounts for the choice questions later in the survey.

(h) the survey design should explore the significance of interaction effects between the attributes of the power outage (e.g. length of outage and the season when the outage occurs)

(i) an accurate and representative database of electricity consumers is needed, with up-to-date consumption and contact information, including email addresses for sending a (computer-based) survey to

(j) if the VOLL is going to be estimated using a survey-based approach, researchers should have the time and budget to do the work properly. If large capital investment decisions are being made based on the VOLL, a properly conducted choice modelling survey is a relatively small investment to assist sound decision-making.

3.7 The 2010 and 2012 VOLL surveys demonstrated that the survey component of VOLL research is not simple to execute. The VOLL is a complex issue and for many electricity consumers the concept of making payments in addition to their current electricity invoices for continuity of supply is a challenging consideration when completing a survey. The benefits of explaining material to survey respondents, conducting surveys as interviews, and using computer-assisted techniques suggest that approaches based on experimental economics could be explored.

4 Key underpinnings of the preferred survey approach used in estimating the VOLL

Basis for an assisted survey approach using choice modelling and direct measurement

Approaches to deriving a VOLL

4.1 As noted earlier, in the absence of a market-determined VOLL, two categories of approaches have predominantly been used to derive a VOLL:

(a) survey-based approaches

(b) model-based approaches.

4.2 The model-based approach is also known as a 'production function' approach. Essentially this approach equates the VOLL within an industry to that proportion of economic value added which is attributable to electricity usage (e.g. the value of production lost because of a power outage, as measured by the ratio of gross domestic product (GDP) per MWh of electricity consumed).[19]

4.3 Survey-based approaches may be categorised as:

(a) 'direct measurement'

(b) 'contingent valuation'

(c) 'stated choice'.

4.4 The direct measurement survey approach relies on providing a detailed description to electricity consumers of one or more particular (hypothetical) outage scenarios and then, for each scenario, asking the consumer a detailed set of questions designed to capture all *direct* and *indirect* costs of the (hypothetical) outage scenario.

4.5 The contingent valuation survey approach relies on providing a detailed description to electricity consumers of one or more particular (hypothetical) outage scenarios and then, for each scenario, asking the consumer about his or her willingness to pay to avoid a power outage and/or his or her willingness to accept compensation for a power outage.

4.6 The stated choice survey approach (also known as 'choice modelling' or 'imputation analysis') relies on providing surveyed electricity consumers with 'choice scenarios' in which a particular power outage scenario is described, and having the consumers pick the scenario they prefer from an experimentally designed set made up of a few scenarios. From the surveyed consumers' responses, the scenarios with which they have been presented, and the consumers' characteristics, it is then possible to statistically estimate the 'value' that consumers place on avoiding power outages (i.e. the VOLL).[20]

4.7 Although contingent valuation and choice modelling are both stated preference methods, and so share some characteristics and concerns, the literature on these two techniques explores somewhat different issues, highlighting that each approach has its own strengths and weaknesses. While choice experiments aim to derive the value of specific features of power outages, the contingent valuation approach aims to estimate a total value of a given outage without a clear link to its underlying characteristics.

[19] Concept Economics (2008) Investigation of the Value of Unserved Energy Stage 1 Report, p. 8.

[20] Ibid, p. 10.

Survey-based approach superior to model-based approach

4.8 Although both the model-based and survey-based approaches for estimating the VOLL have been used internationally, survey-based VOLL studies can produce estimates of the VOLL that are more accurate than model-based VOLL studies, in the sense that they can be used to assess the full range of costs to customers in the event of a supply interruption. In particular, the model-based approach does not, and cannot, measure indirect costs.[21]

Choice modelling

4.9 Of the survey-based approaches, choice modelling survey analysis has been shown, in a large body of economic literature, to give more precise and reliable estimates of consumer preferences than the direct measurement survey approach.[22]

4.10 Having said this, different categories of consumers have different predispositions to be studied with choice model surveys. These surveys are likely to perform best for categories of electricity consumer with good homogeneity of circumstances in terms of electricity usage.

Mail-out surveys no longer preferred for choice modelling

4.11 Despite the recommendation received by the Electricity Commission in Stage 1 of the VOLL study, to conduct a mass mail-out survey using the method of stated choice, such a survey approach has not been the favourite survey method for stated choice surveys for a long time amongst practitioners.

4.12 For stated choice surveys of the type used in the VOLL study (i.e. for the derivation of monetary value estimates), the standard method tends to be in-person surveys conducted with CAPI systems and internet-based panels.

4.13 Such methods have supplanted mail surveys because they allow the collection of better quality data with automatic data entering (thereby decreasing data entry errors and time) and can be quickly validated and corrected if need be. In particular, they allow the creation of scenarios that are relevant to the survey respondent because they are informed by the consumption pattern of each respondent. Most importantly from the viewpoint of inference to the larger population, they suffer much less from sample self-selection, which is a negative consequence often exacerbated in the mail-out approach.

4.14 The international experience of surveys of this type for similar network industries clearly points to an emphasis on quality collection, rather than a large sample of inevitably lower quality data from mail surveys. Because survey respondents need to actively engage in surveys of this type, there is normally a payment to them (in the form of a voucher or bill discount) – they may sometimes be engaged for over 30 minutes and need to be instructed on how to undertake the stated choice part of the survey. It is common practice to reward time and cognitive effort committed to the process by survey respondents. This practice increases both participation rates and data quality.

VOLL study conclusion – use assisted choice modelling and direct measurement surveys

4.15 In Stage 2 of the VOLL study the residential consumer sample and the non-residential small consumer sample had statistically significant coefficient estimates for the cost attribute, as well as plausibly signed outage attribute coefficients. On the other hand this was not the case for the other two non-residential groups of electricity consumers (i.e. medium and large consumers).

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[21] Ibid, p. 34.

[22] Ibid, p. 37.

4.16 One issue that might have caused this lack of information from the choice data was the use of consumer category mean consumption values in the definition of the compensation levels contained in the stated choice survey questions. For individual respondents belonging to a consumer category with a wide variation of electricity bill values, the average might have been too far away from their individual values.

4.17 No model estimate was selected for both the medium and large non-residential consumer categories. For medium non-residential consumers, the variability of compensation used as an attribute was extremely large and probably caused significant model instability. A similar conclusion was reached for the large non-residential consumers surveyed, which was compounded by the small sample size for this group.

4.18 Where an electricity consumer's willingness to accept compensation for a power outage is being used to estimate a VOLL, the compensation amounts offered to an electricity consumer must be reflective of his or her history of electricity consumption, and should not be computed on the basis of the average of the consumer category he or she belongs to. The same applies when surveying an electricity consumer's willingness to pay to avoid a power outage.

4.19 Unassisted mass mail-out surveys are not appropriate for this approach because they do not allow survey design to adapt to respondent feedback, which instead can be achieved with CAPI approaches.

4.20 The choice put before the survey respondent should relate to a power outage described in such a way as to capture both linear and non-linear effects between its attributes (e.g. frequency, duration, timing, price). The stated choice survey therefore requires adequate provision to be made in terms of sample sizes, incentive for response completion, and experimental design. Consideration needs to be given to survey respondents using cognitive shortcuts – i.e. respondents not using all of the information presented to them. Choice modelling can explore this issue through the use of the right tools and with a sufficiently large sample size.

4.21 The conclusion is that in-person CAPI surveys (first choice) and/or telephone assisted internet-based surveys (second choice) should be adopted when surveying electricity consumers using stated choice questions, rather than mass mail-out surveys. This approach enables the survey design to be adapted to the survey respondent's answers, so that each survey is specific to the respondent, and provides for the interviewer to assist the survey respondent to understand the stated choice scenarios.

4.22 Residential and small non-residential electricity consumer categories in the VOLL study have pattern-of-use characteristics that can be better captured by a choice modelling exercise.

4.23 In contrast, the level of heterogeneity of electricity usage and of VOLL for medium and, in particular, large non-residential electricity consumers means it is difficult to apply the findings from a subset of the surveyed population to the general population of medium and large electricity consumer.

4.24 Hence, the conclusion is that large, and possibly medium, non-residential electricity consumers are probably better studied by means of a direct measurement approach. The 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.

4.25 Finally, specific surveys following real life outages could be used to investigate the perceived VOLL in the immediate aftermath of the event, so that survey respondents have a clear case to refer to, rather than a hypothetical scenario.

Basis for presenting the price attribute as an absolute dollar amount

Approaches to presenting the price attribute

4.26 Where the VOLL of different consumers is being investigated using a stated choice survey approach, particular power outage scenarios are described and survey respondents are required to select the scenario they prefer from the choice set under consideration. For example, under one such choice scenario a survey respondent might be asked to select their favourite alternative between the following two:

(a) scenario A: no outages occurred, but the respondent would pay 2 cents/kWh more for his or her electricity

(b) scenario B: the respondent would experience a one-hour outage at 8pm on a winter night, and the respondent's electricity charges would not change.

4.27 The options presented are described by their characteristics or attributes (e.g. cost and timing, frequency and duration of the power outage). These attributes should be important to respondents and should affect their decision-making. The attributes are varied systematically across the options. In order to calculate monetary values, one of the attributes must be a money metric or payment mechanism. As noted earlier, this attribute can be expressed either as a willingness to pay ("What would you pay to avoid a power outage?"), or a willingness to accept ("How much compensation would you want for an outage?").

4.28 When the mail-out surveys undertaken in Stage 2 of the VOLL study were first developed, the price attribute was presented as how much an electricity consumer would be willing to pay to avoid a power outage. It was expressed in cents/kWh, per the example above.

4.29 However, the cognitive testing undertaken for the mail-out surveys revealed that, in an unassisted mail-out survey, respondents found it difficult to calculate the value of the price attribute (i.e. the impact on their electricity bill as a result of paying X, Y or Z cents/kWh to avoid a given power outage scenario). Therefore many survey respondents ignored the price attribute when making a choice between the options set out in the stated choice questions, because the cognitive effort involved in processing such information was too high. The preference of the respondents was to have stated choice survey questions in which the monetary measure was expressed in terms of the cost of electricity consumption.

4.30 To overcome this problem, the price attribute in the stated choice questions contained within the mail-out surveys was changed in two ways:

(a) the willingness to pay approach was changed to be a willingness to accept approach

(b) cents/kWh was replaced with dollars (presented as an annual discount off the survey respondent's electricity bill).

4.31 An additional question was also included in the mail-out surveys on the minimum compensation that would be required by the survey respondent for a worst case power outage. This was posed as a contingent valuation question.

4.32 This combined approach meant the minimum compensation responses could inform the determination of the VOLL for a worst case outage, while the stated choice question sets could be used to identify changes in the VOLL for various levels of attributes (e.g. summer versus winter in the instance of the 'season' attribute).

4.33 Cognitive testing also revealed that survey respondents ignored the stated choice survey questions if the scenarios were unrealistic in regard to their particular annual electricity charges and in regard to the power outage duration.

4.34 To address this problem the 'willingness to accept discount' attribute was scaled for each consumer category and for the estimated energy lost in the scenario.[23] This approach cleared the cognitive issue but introduced associations across attributes, which led to significant stability problems in the econometric analysis and the subsequent model selection.

4.35 A second round of cognitive testing showed that survey respondents were better able to complete a simplified set of stated choice questions, which incorporated these changes.

4.36 However, ensuring that the stated choice question sets worked from a cognitive perspective (i.e. without requiring that interactive assistance be given to survey respondents) gave rise to challenges when modelling and analysing the responses. In particular, scaling the price attribute for each consumer category and for the estimated energy lost in the scenario introduced associations across attributes, which led to significant stability problems in the econometric modelling analysis.

VOLL study conclusion – present the price attribute in dollar terms and as a proportion of consumption

4.37 When the Stage 3 surveys were undertaken, the design of the stated choice questions was amended from being based on an electricity consumer's willingness to accept compensation for a power outage, to being based on the consumer's willingness to pay to avoid a power outage. The quantum of the payment was a percentage of the survey respondent's annual power bill.

4.38 A finding of the research undertaken using the 2012 survey data was that an electricity consumer's willingness to pay to avoid a power outage is best modelled as proportional to that consumer's electricity consumption. Re-analysis of the 2010 VOLL survey data also found that treating an electricity consumer's willingness to accept compensation for a power outage as a proportion of the monthly electricity bill improved results in two out of the three consumer categories reviewed.

4.39 Hence, the conclusion is that, regardless of whether a willingness to pay or willingness to accept approach is used, it is preferable to present the price attribute in dollar terms, and for it to be expressed as a proportion of the electricity consumption of the survey respondent.

[23] To produce the annual discount value for each scenario, an average lost load for each consumer category was assumed and, using the duration of power outage and cents/kWh value for the particular scenario, a discount value (dollars/year) was calculated for each scenario.

Basis for exploring interaction effects between power outage attributes

The ‘linearity’ problem

4.40 One of the limitations of the approach employed in Stage 2 of the VOLL study was that only changes in an electricity consumer’s utility, or satisfaction, could be identified during the data analysis. These changes in the level of consumer satisfaction then needed a baseline against which to be measured, since utility changes are meaningful only in regard to a specific baseline.

4.41 The baseline is arbitrary and can be defined by the analyst. For example, for the 2010 residential survey sample, the combination of power outage attributes that defined the least costly outage for a household was used as a baseline. That is, an outage taking place in summer, at 10am and lasting only 10 minutes. From this baseline it was possible to compute the differences in an electricity consumer’s satisfaction that would be experienced by moving to any of the other 18 power outage scenarios contained in the stated choice survey questions (three more times of the year multiplied by three duration lengths multiplied by two (power outage) events).

4.42 However, the changes in an electricity consumer’s satisfaction need anchoring to some absolute level of compensation to produce compensation estimates for all of the stated choice question scenarios. For this reason, a question on the least amount of compensation associated with the worst case power outage conditions for the electricity consumer was asked of all survey respondents.

4.43 These worst case power outage conditions were expressed in terms of the outage attributes considered in the VOLL study (i.e. an outage taking place in winter, at 6pm and lasting eight hours). Responses to such a question are important because they constitute the link to a given (worst) level of power outage. Along with the compensation estimates for changes in an electricity consumer’s satisfaction, they enable derivation of compensation amounts for all power outage scenarios investigated in the survey design.

4.44 The analysis undertaken in Stage 2 of the VOLL study assumed that the attributes of the power outage would be independent and additively linear. This is quite a standard simplifying assumption in these types of studies. As a consequence, the experimental design implemented such an assumption. Therefore, no interaction between the attributes of the power outage were specifically addressed (e.g. the length of a power outage and time of the year when it occurred). In order to address these issues, a much higher number of choice tasks would have been needed in the experimental survey design, while time and resource constraints imposed limitations on the design structure.

4.45 The end result was that the effects of interactions between the attributes of a power outage, which turned out to be important in the calculations to derive the $/MWh VOLL figures, were ignored. As a result, the effect on an electricity consumer’s utility or level of satisfaction from power outage of 8 hours duration would be accurately estimated from the statistical viewpoint, but its effect on utility in combination with the time of the day at which it occurred was not.

4.46 This issue may be referred to as the `linearity’ problem. The word “problem” is used to indicate that it leads to a less than ideal approximation of the real utility changes experienced by VOLL survey respondents in the evaluated scenarios. The real change in an electricity consumer’s utility is likely to be highly non-linear and certainly dependent on interaction effects between the salient attributes of the power outage event.

4.47 In other words, the weighting of a VOLL attribute is unlikely to be linear (e.g. the VOLL for a one hour outage at a particular time is not six times the VOLL for a 10 minute outage at the same time), as is the ratio of different VOLL attributes (e.g. the difference in VOLL between a one hour outage and an 8 hour outage in summer is likely to be quite different to the difference in VOLL between a one hour outage and an 8 hour outage in winter).

VOLL study conclusion – explore the interaction effects between the attributes of a power outage

4.48 The research undertaken in Stage 3 of the VOLL study indicated that some of the non-linearities and interactions theorised in Stage 2 appear to be important. In particular, the VOLL for power outages of different lengths is affected by the season (e.g. residential survey respondents had a larger per-hour willingness to pay for winter outages than for summer outages).

4.49 It is concluded that the statistical design of choice modelling surveys must be done carefully, and researchers should pay attention to the specific interactions between those attributes of a power outage that they wish to explore. Because of time and resource constraints, this part of the 2010 VOLL surveys was not done as well as it could have been, which affected the quality of the data collected.

The importance of an up-to-date and representative consumer database

Data cleansing a significant cost

4.50 In preparation for the 2010 VOLL surveys the Electricity Commission expended many person hours ‘cleaning’ the survey respondent data provided by retailers and distribution lines companies. For example, not only did the data need to be put into a format useful to be used for mail out of surveys, duplicated data and incomplete data needed to be either completed or removed from the database. The database then needed to be made nationally representative of New Zealand electricity consumers.

4.51 These and other data cleaning activities were not only a significant resource requirement for the 2010 VOLL surveys, but also the 2012 VOLL surveys.

4.52 A further and material issue with the survey respondent database arose in the Stage 3 2012 VOLL surveys. Although the Authority had physical addresses for VOLL survey respondents it did not have email addresses. Consequently, the Authority adopted a hybrid approach to the administration of the 2012 VOLL surveys – it made contact with electricity consumers via standard postal mail and asked them to log in to an area of the Authority’s website and respond to an internet survey.

4.53 This approach was chosen as a compromise. It was a way to use existing contact information available to the Authority, but to get the benefits of computer-assisted surveying. Survey administration turned out to be the weakest part of the 2012 surveys. The surveys to all groups of respondents had very low response rates. The hybrid method chosen did not entice people to participate. The non-completion rate of respondents starting the survey was not high. Therefore, the specific problem was getting respondents to go to the internet to start the survey, rather than getting them to complete the survey once they had started it. Inducements were offered,[24] but these were apparently insufficient. Future efforts should consider repeated reminders, by phone, mail, text message or email.

VOLL study conclusion – an up-to-date and representative consumer database is needed

4.54 The difficulty in contacting potential survey respondents was a key constraint on both the 2010 and 2012 VOLL surveys, particularly the 2012 survey. An up-to-date and representative database of potential VOLL survey respondents reduces significantly the cost of VOLL surveys. A database containing cross-validated email addresses, residential addresses and landline or cellular phone numbers is important in facilitating internet-based surveys, by enabling potential respondents to be sent an email link to the survey and various reminders to take part in it.

[24] Residential survey recipients were provided with a voucher for an energy efficient light bulb, while non-residential survey recipients were offered the opportunity to enter into a prize draw to win one of two new televisions.

5 Key areas of further research on the VOLL methodology

Willingness to pay versus willingness to accept

5.1 As noted earlier, willingness to pay and willingness to accept are two different ways to think about the VOLL to electricity consumers. The research undertaken in the VOLL study does not conclusively show one is better than the other.

5.2 The use of the willingness to accept approach in the 2010 VOLL surveys created the possibility that survey respondents might overstate the impact of a power outage by demanding large amounts of compensation, because of the endowment effect discussed earlier (i.e. a power outage represents the loss of something that is expected, that is, the loss of an endowment), and because of hypothetical bias (discussed in Appendix F). The analysis of the contingent valuation question about the value of an outage to the survey respondent (in the form of required compensation), led generally to reasonable answers given known budget constraints. However, recently undertaken re-analysis of the choice modelling questions suggests the willingness to accept compensation amount was very high in the choice experiment. The two types of questioning in the 2010 VOLL surveys may have led to somewhat different results.

5.3 The 2012 VOLL surveys used the willingness to pay approach. The survey questions framed the price attribute as a payment to avoid an outage rather than compensation for a loss, and reminded survey respondents of their budget constraints.

5.4 In the 2012 surveys, the endowment effect actually took a different form. Some people stated they did not think they should have to pay for security of supply – a continuous power supply was to be expected.[25]

5.5 The VOLL study has not resolved the willingness to pay versus willingness to accept issue. The two sets of VOLL surveys have shown:

(a) the willingness to accept approach can lead to higher values, though not always

(b) the willingness to pay approach appears less intuitive for some survey respondents, either because they do not believe they should have to pay more for their current level of power supply reliability or because they do not believe they should have to pay at all for security of supply. These respondent views may adversely impact the success of unassisted VOLL surveys, through lower quality survey data and/or reduced survey completion rates.

[25] Several survey respondents contacted the Authority by telephone (the contact number was included in survey instructions) making this point.

Experimental economics approaches

5.6 There are different methods for interacting more with survey respondents, which involve a grey area between the choice modelling survey approach and a field of research in economics known as experimental economics.

5.7 One method of surveying for complex issues such as the VOLL involves conducting workshops with survey respondents and then administering the survey. The workshop enables respondents to become familiar with the issue to be surveyed and to ask questions about the topic. This provides for their survey responses to be better informed. Experimental economics approaches can also include learning phases and interactions amongst survey respondents and between researchers and respondents. Such approaches could be trialled with future VOLL research.

5.8 If an experimental economics approach is considered, there will need to be an initial phase of the research to determine the best approach. One possibility is to run computer-assisted surveys in an economics laboratory, which would enable researchers to adjust the information provided to survey respondents and obtain quick feedback on the impacts. A second possible experimental economics approach is to design an experimental 'insurance market' and investigate participants' willingness to pay for insuring against outages.

5.9 However, there are likely to be more complex experiments, which may produce more information on the VOLL. Experimental design might consider:

(a) the structure of the experiment, which could be set up like a market or an auction instead of a survey

(b) the participants required for the experiment

(c) the information provided to the participants

(d) the incentives used, including the amount of endowments provided to participants and the structure of payoffs or compensation

(e) the methods for creating meaningful consequences for participants.

Appendix A Approach to the Stage 2 VOLL surveys

Stage 1 recommendations

A.1 The first stage of the VOLL project included:

- an overview of the concept of unserved energy
- a review of the existing and potential applications of the concept of unserved energy in New Zealand for investment planning purposes and in the energy market
- a review of selected international markets and electricity industries in which the value(s) of unserved energy plays a role
- a survey framework for deriving the value(s) of unserved energy in the New Zealand context.

A.2 An Australian consultancy, Concept Economics, was engaged to undertake Stage 1. In its report,[26] Concept Economics recommended that Stage 2 of the VOLL project should, to establish electricity consumers' views on the VOLL:

- estimate a separate VOLL for different types of electricity consumer (e.g. industrial, residential)
- apply a direct measurement survey approach (face-to-face interviews) for large industrial consumers who account for a significant portion of New Zealand's electricity consumption
- apply a mail-out survey approach using stated-choice questions for other selected consumer types
- test the proposed surveys with a selected number of respondents prior to rolling out the survey.

Stage 2 approach

A.3 Consistent with these recommendations, Stage 2 of the VOLL project involved research using:

- face-to-face interviews for larger non-residential consumers
- mail-out surveys to a large sample of residential and non-residential electricity consumers.

A.4 The research in Stage 2 was focussed on providing an informed assessment of:

- the economic values that consumers place on unserved energy
- the way that these economic values are influenced by certain consumer-specific factors and outage-specific factors.

Direct measurement survey (face-to-face interviews)

A.5 In New Zealand there is a relatively small number of very large industrial consumers and a wide range of much smaller non-residential consumers. It was found that selecting only the largest would not have provided valuable information on the impacts of power outages across a range of consumer classifications. There are a relatively small number of reasonably large consumers connected to distribution networks, and gaining direct measurement-based information on these was considered useful, if only as a point of comparison with information received through the mail-out survey.

[26] This report can be found on the Authority's website at http://www.ea.govt.nz/our-work/programmes/transmission-work/investigation-of-the-value-of-lost-load/.

A.6 Therefore, whilst the recommendation from Stage 1 was that a direct measurement approach (face-to-face interviews) be used only for large industrial consumers who accounted for a significant part of New Zealand's electricity consumption, the approach taken was to select the large consumers and a range of smaller consumers that covered as wide a range as possible of non-residential consumer classifications.[27]

A.7 Using a range of consumer classifications meant that the face-to-face interviews gained input from industrial, commercial, service, infrastructural and public service organisations.[28] The list of large electricity consumers was also compiled to include consumers from multiple regions, and to have a range of consumptions (i.e. not just the largest).

A.8 The approach adopted for undertaking the direct measurement survey may be summarised as follows:

- a database for the face-to-face survey of larger non-residential consumers was developed
- a standard interview template (relating to the structure of the interview, the questions and the data to be obtained) was created. The interview questions were designed to obtain information that could be used to provide comparisons between organisations in different sectors and, where numbers were sufficient, highlight intra-sector differences, as well as to enable the responses to each question to be aggregated for analysis
- electricity consumers were selected, contacted, and interview times arranged. Consumers interviewed were provided with an information pack in advance of the interview, to enable them to prepare for the interview (including assembling the required cost and consumption data)
- face-to-face interviews with a selection of non-residential major electricity consumers were undertaken and information obtained at the interview was reconfirmed via email. Following

[27] The Ministry of Economic Development's classification of industry sectors was used as a basis for selecting the range of organisations to be interviewed, with the intention being to have a consumer from each of the main non-residential consumer categories included in the face-to-face survey.

[28] The sectors covered in the face-to-face interviews were as follows:

- air and space transport
- basic chemicals and chemical products
- basic ferrous metals
- basic non-ferrous metals
- coal mining
- dairy products
- information media, telecommunications and postal services
- log sawmilling and timber dressing, and other wood products
- machinery and equipment manufacturing
- meat and meat products
- non-metallic mineral products
- other food products, beverages and tobaccos
- other mining and quarrying, and services to mining
- other transport and transport support services
- petroleum and coal product manufacturing
- public administration and safety
- pulp, paper and converted paper products
- rail
- water supply, sewerage and drainage services.

the interviews, respondents were provided, by email, with a copy of the interview questions and their responses. Confirmation was sought, and in all cases received, that the responses recorded were correct

- responses were analysed and individual and aggregated VOLLs were calculated.

A.9 Responses to interview requests were positive, with only two approaches declined. Most respondents welcomed the opportunity to provide comments and feedback to the electricity supply industry.

A.10 Thirty three non-residential consumers were interviewed. The questions posed during each interview were structured to cover a range of areas including the nature of the business, key areas of production and experiences of power outages.

A.11 At each interview detailed evidence was sought to support the responses given and the expected costs of outages provided by the organisation. In most interviews this evidence was provided and included information such as financial reports and costs incurred due to actual outages. In many cases the organisation being interviewed had its chief financial officer in attendance.

Mail-out surveys using stated choice questions

A.12 Consistent with the recommendations produced in Stage 1 of the VOLL project, the approach taken in Stage 2 included the use of mail-out surveys, containing stated choice questions, to a large sample (13,347) of residential and non-residential New Zealand electricity consumers.

A.13 The approach adopted for undertaking the mail-out surveys may be summarised as follows:

- a nationally-representative database of electricity consumers was created, with the required input data obtained from electricity retailers and distributors
- consumer categories for use in the surveys were established
- the survey form provided by Concept Economics in Stage 1 of the project was adopted, and cognitive testing was run on a small number of consumers in each consumer category (i.e. residential, non-residential (small), non-residential (medium) and non-residential (large))
- revised survey forms were developed based on the results from cognitive testing
- a pilot of the mail-out surveys and the design of their stated choice questions was undertaken using a representative sample of consumers from each consumer category and the responses assessed[29]
- using the results of the pilot study, revised survey forms and an efficient experimental design for the stated choice questions relating to each consumer category were prepared[30]

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[29] In the stated choice questions an example was given and then 4 choice situations were investigated, each of which presented two experimentally designed alternatives. The pilot study included the following set of choices:

- 308 residential
- 248 non-residential (small)
- 236 non-residential (medium)
- 292 non-residential (large).

[30] The procedure for the derivation of the designs involved estimating a random utility logit model for each consumer category. The estimates of coefficients and their standard errors were then used as Bayesian priors for a multivariate normal distribution from which the Bayesian ‘willingness-to-pay’-efficient design was derived. This produced 36 binary choice tasks for each consumer category, which were orthogonally blocked in 9 blocks of 4 choice tasks each for all consumer categories, except the large non-residential. In this manner a complete design was obtained for every 9 respondents. For the large non-residential consumers, because of the lower number of

- four mail-out VOLL surveys (one for each of the four consumer categories) were undertaken
- the survey data received was coded and analysed, with utility functions and the implied values of lost load estimated.

A.14 The number of individual survey designs used in the mail-out surveys was limited to four, relating to the following categories of consumers:

(i) residential

(ii) non-residential (small) – consumption ≤0.2 gigawatt-hours (GWh) per annum

(iii) non-residential (medium) – consumption >0.2 GWh ≤1 GWh per annum

(iv) non-residential (large) – consumption >1 GWh per annum.

A.15 Specific sector categories (e.g. commercial, agricultural, government agencies, etc) were not used due to the need to construct relatively customised stated choice question sets and general information questions that related to each sector – the cost of which was beyond the budget of the VOLL project.

A.16 Using specific sector categories (e.g. commercial, agricultural, government agencies, etc) for the mail-out VOLL surveys would have required the construction of relatively customised stated choice question sets and general information questions related to each sector. Due to project scope and budget limitations there was a need to limit the number of individual survey designs used. Therefore the categories selected for non-residential electricity consumers were based on levels of energy consumption rather than use. However, a classification question was included in the survey to give the ability to segregate responses by sector category at the analysis stage of the investigation. In this way the number of survey designs could be significantly reduced whilst maintaining the ability to obtain information for specific sector categories.

A.17 Consumer databases were obtained from several retailers and used to develop survey mail-out lists for each consumer category. The range of MWh energy consumptions for respondents in each non-residential consumer category surveyed can be seen in the following charts.

Choice modelling approach to the survey

A.18 Choice modelling is a survey technique used for 'non-market valuation' – research into the value of things for which standard market prices are not readily available. Examples of such things are clean streams, outdoor recreation, and future products. This technique is appropriate for valuing VOLL because there is no market to determine either how much a consumer is prepared to pay to avoid a power outage or how much compensation is required for a consumer who has a power outage. This approach has been used in other Organisation for Economic Co-operation and Development (OECD) countries to investigate the value of outages and other aspects of electricity supply.[31]

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members in this population and the complexity of each operation, it was decided to use a longer panel, with 9 choice tasks each. Longer panels imply more accurate individual estimations.

[31] For recent examples of its use in this regard, see for instance:

1) Abdullah, S., and Mariel, P. (2010) Choice experiment study on the willingness to pay to improve electricity services. Energy Policy, 38(8), pp. 4570–4581.
2) Carlsson, F., and Martinsson, P. (2008) Does it matter when a power outage occurs? A choice experiment study on the willingness to pay to avoid power outages. Energy Economics, 30(3), pp. 1232–1245.
3) Pepermans, G. (2011) The value of continuous power supply for Flemish households. Energy Policy, 39(12), pp. 7853–7864.

A.19 Choice modelling has been used in economics research since the early 1970s, when it was used in transport and market research. Interest in this approach greatly increased in the 2000s when it was extended to the study of regulated utilities (integrated water services, electricity networks, etc.) and social health services. It has also been used to assess non-market values for environmental goods. Its strengths and weaknesses have been explored in detail, and techniques in survey design, administration and analysis have been improved.

A.20 Choice modelling surveys ask a series of questions that are statistically designed to provide information about the value that survey respondents place on a good or service. Each question presents respondents with two or more options – Car A or Car B? Stream 1, 2, or 3? Respondents are asked to choose the option that they prefer. Respondents are assumed to choose the option they perceive as ‘best’, and so the remaining options are not as valuable.

A.21 Where the VOLL of different consumers is being investigated, a particular outage scenario is described and survey respondents are required to pick the scenario they prefer. In such a choice scenario, a survey respondent might be asked to choose between:

(a) scenario A: no outages occurred, but the respondent's monthly electricity bill would increase by $1

(b) scenario B: the respondent would experience a one-hour outage at 8pm on a winter night, and the respondent's electricity bill would not change.

A.22 The options presented are described to respondents by their characteristics or attributes. These attributes should be important to respondents and should affect their decision-making. The attributes are varied systematically across the options according to an experimental design. In order to calculate monetary values, one of the attributes must be a money metric or payment mechanism. This attribute can be expressed either as a willingness to pay (“What would you pay to avoid a power outage?”), or a willingness to accept (“How much compensation would you want for an outage?”).

A.23 Analysis of choice modelling surveys uses the structured choice questions and the selections from the survey respondents to calculate how each attribute contributes to the probabilities associated with the choices respondents make. When a payment mechanism is included, the value of each attribute can be calculated. The result is a ‘price’ for an outage and ‘prices’ for the attributes that describe the outage.

A.24 It is then possible to estimate statistically a 'value' function, given consumers' responses, the scenarios they have been presented with, and consumers' characteristics. This function relates the 'value' that consumers place on avoiding power outages (i.e. the value of unserved energy to the consumer) to the characteristics of the various scenarios (e.g. outage duration, number of outages per annum, time of day, season and price) and to consumers' individual characteristics.

A.25 Stated choice survey analysis has several advantages, the primary one being that it has been shown, in a large body of economic literature, to give more precise and reliable estimates of consumer preferences than contingent valuation survey approaches. It also has the potential to capture a better estimate of a consumer’s willingness to pay for reliability than simply cataloguing direct and indirect costs.

A.26 The main objective of the stated choice study was to estimate from the survey data a multi-attribute utility function for each category of consumer (residential, small non-residential, medium non-residential and large non-residential) from which to derive the VOLL for each consumer category, which would be clearly dependent on the attributes associated with the outage.

Survey design

A.27 Although four mail-out surveys were developed, the significant differences were between the residential and non-residential surveys. Across the three non-residential surveys consistency was maintained in regard to survey design, content and structure.

A.28 The mail-out surveys asked a number of questions related to:

- customers' experiences with loss of power supply
- measuring the costs of the loss of power supply
- stated-choice questions where customers were asked to select their preferred option from between two options
- reliability of power supply – what was acceptable
- the characteristics of their lifestyles (for residential consumers)
- characteristics of their businesses (for non-residential consumers).

A.29 Residential consumers were asked, inter alia, to provide an estimate of the minimum value they would consider appropriate to compensate them for an 8 hour outage at the worst possible time.

A.30 Non-residential consumers were also asked, inter alia, to provide an estimate of the cost to them from outages of the following durations at the worst possible time:

- 10 minutes
- 1 hour
- 8 hours.

A.31 For the stated choice section of the surveys a preference structure was assumed to depend on the various aspects affecting the real consequences for the respondent suffering the outage. In particular, the scenarios were constructed by varying a certain number of attributes:

- the number of outages – one or three outages a year were used
- the length of the outage – a 10 minute, one hour or eight hour outage were assumed
- the season of the outage – a summer and a winter outage were investigated
- the time of the day – outages occurring at either 10am in the morning or at 5pm in the afternoon were assumed
- the request for hypothetical compensation expressed as an annual $ discount on the power bill for the outage was also used.[32]

A.32 Other attributes (e.g. an advance warning attribute, or an attribute for the area affected by the power outage) were considered and dismissed. So too were more articulated levels for those attributes that were considered (e.g. expressing the time of the day in which the power outage occurred as ‘peak’, ‘off-peak’ and ‘intermediate’, or including longer duration outages which might have allowed an assessment of the VOLL for high impact, low probability events).

A.33 These and other ideas were abandoned due to the increased complexity of the associated survey design and cognitive testing revealing that survey respondents were unable to compare the choices being presented.

[32] To calculate the annual dollar discount for each scenario, an average lost load (kW) was assumed for each consumer category and this was then multiplied by the outage duration (hours) and the cents/kWh value for the particular scenario.

A.34 Table 4 contains the attributes and their associated levels for each of the four mail-out surveys.

Table 4 Mail-out survey attributes

Attributes[33]	Number of levels	Levels[34] / Values
Residential		
Number of outages per year	2	1 / 3
Duration of the outage	3	10 minutes / 1 hour / 8 hours
Time of the year	4	10am / 5pm summer and 10am / 5pm winter
Price ($NZ / kWh)	4	0.5 / 5 / 20 / 50[35]
Small non-residential		
Number of outages per year	2	1 / 3
Duration of the outage	3	10 minutes / 1 hour / 8 hours
Time of the year	4	10am / 5pm summer and 10am / 5pm winter
Price ($NZ / kWh)	4	5 / 10 / 20 / 50[36]
Medium non-residential		
Number of outages per year	2	1 / 3
Duration of the outage	3	10 minutes / 1 hour / 8 hours
Time of the year	4	10am / 5pm summer and 10am / 5pm winter
Price ($NZ / kWh)	4	5 / 10 / 20 / 50[37]
Large non-residential		
Number of outages per year	2	1 / 3
Duration of the outage	3	10 minutes / 1 hour / 8 hours
Time of the year	4	10am / 5pm summer and 10am / 5pm winter
Price ($NZ / kWh)	4	5 / 10 / 20 / 50[38]

Source: Electricity Authority

[33] An attribute is one component of a question set scenario, e.g. time of day, season, outage frequency, price.
[34] A level is the quantity of an attribute, e.g. 9am to 11am, winter, 3 times a year, 5 cents/kWh.
[35] $2, $20, $80, $200 basis = 1 kW demand for a 4 hour outage.
[36] $50, $100, $200, $500 basis = 10 kW demand for a 1 hour outage.
[37] $500, $1,000, $2,000, $5,000 basis = 100 kW demand for a 1 hour outage.
[38] $1,750, $3,500, $7,000, $14,000 basis = 350 kW demand for a 1 hour outage.

Cognitive testing

A.35 An initial round of cognitive testing of the draft mail-out survey questionnaires and covering letter was conducted in February 2010 with individuals from each of the four categories of consumers to be surveyed. Cognitive testing involved a researcher meeting face-to-face with a person, and making observations while the person read the covering letter and completed the attached questionnaire. The researcher then probed and followed up on areas of question clarity and flow, as well as understanding. The researcher was able to ascertain from each person his or her thoughts as he or she worked through the covering letter and questionnaire.

A.36 The objectives set for the cognitive testing were to:

- identify any questions that were unclear (e.g. terminology used, ratings, scales)
- ascertain whether respondents had sufficient information to answer questions
- test the flow / sequence of questions
- establish the appropriate length of the questionnaire
- make recommendations to minimise non-sampling error
- evaluate the covering letter and frequently asked questions (FAQ) sheet to ensure it was effective and encouraged survey participation.

A.37 A total of 21 cognitive test observations were conducted by two researchers from UMR. Respondents were selected to cover a range of residential household types and non-residential users according to industry classifications. Interviews were conducted in Auckland, Wellington and Canterbury.

A.38 The first round of cognitive testing of the mail-out surveys indicated a number of changes were required to the survey questionnaire for each category of electricity consumer. The stated choice component of the questionnaire created particular difficulty for both residential and non-residential survey respondents.

A.39 The cognitive testing showed that, in an unassisted mail-out survey, respondents found it difficult to evaluate questions where the price of electricity was stated in cents/kWh. Therefore many respondents ignored the price attribute when making a choice between the options set out in the stated choice questions. The preference of respondents was to have stated choice survey questions where the price of electricity was expressed in terms of the cost of electricity consumption.

A.40 To overcome this problem, the price attribute in the stated choice questions contained within the mail-out surveys was converted to an annual electricity bill discount value, and an additional question was included in the surveys on the minimum compensation that would be required by the survey respondent for a worst case power outage.

A.41 This approach meant the minimum compensation responses could inform the determination of the VOLL for a worst case outage, while the stated choice question sets could be used to identify changes in the VOLL for various levels of attributes (e.g. summer versus winter in the instance of the 'season' attribute).

A.42 A second round of cognitive testing was undertaken in March 2010 once these changes were made to the draft surveys.

A.43 However, using one or more stated choice questions for the mass mail-out surveys as an alternative to, or in conjunction with, the minimum compensation question was problematic. Ensuring that the stated choice question sets worked from a cognitive perspective (i.e. without requiring that interactive assistance be given to survey respondents) gave rise to challenges when modelling and analysing the responses. Nevertheless, these challenges have provided valuable lessons for conducting these types of surveys in the future.

Pilot testing

A.44 Following the two rounds of cognitive testing, a pilot test was undertaken in April 2010 to:

- replicate as much as possible the main mail-out surveys and identify any issues with the questionnaires
- identify scenarios in the stated choice questions that could be omitted so as to reduce the number of scenarios included in each of the main survey questionnaires
- estimate the likely response rate among the four consumer categories, or audiences, being surveyed
- estimate the quality of the database from which the survey sample was drawn
- monitor calls to the free-call helpline to identify issues or concerns relating to the mail-out surveys
- review survey data to test whether the questionnaire was working as intended, in particular, whether:
  - question structure and order (routing) was adhered to
  - questions were being completed as intended
  - respondents were writing additional notes on the questionnaire.

A.45 The approach taken for the pilot was as follows:

- respondents were selected randomly from the database of consumers
- a free-call (0800) phone number was available for respondents to contact with any questions or concerns about the survey
- questionnaires were developed for each main audience – there were 6 block designs necessitating 6 versions of the questionnaire for each audience.

A.46 The questionnaires were distributed to 1186 respondents as detailed below:

Table 5 Distribution of the VOLL pilot survey questionnaires

Audience	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Total
Residential	50	50	50	50	50	50	300
Non-residential – small	50	50	50	50	50	50	300
Non-residential – medium	50	50	50	50	50	50	300
Non-residential – large	48	48	48	48	47	47	286

Source: UMR Research

A.47 The pilot survey response rates, by consumer category, were as follows:

Table 6 Response rates for the pilot mail-out VOLL survey

Audience	Returns	Response rate
Residential	77	25.6%
Non-residential – small	62	20.6%
Non-residential – medium	59	19.6%
Non-residential – large	73	25.5%
Average		***22.85%***

Source: UMR Research

A.48 The main issues with the questionnaire identified in the pilot testing also were in regard to the stated choice scenarios, with some respondents making comments on the returned surveys. Some routing issues were also identified.

A.49 While no major issues were identified with the quality of data being captured, analysis of the stated choice data revealed that there was some correlation between the price attribute and duration attribute.

A.50 As a result of the pilot, the mail-out surveys were amended as follows:

- several design and wording changes were made to clarify instructions and routing
- adjustments were made to the stated choice scenarios.

The main surveys

A.51 Survey questionnaires were distributed to 13,347 respondents as follows:

Table 7 Distribution of the main VOLL survey questionnaires

Block	Residential	NR Small	NR Medium	NR Large
1	556	556	278	210
2	556	556	278	209
3	556	556	278	209
4	556	556	278	209
5	556	556	278	
6	556	556	278	
7	556	556	278	
8	556	556	278	
9	556	556	278	
Total	***5,004***	***5,004***	***2,502***	***837***

Source: UMR Research

A.52 The survey process included a number of factors to improve the response rate for self-complete questionnaires. These included:

- substantial pre-testing and piloting
- including a covering letter from the Chairman of the Electricity Commission
- including an information sheet
- an incentive (an energy efficient light bulb voucher for every residential consumer who received a survey questionnaire, and the opportunity to enter a prize draw to win one of three televisions for non-residential consumers)
- multiple telephone call-backs
- making available a free-call (0800) number for queries.

A.53 The pilot survey response rates, by consumer category, were as follows:

Table 8 Response rates for the main mail-out VOLL surveys

Audience	Returns	Response rate
Residential	1,199	24%
Non-residential – small	1,151	23%
Non-residential – medium	650	26%
Non-residential – large	203	24.25%
Average		***24%***

Source: UMR Research

A.54 These response rates are not considered to be particularly high for a mail survey, which may suggest that sample self-selection could have been an issue with this study. However, given the length of the survey and the topic of 'electricity outages', the response rate may be good. In any case, the response rates obtained were sufficient to obtain the required level of data for the intended purposes of the survey.

Challenges associated with the mail-out VOLL surveys

A.55 Significant challenges were encountered and overcome in the development and analysis of the mail-out VOLL surveys. Poor quality consumer data was provided for the mail-out survey database, which needed extensive cleansing before it could be used for the mail-out surveys.

A.56 Revisions to the survey design and analysis methods had to be made after preliminary testing highlighted issues with the experimental design:

- Cognitive testing - Round 1 (February 2010): respondents were unable to make a rational choice due to the complexity of the stated choice power outage scenarios presented
- Cognitive testing - Round 2 (March 2010): simplification of the stated-choice questions did not entirely remove the difficulty respondents were having in making a choice between the different power outage scenarios presented
- Pilot testing (April 2010): highlighted the importance of respondents only receiving one survey, to avoid responses being provided for a different consumer category to that

intended to be surveyed (i.e. where the survey respondent had a number of sites where electricity was consumed, with these sites falling across two or more consumer categories).

A.57 The main challenges encountered with the mail-out VOLL surveys, and the responses made to them, are listed in the table below.

Table 9 Challenges associated with the mail-out VOLL surveys

Challenge encountered	Action taken
Obtaining a sufficiently clean database from electricity retailers.	Extensive data cleansing work was undertaken. The sample chosen was considered to be nationally representative.
Large sample size of consumers and number of surveys required if categories based on sectors (e.g. commercial, industrial, agricultural, government, residential, etc.) were to be used.	Non-residential consumers were categorised in three groups according to their annual electricity consumption. Identification of specific sector values was undertaken through use of responses to demographic questions.
Consumer information and categorisation	
Obtaining a sufficiently clean database from electricity retailers.	Extensive data cleansing work was undertaken. The sample chosen was considered to be nationally representative.
Large sample size of consumers and number of surveys required if categories based on sectors (e.g. commercial, industrial, agricultural, government, residential, etc.) were to be used.	Non-residential consumers were categorised in three groups according to their annual electricity consumption. Identification of specific sector values was undertaken through use of responses to demographic questions.
An adaptive approach, incorporating the collection of a first wave of mail surveys followed by an interim analysis of its results to evaluate the validity of the field survey format would have been preferred. However, the budget and timeline of the project would not allow such an interim validation.	Sample sizes were chosen to allow a second wave to be surveyed at a later date as an additional stage of the investigation.
Stated choice question design	
The attributes and levels contained in the stated choice question sets had to be limited in order to reduce the number of scenarios to a manageable number.	The number of attributes and levels were reduced. The price attribute levels were adjusted to include a price that tested the current VOLL.
Cognitive testing revealed that respondents found the 'willingness to pay' attribute (e.g. c/kWh they were prepared to pay for a given scenario) too difficult to calculate. They therefore ignored the price attribute.	Price attribute was changed to a 'willingness to accept' annual discount value.
Cognitive testing revealed that respondents ignored the stated choice set questions if the	The 'willingness to accept' discount attribute was scaled for each consumer category and for

Challenge encountered	Action taken
scenarios were unrealistic for their particular annual electricity charges and for the duration of outage.	the estimated energy lost in the scenario. This approach cleared the cognitive issue but introduced associations across attributes, which led to significant stability problems in the econometric modelling analysis.
Moving to a 'willingness to accept' attribute removed the cognitive test issue but led to modelling complications. In particular, because respondents would accept as high a discount as they could get, an upper bound for the attribute had to be found.	An innovative approach was developed using a matrix derived from the responses and then using an additional 'minimum compensation for worst case' question as the upper bound. Model development for this approach proved difficult due to instabilities. It was also found that, whilst the approach produced reliable results for the residential and small non-residential categories, conversion of the values obtained could not be converted into usable $/MWh values. Inclusion of the minimum compensation question has proved to be invaluable as it has allowed $/MWh values to be identified across sectors and VOLL/demand curves to be derived.
Time and budget limitations meant that the use of survey 'waves' was not possible.	It is an established practice to break stated choice surveys into a number of separate mail-out events or waves. This enables analysis of the results obtained to be used to revise the experimental design used or focus the scenarios used in subsequent waves. Due to time and budget limitations this survey was undertaken in a single wave. The pilot survey was used to some extent as a wave and it was accepted that further waves could be undertaken in the future following this investigation. The survey was therefore limited to a single wave with no facility to consider adjustments to scenarios.

Source: Strata Energy Consulting

A.58 It was found that the responses taken to the challenges encountered took the stated choice component of the survey design into ground-breaking areas, particularly in regard to resolving the difficulties encountered in obtaining reliable outputs from the stated choice question sets. A discussion on the modelling challenges encountered and the results obtained from the stated choice section of the surveys is provided in Appendix E.

A.59 Despite the challenges encountered in the stated choice question set section of the mail-out surveys, the inclusion of a 'minimum compensation' question enabled significant information to be gained on the cost of power outages for consumers. The use of this feature enabled the VOLLs to be derived, as well as enabling an improved method for estimating the VOLLs.

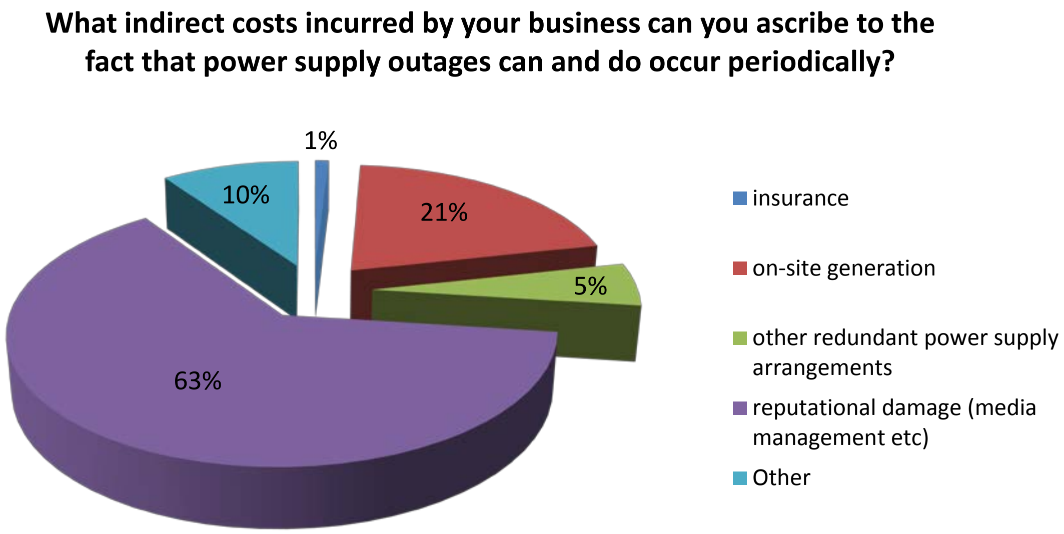
Appendix B VOLL calculation methodologies used in Stage 2

Methodology used to calculate the direct measurement survey VOLL

B.1 Organisations were asked to quantify the direct costs for a base case scenario of a 10 minute electricity outage. They were then asked to quantify the additional direct costs above the base case for 1 hour, 3 hour, and 8 hour outages.

B.2 Organisations were also asked to quantify the indirect costs of outages. This question proved difficult for organisations, with only a relatively small number providing values. The values that were given were limited to the cost of providing back-up supplies (generators and uninterrupted power supply (UPS)) and the damage to reputation. The latter of these was particularly important for a number of respondents, with one respondent applying a $30 million value to reputational damage.

Figure 2 'Demand' indirect costs of power outages



Source: Strata Energy Consulting, NZIER

B.3 Given the difficulties in establishing evidence-based values for indirect costs, the calculated VOLL was derived from the values obtained for the direct costs of outages only. It was considered that those organisations with exceptionally high indirect costs from power outages were likely to have taken measures to minimise these potential losses. The costs of measures such as back-up generation, fuel costs and insurance were included in the direct costs of outages.

B.4 The calculations used to derive the VOLL in the direct measurement survey were as set out in Table 10.

Table 10 Direct measurement survey VOLL calculation methodology

Outage duration	VOLL calculation
Base case VOLL (10 minute outage)	(sum of base case direct costs) / (peak demand coincident with time (hour) of greatest outage impact) * (0.167)
1 hour outage VOLL	(sum of base case direct costs) / (peak demand coincident with time (hour) of greatest outage impact)
3 hour outage VOLL	(sum of base case direct costs) / (peak demand coincident with time (hour) of greatest outage impact) * (3)
8 hour outage VOLL	(sum of base case direct costs) / (peak demand coincident with time (hour) of greatest outage impact) * (8)

Source: Strata Energy Consulting

Direct measurement survey VOLL

B.5 The following table shows the estimated VOLL for 10 minute, 1, 3, and 8 hour outages for, respectively:

(a) all direct measurement survey respondents

(b) only grid-connected direct measurement survey respondents

(c) only non-grid-connected direct measurement survey respondents.

Table 11 Non-load-weighted VOLL from direct measurement survey

All respondents				
	10 minute outage	*1 hour outage*	*3 hour outage*	*8 hour outage*
Maximum	$2,215,569	$370,000	$290,667	$109,000
Minimum	$0	$286	$190	$159
Mean	$152,269	$30,547	$28,321	$16,798
Median	$19,960	$6,439	$5,042	$4,167
Upper quartile	$86,228	$16,320	$21,642	$16,304
Lower quartile	$4,196	$3,256	$2,381	$1,875
Standard deviation	$401,590	$67,183	$56,292	$27,917
Grid-connected respondents				
	10 minute outage	*1 hour outage*	*3 hour outage*	*8 hour outage*
Maximum	$86,228	$16,320	$290,667	$109,000
Minimum	$1,711	$286	$190	$286
Mean	$41,283	$8,814	$62,637	$24,598
Median	$32,934	$5,714	$2,381	$1,339
Upper quartile	$59,880	$16,250	$17,917	$11,406
Lower quartile	$25,663	$5,500	$2,032	$960
Standard deviation	$29,139	$6,402	$114,194	$42,399

Non-grid-connected respondents				
	10 minute outage	*1 hour outage*	*3 hour outage*	*8 hour outage*
Maximum	$2,215,569	$370,000	$133,718	$107,833
Minimum	$0	$463	$217	$159
Mean	$172,088	$34,428	$22,193	$15,405
Median	$16,500	$6,445	$5,621	$5,029
Upper quartile	$112,729	$38,406	$21,666	$16,481
Lower quartile	$4,012	$3,136	$3,114	$2,433
Standard deviation	$432,816	$72,200	$34,033	$24,180

Source: NZIER

B.6 The table below provides non-load-weighted VOLL figures for each sector classification in the direct measurement survey.

Table 12 VOLLs by sector classification

No.	Load (MW)	Industry	10 minute outage ($/MWh)	1 hour outage ($/MWh)	3 hour outage ($/MWh)	8 hour outage ($/MWh)
1.	30	Air and space transport	$1,212	$1,214	$1,905	$1,842
2.	19	Basic chemicals and chemical products	$11,976	$4,000	$4,333	$4,125
3.	1,000	Basic ferrous metals	$25,663	$5,714	$2,381	$1,339
4.	5,475	Basic non-ferrous metals	$86,228	$16,320	$290,667	$109,000
5.	27	Coal mining	$32,662	$6,182	$17,818	$8,727
6.	14	Dairy products	$192,398	$35,652	$27,246	$22,663
7.	93	Dairy products	$390,523	$65,217	$21,739	$16,304
8.	244	Dairy products	$2,171	$463	$217	$159
9.	147	Information media, telecommunications and postal services	$0	$11,143	$15,206	$17,012
10.	58	Log sawmilling and timber dressing, and other wood products	$3,460	$1,267	$874	$747
11.	120	Log sawmilling and timber dressing, and other wood products	$89,820	$15,000	$5,000	$1,875
12.	12	Machinery and equipment manufacturing	$2,215,569	$370,000	$123,333	$46,250
13.	1	Meat and meat products	$181,455	$76,479	$133,718	$50,144
14.	11	Meat and meat products	$12,850	55,794$	$72,961	$107,833
15.	41	Meat and meat products	$10,701	$3,256	$49,229	$68,950
16.	7	Non-metallic mineral products	$199,601	$46,667	$18,333	$8,542
17.	51	Non-metallic mineral products	$3,114	$1,520	$2,007	$3,440
18.	14	Other food products, beverages and tobaccos	$16,367	$4,567	$6,200	$5,892
19.	18	Other food products, beverages and tobaccos	$19,960	$5,000	$10,000	$4,167
20.	23	Other food products, beverages and tobaccos	$74,850	$13,375	$5,042	$2,438
21.	45	Other food products, beverages and	$44,625	$7,452	$2,484	$932

No.	Load (MW)	Industry	10 minute outage ($/MWh)	1 hour outage ($/MWh)	3 hour outage ($/MWh)	8 hour outage ($/MWh)
		tobaccos				
22.	193	Other mining and quarrying, and services to mining	$23,952	$6,439	$4,098	$3,366
23.	25	Other transport and transport support services	$856,287	$143,064	$47,816	$19,556
24.	275	Petroleum and coal product manufacturing	$388,775	$64,925	$21,642	$9,235
25.	33	Public administration and safety	$4,196	$3,317	$3,324	$3,241
26.	50	Public administration and safety	$16,152	$9,605	$15,175	$7,763
27.	265	Pulp, paper and converted paper products	$32,934	$5,500	$2,032	$960
28.	538	Pulp, paper and converted paper products	$1,711	$286	$190	$286
29.	600	Pulp, paper and converted paper products	$59,880	$16,250	$17,917	$11,406
30.	80	Rail	$4,829	$6,452	$4,301	$2,419
31.	2	Water supply, sewerage and drainage services	$2,994	$2,500	$5,033	$3,188
32.	4	Water supply, sewerage and drainage services	$16,633	$2,778	$1,852	$10,069
33.	30	Water supply, sewerage and drainage services	$1,331	$667	$519	$472

Source: NZIER

Methodology for calculating a single VOLL for mail-out survey respondents for an 8 hour outage

B.7 When calculating the VOLL for electricity consumers who responded to the mail-out surveys, the following input information was obtained from the surveys:

(a) the electricity consumer's most recent monthly total electricity bill

(b) the cost of outages to electricity consumers:

(i) for residential electricity consumers this was the cost of three 8 hour outages at the most inconvenient time(s) for the consumer (obtained by asking the survey respondent for the minimum discount he/she would want in order to be compensated for these losses of power supply)

(ii) for non-residential electricity consumers this was the cost of outages of the following durations – 10 minutes / 1 hour / 8 hours.

B.8 As can be seen, 8 hours was the outage duration for which VOLL input information was obtained from both residential and non-residential electricity consumers.

B.9 This input information was then combined with the input assumptions in Table 13 to derive a VOLL ($/MWh) from each mail-out survey response to the minimum compensation question.

Table 13 Mail out survey VOLL input assumptions

Type of respondent	% of electricity bill that is for energy	Energy price paid per MWh	Days per month (residential) / Working days per month (non-residential)	Electricity use per day (hours) / Electricity utilisation factor[39]
Residential	50%	$120	30	14.4 hours / 60%
Non-residential – small	50%	$120	25	10 hours / 42%
Non-residential – medium	60%	$100	25	12 hours / 50%
Non-residential – large	70%	$80	25	16 hours / 66.67%

Source: Strata Energy Consulting

B.10 The following steps were then followed to calculate a single VOLL for mail-out survey respondents for an 8 hour outage.

Step 1: Calculate the cost of each MWh unserved (i.e. the VOLL) for individual residential electricity consumers

B.11 *Step 1)a):*

Multiply the [most recent monthly TOTAL electricity bill] (obtained from the mail-out survey responses) by the [(estimated) percentage of TOTAL electricity bill that is for energy] (obtained from the table of input assumptions).

This gives the estimated monthly energy cost for each residential electricity consumer survey respondent.

B.12 *Step 1)b):*

Multiply [days per month] by [hours of electricity use per day] by [energy price paid per MWh] (all obtained from the table of input assumptions)].

This gives the estimated monthly energy cost for a residential electricity consumer paying 12 cents/kWh for the energy component of its electricity bill, and consuming the overwhelming majority of its daily electricity requirement over a period of 14.4 hours each day (defined here as the representative residential electricity consumer).

B.13 *Step 1)c):*

Divide the [monthly energy cost for each residential electricity consumer survey respondent] from 1)a) by the [monthly energy cost for a representative residential electricity consumer] from 1)b).

[39] For example, a 60% electricity utilisation factor for residential mail-out survey respondents means a representative domestic household is estimated to consume the overwhelming majority of its daily electricity requirement over a period of 14.4 hours each day. NB: this utilisation factor is not to be confused with the residential electricity consumer's load factor (average power divided by peak power over a defined time period).

This gives the hourly consumption for each residential electricity consumer survey respondent, measured in MWh. [40]

B.14 *Step 1)d):*

Multiply the [hourly consumption for each residential electricity consumer survey respondent] by the [duration of the outage] (in this case 8 hours).

This gives the consumption foregone during an 8 hour outage by each residential electricity consumer survey respondent,[41] measured in MWh.

B.15 *Step 1)e):*

Divide the [cost of three 8 hour outages to each residential electricity consumer survey respondent] (obtained from the survey responses) by [three].

This gives the cost of an 8 hour outage to each residential electricity consumer survey respondent, measured in MWh.

B.16 *Step 1)f):*

Divide the [cost of an 8 hour outage to each residential electricity consumer survey respondent] by the [consumption foregone during an 8 hour outage by each residential electricity consumer survey respondent].

This gives the cost of each MWh unserved during the outage (i.e. the VOLL), for each residential electricity consumer survey respondent.

Step 2: Calculate the cost of each MWh unserved (i.e. the VOLL) for individual non-residential electricity consumers

B.17 *Step 2)a):*

Multiply the [most recent monthly TOTAL electricity bill] (obtained from the mail-out survey responses) by the [(estimated) percentage of TOTAL electricity bill that is for energy] (obtained from the table of input assumptions).

This gives the estimated monthly energy cost for each non-residential electricity consumer survey respondent.

B.18 *Step 2)b):*

Multiply [working days per month] by [work hours per day] by [energy price paid per MWh] (all obtained from the table of input assumptions)].

This gives the estimated monthly energy cost for a small / medium / large non-residential electricity consumer paying, respectively, 8 / 10 / 12 cents/kWh for the energy component of its electricity bill, and consuming the overwhelming majority of its daily electricity requirement over a period of, respectively, 10 / 12 / 16 hours each day (defined here as, respectively, the representative small / medium / large non-residential electricity consumer).

[40] In units: the result from 1)a) is measured in $/month; the result from 1)b) is measured in days/month * hours/day * $/MWh, or hours * $ / month * MWh; the result from 1)c) is measured in MW / hour or MWh.

[41] Because the mail-out surveys were undertaken during July-August, the consumption foregone relates to, generally speaking, a period of high (if not the highest) electricity consumption for a New Zealand residential electricity consumer.

B.19 *Step 2)c):*

Divide the [monthly energy cost for each category of non-residential electricity consumer survey respondent (i.e. small / medium / large)] by the [monthly energy cost for a representative small / medium / large non-residential electricity consumer)].

This gives the hourly consumption for each non-residential electricity consumer survey respondent, measured in MWh.

B.20 *Step 2)d):*

Multiply the [hourly consumption for each non-residential electricity consumer survey respondent] by the [duration of the outage] (i.e. 10 minutes / 1 hour / 8 hours).

This gives the consumption foregone during the outage by each non-residential electricity consumer survey respondent, measured in MWh.

B.21 *Step 2)e):*

Divide the [cost of a 10 minute / 1 hour / 8 hour outage to each non-residential electricity consumer survey respondent] by the [consumption foregone during the outage by each non-residential electricity consumer survey respondent].

This gives the cost of each MWh unserved during the outage (i.e. the VOLL), for each non-residential electricity consumer survey respondent.

Step 3: Calculate the cost of each MWh unserved (i.e. the VOLL) for all electricity consumers (for an 8 hour outage only)

B.22 *Step 3)a):*

Sum the [cost to each electricity consumer survey respondent of each MWh of unserved energy during an 8 hour outage] and divide by the [total number of electricity consumer survey respondents].

This gives the estimate of the non load-weighted VOLL for all electricity consumer survey respondents (measured in $/MWh).

B.23 *Step 3)b):*

Multiply the [cost to each electricity consumer survey respondent of each MWh of unserved energy during an 8 hour outage] by the [electricity consumer survey respondent's hourly consumption]. Then sum these products. Then divide this total by the [total hourly consumption of all the electricity consumer survey respondents].

This gives the estimate of the load-weighted VOLL for all electricity consumer survey respondents (measured in $/MWh).

B.24 In other words, step 3)b) involves: Dividing the [load-weighted total cost to all electricity consumer survey respondents of 1 MWh of consumption foregone due to an 8 hour power outage] by the [total hourly consumption of all the electricity consumer survey respondents].

B.25 It is important to note this estimated VOLL applies only to those electricity consumers who responded to the mail-out surveys. The VOLL should not be considered representative of other New Zealand electricity consumers.

Mail-out survey VOLL

B.26 The following table shows the estimated VOLL for each consumer category surveyed in the mail-out surveys.

Table 14 VOLL for an 8 hour outage, from mail-out surveys

Consumer category	Mean ($/MWh)	Load-weighted average ($/MWh)
Residential	$12,845	$10,966
Small non-residential	$107,340	$50,559
Medium non-residential	$41,934	$20,971
Large non-residential	$18,911	$8,212

Source: NZIER

Sensitivity analysis for the mail-out survey VOLL

B.27 Sensitivity analysis of the estimated VOLL derived from the mail-out surveys was undertaken to assess the movement in the VOLL due to changes to the input assumptions contained in Table 13. This sensitivity analysis is shown below. The 'base case' VOLL figures use the input assumptions in Table 13. It should be noted the figures contained in the sensitivity analysis exclude the Tiwai Point aluminium smelter's VOLL.

Table 15 Sensitivity analysis – Base case assumptions and results

Type of respondent	% of electricity bill that is energy	Energy price paid per MWH	Days per month (residential) / Working days per month (non-residential)	Electricity use per day (hours)
Residential	50%	$120	30	14.4 hours
Non-residential – small	50%	$120	25	10 hours
Non-residential – medium	60%	$100	25	12 hours
Non-residential – large	70%	$80	25	16 hours
Mean non-load-weighted VOLL = $48,236 / MWh				
Mean load-weighted VOLL = $15,631 / MWh				

Source: NZIER

Table 16 Sensitivity to energy component of electricity bill (medium and large non-residential consumers only)

Type of respondent	% of electricity bill that is energy	Energy price paid per MWH	Days per month (residential) / Working days per month (non-residential)	Electricity use per day (hours)
Residential	50%	$120	30	14.4 hours
Non-residential – small	50%	$120	25	10 hours
Non-residential – medium	***50%***	$100	25	12 hours
Non-residential – large	***50%***	$80	25	16 hours
Mean non-load-weighted = $50,237 / MWh				
Mean load-weighted VOLL = $20.112 / MWh				

Source: NZIER

Table 17 Sensitivity to working hours per day

Type of respondent	% of electricity bill that is energy	Energy price paid per MWH	Days per month (residential) / Working days per month (non-residential)	Electricity use per day (hours)
Residential	50%	$120	30	14.4 hours
Non-residential – small	50%	$120	25	***8 hours***
Non-residential – medium	60%	$100	25	***10 hours***
Non-residential – large	70%	$80	25	***12 hours***
Mean non-load-weighted = $39,928 / MWh				
Mean load-weighted VOLL = $12,211 / MWh				

Source: NZIER

Table 18 Sensitivity to energy price paid

Type of respondent	% of electricity bill that is energy	Energy price paid per MWH	Days per month (residential) / Working days per month (non-residential)	Electricity use per day (hours)
Residential	50%	***$140***	30	14.4 hours
Non-residential – small	50%	***$140***	25	10 hours
Non-residential – medium	60%	***$120***	25	12 hours
Non-residential – large	70%	***$100***	25	16 hours
Mean non-load-weighted = $56,627 / MWh				
Mean load-weighted VOLL = $19,160 / MWh				

Source: NZIER

Table 19 Sensitivity to high energy component of bill, low energy price, low hours worked

Type of respondent	% of electricity bill that is energy	Energy price paid per MWH	Days per month (residential) / Working days per month (non-residential)	Electricity use per day (hours)
Residential	50%	***$100***	30	14.4 hours
Non-residential – small	50%	***$100***	25	***8 hours***
Non-residential – medium	***75%***	***$80***	25	***10 hours***
Non-residential – large	***75%***	$80	25	***12 hours***
Mean non-load-weighted = $32,102 / MWh				
Mean load-weighted VOLL = $9,874 / MWh				

Source: NZIER

Table 20 Sensitivity to low energy component of bill, high energy price, high hours worked

Type of respondent	% of electricity bill that is energy	Energy price paid per MWH	Days per month (residential) / Working days per month (non-residential)	Electricity use per day (hours)
Residential	50%	***$150***	30	14.4 hours
Non-residential – small	50%	***$150***	25	***12 hours***
Non-residential – medium	***50%***	***$150***	25	***16 hours***
Non-residential – large	***50%***	***$140***	25	***24 hours***
Mean non-load-weighted = $80,358 / MWh				
Mean load-weighted VOLL = $44,262 / MWh				

Source: NZIER

Stage 2 conclusions about the calculation of estimated VOLLs

B.28 In Stage 2 of the VOLL study two main conclusions were reached in regard to the calculation of the VOLL.

A 'matrix-based' approach

B.29 To produce a single $/MWh VOLL figure, specific variables such as consumer category profile, duration of outage, and frequency of outage need to be defined.

B.30 If a mean national VOLL in the Code is necessary, the 2010 VOLL survey data should be scaled to reflect the national consumer demand profile, so as to achieve a more representative national VOLL. This could be done by making a high level adjustment to the consumer categories (e.g. defining the non-residential (large) consumer category to be >2 GWh per annum), or using a more detailed basis for defining the consumer categories when making the adjustment (e.g. creating a consumer category of 'agricultural').

B.31 A regional load-weighted average VOLL could also be produced using the 2010 VOLL survey data, by scaling the survey response data in accordance with a regional consumer demand profile. Input assumptions for the calculation of consumer hourly energy demand could be adjusted to more closely represent the region. This is shown in Table 21.

B.32 This would be a 'matrix-based' approach, whereby input variables can be changed to match regional profiles, enabling users to determine a customised VOLL for a region, or selected portion of a transmission or distribution network. This is likely to lead to an improvement in decision making wherever the VOLL is used.

Table 21 Mail out survey VOLL input assumptions

Type of respondent	% of regional load by consumer category	% of electricity bill that is energy	Energy price paid per MWH	Days per month (residential) / Working days per month (non-residential)	Electricity use per day (hours) / Electricity utilisation factor[42]
Residential	37%	50%	$120	30	14.4 hours / 60%
Non-residential – small	36%	50%	$120	25	10 hours / 42%
Non-residential – medium	20%	60%	$100	25	12 hours / 50%
Non-residential – large	7%	70%	$80	25	16 hours / 66.67%

Source: Strata Energy Consulting

CPI-adjusted VOLL

B.33 Currently, the VOLL contained in the Code makes no allowance for inflation. Over time this will have a material impact on the accuracy of the VOLL.

B.34 Hence, if a single VOLL is retained in the Code, it should be an inflation-adjusted figure (e.g. referenced in base year dollars).

[42] For example, a 60% electricity utilisation factor for residential mail-out survey respondents means a representative domestic household is estimated to consume the overwhelming majority of its daily electricity requirement over a period of 14.4 hours each day. NB: this utilisation factor is not to be confused with the residential electricity consumer's load factor (average power divided by peak power over a defined time period).

Appendix C VOLLs estimated from Stage 2 survey data

Introduction

C.1 Using data obtained from the 2010 survey, estimated VOLLs were calculated for non-residential and residential electricity consumers located:

(a) in Auckland

(b) in Christchurch

(c) in Taranaki

(d) throughout New Zealand.

C.2 These estimates serve to highlight the variability of the VOLLs:

(a) in dollar terms, particularly in relation to the current figure of $20,000/MWh

(b) geographically within New Zealand, not only between regions, but also between the regions and the country as a whole

(c) across categories of electricity consumers.

C.3 Non-residential survey respondents were surveyed about three lengths of outage: 10 minutes, 1 hour, and 8 hours. Residential survey respondents were surveyed only about 8 hour outages (to align with the longest duration outage put to non-residential survey respondents).

C.4 The VOLL figures presented here are not derived from the choice modelling questions of the 2010 survey. Instead, they are derived from a question about the compensation that respondents would require as the result of a power outage. This is a type of contingent valuation question.

C.5 Respondents to the 2010 VOLL survey were asked to state the cost to them of a loss of electricity. No questioning or analysis was done to determine whether individual answers were realistic, so it is possible that some were affected by hypothetical bias – that is, respondents give hypothetical answers to hypothetical questions, and these answers may not be grounded in real experiences, prices and markets.

C.6 Analysis undertaken to gain an understanding of the impact of hypothetical bias on the results of the Stage 2 mail-out residential surveys indicated that residential electricity consumers were not biased by the hypothetical nature of the situation described in the compensation question in the survey (refer to Appendix F).

C.7 In addition, the law of large numbers was found to apply to the 2010 survey results. Although a few high values materially increase the VOLL for subsamples of electricity consumers, the VOLL figures have a central tendency. Average estimates from the larger subsamples and the full sample are therefore unlikely to show much bias from any individual hypothetical answers.

C.8 Lastly, the 2010 survey results dataset was checked casually in regard to large compensation amounts. Sometimes the large numbers were explicable (e.g. a medical business), while sometimes the large number appeared to be a reasonable estimate of cost (e.g. $1,000) over a very small consumption quantity. There was no obvious trend that could be used to eliminate data points.

C.9 Therefore, the analysis reported on below has not removed any responses for each type of survey respondent (residential, small non-residential, medium non-residential and large non-residential).

Regional VOLLs

C.10 Presented below are the average regional VOLL figures by economic sector, size of firm, and length of outage.

Representativeness

C.11 The data used for estimating the Christchurch VOLL figures was also assessed for representativeness. The survey was found to be not representative. Although a similar assessment was not undertaken for the Auckland, Taranaki and national data, it is anticipated that this data would also not be representative.

Auckland VOLLs

VOLL during a 10 minute outage

C.12 The VOLL for a 10 minute outage in Auckland is **$135,496**, weighted by electricity demand.

C.13 The VOLL for small and medium electricity users is much higher than the VOLL for large users. However, the higher consumption of the large users is reflected in the relatively low weighted average VOLL.

Table 22 VOLL for Auckland non-residential respondents, 10 minute outage

By respondent type and average across samples

Respondent	VOLL
Small non-residential	$147,078
Medium non-residential	$439,122
Large non-residential	$15,572
Average	**$135,496**

Source: NZIER
Note: The average is weighted by consumption, so it is not the mean of the other figures shown in the table.

VOLL during a 1 hour outage

C.14 The VOLL for a 1 hour outage in Auckland is **$29,189**, weighted by electricity demand.

C.15 The VOLL is higher for small and medium electricity users than for large users. The average VOLL is weighted more towards the large users.

Table 23 VOLL for Auckland non-residential respondents, 1 hour outage

By respondent type and average across samples

Respondent	VOLL
Small non-residential	$79,332
Medium non-residential	$58,884
Large non-residential	$7,884
Average	**$29,189**

Source: NZIER
Note: The average is weighted by consumption, so it is not the mean of the other figures shown in the table.

VOLL during an 8 hour outage

C.16 The VOLL for an 8 hour outage in Auckland is **$14,900**, weighted by electricity demand.

C.17 The VOLL shows the same trend for non-residential electricity users as for the 10 minute and 1 hour outages – higher for small and medium non-residential users than for large users.

C.18 Residential survey respondents indicated a relatively low VOLL, less than the small and medium users, and less than the average across the entire sample.

Table 24 VOLL for Auckland respondents, 8 hour outage

By respondent type and average across samples

Respondent	VOLL
Residential	$11,980
Small non-residential	$56,815
Medium non-residential	$27,992
Large non-residential	$3,906
Average	**$14,900**

Source: NZIER

Note: The average is weighted by consumption, so it is not the mean of the other figures shown in the table.

Averages by industry and size

C.19 The following tables present the average VOLL figures for Auckland survey respondents with primary (agriculture), commercial, and industrial businesses. The non-residential figures are separated into small, medium, and large respondents.

Table 25 Average VOLL by sector and size, 10 minute outage, Auckland non-residential

Price of MWh during 10 minute power loss, weighted by consumption

Sector	Small users	Medium users	Large users
Primary (agriculture)	$667,270	$20,151	N/A
Commercial	$126,271	$1,187,544	$23,349
Industrial	$277,290	$60,519	$8,214

Source: NZIER

Table 26 Average VOLL by sector and size, 1 hour outage, Auckland non-residential

Price of MWh during 1 hour power loss, weighted by consumption

Sector	Small users	Medium users	Large users
Primary (agriculture)	$29,945	$7,586	$7,725
Commercial	$59,900	$96,347	$11,622
Industrial	$111,239	$39,879	$3,811

Source: NZIER

Table 27 Average VOLL by sector and size, 8 hour outage, Auckland non-residential
Price of MWh during 8 hour power loss, weighted by consumption

Sector	Small users	Medium users	Large users
Primary (agriculture)	$40,156	$8,230	$7,725
Commercial	$53,871	$28,605	$2,343
Industrial	$76,561	$28,247	$3,881

Source: NZIER

C.20 A few general observations can be made about the VOLLs in the tables above:

(a) small electricity users have much higher VOLLs than other users

(b) VOLL per hour changes with the length of the outage

(c) VOLL varies by industry, with the industrial sector much higher than the primary sector

(d) for small electricity users, longer outages have lower VOLLs, but the same is not always true for other electricity users.

Christchurch VOLLs

VOLL during a 10 minute outage

C.21 The VOLL for a 10 minute outage in Christchurch is **$28,755**, weighted by electricity demand.

C.22 The VOLL for small and medium electricity users is much higher than the VOLL for large users. However, the higher consumption of the large users is reflected in the relatively low weighted average VOLL.

Table 28 VOLL for Christchurch non-residential respondents, 10 minute outage
By respondent type and average across samples

Respondent	VOLL
Small non-residential	$177,766
Medium non-residential	$62,001
Large non-residential	$16,828
Average	**$28,755**

Source: NZIER
Note: The average is weighted by consumption, so it is not the mean of the other figures shown in the table.

VOLL during a 1 hour outage

C.23 The VOLL for a 1 hour outage in Christchurch is **$17,946**, weighted by electricity demand.

C.24 The VOLL is higher for small and medium electricity users than for large users. The average VOLL is weighted more towards the large users.

Table 29 VOLL for Christchurch non-residential respondents, 1 hour outage

By respondent type and average across samples

Respondent	VOLL
Small non-residential	$107,218
Medium non-residential	$30,359
Large non-residential	$10,783
Average	**$17,946**

Source: NZIER

Note: The average is weighted by consumption, so it is not the mean of the other figures shown in the table.

VOLL during an 8 hour outage

C.25 The VOLL for an 8 hour outage in Christchurch is **$18,690**, weighted by electricity demand.

C.26 The VOLL shows the same trend for non-residential electricity users as for the 10 minute and 1 hour outages – higher for small and medium non-residential users than for large users.

Table 30 VOLL for Christchurch respondents, 8 hour outage

By respondent type and average across samples

Respondent	VOLL
Residential	$14,818
Small non-residential	$69,761
Medium non-residential	$46,686
Large non-residential	$10,940
Average	**$18,690**

Source: NZIER

Note: The average is weighted by consumption, so it is not the mean of the other figures shown in the table.

Averages by industry and size

C.27 The following tables present the average VOLL figures for Christchurch survey respondents with primary (agriculture), commercial, and industrial businesses. The non-residential figures are separated into small, medium, and large respondents.

Table 31 Average VOLL by sector and size, 10 minute outage, Christchurch non-residential

Price of MWh during 10 minute power loss, weighted by consumption

Sector	Small users	Medium users	Large users
Primary (agriculture)	$8,456	$49,606	N/A
Commercial	$336,160	$28,096	$7,448
Industrial	$23,433	$79,834	$18,062

Source: NZIER

Table 32 Average VOLL by sector and size, 1 hour outage, Christchurch non-residential

Price of MWh during 1 hour power loss, weighted by consumption

Sector	Small users	Medium users	Large users
Primary (agriculture)	$127,777	$10,302	N/A
Commercial	$175,249	$19,349	$6,982
Industrial	$11,749	$47,526	$9,449

Source: NZIER

Table 33 Average VOLL by sector and size, 8 hour outage, Christchurch non-residential

Price of MWh during 8 hour power loss, weighted by consumption

Sector	Small users	Medium users	Large users
Primary (agriculture)	$8,456	$9,812	N/A
Commercial	$104,006	$75,047	$8,786
Industrial	$11,157	$53,143	$8,782

Source: NZIER

Taranaki VOLLs

VOLL during a 10 minute outage

C.28 The VOLL for a 10 minute outage in Taranaki is **$73,090**, weighted by electricity demand.

C.29 The VOLL for small non-residential electricity users is much higher than the VOLL for medium and large non-residential electricity users. However, the higher consumption of the medium and large users is reflected in the relatively low weighted average VOLL.

Table 34 VOLL for Taranaki non-residential respondents, 10 minute outage

By respondent type and average across samples

Respondent	VOLL
Small non-residential	$77,340
Medium non-residential	$10,220
Large non-residential	$115,963
Average	**$73,090**

Source: NZIER

Note: The average is weighted by consumption, so it is not the mean of the other figures shown in the table.

VOLL during a 1 hour outage

C.30 The VOLL for a 1 hour outage in Taranaki is **$19,190**, weighted by electricity demand.

C.31 The VOLL for small non-residential electricity users is again much higher than for medium and large non-residential electricity users (whose respective VOLLs are almost identical). The average VOLL is weighted more towards the medium and large users.

Table 35 VOLL for Taranaki non-residential respondents, 1 hour outage

By respondent type and average across samples

Respondent	VOLL
Small non-residential	$54,726
Medium non-residential	$9,552
Large non-residential	$22,327
Average	**$19,190**

Source: NZIER

Note: The average is weighted by consumption, so it is not the mean of the other figures shown in the table.

VOLL during an 8 hour outage

C.32 The VOLL for an 8 hour outage in Taranaki is **$9,377**, weighted by electricity demand.

C.33 The VOLL is again higher for small non-residential electricity users than for other electricity users (residential and non-residential). Medium non-residential users have the lowest VOLL of all users.

Table 36 VOLL for Taranaki respondents, 8 hour outage

By respondent type and average across samples

Respondent	VOLL
Residential	$21,049
Small non-residential	$32,101
Medium non-residential	$9,906
Large non-residential	$7,383
Average	**$9,377**

Source: NZIER

Note: The average is weighted by consumption, so it is not the mean of the other figures shown in the table.

Averages by industry and size

C.34 The following tables present the average VOLL figures for Taranaki survey respondents with primary (agriculture), commercial, and industrial businesses. The non-residential figures are separated into small, medium, and large respondents.

C.35 There were fewer VOLL survey respondents in Taranaki than in Auckland or Christchurch. As a consequence, some of the analysis depends heavily on a few specific survey respondents, especially in the industry-by-size analysis (the large non-residential group is just four or five respondents with complete responses).[43] Hence, it is important to bear in mind that the number of responses in a cell in the following tables may be small – just a single response in some cases. In addition, a major electricity user listed its industry as 'Other', so it does not appear in these tables.

[43] There were four survey respondents for one of the power outage lengths, and five survey respondents for each of the other two power outage lengths.

Table 37 Average VOLL by sector and size, 10 minute outage, Taranaki non-residential

Price of MWh during 10 minute power loss, weighted by consumption

Sector	Small users	Medium users	Large users
Primary (agriculture)	$15,234	N/A	N/A
Commercial	$113,657	$75,563	$14,838
Industrial	N/A	$3,651	$1,170

Source: NZIER

Table 38 Average VOLL by sector and size, 1 hour outage, Taranaki non-residential

Price of MWh during 1 hour power loss, weighted by consumption

Sector	Small users	Medium users	Large users
Primary (agriculture)	$33,274	N/A	N/A
Commercial	$51,748	$60,440	$3,710
Industrial	N/A	$3,238	$8,381

Source: NZIER

Table 39 Average VOLL by sector and size, 8 hour outage, Taranaki non-residential

Price of MWh during 8 hour power loss, weighted by consumption

Sector	Small users	Medium users	Large users
Primary (agriculture)	$20,666	$3,410	N/A
Commercial	$22,040	$65,208	$5,564
Industrial	#N/A	$3,376	$3,476

Source: NZIER

National VOLLs

C.36 National VOLL figures were estimated using data obtained from the 2010 survey to enable a comparison against the VOLL figure currently in the Code, and to highlight the variability of the VOLL not only between different categories of electricity consumers, but also geographically across New Zealand.

Mail-out survey results

C.37 Using the results from the mail-out surveys only, the research undertaken in Stage 2 of the VOLL project produced *for all categories of electricity consumers*:[44]

(a) a mean *non-load-weighted*[45] VOLL of **$48,236/MWh**, for an 8 hour outage at the worst possible time for consumers

(b) a mean *load-weighted* VOLL of **$15,631/MWh**, for an 8 hour outage at the worst possible time for consumers.

Direct measurement survey results

C.38 Using the results from the direct measurement (face-to-face) survey of large electricity consumers only, the research undertaken in Stage 2 of the VOLL project produced:

(a) a mean *non-load-weighted* VOLL of **$16,798/MWh**, for an 8 hour outage at the worst possible time for consumers (non-grid connected = $15,405/MWh and grid connected = $24,598/MWh)[46]

(b) a mean *load-weighted* VOLL of **$64,948/MWh**, for an 8 hour outage at the worst possible time for consumers (non-grid connected = $8,063/MWh and grid connected = $76,843/MWh).

Combining the results from the mail-out and direct measurement surveys

C.39 When the results from the mail-out and direct measurement (face-to-face) survey are combined, the research undertaken in Stage 2 of the VOLL project has produced for all categories of electricity consumers:

(a) a mean *non-load-weighted* VOLL of **$47,842/MWh**, for an 8 hour outage at the worst possible time for consumers

(b) a mean *load-weighted* VOLL of **$50,031/MWh**, for an 8 hour outage at the worst possible time for consumers.

Qualifications

C.40 It must be noted the mean national VOLLs listed above are subject to various qualifications.

Results non-representative – hold only for consumers surveyed

C.41 These results hold only for those electricity consumers surveyed. In particular, for the large electricity consumers surveyed the mean VOLL is very sensitive to:

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[44] That is, residential, small non-residential, medium non-residential, and large non-residential electricity consumers.

[45] The *non-load-weighted* values give each survey respondent equal weighting regardless of the quantity (size) of the respondent's electricity consumption. In effect each respondent is given a single 'vote'. The *load-weighted* values adjust the responses to reflect respondent electricity consumption.

[46] 'Grid-connected' refers to consumers connected to the transmission network; 'non-grid connected' refers to consumers connected to a distribution network.

(a) the individual organisations included in the VOLL calculation

(b) the duration of the outage

(c) the method of weighting the responses to the surveys.[47]

C.42 A regional load-weighted average VOLL could be produced by scaling the survey response data with a scaled regional consumer demand profile. Similarly, the survey data on the VOLL could be scaled to reflect the national consumer profile.

Individual respondents' VOLLs are dependent on the duration of outages

C.43 Although the cost can be the same for both a 10 minute outage and an 8 hour outage, the amount of unserved energy (MWh) can be significantly different. In this instance, the $/MWh values for a 10 minute outage will be higher than those for an 8 hour outage because the MWh values are significantly less than for an 8 hour outage.

The VOLL varies across and within consumer classifications

C.44 Organisations within the same industrial classification may have strikingly different tolerances to outage durations, and therefore significantly different VOLLs.

C.45 For instance, for some electricity consumers short duration outages can be as costly as longer outages, and in some instances even more costly. For other consumers, short duration outages can be handled relatively easily with minimal or no cost, but longer duration outages increase costs significantly.

The VOLL varies across regions

C.46 The VOLL for a given region in New Zealand will be sensitive to the type and range of consumers within that region.

C.47 An estimated load-weighted VOLL derived from the load profile of consumers that responded to the face-to-face and mail-out surveys is unlikely to be regionally representative.[48]

Findings / observations from the 2010 direct measurement VOLL survey

C.48 In addition to estimated VOLLs, the direct measurement survey of large electricity consumers also produced a number of key findings / observations, as follows:

(a) the results demonstrate the sensitivity of the VOLL to the sectors included in the survey, the relative size of respondents, and respondents' sensitivity to the duration of outages

(b) there is a wide spread of VOLLs across sectors

(c) the results for a 1 hour duration outage contained 2 significant outliers which have a significant impact on the mean non-load-weighted VOLL and the mean load-weighted VOLL for the aggregated results for all respondents

(d) the frequency of outages appears to be less of a concern to both grid-connected and distribution-connected respondents. However, the cost impacts of outage frequency rise steeply for distribution-connected respondents if there are more than two outages per year

[47] To account for variations in consumer energy demands, and thereby account for the range of energy lost by each consumer in each hour of an outage, it is necessary to calculate the load-weighted average VOLL. When this was done as part of the analysis of the studies undertaken in Stage 2 of the VOLL study, the mean VOLL altered significantly.

[48] Given the uneven distribution of population and industrial loads across the country, this issue is more likely to be relevant in New Zealand than many overseas jurisdictions.

(e) despite the potential cost and reputational damage of outages, relatively few organisations were found to have invested in alternative energy supplies. Out of the 33 organisations interviewed, whilst 17 had invested in alternative supplies, only five had the ability to cover more than 50% of their respective loads

(f) there is a wide divergence and range in energy risk management practices across organisations

(g) many organisations had not previously calculated the cost of a loss of electricity supply or the value to them of secure electricity supply

(h) relatively short duration outages can result in hours or days of lost production for some organisations. This means that, generally, longer outages have lower $/MWh costs, as the cost of restoration of production is spread across a higher quantity of MWh

(i) momentary fluctuations in supply quality fell outside the scope of the interviews but many organisations identified these as being at least as damaging and occurring more frequently than longer-period outages

(j) how perishable input raw materials are impacts on the cost of outages, e.g. a food harvest perishes within days if not used by manufacturers, whereas materials such as trees can remain in the ground and be harvested later

(k) service industries can have relatively low direct costs arising from supply interruptions but high external impacts arising from the loss of service (e.g. an oil refinery loss could lead to major economic consequences for New Zealand)

(l) overall, organisations rated the service provided by their electricity supplier to be reasonable, with an average rating of 5 from a possible maximum of 7.

Appendix D Approach to the Stage 3 surveys

Stage 2 recommendation – Conduct at least one further survey of electricity consumers

D.1 A key recommendation out of Stage 2 of the VOLL study was that the Authority conduct at least one further survey of electricity consumers, using a combination of in-person and internet-based, telephone-assisted interviews.

D.2 The results of these interviews would be used to estimate:

(a) the cost to those electricity consumers in the medium non-residential category of a power outage at the most inconvenient time for them

(b) the interaction effects between the attributes of the outage (e.g. the change in cost associated with varying the length of the outage or changing the time of the outage).

A national survey or regional surveys?

D.3 While the 2010 survey was a national survey, it was not necessary for any follow-up survey to also be a national survey. The findings from one or more regional surveys could be used to validate or improve upon the findings in the national survey.

D.4 A key benefit from adopting a regional survey approach was the ability to target survey respondents with relatively recent significant electricity outages. As noted in Appendix E, specific surveys following real life outages have the benefit of enabling respondents to have a clear case to refer to, rather than a hypothetical scenario, when assessing the perceived value of the lost load.

Stage 3 approach

D.5 Building on the lessons learned from the 2010 mail-out survey, in the second half of 2012 the Authority conducted a further survey of electricity consumers, using an internet-based survey approach.

D.6 Due to budget constraints, in-person surveys were not undertaken and nor was proactive telephone assistance provided with the internet surveys. Reactive telephone assistance was provided via a free-call (0800) phone number.

D.7 It was considered there were at least a couple of benefits from doing one or more regional surveys that would not arise to the same extent from undertaking a follow-up national survey.

D.8 Firstly, adopting a regional survey approach enabled better targeting of survey respondents with relatively recent significant electricity outages, which, it was hoped, would improve the robustness of the survey data. The Canterbury earthquakes, the weather bombs in Taranaki in 2011, and the power outages caused around the North Island by the tripping of the automatic under-frequency relays in December 2011 were examples used by the Authority as an input into proceeding with a regional survey approach and thence in considering which regions to survey.

D.9 Secondly, it was hoped that undertaking VOLL surveys in one or more regions would provide more useful data for the local distributor than the data that could be drawn upon by distributors more generally under a national survey approach. For a distributor such as Orion, which has a significant network rebuild to do as a result of the Canterbury earthquakes, this more detailed information may be quite beneficial.

D.10 Consistent with the recommendations coming out of Stage 2 of the VOLL study, no further surveys of electricity consumers in the non-residential large consumer category were undertaken.

D.11 The approach adopted for undertaking the internet survey may be summarised as follows:

(a) the database of electricity consumers created for the 2010 VOLL surveys was updated for Orion's network, Powerco's Taranaki network and Wellington Electricity's network

(b) the 2010 survey forms were shortened and refined, incorporating findings from the 2010 survey, and the design of the stated choice questions was amended from being based on a consumer's willingness to accept compensation for one or more power outages, to being based on a consumer's willingness to pay to avoid one or more power outages

(c) internet surveys were undertaken of Canterbury, Taranaki and Wellington electricity consumers in the residential and small non-residential consumer categories

(d) internet surveys were undertaken of Canterbury, Taranaki and Wellington electricity consumers in the medium non-residential consumer category who did not participate in the 2010 VOLL surveys, as well as all medium non-residential consumers who responded to the 2010 survey[49]

(e) the survey data received was coded and analysed, with utility functions and the implied VOLLs estimated.

D.12 As with Stage 2 of the VOLL study, a choice modelling survey approach to estimating VOLL was used, on the basis that it would give more precise and reliable estimates of customer preferences than other approaches.

Stage 3 conclusions

D.13 The key conclusion from the 2012 survey of electricity users is that a single VOLL figure does not account for considerable variation in the VOLL across users and time. This finding supports the earlier 2010 findings that a single VOLL should be replaced by tables of multiple VOLL figures, derived using a matrix-based approach. This VOLL depends in complex ways on the length of outage and time of year, as well as characteristics of the electricity consumer.

D.14 A second finding of the 2012 research is that an electricity consumer's willingness to pay to avoid a power outage is best modelled as proportional to that consumer's electricity consumption. Re-analysis of the 2010 VOLL survey data also found that treating an electricity consumer's willingness to accept compensation for a power outage as a proportion of the monthly electricity bill improved results in two out of the three consumer categories reviewed.

D.15 The third finding is that a survey method, in particular choice modelling, can be used to derive VOLL figures. However, the research is not simple to undertake. If it is going to be used in future research, then researchers should have the time and budget to do the work properly. In the context of the large capital investments at stake, a properly conducted choice modelling survey is a small investment in robust decision-making.

[49] Resurveying in 2012 all of the non-residential electricity consumers in the medium-sized consumer category who completed the 2010 main VOLL survey was necessary because of the limited survey sample size for this consumer category.

Appendix E Discussion on the stated choice question sets used in Stage 2 of the VOLL study

Introduction

E.1 This section of the report has been contributed by Professor Riccardo Scarpa of the University of Waikato Management School, and considers:

(a) issues encountered in modelling the responses to the stated choice question sets used in Stage 2 of the VOLL investigation

(b) results obtained from this modelling

(c) lessons learnt from the approach used in Stage 2 in relation to stated choice questions.

Modelling issues

E.2 For the stated choice question sets a standard set of model specifications was estimated for each of the four consumer categories. The specifications included, from the simplest to the most complex:

(a) *binary logit model*: This model assumes all survey respondents display identical preferences, and it is normally used as a benchmark. All coefficients were showing significant estimates and expected signs except for the compensation coefficient. This precludes its use in deriving significant estimates of the VOLL

(b) *panel binary logit with random parameters*: This model improves on the binary logit model because it assumes that coefficients for attributes vary randomly up to a distribution of choice across respondents. It is also a more realistic model as it also recognises the correlation between sequences of choices made by each respondent. As with the binary logit model, all coefficients were showing significant estimates and expected signs except for the compensation coefficient, which was insignificant

(c) *panel binary latent class logit*: This model is somewhat similar to the previous model, but it brings a bit more structure to the data by assuming the existence of a limited number of classes with homogeneous preferences. Respondents in the same class share the same preference intensities for all attributes of outage, but they hold different intensities from those in other classes. The number of classes needs to be established by trial and error and identified by means of information criteria. The panel nature of the sequence of choices is recognised. Again, all coefficients were showing significant estimates and expected signs except for the compensation coefficient, which was insignificant, thereby precluding the derivation of class-specific values for the outage attributes.

(d) *panel binary logit with class constrained attribute non-attendance*: In an attempt to account for a typical result in these studies which results in some people ignoring some of the attributes of outages, a final model was used that allowed for various forms of non-attendance of attributes, while constraining all the coefficients to be the same across classes. This model assumes that if a difference exists between survey respondents, it is limited to what attributes matter to them, but if the attribute does matter, then it has the same coefficient value as for everyone else. This model was successful in identifying some specifications that produced significant estimates for the compensation coefficient for the residential and the small non-residential.

E.3 Altogether, for the four categories of models above, and the four categories of consumers and their respective datasets, a total of over 100 specifications were estimated. All of these specifications suffered from similar shortcomings, described below.

Limitations and implications of the approach

E.4 Despite a recommendation to use an adaptive approach, implying the collection of a first wave of mail-out survey results followed by an interim analysis of those results to evaluate the validity of the field survey format, it was felt that the timeline and budget of the project could not allow such an interim validation. Sample sizes were chosen to allow a second wave to be surveyed later on, after the establishment of the Authority.

E.5 One of the limitations of the approach employed in this study concerns the fact that only changes in utility can be identified during the data analysis. These then need a baseline to be meaningfully measured, since utility changes are meaningful only with respect to a specific baseline. The baseline is arbitrary and can be defined by the analyst. For example, for the residential survey sample we used as a baseline the combination of attributes that define the least costly outage for the household. That is, an outage taking place in summer, at 10am and lasting only 10 minutes. From this baseline we can compute the utility difference that can be experienced by moving to any of the other 18 scenarios (3 more times of the year multiplied by 2 events (number of outages) multiplied by 3 duration lengths of these events). However, the utility changes need anchoring to some absolute level of compensation to produce compensation estimates for all the scenarios, and for this reason a question on the least amount of compensation associated with the worst outage conditions was asked of all respondents. These worst outage conditions were expressed in terms of the outage attributes considered in the study. Responses to such a question are important because they constitute the link to a given (worst) level. Along with the compensation estimates for utility changes they allow the derivation of compensation estimates for all scenarios investigated in the survey design.

E.6 Furthermore, the study assumed that the attributes of the outage would be independent and additively linear. This is quite a standard simplifying assumption in these studies. As a consequence, the experimental design implemented such an assumption. Therefore, no interaction between, for example, length of outage and the time of the year when it occurred, were specifically addressed. In order to address these issues, a much higher number of choice tasks would be needed in the experimental design, however as already noted out above, time and resource constraints imposed limitations on the design structure. The end result was that the effects of such interactions, which turned out to be important in the calculations to derive the VOLL ($/MWh), were ignored. Consequently, the effect on utility of an 8 hour duration outage would be accurately estimated from the statistical viewpoint, but its effect in combination with the time of the year when it occurred would not. We will refer to this issue as the `linearity' problem. The word “problem” is used to indicate that it leads to a less-than-ideal approximation of the real utility changes experienced by survey respondents in the evaluated scenarios. The real effect is likely to be highly non-linear and certainly dependent on interaction effects between the salient attributes of the outage event.

Results obtained

E.7 For each category of consumer we had survey samples data to use to estimate group-specific utility functions. Standard models used in the specification search of each group suggested that while outage attributes had the expected signs, the coefficients associated with the amount of compensation offered was never significant. This runs counter to our theoretical expectations and is considered an anomaly, which unfortunately prevents us from deriving estimates of values from these conventional models (multinomial logit (MNL) and mixed logit (MXL)).

E.8 Recent research in the field of choice data analysis suggests that such anomalies might be overcome by models that account for the fact that some variation exists within the survey sample, in terms of what outage attributes are considered by survey respondents. For example, some respondents might either genuinely not care about some aspects of the power outage, or be induced not to care about the amount of hypothetical compensation they require, because of the fact that the scenario is indeed hypothetical. This is the "ask a hypothetical question get a hypothetical answer" issue, which is often encountered in survey research.

E.9 By applying models that accounted for attribute non-attendance by means of latent class models it was in fact found that some specifications produced significant coefficient estimates for the cost attribute, as well as plausibly signed outage attribute coefficients. This was so for the residential consumer sample and for the non-residential small consumer sample. On the other hand, for the other two non-residential groups (i.e. medium and large consumers) even these more advanced specifications provided little guidance. One issue that might have caused this lack of information from the choice data was the use of consumer category means in the definition of the compensation levels. For individual respondents belonging to a consumer category with a wide variation of electricity bill values, the average might have been too far away from their individual values.

Table 40 Residential consumer category utility estimates

Utility estimates from constrained latent class logit model					
	Estimate	***Significance***	***Standard error***	***z-value***	***p-value***
From 10 mins to 1 hour	-0.39732	**	0.15438	-2.57	0.0101
From 1 hour to 3 hours	-0.65317	***	0.16183	-4.04	<0.001
From 1 hour to 8 hours	-2.85419	***	0.47092	-6.06	<0.001
Summer at 5pm	-1.77524	***	0.36859	-4.82	<0.001
Winter at 10am	-1.99574	***	0.39398	-5.07	<0.001
Winter at 5pm	-4.06529	***	0.66593	-6.1	<0.001
PRICE	0.10144	***	0.02041	4.97	<0.001
Probabilities of each class					
Probability for Class 1	0.01988		0.05667	0.35	0.7257
Probability for Class 2	0.07617		0.05241	1.45	0.1461
Probability for Class 3	0.25741	***	0.05106	5.04	<0.001
Probability for Class 4	0.15687	**	0.06473	2.42	0.0154
Probability for Class 5	0.48967	***	0.04524	10.82	<0.001

Model diagnostics					
Latent class logit model					
Dependent variable	Y1				
Log likelihood function	-2874.42892				
Restricted log likelihood	-3072.02830				
Chi squared (11 degrees of freedom)	395.19877				
Significance level	.00000				
McFadden Pseudo R-squared	.0643221				
Estimation based on N = 4432	K = 11				
Information Criteria	Normalisation = 1/N				
	Normalised	*Unnormalised*			
AIC	1.30209	5770.85784			
Fin.Smpl.AIC	1.30210	5770.91757			
Bayes IC	1.31796	5841.22051			
Hannan Quinn	1.30769	5795.67005			
Model estimated	18 October 2010	19:38:45 hours			
*R^2=1-LogL/LogL*Log-L function*					
		R-squared	*R-squared Adjusted*		
No coefficients	-3072.0283	.0643	.0620		
Constants only	-3064.1608	.0619	.0596		
At start values	-2975.6324	.0340	.0316		
Response data are given as independent choices					
Number of latent classes	5				
Average class probabilities	.020	.076	.257	.157	.490
LCM model with panel has 1108 groups					
Fixed number of observations per group	4				
Number of observations	4432	(skipped 0 observations)			

Source: Professor Riccardo Scarpa, University of Waikato Management School

E.10 From the above model we derived estimates of mean willingness to accept compensation for the various jumps in utility associated with the various independent components of the linear utility function (reported below in Table 41).

E.11 These were then assembled into all the different outage scenarios that can be composed by using the various mutually exclusive values (shown against a blue background in Table 41), which in turn were then anchored to the highest mean value for the group, obtained from the minimum compensation for the worst scenario, assuming that the worst scenario is represented by 3 outages with 8 hours duration each happening in winter at 5pm. The compensation levels implied for each scenario are shown against a yellow background in Table 41.

E.12 A scrutiny of these numbers reveals that the change between 1 and 3 scenarios in terms of compensation expected is unrealistically low. This is due to the absence of interaction effects between attributes and the number of events, as mentioned above.

E.13 This issue becomes even more apparent when these values are mapped back into the implied values of kW lost (the numbers shown against a terracotta background in Table 41), at which it becomes apparent that this model implies values for the lost kW that range between two orders of magnitude.

E.14 Of course it might well be possible that there is no clear way to map back the value of a kW from the outage scenarios depicted in terms of the current attributes and attribute levels. This is because there is too much heterogeneity amongst consumers in terms of what use (and therefore value) the lost kW might have across different realities (both for residential and non-residential consumers). Indeed, it may well be that one should omit the number of outages in a year and just focus on the single outage, its duration and the time of day and season when it happens, inclusive of non-linear interactions. From these single event values one could then derive the cost of the kW and/or that of multiple events.

Table 41 Estimated 'willingness-to-accept' compensations for residential consumers

Mean WTA for worst scenario = $100.	This figure is the average minimum compensation for a worst case scenario. It is used to derive the values in the yellow cells below.				
Estimated WTA compensations					
	Estimate	***Significance***	***Standard error***	***z-value***	***p-value***
From 1 to 3 outages	6.44	***	1.63	3.94	<0.001
From 10 min to 1 hour	3.92	***	1.47	2.66	0.0079
Up to 8 hours in length	28.14	***	5.30	5.31	<0.001
Summer at 5pm	17.50	***	4.30	4.07	<0.001
Winter at 10am	19.67	***	4.82	4.09	<0.001
Winter at 5pm	40.08	***	8.52	4.71	<0.001
Sum of part-worths	115.74				

Scenarios from baseline (one 10 minute outage in summer at 10am)						
Outage duration	***10 minutes***		***1 hour***		***8 hours***	
Number of outages	***1***	***3***	***1***	***3***	***1***	***3***
Summer at 5pm	$17.50	$23.94	$21.42	$27.86	$45.64	$52.08
Winter at 10am	$19.67	$26.11	$23.59	$30.03	$47.81	$54.25
Winter at 5pm	$40.08	$46.51	$43.99	$50.43	$68.21	$74.65
Derivation of baseline values from mean WTA for worst scenario						
Summer at 10am	$25.35	$31.79	$29.27	$35.71	$53.49	$59.92
Summer at 5pm	$42.85	$49.29	$46.77	$53.21	$70.99	$77.42
Winter at 10am	$45.02	$51.46	$48.94	$55.38	$73.16	$79.60
Winter at 5pm	$65.42	$71.86	$69.34	$75.78	$93.56	***$100.00***

If the above (yellow) values are $ per hour, then by dividing these by the estimated median kW at the time of the power outage for the 4 time attributes we get the following **$/kWh WTA** for the outage

Outage duration	***10 minutes***		***1 hour***		***8 hours***		
Number of outages	***1***	***3***	***1***	***3***	***1***	***3***	***kW at time of outage***
Summer at 10am	$76	$32	$15	$5.95	$3.34	$1.25	2
Summer at 5pm	$86	$33	$16	$5.91	$2.96	$1.08	3
Winter at 10am	$90	$34	$16	$6.15	$3.05	$1.11	3
Winter at 5pm	$98	$36	$17	$6.32	$2.92	$1.04	4

Source: Professor Riccardo Scarpa, University of Waikato Management School

E.15 A similar result was obtained for the non-residential small consumer category. The structural model from which the compensation estimates for these consumers were obtained is the following, which includes some interaction effects between:

(a) time and 8 hour length

(b) number of events and 8 hour length.

Table 42 Non-residential (small) consumer category utility estimates

Utility estimates from constrained latent class logit model					
	Estimate	***Significance***	***Standard error***	***z-value***	***p-value***
From 10 mins to 1 hour	-4.27061	***	0.76456	-5.59	<0.001
From 1 hour to 3 hours	-2.45842	***	0.62137	-3.96	<0.001
From 1 hour to 8 hours	-19.411	***	4.1255	-4.71	<0.001
Summer at 10am	-13.3927	***	2.85063	-4.7	<0.001
Summer at 5pm	-6.92408	***	1.54491	-4.48	<0.001
Winter at 10am	-12.1036	***	2.70611	-4.47	<0.001
Summer at 10am for 8 hours	-2.75753	*	1.44099	-1.91	0.0557
Winter at 10am for 8 hours	0.29202		1.58846	0.18	0.8541
3 times 8 hours	-6.35228	***	1.51985	-4.18	<0.001
Compensation	0.00323	***	0.00089	3.63	0.0003
Probabilities of each class					
Probability for Class 1	0.16549D-12		1.01984	0	1
Probability for Class 2	0.06352	**	0.02852	2.23	0.0259
Probability for Class 3	0.20737	***	0.03494	5.94	<0.001
Probability for Class 4	0.22293	***	0.03585	6.22	<0.001
Probability for Class 5	0.50618	***	0.02268	22.32	<0.001

Model diagnostics	
Latent class logit model	
Dependent variable	CHOICE
Log likelihood function	-2648.05336
Restricted log likelihood	-3033.90521
Chi squared (14 degrees of freedom)	771.70370
Significance level	.00000
McFadden Pseudo R-squared	.1271799
Estimation based on N = 4377, K = 14	K = 11
Information Criteria	Normalisation = 1/N

Model diagnostics					
	Normalised		*Unnormalised*		
AIC	1.21638		5324.10671		
Fin.Smpl.AIC	1.21640		5324.20300		
Bayes IC	1.23680		5413.48438		
Hannan Quinn	1.22359		5355.64422		
Model estimated	23 October 2010		21:59:25 hours		
*R^2=1-LogL/LogL*Log-L function*					
		R-squared	*R-squared Adjusted*		
No coefficients	-3033.9052	.1272	.1244		
Constants only	-3033.1557	.1270	.1242		
At start values	-2819.6623	.0609	.0578		
Response data are given as independent choices					
Number of latent classes	5				
Average class probabilities	.000	.064	.207	.223	.506
LCM model with panel has 1117 groups					
Variable number of observations per group	PDS				
Hessian is not PD. Using BHHH estimator	(skipped 0 observations)				

Source: Professor Riccardo Scarpa, University of Waikato Management School

E.16 Similar calculations to those carried out for the residential sample led us to the same conclusions. In short, the compensation estimates for the value of the lost load (kW) based on this structural model have large variability and depend in a counter-intuitive way on the underlying factor. The same considerations made in the residential consumer case can be extended to this instance. While the choice modelling approach employed here might be adequate to value the outages and its attributes, it is clear that the implied values of the lost kW due to the outage scenario are very variable and might be more accurately estimated using alternative approaches, such as industry output modelling.

Table 43 Estimated 'willingness-to-accept' compensations for non-residential (small) consumers

Mean WTA for worst scenario = $13,000.	This figure is the average minimum compensation for a worst case scenario. It is used to derive the values in the yellow cells below.

Estimated WTA compensations

	Estimate	***Significance***	***Standard error***	***z-value***	***p-value***
From 1 to 3 outages	761.65	***	128.37	5.93	<0.001
From 10 mins to 1 hour	1323.09	***	210.97	6.27	<0.001
Up to 8 hours in length	6013.78	***	978.57	6.15	<0.001
Summer at 10am	4149.24	***	758.51	5.47	<0.001
Summer at 5pm	2145.17	***	416.68	5.15	<0.001
Winter at 10am	3749.86	***	719.82	5.21	<0.001
Winter at 10am for 8 hours	-90.47		508.54	-0.18	0.8588
Summer at 10am for 8 hours	854.32	***	322.74	2.65	0.0081
3 times 8 hour outages	1968.02	***	241.53	8.15	<0.001
Sum of part-worths	18142.79				

Scenarios from baseline (one 10 minute outage in summer at 10am)

Outage duration	***10 minutes***		***1 hour***		***8 hours***	
Number of outages	***1***	***3***	***1***	***3***	***1***	***3***
Summer at 5pm	$2,145.17	$2,906.82	$3,468.26	$4,229.91	$8,158.95	$10,888.62
Winter at 10am	$3,749.86	$4,511.51	$5,072.95	$5,834.60	$9,763.64	$12,493.31
Summer at 10am	$4,149.24	$4,910.89	$5,472.33	$6,233.98	$10,163.02	$12,892.69

Derivation of baseline values from mean WTA for worst scenario						
Summer at 10am	$4,256.55	$5,018.20	$5,579.64	$6,341.29	$10,270.33	***$13,000.00***
Summer at 5pm	$2,252.48	$3,014.13	$3,575.57	$4,337.22	$8,266.26	$10,995.93
Winter at 10am	$3,857.17	$4,618.82	$5,180.26	$5,941.91	$9,870.95	$12,600.62
Winter at 5pm	$107.31	$868.96	$1,430.40	$2,192.05	$6,121.09	$8,850.76

If the above (yellow) values are $ per hour, then by dividing these by the estimated median kW at the time of the power outage for the 4 time attributes we get the following **$/kWh WTA** for the outage

Outage duration	***10 minutes***		***1 hour***		***8 hours***		
Number of outages	***1***	***3***	***1***	***3***	***1***	***3***	***kW at time of outage***
Summer at 10am	$1,596	$627	$349	$132	$80	$34	16
Summer at 5pm	$845	$377	$223	$90	$65	$29	16
Winter at 10am	$1,446	$577	$324	$124	$77	$33	16
Winter at 5pm	$40	$109	$89	$46	$48	$23	16

Source: Professor Riccardo Scarpa, University of Waikato Management School

E.17 No model estimate was selected for both the medium and large non-residential consumer categories. For medium non-residential consumers, the variability of compensation used as an attribute was extremely large and probably caused significant model instability. A similar consideration is to be made for the large non-residential consumers surveyed, which was compounded by the small sample size for this group.

Conclusions

E.18 Compensation amounts offered to specific electricity consumers must be reflective of the consumer's history of electricity consumption and should not be computed on the basis of the average of the consumer category or group they belong to. This leads to the conclusion that unassisted mass mail-out surveys are not appropriate for this approach. CAPI systems that enable a respondent's feedback to be incorporated in the survey design have the necessary adaptive capacity and should be considered in future.

E.19 The focus of choice for the survey respondent should be the single outage described in terms of both linear and non-linear effects. It hence requires adequate provisions to be made in terms of sample sizes, incentive for response completion, and experimental design. Internet-based surveys and/or computer-assisted personal interview (CAPI) systems should be adopted rather than mass mail-out surveys. Finally, specific surveys following real life outages could be used to investigate the perceived value of the lost load in the immediate aftermath of the event, so that respondents have a clear case to refer to, rather than a hypothetical scenario.

E.20 Compensation for a different number of outages is most likely to be interpreted as a separate quantity from the compensation required for a single outage event.

E.21 Different categories of consumers have different predispositions to be studied with choice model surveys. These surveys are likely to perform best in consumer categories with good homogeneity of circumstances in terms of electricity usage. For example, the residential and small non-residential consumer categories in the VOLL project have pattern-of-use characteristics that can be better captured by a choice modelling exercise. On the other hand, medium and large non-residential electricity consumers are probably better studied by means of engineering calculations and case studies since the 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.

E.22 Despite the recommendation received by the Electricity Commission in Stage 1 of the VOLL project, to conduct a mass mail-out survey using the method of stated choice, such a survey approach has not been the favourite survey method for stated choice surveys for a long time amongst practitioners. For stated choice surveys of the type used in the VOLL project (i.e. for the derivation of monetary value estimates), the standard method tends to be in-person surveys conducted with CAPI systems and internet-based survey panels.

E.23 Such methods have supplanted mail surveys because they allow the collection of better quality data using automatic data entry (thereby decreasing data entry errors and time), are responsive to feedback from respondents, and can be quickly validated and corrected if need be. In particular, they allow the creation of scenarios that are relevant to the respondent because they are informed by the consumption pattern of each respondent. Most importantly from the viewpoint of inference to the larger population, they suffer much less from sample self-selection.

E.24 The international experience of surveys of this type for similar network industries clearly points to an emphasis on the quality of data collection, rather than on a large sample of inevitably low quality data from mail surveys. Because respondents need to actively engage in surveys of this type, there is normally a payment (in the form of a voucher or bill discount) made to respondents, who sometimes are engaged for over 30 minutes and need to be instructed on how to tackle the stated choice part of the survey.

Appendix F Limitations associated with using a minimum compensation question

Introduction

F.1 As noted in the description of the approach to Stage 2 of the VOLL investigation, the compensation (price) attribute in the stated choice questions contained in the mail-out surveys was converted to an annual electricity bill discount value, and an additional question was included in the surveys asking the survey respondent about the minimum compensation that would be required by the respondent for a worst case power outage.

F.2 In this way the stated choice questions in the Stage 2 mail-out surveys adopted a ‘willingness-to-accept’ compensation approach rather than a ‘willingness-to-pay’ approach.

F.3 This approach meant the minimum compensation responses could inform the determination of the VOLL for a worst case outage, while the stated choice question sets could be used to identify changes in the VOLL for various levels of attributes (e.g. summer versus winter in the instance of the 'season' attribute).

F.4 Asking a direct question to consumers about the minimum cost of a power outage at the worst possible time for them appears, on the surface, to be relatively straightforward. However, a consumer’s response may be conditioned by a range of factors. Limitations arising from the use of the minimum compensation question are discussed in this appendix.

Sample size

F.5 One potential limitation of the research based on the minimum compensation question is the sample sizes. The research is attempting to estimate the VOLL for all of New Zealand based on samples. As with all sample-based estimates, the values estimated from the survey are likely to have some error. Larger sample sizes tend to reduce the sampling error. Therefore, it is always better to have more observations or responses, although the marginal accuracy increase to sample size increase falls rapidly.

F.6 The actual number of responses received in the Stage 2 mail-out surveys varied by the specific compensation question. The mail-out surveys had the following maximum numbers of responses about compensation for each surveyed group:

(a) 165 – large non-residential

(b) 497 – medium non-residential

(c) 863 – small non-residential

(d) 834 – residential.

F.7 For estimating population-level statistics, the number of responses in the residential and small non-residential consumer categories is likely to be sufficient. Without knowledge of the population distribution, it is difficult to calculate the exact sample size necessary to achieve a specific confidence interval at statistical power. However, for these two consumer categories the standard errors are very small compared to the respective means, which suggests that the estimates are accurate and robust.

F.8 Although the number of medium non-residential responses is about one-half of the small non-residential responses, there are still likely to be sufficient observations, because the standard error is still very small compared to the sample mean.

F.9 However, the large non-residential consumer category has materially fewer observations, so the standard error is correspondingly larger. As a result, the statistical significance of the estimates is lower.

F.10 Although the sample sizes for each survey group appear to be large enough, with the possible exception of the large non-residential consumer category, the same cannot be said about sub-samples (sector categories). For example, it was possible to group non-residential respondents into their industrial classifications. However, the number of respondents in each sub-sample was very small in some cases, so estimates for sub-samples are much less robust and accurate.

Hypothetical bias

F.11 In order to estimate the VOLL, survey respondents were asked to consider the compensation they would demand for specific numbers of, or periods of, outages. This was a hypothetical situation, as opposed to an actual transaction in a real market. Such questions are known to cause 'hypothetical bias', which is a potential limitation for this research. Respondents give hypothetical answers to hypothetical questions, and these answers may not be grounded in real experiences, prices, and markets. An extreme example of hypothetical bias is when a respondent indicates a willingness to pay an amount greater than his or her annual income in order to preserve some environmental amenity, perhaps because of the social importance of such an amenity.

F.12 It is possible to get some idea of the impact of hypothetical bias on the results of the Stage 2 mail-out surveys. For example, the residential respondents indicated the number of outages experienced in the prior 12 months. The question should be less hypothetical for respondents who had experienced a power outage than for those who had not. By comparing the results of those who had outages with those who had not, it is possible to obtain some sense of the impact of hypothetical bias amongst the residential respondents.

Table 44 Median and average required compensation for residential respondents, by number of outages experienced in last 12 months

Frequency (in last 12 months)	Responses	Median compensation	Mean compensation	Standard error	95% confidence interval	
					Lower bound	Higher bound
No loss of power	153	$100	$174.67	$17.94	$139.50	$209.84
1-2 losses of power	373	$100	$182.91	$11.97	$159.46	$206.37
3-5 losses of power	177	$100	$238.38	$22.56	$194.17	$282.60
6-10 losses of power	41	$100	$158.20	$28.66	$102.03	$214.36
> 10 losses of power	20	$150	$243.80	$58.57	$129.00	$358.60
Don’t know	29	$200	$335.82	$61.51	$214.96	$456.08
No answer	24	$125	$210.42	$45.11	$121.99	$298.84

Source: NZIER

F.13 The table above compares the median and average compensation values for residential mail-out survey respondents, grouped by the number of outages experienced. The median value for respondents with no outages was the same as the median values for respondents in the groups for 1-2 outages, 3-5 outages and 6-10 outages. The average values for these groups are also statistically similar. The table provides 95% confidence intervals for each of the mean (average) values. These confidence intervals overlap, which suggests that the average values for the groups are similar to each other. Therefore, whether or not residential respondents had experienced outages did not affect their stated compensation values.

F.14 The compensation figures above are dollar values for specific outages. To obtain a VOLL it is necessary to calculate a $/MWh value using the duration and expected demand for electricity at the time of the outage.

F.15 The findings above suggest that the values obtained in the mail-out survey of residential consumers were not biased by the hypothetical nature of the situation described in the compensation question.

Transformation of responses into a MWh value

F.16 Another potential limitation of the research based on the minimum compensation question is the difference between the questions asked, which were about experiences of power outages, and the measure derived from those questions, which is the value per MWh. Respondents were not asked directly about the value they placed on a MWh. Instead, they were asked about the cost of different types of outages, or about the compensation they would require for outages. The research has then had to transform the answers to those questions into the VOLL. To make the calculation, some assumptions are required about the energy consumption for each type of energy user. If these assumptions are inaccurate, then the value that a respondent placed on a MWh, as opposed to a power outage, would be calculated incorrectly.

F.17 This situation is a typical problem for survey-based research. In order to minimise the hypothetical bias, it is best to survey respondents about something they know and understand. Therefore, the mail-out survey question referred to loss of power, which is something people have experienced. Had the survey question referred to MWh or kW of power, it would have increased the hypothetical bias and the uncertainty due to cognitive effort on the part of the respondent. The method used for this research has therefore substituted some unknown error regarding power consumption for some other unknown error from hypothetical bias. Given the encouraging results regarding the general lack of hypothetical bias, the trade-off was considered to be useful.

F.18 In addition, the survey did contain a question regarding the size of a respondent's power bill. If the self-reports of power bills are correct, this data does provide a way to check the assumptions made about power consumption. Of course, reliance should not be placed solely on these figures. It is possible that some respondents did not accurately report their power bills, either on purpose or by mistake.

F.19 Sensitivity testing can be carried out across a range of input assumptions to provide information on the implications of potential limitations arising from the transformation of survey responses.

Treatment of outliers

F.20 The results from the surveys indicate there are clear outliers in the responses to the compensation or cost questions. Some reported values are so large, they vary from the median or mean by orders of magnitude.

F.21 There are three main reasons for these outliers:

(a) *True outliers*: the survey respondent really places a much higher value on power than other users. In such cases, there should be other measures taken to ensure continuity of power supply, such as use of a back-up generator

(b) *Strategic bias*: the survey respondent places a high value on continuity of power supply and overstates the personal VOLL in order to increase the survey average. Median values are less susceptible to strategic bias than average values. The stated VOLL is not the actual value

(c) *Protest votes*: the survey respondent is protesting against the project, the survey, the type of question, or some other element of the research project. Often, debriefing questions are used to explore the reasons for protest vote responses. However, the stated VOLL is again not the actual value.

F.22 To gain a perspective on this issue, box and whisker plots were used to identify outliers. The inter-quartile range (the distance between the 25th and 75th percentiles) was calculated for each consumer category in the mail-out surveys.

F.23 The analysis revealed the presence of outlier responses, which placed a much higher value on electricity than other respondents. The outliers were assessed to determine whether they were true outliers. One method used to assess the outliers was to consider how they had answered the question on whether they had arranged alternative supplies of power in case of loss of power.

F.24 It was found that most respondents whose compensation responses were outliers had not secured back-up generation. This result suggests that the actual willingness to pay for continuity of power is not as high as stated in the survey. As a result, it is likely that the outliers in the dataset represent either strategic behaviour on the part of respondents, or protest voting.

F.25 The characterisation seen above was further confirmed by the close correlation between compensation/cost measures and stated acceptability of power outages.

F.26 The density of responses at the lower end of the compensation scale suggests that most mail-out survey responses reflected true costs rather than inflated compensation expectations.

F.27 Similar results were found for the three non-residential categories.

Focus on compensation (willingness to accept versus willingness to pay)

F.28 An important limitation of the research based on the minimum compensation question is the reliance on willingness-to-accept measures of economic value, rather than willingness-to-pay measures. There is a large literature on the theoretical and empirical differences between these measures. Only a brief discussion is included here.

F.29 Willingness to pay and willingness to accept are two different ways to think about the value to customers. The research does not conclusively show one is better than the other.

F.30 The central problem with willingness to accept is that it is 'unbounded'. If a survey respondent is asked, “How much money would you be willing to accept in order to give up X?”, the respondent is free to state any amount of compensation. The amount stated can be difficult to confirm or disprove, and the respondent can maintain that this amount accurately represents his or her preferences. This is how hypothetical bias can create biased estimates of value.

F.31 In contrast, willingness to pay is bounded. First, it is bounded simply by the survey respondent’s income constraint. Secondly, any actual payment for one good reduces the money available for other things, meaning that willingness to pay is also constrained by other preferences.

F.32 In practice, surveys that ask about a survey respondent's willingness to accept generally produce values that are higher, sometimes much higher, than surveys about a respondent's willingness to pay.

F.33 One explanation for this result is the 'endowment effect' – people value what they have more than they value what they do not have. That is, endowing people with something adds to its value. This effect has been demonstrated in psychological and behavioural economics. It is also related to prospect theory, which holds that people feel losses more keenly than they feel gains.

F.34 For research into the VOLL, the difference between willingness to accept and willingness to pay presents a real problem. A power outage is, in fact, a loss. People lose the opportunity to use power; they also potentially lose the business associated with the use of that power.

F.35 In addition, electricity is generally considered an essential service in 'First World' countries, alongside other 'essentials' such as potable water. Various jurisdictions have laws and standards in place that are intended to minimise power outages, resulting in a very high level of reliability of power supply, often at or near 100% availability. Consequently, amongst many consumers in these jurisdictions there is increasingly a sense of entitlement to continuous power supply.

F.36 Therefore, it is theoretically plausible that willingness to accept compensation is the correct measure of the economic cost of power loss. However, focusing on willingness to accept allows respondents to claim extremely large compensation that is out of proportion to any real harm.

F.37 Research can deal with the unbounded nature of willingness to accept in the aggregated by excluding outliers. It cannot deal with respondents inflating their 'true' VOLL. However, simply noting that willingness to accept does not equal willingness to pay does not invalidate the former as the appropriate measure. However, it should be noted that the use of willingness to accept in this research may have produced higher values than a willingness to pay approach would have done.

F.38 When considering the question of investing in future capacity for electricity transmission and distribution, including a large endowment effect and inflated valuations might overstate the VOLL relative to other potential uses of the investment funds. In that case, a better measure might be willingness to pay. Willingness to pay forces people to think more carefully about the trade-offs they need to make with their own budgets, and helps remove the endowment effect. A consumer's willingness to pay to avoid a power outage can be analogised with that consumer paying for insurance that reimburses the economic cost to him or her of the outage.

F.39 Finally, the cognitive dimension should be recognised. Willingness to accept is more intuitive to electricity consumers because of the view that electricity is an essential service: "if my electricity is disrupted, I will be compensated". Willingness to pay is less intuitive because it requires respondents to adjust their prior expectation that electricity will simply be there when they want it, and that they need to believe in some form of insurance-type mechanism whereby they pay to avoid power outages. The cognitive difficulty can be addressed through various research techniques, such as one-on-one interviews or group surveys that are preceded by an informational workshop.

Aggregation procedure

F.40 The final limitation to discuss regarding the research based on the minimum compensation question is the method of moving from a collection of individual responses to an aggregate measure of the VOLL. There are many ways to summarise a set of data. Two common ways are medians and averages. These figures have been reported for all the surveys and many sub-samples.

F.41 Figures have been reported using unit weights (where each response is given the same weight as all other responses) and weighted averages. In order to derive a weighted average it is necessary to decide on a weighting criterion. For example, in each case the VOLL could be weighted by the amount of electricity consumed, or by some deviation from the mean electricity consumption. In the VOLL investigation, weighting by the amount of electricity consumed was chosen.

F.42 Having done this, there is the issue of combining the results from the different surveys. The residential and non-residential survey results need to be compared with each other and some weighting placed on the responses.

F.43 There are clear central tendencies in the results for each of the four consumer categories surveyed in the mail-out surveys, which the median and average represent well. However, in each of the consumer categories there are also many respondents whose VOLL is either much greater than or much less than the median and average. Regardless of how the data is aggregated or summarised, users of the results of the VOLL investigation should bear in mind the diversity of preferences expressed in the survey results.

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Glossary of abbreviations and terms

Act	Electricity Industry Act 2010
Authority	Electricity Authority
CAPI	Computer-assisted personal interview
Code	Electricity Industry Participation Code 2010
GWh	Gigawatt-hour
kW	Kilowatt
kWh	Kilowatt-hour
MWh	Megawatt-hour
OECD	Organisation for Economic Co-operation and Development