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Melbourne Energy Institute

Estimating values of customer reliability using Revealed Preference approaches

A report by the Melbourne Energy Institute at the University of Melbourne in support of the AER review of the Value of Customer Reliability (VCR)

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MarketWise SOLUTIONS

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1. Executive summary

Values of customer reliability (VCRs) represent customers' willingness-to-pay (WTP) for reliable electricity supply, and commonly expressed in dollars per kilowatt hour ($/kWh). VCR estimates play an important role in balancing the need to deliver reliable electricity supplies and to maintain reasonable costs for consumers. Since 2018, the Australian Energy Regulator (AER) has been responsible for developing a methodology for estimating VCRs, including those that may be used in network planning and investment.

This paper considers a range of Revealed Preference approaches for estimating VCRs as they relate to potential outages that are up to 12 hours in duration. The purpose of this paper is to inform the AER and its stakeholders regarding:

- a range of Revealed Preference methods that may be applicable to estimating VCRs;
- the advantages and challenges associated with the different types of Revealed Preference methods; and
- whenever available, examples of case studies, experiments, and field trials of how Revealed Preference methods have been applied in estimating VCRs.

The Revealed Preference approaches explored in this paper can be grouped as estimations based on:

- *existing actual markets*: products or services traded are directly related to reliability*;*
- *proxy markets*: products or services are indirectly or partially related to reliability;
- *experimental markets:* market-like environments that are designed to elicit customers' choices under various scenarios;
- *defensive expenditure*: values inferred from expenditures on avoiding costs of outages; and
- *hedonic pricing methods*: values inferred from prices paid for different characteristics of products or services.

An option of using *joint estimation* is also discussed. This option combines Stated and Revealed Preference approaches, building on the relative advantages of the two different types of estimation methods.

Whilst the Revealed Preference approaches discussed in this study have theoretical appeal, their practical implementation is at times challenging. Economists often instinctively reach for Revealed Preference information in the form of market prices. The advantages and challenges associated with alternatives to existing markets are therefore discussed in the study.

2. Introduction

In July 2018, the Australian Energy Market Commission (AEMC) amended the National Electricity Rules (NER) to make the Australian Energy Regulator (AER) responsible for developing a methodology for estimating values of customer reliability (VCRs).[1] VCRs represent customers' willingness-to-pay (WTP) for reliable electricity supply and it is expressed is dollars per kilowatt hour (kWh). VCR estimates play an important role in balancing the need to deliver reliable electricity supplies and to maintain reasonable costs for consumers.

According to the NER, the AER must develop a methodology for estimating VCRs, and the methodology must be fit for purpose for any current and potential uses of customer reliability that the AER considers relevant. Both the VCR methodology and VCR estimates are required to be updated at least every 5 years, and the AER must provide a mechanism for adjusting the VCRs on an annual basis. The NER also requires that the AER engages with customers to determine the VCRs. Moreover, the AER must develop the VCR methodology and calculate the first VCRs under that methodology by 31 December 2019.

In October 2018, the AER commenced its review of methodologies that have the potential to be used for calculating VCRs.[2] During its consultation process the AER considered the following methodologies:

- stated preference approaches that are typically based on consumer surveys;
- Revealed Preference approaches that are typically based on consumers' market behaviour; and
- model based approaches which typically rely on estimates of production losses (for business customers), and benefit losses (for residential customers).

For the determination of VCRs, the AER consulted with a wide range of stakeholders to assess the preferred methodology. For the 2019 VCR methodology, the AER considered that, given timelines and the requirement to directly engage with customers, adopting a combination of stated preference and model-based approaches was the most suited approach. There was a broad agreement among stakeholders and the AER, that the benefits of Revealed Preference methods should be further explored.

The purpose of this report is to provide information to the AER and its stakeholders on:

- a range of Revealed Preference methods that may be applicable to estimating VCRs;
- the advantages and challenges of different types of Revealed Preference methods; and

[1] AEMC (2018) Rule Determination – National Electricity Amendment (Establishing values of customer reliability) Rule 2018, 5 July 2018.

[2] See AER (2018) Values of Customer Reliability, Consultation Paper, 19 October 2018 and AER (2019) Values of Customer Reliability, Consultation Update Paper, 18 April 2019 for further details.

- whenever available, examples of case studies, experiments, and field trials examining how Revealed Preference methods have been applied in estimating VCRs for electricity supply and related areas.

For most customers, loads may be grouped as discretionary and non-discretionary loads with customers attributing substantially higher values to non-discretionary loads. Network outages may occur in various shapes and forms. The outages that are the subject of this study can be characterised as full outages that occur without any prior notice and impact all types of the loads of the customers (both discretionary and non-discretionary). Customers have no opportunity to opt-out. They are also more likely to occur under certain conditions (e.g. summer peak times). Generally, the network outages that are the focus of this study are up to 12 hours long.[3]

2.1 VCRs in network investment decisions

While the NER requires that the AER considers both current and potential uses of VCRs, the submissions to the AER's consultation process suggested[4] that the 2019 review should focus on deriving values that are fit for purpose for network planning and investment tests, in particular when these are driven by a need to meet regulated reliability requirements.[5] The objective of the network planning and investment framework is to maintain existing levels of reliability, rather than to improve reliability from current regulated levels.

The AER and network service providers currently use the VCR estimates to inform their cost-benefit analysis in assessing whether proposed steps to prevent outages, including network and non-network options, are economically justified. In this context, the consequence of the outages is typically monetised by measuring the amount of load that is at risk of interruption (MW), the duration of loss of supply (hours), and the value of lost load per MWh of interruption.[6]

2.2 VCRs in the context of increasing uptake of distributed energy resources

The energy system is undergoing a significant transformation. One of the changes relates to the increasing uptake of distributed energy resources (DERs) such as batteries, solar PVs, and electric vehicles. Perhaps the benefit that is most readily associated with batteries, is their ability to be paired with solar PVs and help with bill savings. Some batteries can also provide a level of electricity supply

[3] Momentary outages (less than 1 minute long) and high-impact, low-probability (HILP) outage events are outside the scope of the current study.

[4] AER (2019) Values of Customer Reliability, Consultation Update Paper, 18 April 2019, p. 8.

[5] The AEMC estimated that, between 2007 and 2017, 96.6% of interruptions (in terms of GWh) were network interruptions, specifically from distribution networks. Other causes of supply interruptions to customers included system security issues (3.2%) and inadequacy of supply (0.23%). For further details, see AEMC (2018) Reliability Frameworks Review, 26 July 2018.

[6] AER (2019) Industry practice application note – Asset replacement planning, January 2019, p. 41.

during outages if fitted with additional technology for this purpose, at extra cost. The extent that a battery may be considered a substitute for network electricity supply during an outage depends on the technical characteristics of the battery, how it is connected, how it is being used, and the nature of the outage.

Currently, there appears to be a degree of uncertainty among customers as to what (combination of) technical features of DERs may provide reliability, under what circumstances, and to what extent.[7]

With the increased offerings and uptake of DERs, customers in the future will become more informed, and they will have more options and flexibility to minimise costs and impacts of outages. In this context, rather than experiencing sudden outages, some of the network related events may manifest in the form of customers losing some control over some of their discretionary loads.[8]

Several stakeholders noted during the AER's methodology consultation process that customers' access to DERs is likely to play an increasingly important role in the reliability preferences and VCR estimates.[9] Less understood is, however, the direction and the magnitude of the potential change in VCRs. In the future, estimating VCRs will face complexities in that customers' preferences may diverge according to whether they own, for example, batteries and if so what the technical features of their batteries are.

As discussed earlier, certain types of batteries, when fitted with the right technology, and appropriately connected and installed, can provide a level of reliability. Having access to such a battery may reduce the value these customers place on reliable electricity supply relative to those customers who do not have access to such batteries.

Currently the number of customers that own the kinds of batteries that can provide a reliable electricity supply during the types of outages that is the subject of this study is small but increasing. Without gathering extensive information about the characteristics of the customers and how the technical features of their DERs translate to increased reliability, it may be challenging to establish the driving forces behind the customers' purchasing behaviour.

For example, it may be difficult to isolate whether the battery purchase was motivated by customers' intention to avoid supply outages, a desire to achieve bill savings, or a combination of the two.

[7] Several blogs discuss this topic in response to questions posed by blog user. Some websites contribute to the discussion by helping customers navigate through terminology such as 'full home backup', 'partial backup' and 'off-grid power system'. For example, Solar Choice provides some definitions and some helpful comments. See https://www.solarchoice.net.au/blog/backup-power-with-home-solar-battery-storage-what-are-your-options-2/

[8] Reflecting on the energy system transformation, AEMO notes that "the advent of advanced intelligence in the networks, and increased levels of distributed energy resource investment that supports more elastic and flexible price responsive demand, can become an asset for supporting reliability in a more efficient manner." For further details, see AEMO (2018) AEMO observations: Operational and market challenges to reliability and security in the NEM, March 2018, p.9.

[9] AER (2019) Values of Customer Reliability, Consultation Update Paper, 18 April 2019, p. 8.

Furthermore, there are a range of other factors that could play a role in customers' purchasing behaviour, some of which may not be easily quantified (environmental considerations, peer pressure).

In short, this is a complex but important area that requires detailed consideration. Rising to this challenge will be increasingly important in the changing energy landscape. As the uptake of DER increases as a result of well-informed decisions by households and businesses, it will be increasingly important to consider them in VCR estimation studies.

Given the relatively small number of households and businesses that currently own the kind of batteries that can provide reliability benefits, this study does not specifically focus on these cases. The impact of DERs on VCRs is considered in the current study to the extent that they are already reflected in customers' decisions. For the purpose of establishing 'generic' VCRs, it is important that the valuations are drawn from a representative population which would necessarily include households and businesses with a range of DERs.

There are likely to be benefits in undertaking a more bespoke study that aims to understand the various technical features of DERs and how customers may consider these features in their decision-making in relation to reliability.[10]

2.3 VCRs in the context of a changing regulatory landscape

In recent years a series of regulatory changes have occurred that have enabled customers, including residential and business customer, to participate in different demand management schemes. Regulatory changes now incentivise network service providers, retailers, and third-party aggregators, to consider making use of customers' DERs to help alleviate network constraints, manage wholesale price risks, provide ancillary services, and participate in emergency events.[11] For example, the demand management incentive scheme (DMIS) and the demand management incentive allowance (DMIA) encourage network businesses to pursue demand side alternatives when these are more cost-effective than building poles and wires in the system.[12]

Voluntary, paid demand management schemes provide customers an opportunity to receive financial rewards for the services they can provide using their loads, including DERs. The demand management programs typically involve load shifting and perhaps some interruption to the discretionary

[10] For example, this may be a 'before-after' type 'within-subject' study that aims to understand how the decision to purchase a battery may impact on the values that customers associate with the reliability of the network. This is outside the scope of the current study.

[11] Recognising the increasing importance of demand side participation, AEMO notes that "regulators and market operators are increasingly revising regulatory and market constructs to ensure accurate and full value is paid for these resources to help support optimal market outcomes." AEMO (2018) AEMO observations: Operational and market challenges to reliability and security in the NEM, March 2018, p. 46.

[12] AEMC (2015) Rule Determination – National Electricity Amendment (Demand Management Incentive Scheme) Rule 2015, 20 August 2015.

component of customers' loads. Although participating in demand management schemes do not require customers to experience outage-like events, these programs may have some relevance for VCRs estimates. For example, in the future VCR estimates may need to consider not only the 'use value' (production, heating, cooling, etc) of electricity but also the 'opportunity cost' (or forgone revenue) that arises when customers are prevented from earning revenue from their DERs during outages (e.g. earning feed-in-tariffs or demand response payments).

Also, in accordance with the Demand Side Participation (DSP) Information guidelines, AEMO can request retailers, network service providers, and demand aggregators to provide details and participation rates in their demand management programs. To the extent that these programs reveal information about customers' willingness to trade off some portion of their discretionary load for financial rewards, these programs may be used to 'cross-check' the VCR estimates. Payments made under the various demand management programs for discretionary loads are expected to be lower than customers' VCRs. This is because outages represent greater costs and higher inconveniences for customers, so the value for customers of avoiding these are greater.

3. Valuation methods

Although sometimes used interchangeably, prices and values in economics are not the same. Price is the amount paid for a product or service; value is the utility of the product or service. Given that values (utilities) are unobservable, methodologies have emerged to infer the values through observable actions, in particular financial transactions. For example, the values (utilities) that people obtain from consuming apples are not directly observable but financial transactions relating to the purchase of apples are. Values are then inferred from these transactions.

Pertinent to valuation methods is the disparity between willingness-to-pay (WTP) and willingness-to-accept (WTA). WTP is the maximum price a person would pay to obtain a product or service; WTA is the minimum amount of compensation that a person would require to relinquish a product or service.

It is a well established trend that WTP and WTA estimates tend to differ, and the latter considerably exceeds the former even when the estimates are elicited from the same person in relation to the same product or service. This means that whether studies adopt a WTP or a WTA approach, can have implications for the estimates that are obtained. This is due to several factors that Kahneman et al. (1991) summarises as:

- Endowment effect, which is the tendency to require higher compensation to give away something than the amount the person would pay to purchase the same thing;
- Status quo bias, which is the tendency for people to show a certain resistance to change, regardless of whether it entails improvement or deterioration from the initial state;
- Loss aversion, whereby people tend to assign a higher value to any change that generates losses than to any change of the same magnitude that generates gains.

In general, WTP studies where people potentially incur costs lead to lower estimates than WTA studies where people may get paid. For this reason, when lower estimates may be considered a more desirable or 'safer' approximation, using WTP measures may be the preferred approach. In the current context of network planning and investment decisions, the potential implications of underestimating customers' preferences are significant. While relying on higher estimates may lead to higher than optimal network investments costs, relying on the lower estimates may lead to longer than desirable or more frequent outages. Therefore, in this specific context, there may be compelling arguments for using WTA measures for VCR estimates.

An example of the disparity between WTP and WTA estimates, in a stated preference study in the context of service outages in Italy, is presented in Box 1. Bertazzi et al (2005) demonstrate that, for both households and businesses, the WTA responses are systematically higher than WTP responses. For example, residential customers' WTA responses for the one hour long outage are 4.5 times higher than their WTP responses. Similarly, business customers' WTA responses for the one hour long outage duration are 7.5 times higher than their WTP responses.

There is another issue with WTP elicitation. Customers (especially residential customers) may assume that they are entitled to a reliable supply as they are paying for it. Therefore, customers may consider that it is the electricity provider that is at fault, and customers may consider that paying to avoid interruptions is unacceptable. For instance, Woo et al. (2014) highlight that when consumers are asked to state their WTP, "zero" is a frequent response. For this reason, eliciting prices in the form of WTA is likely to be more practicable.[13]

[13] Similar sentiments were echoed during the focus group and in-depth interview process conducted by Insync. See Insync (2019) Focus group and in-depth interview report for the Australian Energy Regulator, 31 May, 2019. p. 9.

Box 1. Estimating WTA and WTP for service interruptions – The case of Italian residential and business customers

In 2003 the Italian regulatory authority conducted a stated preference survey across a wide range of residential and business customers in order to determine customers' outage cost. The questionnaire elicited information in relation to hypothetical interruption scenarios in the form of

- WTP, expressed as the price the consumer would be willing to pay to a service provider to receive 'reserve service' in the event of supply interruptions; and
- WTA, expressed as the amount that the customer would consider satisfactory each time an interruption occurs.

From an economic point of view these two aspects express the same concept of valuation. Practical experience shows that WTP responses are systematically lower than WTA responses and the disparity between the two is often very significant. The tables below summarise the normalised values (€/kWh) for residential and business customers.

The table below demonstrated households' WTA and WTP normalized values in €/kWh (3 min interruptions, €/kWh).

	WTA	WTP	$\frac{WTA+WTP}{2}$
3 minutes	5.35	1.38	3.36
1 hour	17.03	3.75	10.39
2 hours	13.92	2.68	8.36
4 hours	11.24	2.25	6.75
8 hours	6.89	1.36	4.12

The following table lists business customers' WTA and WTP normalized values in €/kWh (3 min interruptions, €/kWh).

	WTA	WTP	$\frac{WTA+WTP}{2}$
3 minutes	34.16	4.90	19.53
1 hour	79.75	10.70	45.23
2 hours	57.09	7.75	32.41
4 hours	48.42	6.63	27.53
8 hours	28.99	3.98	16.48

Source: Bertazzi, A., E. Fumagalli, L. Lo Schiavo (2005) The use of customer outage cost surveys in policy decision-making: the Italian experience in regulating quality of electricity supply, June 2005, Proc. 18th International conference and exhibition on electricity distribution, CIRED, Turin, Paper 300.

4. Revealed Preference approaches

Revealed Preference approaches are based on actual choices consumers make and the real costs associated with these choices. Customers committing to pay a given or self-nominated price for an option, from a set of choice alternatives, is one of the most straightforward approaches to establishing values. In an ideal case, all relevant choices are readily available to customers and so are observations on how and when customers select from available choice alternatives.

Continuing on from the previous example, a Revealed Preference study that intends to estimate how much people value apples could analyse how and when people choose apples and how much they are willing to pay for apples given other choice alternatives (other fruits available) and other attributes that are relevant to their decisions (type of apple, freshness). There are well established markets where apples and other fruits are readily traded, and transactions are plentiful.

Sometimes there are no markets for the product or service that is subject to the valuation. For example, in the case of network service reliability, the provision of the service is mandated at a level that is considered appropriate by regulatory agencies. Currently, customers and network service providers do not engage in financial transactions to pay for more (or accept a financial compensation for less) network reliability. In absence of these transactions, customers do not have an opportunity to reveal their preferences for network reliability in *existing actual markets*.

In the absence of markets for network reliability, one option is to evaluate customers' decisions in *'proxy' markets* where the products or services traded are indirectly or partially related to reliability. From the choices and prices revealed by customers in proxy markets, analysis may be able to establish to what extent customers' decisions are motivated by the desire for reliability.

In the absence of a suitable existing market, *experimental markets* may be designed to elicit relevant information from customers. Given that these are designed, experimental markets have important advantages in that they can provide greater control over studying the most relevant aspects of the decision environment.

Another form of Revealed Preference approach is the *defensive expenditure* method that uses observations on how much households or businesses spend to avoid adverse effects relating to service outages. From this it can be inferred how much they value avoiding such adverse effects.[14]

Besides market prices and defensive expenditure, *hedonic pricing methods* offer a third approach. Hedonic pricing methods are based on the premise that people value a product or service based on its characteristics and thus the price customers pay is a function of the characteristics of that product

[14] Defensive expenditure methods are sometimes also referred to as preventive expenditure or averting behaviour methods in the literature.

or service. When customers pay different prices for different products, it is because the relevant characteristics of the products differ, and people value these characteristics differently.

Chart 1 summarises the above mentioned Revealed Preference approaches. The approaches are grouped as using market prices – obtained through existing and experimental markets, defensive expenditure, and hedonic pricing methods. These approaches are further detailed in the following sections.

Chart 1. Revealed Preference approaches relevant for VCR estimates

5. Existing markets

As discussed above, one Revealed Preference approach is to analyse market transactions that relate to electricity supply reliability and from these infer customers' VCRs. From the customers' point of view, reliability (or the lack of it) is experienced as supply interruptions. Market transactions would include examples where customers have the opportunity to (voluntarily) trade off interruptions to their loads in return for some financial rewards.

There may be markets where customers are paid to help manage congestion in a network. In other markets customers are paid to provide other services (frequency control or emergency reserve) but the inconveniences incurred may be comparable to those in an outage scenario. To the extent that there are similarities between the markets from the customers' point of view, we may be able to learn about VCRs in these proxy markets.

5.1 Actual markets

Markets for interruptible load contracts that impose strict outage-like scenarios on customers do not exist in Australia. Indeed, no examples of such a strong form of interruptible contracts were found in the international literature either. Therefore, to the best of our knowledge no market transactions exist where customers' behaviour – such as accepting an interruption contract for financial reward – would directly reveal their preferences for reliability.

There are some examples of programs where customers can enter into agreements and accept interruptions to their discretionary loads in return for some financial rewards. To what extent such existing markets may be relied upon for VCR estimates is discussed below.

Interruptible load contracts

Interruptible load contracts provide a choice to customers to accept (or not) some level of interruptions to their loads in return for financial rewards. Customers are paid a pre-agreed amount and their loads can be interrupted – subject to agreed conditions – when needed. Given that customers are likely to weigh up the values they gain from their use of electricity against the financial rewards, the uptake (or rejection) of these contracts can reveal information about customers' values. Customers' decisions also depend on their perception of the risks (or probabilities) of interruptions.

Some important lessons may be drawn from California's interruptible load program regarding the carefulness that is required to be exercised when using data relating to specific programs.

California's three major utilities, Pacific Gas and Electric Company (PG&E), Southern California Edison Company (Edison), and San Diego Gas & Electric Company (SDG&E), have operated an interruptible program for business customers since the mid-1980s. Initially, the program was based on the utility company having a "right to interruptions" through a compulsory but rotating arrangement. In 1992

an incentives-based program was introduced where consumers who accepted an interruptible load contract paid lower rates. Box 2 below contains a description of Edison's interruptible load contract program.

Box 2. Edison's incentives-based interruptible load program

Edison's interruptible load program was introduced to business customers in 1992. The contract consisted of business customers nominating loads that could be interrupted with 30 minutes notification, up to 25 times a year, and up to a total of 150 hours. In return, customers received an approximate 15% discount off the electricity tariff rates for the self-nominated interruptible proportion of their total loads. Interruptions were carried out by participating business customers, rather than by Edison.

The program appeared very popular, over 78% of Edison's business customers signed up and those that did nominated over 99% of their loads (approximately a total of 2900 MW) as being interruptible.

After a long period of no interruptions in the Edison service area, in 1998 and 2000, four and fourteen interruption events occurred, respectively. In 1998 only 56% and in 2000 only about 62% of the participating customers responded to the request to interrupt their loads. Most interrupted only a fraction of their nominated loads. Penalties applied for non-compliance but the benefits from ongoing rate reductions were higher than the penalties during the times of interruptions.

It became obvious that a number of customers that elected to join the program were unable or unwilling to reduce their load upon request. Several customers – most notably schools and hospitals that experienced virtually no interruptions during the decades prior to the program being rolled out – nominated unrealistic levels of load interruptions. Allowing customers who over-nominated their interruptible loads to leave the program became a sensitive topic. This option was viewed by some as rewarding those customers who "gamed" the program.

Overall participating customers received almost $1 billion in reduced rates between 1992 and 2000. In 2001 the program was suspended and reviewed.

Source: California Public Utilities Commission (2001) Energy division's report on interruptible programs and rotating outages.

In Edison's program customers accepted interruptible load contracts in return for discounts on their bills. When opting in the program, customers made trade-offs between 'units of interruptible loads' and financial rewards. In theory, from these transactions the values that customers attribute to the discretionary component of their loads can be inferred.

However, there are several reasons why Edison's interruptible load program may not result in reliable VCR estimates. First, customers did not actually face the consequences of their decisions and were essentially allowed to opt-out. Second, customers had the choice to nominate the discretionary (lower value) component of their loads only, rather than having all their loads interrupted. Extracting information that may be applicable under full outage scenarios that impact both discretionary and non-discretionary loads requires further considerations.

An important lesson from Edison's program is that the Revealed Preferences by customers are inherently interlinked with the incentives embedded in the decision-making environment (program design) from which they arise. There are several program features that likely to have contributed to higher levels of interruptible loads being nominated than what could truly be relied on. For example, the program allowed customers to take advantage of immediate rate discounts in return for some low probability future inconvenience, and it allowed customers to pay penalties instead of demonstrating compliance through load reduction.

Although the program may be considered an example of "Revealed Preference" as customers entered into real agreements in return for real payments, the outcome of the customers' decision could not be relied on for the purpose of estimating customers' value of reliability of service. As discussed above, this is primarily due to the nature of Edison's interruptible load contract program design that facilitated 'inflated levels' of transactions where not all parties had the intention to honour the agreement.

Another, "Revealed Preference" program, the GoodGrid Program by AusNet Services, is described in Box 3.

Box 3. GoodGrid Program by AusNet Services 2018-19

The GoodGrid Program was available to the first 1000 customers in selected postcodes in key AusNet Services areas during the summer of 2018-19. Both residential and business customers were eligible to participate. Customers that signed up were offered to go into the draw to win a $1000 RACV Resorts Voucher.

AusNet Services informed customers to expect between five and eight GoodGrid events during the extended summer period (1 Dec 2018 - 31 Mar 2019), usually in the afternoon or early evening (between 4-8pm), and that each event would last four hours. AusNet Services would alert customers the day before the event was expected and again on the day of the event. AusNet Services gave participants tips about how they could cut their energy use during very high demand days. For example, advice included changing the way customers use appliances or planning a trip to the shops or movies.

Participants had no obligation to reduce power use during a GoodGrid event, that is they could opt out. If a participant did reduce their energy usage during the event to a level below what the participant had used on similar days previously, AusNet Services paid the participant $15 – no matter how big or small that reduction was. In addition to financial incentives, AusNet Services also stressed the "community benefits" in terms of "helping to keep the lights on".

Source: AusNet Services, GoodGrid Program - Frequently Asked Questions.

While the program offers some insights into customers' WTA to engage in demand management, some of the program characteristics are likely to weaken the conclusions that may be drawn. On the one hand, the program appears to be clearly articulated to customers and the potential financial rewards of $15 per event can easily be considered by customers. The scenario under which GoodGrid events are most likely to happen is also well articulated. Location, timing and duration of events are representative of the ones relevant for network investments.

On the other hand, the program relates only to the discretionary component of the customers' loads, customers receive prior notice, and have the opportunity to opt-out. That is, the scenario that customers face when enrolled in the program does not entirely resemble to a real outage scenario. That is, the program may only be considered a 'proxy' market to the extent that it replicates some but not all of the important features of a 'reliability' or 'interruption' market.

There are several other program design features that make using the outcome of this program for estimating VCRs problematic. For example, given that participation rate was capped at 1000, and that signing up was on a first-come-first-serve basis, it is not possible to gauge the real participation rate

and the ratio of residential and business customers who would have been genuinely interested in trading off some of their discretionary loads for the amount offered.[15]

Also, the program adopted a very simple pricing; both residential and business customers were offered $15 even if it is likely that the two customer segments have substantially different VCRs.

The above examples demonstrate that even real transactions and financial payments do not, in themselves, guarantee accurate market valuations. There are several aspects of the decision environment that may be considered almost 'arbitrary' and this may have a significant impact on the 'market outcome'.

Critical peak demand pricing

In response to regulatory requirements and incentives, network service providers have introduced a range of tariff structures that may better reflect the efficient cost of providing network services to business and direct connect customers.[16] For example, critical peak demand (CPD) tariff structures have been implemented by some network service providers in order to better allocate cost recovery of network services. Box 3 provides an example of the critical peak pricing arrangements introduced by AusNet Services.

CPD pricing offers an opportunity to estimate the extent that customers are willing to reduce or shift their load to avoid costs. As described in Box 4., AusNet Services' large business customers were required to demonstrate compliance on five nominated days to receive a lower CPD network tariff rate component on their bills. This program is similar to Edison's interruptible load curtailment program, except that bill reductions were subject to demonstrating prior compliance.

[15] The potential to win an $1000 RACV gift voucher further muddies the incentives to sign up. Some customers who had no intention to carry out demand management may have signed up just to participate in the $1000 voucher raffle. Given that overall participation rate was capped, the customers that were only motivated by the gift voucher and had no intention to reduce their loads, may have prevented others with genuine intentions to participate.

[16] See AEMC (2014) Distribution Network Pricing Arrangements, Rule Determination, 27 November 2014.

Box 4. Case study: Critical peak demand (CPD) tariff by AusNet Services

In 2010 AusNet Services introduced a critical peak demand tariff for large business customers. Each year AusNet Services nominates five CPD days based on which the 'CPD component' of customers' bills would be calculated.

The CPD component is based on the average maximum power (kVA) recorded on the five nominated CPD days (between 3-7pm). The nominated CPD days are sometime between 1 December and 31 March, and tend to coincide with extreme temperatures. The CPD bill component established during the five days remains applicable for rest of the year until new CPD is established. Customers can minimise electricity use or seek alternative supply sources to lower their maximum power on the nominated days.

The table below demonstrates AusNet Services' CPD tariffs to be applied to the 'CPD component' (effective 1 January 2019) for customers with different annual consumption levels.

Annual consumption (MWh)	Critical peak demand $/kVA/year (exc GST)
160-400	31.45
400-750	76.89
750-2000	80.84
2000-4000	86.99
4000+	95.38

In 2012-13 70% of businesses reduced their demand on the nominated CPD days, achieving a combined reduction of 42MW. 181 businesses reduced their demand by more than 40% and some businesses in agriculture, water supply and manufacturing totally cut their demand on all of the five days.

Sources:
AusNet Services, Critical Peak Demand Tariff.
Goldsmith, M. (2014) Critical Peak Demand program launched in VIC, Utility Magazine, January 10, 2014.

Metering data obtained from a selection of large business customers (both responding and not responding to the CPD pricing incentives) can help estimate the ratio of large business customers that responded to the ones that did not.[17] The costs that large businesses customers were able to avoid can also be calculated. From historical load data the load that was reduced on the CPD days may be calculated. From these figures (participation rate, costs avoided, and load reduced) customers' VCR estimates may be inferred.

The program setup has several desirable design features that makes the data a good candidate for calculating some trade-offs. For example, compliance had to be demonstrated in order to receive tariff discounts and this ensures that actual savings and actual load reductions are aligned. However, the program is a voluntary network demand management program and will only provide information

[17] This may be done, for example on an average consumption or maximum power basis.

about values relating to discretionary loads. These values are likely to be lower than VCRs that are relevant for network outages.

5.2 Proxy markets

When the product or service that is subject of our study is not directly traded, other products or services may be considered close substitutes from the point of view of the customers. In this case, we may be able to learn about VCRs in these proxy markets. For example, customers may participate in demand management schemes such as wholesale, ancillary services, and emergency reserve markets. These proxy markets and their relevance for network reliability management, are further detailed below.

Table 1 summarises the schemes in the network, wholesale, ancillary services, and emergency demand management markets that different customer segments are currently eligible to participate in. The circumstances under which network outages tend to occur may differ from the typical circumstances under which customers' load reductions are required in the demand management schemes.[18]

Given that network interruptions impact both discretionary and non-discretionary loads, network outages typically result in greater inconvenience for customers than what customers are likely to experience when they voluntarily participate in demand management schemes. Despite the differences, demand management schemes are likely to have several similarities.

Table 1. Demand management schemes in the NEM

	Network	Wholesale	Ancillary service	Emergency
Objective	Provide an alternative to planned network augmentation	Reduce wholesale price risks	Help maintain system frequency	Help balance supply and demand
How	Reduce load at times of network capacity constraints	Reduce or shift load to avoid high wholesale prices	Reduce load and thus provide "frequency raise" service	Reduce load at times of extreme supply shortages
Regulation allows customers to engage	Direct connect Business Residential	Direct connect Business	Direct connect Business Residential	Direct connect Business Residential
Examples	AusNet Services GoodGrid Program AusNet Services Critical Peak Demand Tariff	Retailers spot price pass-through contracts Wholesale Demand Response Mechanism	Enel X FCAS program	ARENA – AEMO RERT Trial Alcoa on RERT Panel

[18] For example, emergency demand management is typically associated with several consecutive hot summer days and is most likely to result in interruptions during peak hours whereas network demand management may relate to maintenance during off-peak hours. For this reason, customers' WTA in an emergency demand management program may be higher than, say, in the network demand management program.

In the future, instead of full load interruption, network service providers may only need to reduce or shift some of the loads of some customers. Therefore, costs that customers will incur as a result of network constraints may be similar to the inconveniences that customers currently face in discretionary demand management schemes. For this reason, discretionary demand management schemes are likely to be increasingly relevant in estimating future VCRs.

Since 2018, network service providers, retailers, and demand aggregators have been required to report to AEMO when their customers are exposed to price incentives or rewards. The details of the data that is needed to be provided to AEMO is described in the DSP Information guidelines and include, for example, participation in network, wholesale, emergency reserve, and ancillary services markets or other arrangements where customers may be expected to respond to price incentives.[19]

Importantly, data reporting is required if and when a customer faces any kind of incentive and not only when the customer responds to these incentives. This allows for an analysis to be undertaken to establish the extent to which customers consider that the price incentives outweigh their value associated with the use of electricity.

Demand management in wholesale markets

Business and direct connect customers have a suite of options in which to participate in wholesale demand management programs. For example, businesses may enter into spot price pass-through contracts with their retailers. Under this arrangement, customers accept exposure to the wholesale market price for either all or some of their loads.[20]

Wholesale demand response mechanisms have several similarities with earlier discussed interruptible load programs. In wholesale demand response markets customers nominate their (discretionary) loads that they are willing to interrupt if wholesale prices are higher than their WTP. When making decisions whether to respond with demand reduction, customers consider the value of the electricity supply relative to the cost of supply. Unlike in a real outage scenario, participation is voluntary, and only load that is nominated by the customer is interrupted. Customers typically receive some

[19] DSP reporting requirements are at an individual customer level and include the National Meter Identifier (NMI) which allows for the data to be mapped to a geographic area, and to the customer's electricity consumption data. Furthermore, for large business and direct connect customers industry classification must also be provided using the Australian Bureau of Statistics (ABS) classification such as A. Agriculture, B. Mining, C. Manufacturing etc.

[20] The spot price pass-through arrangements discussed in this section are similar to the real-time pricing (RTP) arrangements in the US. In the NEM, most retailers make spot price pass-through contracts available to large customers. There are also a few small to medium size retailers such as Simply Energy, ERM Power, and Flow Power that specifically target customers with flexible loads and back-up generation capacity. A survey completed by Oakley Greenwood in 2016 estimates that, across all regions, retailers have at least 235MW of demand response capacity under contract, of which 200MW is capacity that is directly exposed to the spot price. An additional 310MW of demand response capacity is managed by energy management service providers and a large portion of this is under a spot price pass-through contract. For further details see Oakley Greenwood (2016) Current Status of DR in the NEM: Interviews with Electricity Retailers and DR Specialist Service Providers, Final Report, 30 June 2016.

notification of the upcoming wholesale price events and they may have an opportunity to opt-out of specific events.

There may be some benefits in considering customers' participation in wholesale demand response programs. First, customers' consideration about participating in wholesale demand response is based on customers' WTP estimates. Participation is voluntary so demand response only takes place if prices equal or are higher than customers' WTP.[21] Second, prices in the wholesale market vary between -$1000 and $14,500 per MWh (wholesale price cap). This allows price responses to be assessed at a range of price levels (up to the wholesale price cap) when and where they occur. This richness of price exposure is in direct contrast, for example, with interruptible load programs that provide a single fixed price and customers have a choice to either accept that price or not.

Box 5. contains AEMO's estimates of customers' demand response at various price levels.

[21] Generally, customers have no incentives to inaccurately report their willingness to participate at given price levels. Nominating prices that are lower than true WTP results in demand reductions when the VCR is higher than the avoided electricity cost. Nominating prices that are higher than true WTP results in no demand response when the electricity costs are greater than customers' VCR estimates.

Box 5. AEMO's estimates of demand response at various price levels

As part of the Lack of Reserve procedures, AEMO performs a rudimentary assessment of demand response at various price levels. These responses include responses as part of wholesale demand response and network reliability programs. Data is included from each of the five NEM regions and separately for Summer and Winter periods. The load response is cumulative, meaning that load that is expected to respond when prices reach $1000 is also expected to respond when prices reach $14,500.

Estimated DSP by price levels and reliability response, Summer 2017-18

Trigger	NSW	QLD	SA	TAS	VIC	NEM
>$300/MWh	78	32	1	6	28	145
>$500/MWh	78	33	2	19	31	163
>$1000/MWh	78	34	2	19	33	166
>$2500/MWh	92	40	2	22	33	188
>$5000/MWh	97	40	5	22	33	197
>$7500/MWh	105	40	6	22	34	207
Reliability response*	105	66	6	23	77	278

* Reliability response refers to situations where a Lack of Reserve notice (LOR2 or LOR3) is issued (see National Electricity Rules, rule 4.8.4 for definitions).

Estimated DSP by price levels and reliability response, Winter 2018

Trigger	NSW	QLD	SA	TAS	VIC	NEM
>$300/MWh	78	32	1	6	28	145
>$500/MWh	78	33	2	19	31	163
>$1000/MWh	78	34	2	19	33	166
>$2500/MWh	92	40	2	22	33	188
>$5000/MWh	97	40	5	22	33	197
>$7500/MWh	105	40	6	22	34	207
Reliability response	105	46	6	23	40	221

* Reliability response refers to situations where a Lack of Reserve notice (LOR2 or LOR3) is issued (see National Electricity Rules, rule 4.8.4 for definitions).

Source: AEMO (2018) Demand side participation.

Customer participation in emergency reserve markets

In the future, there are likely to be increasing opportunities for residential, business and direct connect customers to participate in AEMO's emergency reserve market, the Reliability and Emergency Reserve Trader (RERT) program. In this program customers can enter in an interruption contract with AEMO and nominate the loads they are willing to interrupt, and their WTA to do so. AEMO considers all offers from generators and customers and procures the lowest cost combination of RERT interruption contracts. Depending on the notice period required, some customers receive an ongoing availability payment whereas others receive a (higher) activation payment only when load reductions are needed.

Participation in the RERT is voluntary but those that do participate must reduce their loads when they are called upon.

For example, Alcoa, a direct connect customer, regularly participates in the RERT by making over 400MW load available for interruptions under extreme, emergency situations. While Alcoa does not participate in the above discussed wholesale demand response market even when prices reach the cap, it does participate in the RERT program. This indicates that their VCR estimates are above the market price cap (currently set at $14,500). The RERT interruption contract prices are in the WTA form; customers nominate prices that compensate them for the service interruptions. These prices are expected to be above the customers' VCR estimates. Customers are likely to seek to receive some 'surplus' in return for incurring inconveniences rather than just simply being compensated for the losses as a result of interruptions.

The Australian Renewable Energy Agency (ARENA), together with AEMO, designed a trial to test how demand side may be able to participate in the RERT. The ARENA-AEMO joint trial involves a range of residential, commercial and industrial customers in providing similar services as Alcoa.

There are ten participating projects in the trial. If and when requested by AEMO, participating projects must deliver demand reduction for up to 4 hours at a time. Some customers receive only 10 minutes notice whereas others receive 60 minutes notice. Standardisation of the demand response was motivated by reducing operational complexity and allowing AEMO to facilitate auction processes leading to more competitive price outcomes. Although the program is a trial, from the point of view of the customers they were 'real' and customers face real choices and trade-offs. Therefore, the trial may provide some insights into customers' Revealed Preference s and their VCRs.[22]

Box 6. below contains a description of the key features AGL's project as part of the ARENA – AEMO trial.

[22] Customers, representing about 15-200MW of reserve capacity across Victoria, New South Wales and South Australia are involved in the trial. The trial pans across three years, 2017-2020. The trial is intended to inform the design of a new market, or other mechanism, to assist with network reliability. For further details on the trial see, ARENA-AEMO (2018) ARENA – AEMO joint response to AEMC Directions Paper - Reliability Frameworks Review, 17 April 2018.

Box 6. AGL's Peak Energy Rewards – Managed For You Program

AGL's Peak Energy Rewards – Managed For You Program is a direct load control program that allows residential customers to nominate their own devices, such as air conditioners and electric vehicle charging stations, to be remotely controlled by AGL during emergency demand events. The 'peak events' run for up to two hours and may occur up to eight times during the year. AGL conserves electricity use by remotely adjusting the customers' air conditioners.

Customers are sent an SMS and offered an opportunity to opt-out. Customers receive an initial $300 financial incentive for signing up, and an additional $30 reward for each peak event they participate in.

Source: AGL, Peak energy rewards – Managed For You.

Although the purpose of the trial is to dispatch strategic reserve at times when supply-demand conditions in the wholesale market are tight, it could also help understand how customers may respond to price signals, and different incentives at different times.

5.3 Advantages and challenges of using existing markets for estimating VCRs

The primary purpose of a Revealed Preference approach is that customers' actual behaviour is used as a basis for estimating values and the trade-offs they are willing to make. However, 'electricity supply reliability' is not readily traded. There are no existing markets from where transactions relating to service interruptions that replicate the features of outages could be readily obtained. Regarding the 'proxy' markets that were considered in this study, the decision that customers face in these markets do not appear to be sufficiently similar to those being confronted with in a real outage scenario.

The following table summarises the advantages and challenges relating to estimating VCRs using market data from existing markets.

Advantages	Disadvantages
• Transactions are real and reflect a level of consideration by the customers to trade-off some of their loads. Customers have to face the reality of the consequences of their decisions. • The number and types of programs that may be used as 'proxy' markets are increasing. In the future, the program designs may better mimic real outages and replicate the costs and inconveniences that customers face in real outages. Alternatively, outages may become more 'voluntary' in nature. • A customer's load profile can be used to establish the extent to which customers respond to price incentives. This can be used to deduce price elasticities and demand curves. • Data is likely to be available through, for example, the DSP Information provision requirements.	• Programs may not replicate important features of real supply interruptions, for example because: – they only relate to discretionary loads; – there are opportunities to opt out; and – enforcement may be lax and hence customers may opt in without the intention to comply. • Program features can muddy incentives and can undermine the reliability of the data for VCR estimation (e.g. inflated incentives to participate). Preferences revealed through these markets must be considered with the specific program design in mind. • Lack of control over the representativeness of the participants. • Lack of control over assessing important attributes and levels of attributes of the outages and these may impact on customers' WTA or WTP. Obtaining estimates are limited to the price estimates faced by customers in the programs. • For residential and small business customers, participation in most of the demand management markets is enabled but not mainstream. Programs may be limited to certain locations or customer types and hence they may not be fully representative.

6. Experimental markets

As discussed in the previous section, estimating VCRs using existing market data may be challenging. Markets, or market-like decision environments may be designed to elicit relevant information from customers. Field experiments have been employed by economists to learn about decision making in a diverse range of settings. Levitt and List (2009) reflect that moving the controlled experiments outside the laboratory environment meant that "the number and types of questions that can be explored using field experiments has grown tremendously."[23]

Framed field experiments are a type of experiment that uses the general population in stylised but non-laboratory settings.[24] Estimating the values associated with electricity supply reliability is a complex task for customers; it may involve evaluating chances of supply interruptions, and weighing up costs and inconveniences across various domains (lack of heating, cooking, entertainment).[25] Framed field experiments do not intend to capture all complexities of the real world. Instead, experiments offer stylised choices with the intention to capture the important characteristics of the decision environment.

In order to induce customers to consider 'reliability' in their decision making, we need to construct a decision scenario that enables customers to trade off monetary values for incremental changes in service reliability. In the following sections, a range of these experimental design options are canvassed for this purpose. A discussion on the advantages and challenges associated with the field experiments are also included.

6.1 "Take it or leave it" service interruption contracts

6.1.1 Experimental design

Decision-making environment: In the proposed field experiment, selected customers are mailed (letter or email) an offer of a service interruption contract. In this "take it or leave it" service interruption contract offer, customers can enter into a contract to accept an interruption to their service in return of financial rewards.[26] Importantly, customers must understand the outage is in

[23] Levitt, S. D., & List, J. A. (2009). Field experiments in economics: The past, the present, and the future. European Economic Review, 53(1), 1-18., p. 1.

[24] Other categories of field experiments by Harrison and List (2004) include artefactual field experiments that use members of the public (instead of university students) in a stylised laboratory setting and natural field experiments where subjects naturally undertake the experimental activities and in fact do not even realize they are in an experiment.

[25] Typically, decision making is considered at the household level and thus values may also be estimated at a household level. This assumes that there are no significant trade-offs for household members from these decisions. For example, it may be the case that children value watching TV more than parents do. The value that kids place on watching TV may not be accurately represented in the household level decisions.

[26] This contract is independent of the customer's normal retail (and network) contract. That is, for the purpose of the experiment, we assume that electricity supply reliability is unbundled from the retail contracts. Customers' decision to enter into a contract does not affect their retail tariff rate.

addition to the current or 'status quo' level of interruption. That is, if it occurs it would be in addition to any interruptions that may occur had the customer not entered into the contract.

Contract specification - Introductory text: The service interruption contact replicates the important characteristics of current network outages. Customers are made aware that the interruption is:

- unannounced (no notice given)
- full outage, impacts all loads of the customer (discretionary and non-discretionary)
- externally controlled by an operator and
- once entered into the contract, the customer has no opportunity to opt out.

To ensure that the results are directly relevant for network planning and investments, the standard contract includes those attributes and levels that are most 'typical' or applicable to situations that necessitate network augmentations. For example, the standard contract may relate to summer period, weekdays, peak hours, and may be 1-3 hours in length.

Given that in this experimental design there is only one type of service interruption contract, the contract attributes may be included in the introductory text. The chosen attributes levels are important as they are likely to influence customers' decisions regarding taking up the offer. The outage attributes and contract features need to be clearly articulated and explained to customers.

Selected attribute: Only one attribute level is varied in this experimental design and that is the offer price at which the service interruption contract is being offered to customers.

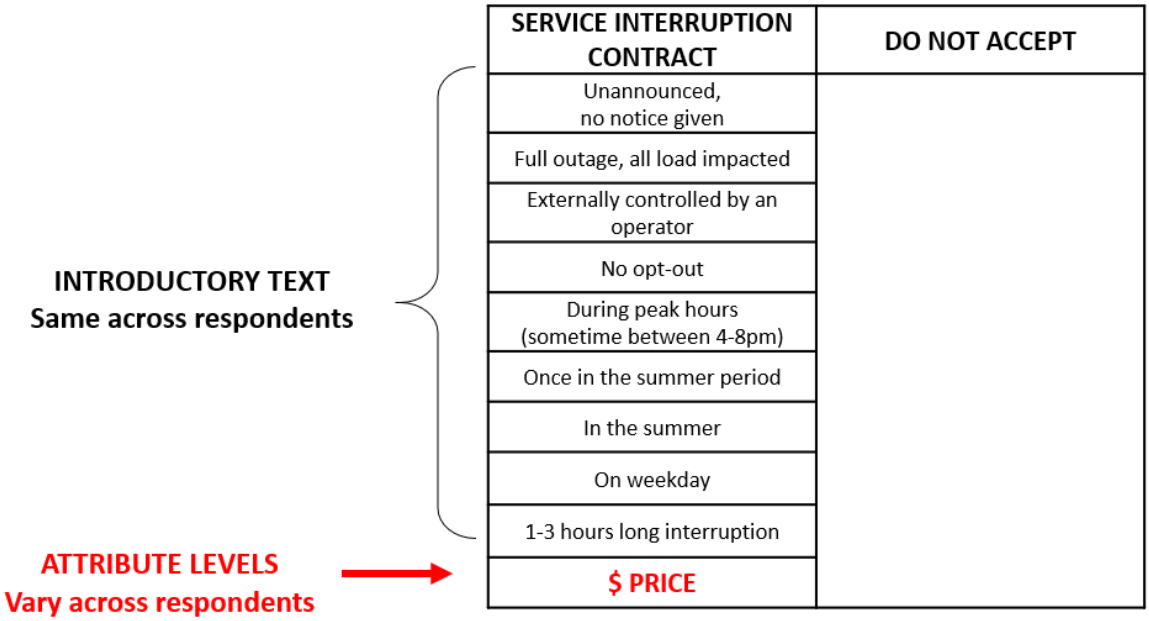
Attribute levels: In order to vary the offer price, a lower and upper price range needs to be established and a series of price levels in between. For example, the supply interruption contract may be offered to customers at prices ranging from, say $10 to $250. There could be, say, 7 price points between this range.[27] Setting of appropriate levels for the offer price attribute is an important consideration in the estimation process. This specific design offers some flexibility in this regard as prices can be adjusted relatively easily if required, for example, if some feedback is received about response rate during a pilot.

Status quo alternative: Customers are given a choice not to accept the offer and hence a 'status quo' choice alternative is included. This option makes it possible to estimate the value of choosing the given supply interruption contract compared to the current, status quo levels.

[27] The range and the price points between the upper and lower bound can be adjusted for different customer groups (household, small business, large business). Also, the 'typical' service interruption may differ for business customers. The 2014 AEMO study indicated that business customer incur most of their costs in the first hour of interruption, whereas for residential customers this is during the 1-3 hours.

Decision task: Customers are selected randomly and are sent (mail/email) the service interruption contract offered at one of the randomised prices. Each customer is only made one offer and the customer only has the option to accept or decline the contract.

An example of the details of what a service interruption contract may contain is included below. A simple example of what information may be provided to customers is in included in Appendix 1.



6.1.2 Some technical considerations

If there is a significant prejudice against accepting service interruptions (in the whole population or some part of it), there may be limited participation, regardless of the level at which prices are offered.

Although previous studies did not indicate so, it may be the case that the status quo level of interruption varies across respondents or groups of respondents. For example, there may be some difference between the status quo outage levels in CBD and rural areas. The 2014 AEMO study did not find differences in VCR estimates according to location of customers. If concerns of such heterogeneity arise from the observations, customers status quo outage level may be included in the analysis through actual outage level information.[28]

Sampling: The residential and business customer groups require different sampling techniques. Simple random sampling would be suitable for residential households. All customers from the

[28] For example, the AER's Regulatory Information Notices database is a credible and public data source. Alternatively, respondents could be asked to fill out a "report card". The report card would detail the attribute levels that respondents consider most closely describe their particular status quo. These reported values could be used in model estimation. However, given the generally high level of electricity reliability in the NEM, it may be difficult for electricity customers to accurately recall their last outage experience.

residential customer sample frame have equal opportunity to be chosen as potential respondents. Stratified random sampling is another option, with strata determined by (for example) location or electricity usage. Business customers would be further grouped according to industry, and sampling would need to ensure that different industry types are adequately represented and that the sample responses provide sufficient precision.[29]

The required sample size is highly dependent on several factors, including the number of price levels that are chosen to be included in the experiment and the response rate by customers to these prices offers. The data arising from a pilot study, together with expert judgment regarding assumptions, could be used to determine the sample size required to provide estimates of the required precision.

6.1.3 Advantages and disadvantages "take it or leave it" service interruption contracts

Advantages	Disadvantages
• Provides information in relation to preferences that are otherwise not revealed. • The choices observed are real choices in which consumers have considered the real trade-offs relative to status quo. • Inclusion of status quo alternative is in line with consumer theory and reality. • Low cognitive complexity – simple for customers to understand. • The "take-it-or-leave it" decision format is common in market settings. • Can easily apply to residential and small business customers. • Allows for the extensive exploration of WTA in relation to the 'standard contract'. • Provides a way to explore VCRs associated with the 'typical' outage. • Estimates obtained are relative to the status quo and what the 'typical' outage would mean for customers; this is likely to be highly relevant in the context of network planning and investment. • Can be considered a base case and further outage types may be included at a later	• The sample size requirement is relatively large as only one observation is obtained from each respondent. However, no-response attracts no financial payments, so not costly. • Outcome may be sensitive to the offer price level selection. The more granular the offer prices the better the estimates likely to be. • Large gaps between price levels may lead to less accurate estimates. • If significant prejudice exists in population against accepting service interruption contracts, prices will need to be high to achieve desired response rate. • Responses are an upper bound (overestimate) of WTA. Customers respond if price offer is greater than their true WTA. More granular price levels can limit the 'surplus' in the estimates. • Does not provide any information about WTP or WTA in relation to contracts with different attributes. • Provides only one VCR estimate for one specific 'standard contract'. This may be considered arbitrary without

[29] This approach is unlikely to be cost effective for large and direct connect customers, so it is not discussed here.

stage by altering attributes of interruption contract offered to customers. • Can be combined with stated preference data (to be discussed later). • May be used as a (limited) pilot so could be considered a 'no regrets' option. • Allows flexibility and control over the price ranges and price levels. Price levels may be adjusted until sufficient response rate is achieved. • Allows control over the experimental cost. • Can be extended to some variations of the standard contract to test some differences in response rates (e.g. in Tasmania response rate between winter/summer can be tested).	understanding how this fits into VCR estimate of other contract specifications. • High levels of 'no response' can make assessment challenging. • May be too costly to apply to large business and direct connect customers.

6.2 "Name your price" service interruption contracts

6.2.1 Experimental design

In this experimental design the same 'standard' service interruption contract is offered to customers as in the previous "take it or leave it" service interruption contracts. Instead of pre-determined price levels, respondents are asked to nominate their price (WTA) that they wish to be paid in return for accepting the contract. To apply some competitive pressure, customers would be told that their responses would be ranked against all other customers' prices and only the lowest, say, one hundred offers will be accepted. This is essentially a reverse auction design in which customers 'compete' to sell their load interruption services.

6.2.2 Some technical considerations

Under the proposed open-ended price elicitation (reverse auction) design respondents have the tendency to nominate prices that are above their true WTA. This is because respondents typically want to be compensated for the costs and inconveniences caused by the outage and, in addition, receive some 'surplus' from the transaction.

Specific price determination methods exist that may be used in auctions to limit the surplus. For example, the second-price Vickery auction design does, in theory, elicit truthful revelation of WTA; bidders have no incentives to bid above their true costs in this design. However, the auctions that

have these desirable design properties are complex and could not be relied upon to be followed by customers.[30]

The fact that receiving payment (or not) is related to the probability of being one of the hundred 'winning' customers, may influence the outcome. Respondents either may not participate as they think their prices are higher than that of others or, alternatively, they may treat it as a gamble and nominate unrealistically high prices in the hope that they have a small chance to win.

The open-ended design may result in some customers bidding unrealistic amounts.

6.2.3 Advantages and disadvantages of "name your price" service interruption contracts

Advantages	Disadvantages
• Open ended price elicitation avoids bias arising from experimentally setting prices. • Allows for the extensive exploration of WTA in relation to the 'standard contract'. • Provides a way to explore VCRs associated with the 'typical' outage. • Estimates obtained are relative to the status quo and the 'typical' outage scenario; this is likely to be highly relevant in the context of network planning and investments. • Only lowest WTA customers need to be paid out and hence could be a low cost way to collect data. • Allows control over the experimental cost. • Can be extended to some variations of the standard contract to test some differences in responses (e.g. in Tasmania response rate between winter/summer can be tested). • Can apply to residential and small business customers.	• Some compromise to the credibility of the market environment. Customers have typically little experience in auction type situations, especially in the context of service interruptions. • The estimates are likely to result in values that are above the true WTA due to the 'surplus' seeking behaviour. As a result, question format may lead to overestimating VCRs. • May lead to some extremely high prices being nominated on the open-ended design although some options exists to mitigate these.[31] • Difficult to differentiate between genuine high prices and those that are the outcome of incentives described above. • Customers response rate will depend on their assessments of how they compare to other customers (due to payment being conditional upon being in the lowest 100 customer group).

[30] In the Vickery auction the purchase price is determined by the first unsuccessful bid price. In the current context of a WTA price elicitation format and one hundred contracts being available, the Vickey auction format would mean that customers with the lowest one hundred WTA offers would 'win', and that winning customers would be paid the WTA offer price nominated by the customer that 'just missed out' (i.e. the one hundred and first lowest WTA offer customer).

[31] Similar issues were also raised and discussed 13 June 2019 VCRCC Meeting. See Values of Customer Reliability Consultative Committee (VCRCC) Meeting Minutes, 13 June 2019.

6.3 "Choose one or none" service interruption contracts

6.3.1 Experimental design

The same introductory text is used for this experiment as in the "take it or leave it" service interruption contract, with the exception that one of the attributes is included and is varied along the offer price levels. For example, instead of keeping duration of outage as 'fixed' at 1-3 hours, it is now treated as an attribute with various levels. Previous studies indicate that the duration of outages is a significant factor influencing customers' costs and inconveniences.[32]

In this option, outage duration is incorporated through additional attribute levels while the existing offer price attribute levels are retained. For example, the outage duration attribute could take the following four levels that were used in the 2014 AEMO study: 0-1 hours; 1-3 hours; 3-6 hours; and 6-12 hours. The other attributes of the 'standard contract' remain 'fixed' as they were in the "take it or leave it" experimental design.

Marginal rate of substitution: In this design the level range of the offer price attribute becomes particularly important as the prices could be used to calculate marginal rates of substitution (MRS). MRS are the implicit prices of other attributes. For example, in this specific design, the MRS could be used to calculate the additional payments respondents require to accept an additional 3 hours duration of outages.

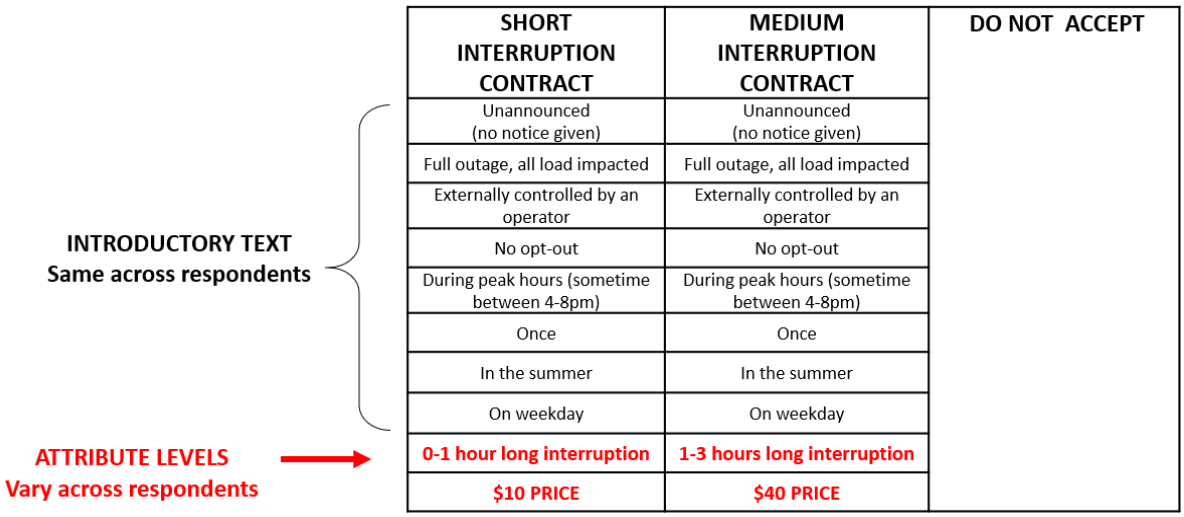
Factorial design: The four outage duration levels, combined with seven offer prices levels results in a 4x7 = 28 factorial design. In this experimental setup the full factorial design is suggested to be retained with some non-plausible options potentially eliminated.

Choice sets: Choice sets are constructed using two of the above described 28 potential contract profiles, plus the status quo contract.

Decision task: Respondents are selected randomly and are sent (mail/email) one of the randomly drawn choice sets consisting of three choice alternatives: two service interruption contract options and a status quo option. Each respondent receives only one offer and is required to decide to accept one or none of the interruption contracts.

An example of the "choose one or none" type contract offer that may be considered by a respondent is displayed below.

[32] In respect of the outage scenarios and attributes selected for testing, in the 2014 AEMO study estimates from a pilot study were used to conclude which attributes were worth including. As a result, only duration of outages was further explored in the study; the remainder of the attributes were only assessed as part of the pilot study.



6.3.2 Some technical considerations

When moving from binary to multiple discrete choice setup, respondents face more than two choices because of more than one attribute being varied. As a result, the derivation of useful choice models and appropriate estimation methods becomes considerably more complex but potentially more rewarding.

For example, it is no longer sufficient to consider the differences in acceptance rate due to changes in levels of a single attribute (price). Instead, the interaction between the two attributes needs to be considered. The full factorial design that is suggested in this option allows estimation of both main effects (price and duration) and interaction effects.

In stated preference methods respondents often face multiple pairwise choices. In fact, sometimes they are presented with all the factorial choices. This design is not possible or desirable in a Revealed Preference setting for several reasons:

- The task would be cognitively demanding.
- It would not be realistic as a market setting.
- Choices made in Revealed Preference study result in real payments and real consequences. Respondents' choices would be highly dependent on the order of the choices in which they are presented (e.g. after choosing to take the first few outages and receiving some payment, respondents may choose the status quo option for the remainder of the options).

Not all contract pair comparisons are plausible. For example, it is not reasonable to expect that anyone would choose a 6 hour long outage with $15 compensation over a 3 hour long outage with $110 compensation. But it could be reasonable that a customer prefers a 3 hour long outage with $15 compensation over a 12 hour long outage with $110. There are therefore design choices that need to

be considered, in particular, which combinations should be included. Any simplification of the factorial design comes at a potential compromising of estimating the interaction effects, some of which are likely to be important.

Sampling: As with the "take it or leave it" and "name your price" experimental designs, different customer groups (residential, small business) may require different sampling plans.

Simple random sampling may be applicable for residential households. All customers from the sample frame have equal opportunity to be chosen as potential respondents. Business customers may be grouped according to their industry and random samples may be drawn from these groups to ensure representation.

Determining the appropriate sample size requires *a priori* knowledge about the choice probabilities which is not available. Ways to obtain such information include conducting a pilot study or reviewing results from previous Revealed Preference studies.[33] The pilot study is particularly important as it can verify the ability for the experiment to deliver estimated VCR estimates and coefficients at required levels of accuracy.

Computer software can help calibrate sample size requirements once some initial information of the population has been obtained. Sample size depends on a range of factors. For example, the following questions would need to be clarified as responses to these questions have the potential to influence the sample size calculations.

- Are the differences in preferences associated with different attributes and attribute levels subtle or strong for customers?
- How homogenous are customers in their preferences? Do people tend to think alike, or are there strong differences in preferences among customers or business types?
- What level of certainty is required to be able to act upon the conclusions: 99% confidence, 90% confidence, or something else?
- Are the values obtained for specific attributes (the MRSs) important and if so, how accurate should they be?

The calculation of the minimum required sample size also depends on the type of statistical model that will be used to analyse the data. This in turn is dependent on the chosen experimental design. Should any of the described experiments be chosen for further study, it is suggested that the AER

[33] The 2014 AEMO study used a pilot approach and adjustments to the target sample size were made as periodic assessments were performed.

should consider the above questions to ensure that the design of the study can be addressed in a practical manner.[34]

6.3.3 Advantages and disadvantages of "choose one or none" service interruption contracts

Advantages	Disadvantages
• Represents the standard contract (or 'typical' outage) with variations along the attribute that matters the most. • More information is obtained than in the "take it or leave it" and the "name your price" experimental designs. For example, MRS are also revealed. Marginal willingness to accept additional duration of outages (or other attributes) may be useful in the network planning and investment context. • Outcomes can be relatively easily interpreted. • Allows for further extensions along the existing, and new attributes if required. (Can be considered as a 'block' with additional blocks added later by varying one of the 'fixed' attributes.) • Can be taken as a base case to which further features are added. • Can be combined with stated preference data (to be discussed later). • May be used as a form of (limited) pilot so could be considered a 'no regrets' option to test experimental design features. • Provides information in relation to preferences that are otherwise not revealed. • Allows some flexibility over adjusting the attribute levels as the experiment unfolds. • The choices observed are real choices in which consumers have considered the real trade-offs relative to status quo.	• Less control over the experimental cost compared with "take it or leave it" and "name your price" service interruption contract design. • Sample size requirement is bigger than in a within-subject stated preference design as respondents reveal only one choice. • Assessment is conditional upon respondents choosing one of the options. • Outcome may be sensitive to the offer price and duration level selection. Efficient design can help with this, but requires prior knowledge (pilot). • Large gaps between price levels may lead to less accurate estimates. • If significant prejudice exists in population against accepting service interruption contracts, prices will need to be high to achieve desired response rate. • If there are unobservable variables that influence acceptance of service interruption contracts, these will not be captured and can bias the outcome. • Responses are an upper bound (overestimate) of WTA. Customers respond if price offer is greater than their WTA. • High levels of 'no response' can make assessment challenging. • May be too costly to apply to large business and direct connect customers.

[34] de Bekker-Grob et al (2015) describes some of the complexities of sample size calculations. Note that there is a significant difference between within subject (typically stated preference) and between-subject (typically revealed preference) experimental designs and this is not well explored in the literature.

• Inclusion of status quo alternative is in line with consumer theory and also reality. • Low cognitive complexity – simple for customers to understand. • The choice required to be made between choice profiles is similar to decision being made in a market setting. • The format focuses a consumer's attention on the trade-offs between attributes. • Can be applied to residential and small business customers.	

6.4 Back-up battery offer and lottery

6.4.1 Experimental design

Back-up battery offer

In the "back-up battery offer" experiment a sample of customers are offered a back-up battery to be attached to their premises that turns on automatically when an outage occurs. The battery takes the customer through a typical outage and recharges after the outage. Customers must clearly understand that the batteries that are subject to the offer are 'single-purpose' batteries, their only use is to overcome outages, and could not be used for any other purpose.[35]

The price at which the battery is offered varies across customer samples. The share of customers who commit to purchase the battery at the given price provides information on the statistical distribution of customers' WTP to avoid the outages. The VCR could be estimated from the statistical distribution of customers' WTP for the back-up battery.

Back-up battery lottery

In the "back-up battery lottery" experiment customers are told that several back-up batteries are available at given prices to 'some lottery winning customers'. The prices presented to customers would vary over the customer samples. Each customer is offered the option to join the lottery, and if they win, the battery will be installed at their premises and they will be charged for the battery. Customers that join the lottery will not have the option to opt out once they join the lottery.

[35] In a 2013 Italian stated preference study the WTP elicitation was in the context of a hypothetical 'reserve service' contract that would offer customers electricity supply at times of outages. There was no discussion or description of how this service would be provided and customers were not required to make any financial commitment as the study was hypothetical. Such 'reserve service' was also considered in the context of the current Revealed Preference study.

Using this approach, the choice is real (rather than hypothetical) because even though the customer might not win the lottery, they will have to pay the money if they win the lottery. Conversely, if customers do not join, they have no chance of getting the battery at that price.

Similar to the "back-up battery offer" option above, customers must know and understand that batteries would be restricted to operate only during outages. Batteries would be offered at different prices for sub-samples of customers and this would be used to obtain a distribution of VCRs among customers.

Battery bulk purchase offer

In this experiment customers are told that a service provider is bulk purchasing batteries and is negotiating a deal on behalf of customers. The service provider invites customers to place an offer for one of these batteries. Customers are told that if their offer is higher than the price at which the service provider secures the battery, the service provider will commit to purchase the battery, order it and install it at the premise of the customer. The customer will only be charged if the price is at or below the customer's nominated WTP offer. Submitting an offer is entirely voluntary but once participating, customers cannot opt out.

Again, customers must know that the only use of the battery is to provide reliability service at times of outages. A sample of how this may be communicated to customers is included in Appendix 2.

6.4.2 Advantages and disadvantages of back-up battery offer, lottery, and bulk purchase offer

Advantages	Disadvantages
• The estimates are in WTP form rather than WTA. • Scenarios require customers to consider the real consequences of their decisions. • Batteries are an increasingly viable option as an alternative to some network augmentation.	• May be complexities in converting WTP for batteries to "dollars per kWh" estimates. • WTP will depend on customers' perception of the probability and nature of outages that may be avoided. • May be difficult for customers to isolate 'reliability' attribute of the battery from other benefits that may be associated with them. • May be difficult to ensure that a wide range of customers are represented (e.g. tenants or vulnerable customers will not be able to participate).

	• Customers may raise questions regarding issues that could influence their WTP, these may include:
	  ○ whether they would have to pay for the maintenance and ongoing charging costs of the batteries;
	  ○ the expected lifetime of the battery and whether customers can transfer the batteries to others if they sell their premise.
	• There may be limited interest in the battery offer or lottery.[36]

6.5 Joint estimation: Revealed Preference and stated preference estimation

It is sometimes suggested that the strength of the Revealed Preference method is the weakness of the stated preference method, and vice versa. Stated preference methods can more easily provide the needed variation in attributes, whilst Revealed Preference methods are better at grounding the predictions in reality. Joint estimation combines the desirable features of the two methods. For example, Revealed Preference could be used to establish VCRs for a 'standard contract' and stated preference techniques could be used to establish 'deviations' from the standard contract.[37] Revealed Preference s could also be used to gauge the price ranges that may be used in stated preference.

For example, the "take it or leave it" or "name your price" experimental design may be used to produce a value for a 'typical' outage scenario. Once this value is established, stated preference methods may be used to derive the differences in value of outages with different attribute levels (e.g. winter, weekend, off-peak).

The need for joint estimation arises due to the significant challenges that present themselves when further attributes are added to the experimental design. The number of possible alternatives increases exponentially with the number of attributes and levels. For example, including winter/summer, weekend/weekday, and peak/off-peak attribute levels in addition to the above discussed 4x7 = 28 factorial design expands the decision space to a 4 x 7 x 2 x 2 x 2 = 224 factorial design.

[36] Similar concerns were raised at the 7 February 2019 VCRCC meeting. See Values of Customer Reliability Consultative Committee (VCRCC) Meeting Minutes, 7 February 2019, p. 4.

[37] That is, in technical terms, the stated preference method would be used to estimate the ratios of coefficients, while the Revealed Preference method would be used to estimate the alternative-specific constants and overall scale of the parameters.

As discussed above, in Revealed Preference methods it is not possible or desirable to ask customers more than a few of the choice options. The sample size required in a Revealed Preference study could be prohibitively large as each customer is only sent one of potentially 224 contract offers.

Attribute selection: The decision about which attributes to include is a very complex task. Both the inclusion of attributes and the exclusion of some important attributes could lead to biased estimates.

First, it needs to be considered how the inclusion/exclusion of each of the attributes is relevant in the context of network planning and investment decisions. For example, would knowing customers VCRs in both summer or winter periods help with network investment decisions? If so, then these are important considerations. Also, it needs to be considered to what extent the attributes are meaningful and important to the customers. The design need not include every attribute that may be important, but it is important to capture attributes salient to most respondents.

Next, the level and importance of the interaction between attributes needs consideration. For example, customers consideration of peak/off-peak time outages may depend on the weekday/weekend attribute. Similarly, the consideration of the duration of the outage may depend on the winter/summer attribute. There are ways to overcome these challenges (e.g. combining the two attributes into one or 'fixing' an attribute across a sub-sample) but this simplification comes at a cost to specific predictions.[38]

Joint estimation can help with these challenges. The within subject design of stated preference methods are well suited to gain detailed understanding of customers' trade-offs between attributes. Revealed preference methods can help with grounding the dollar estimates in reality.

Joint estimation offers an 'enrichment' of the Revealed Preference estimation. When choice attributes and levels cannot easily be controlled through real life settings, and experiments where subjects face all the factorial designs are prohibitive, the combination of revealed and stated preference estimations offers greater variability in information than is typically observed in real market settings.

[38] The types of discrete choice experiments that are explored in this section are most typically analysed using (a form of) multinomial logit model (MNL). This model assumes an *independence of irrelevant alternatives* (IIA). This implies that the ratio of the probabilities of choosing one alternative over another is unaffected by the presence or absence of any additional alternatives in the choice set. In the present context this means, for example, that the inclusion (or exclusion) of the weekday/weekend attribute does not affect the ratio of the probabilities at which, say, the 3 hour long outage is chosen over 6 hour long outage by the respondents. Whether IIA holds is an empirical question, tests for which are outlined in Train (2003).

6.5.1 Advantages and disadvantages of joint estimation

Advantages	Disadvantages
• Cost can be controlled as only a fraction of the data collection requires financial payments (only Revealed Preference respondents are paid). • Can be applied to residential and small business customers. • Can improve the estimates of studies that include only stated preference or only Revealed Preference estimation; it uses the strength of each approach. • Well suited when the revealed and stated preference data is obtained from the same customer sample frame.	• Requires careful consideration of the compatibility of the estimates and ensuring that the two types of data relate to the same types of customers.

7. Defensive expenditure methods

Another class of Revealed Preference approach, defensive expenditure, or also referred to as preventative cost method, infers the value of electricity supply reliability by observing customers' expenditures on equipment that help maintain supply at time of outages.[39] Households and businesses have multiple equipment to consider such as solar PV systems, batteries, backup generators, or uninterruptible power supply (UPS) systems. Taking out an insurance that covers the costs resulting from outages may also be viewed as a defensive expenditure. Expenses incurred in order to prevent or mitigate the impact of outages may be used to estimate VCRs.

The Energy Users' Association of Australia (EUAA) noted that many businesses have invested in measures to increase reliability. In recent years there has been a technological shift which has made alternative arrangements possible and more commercially attractive.[40]

For businesses the most commonly applied means of improving the reliability of the electrical supply is the use of backup generators. As long as fuel is available, backup generators are able to provide both short- and long-term reliable power and are able to restore the power within a few seconds to minutes dependant on the connection methodology.

For loads that cannot tolerate even a momentary loss of power, or that require a clean, stable source of power, there are UPS systems. A UPS system may have a power rating ranging from a few hundred watts to a few megawatts and it may provide power for durations ranging from 10 to 20 seconds to several hours. Typically, their purpose is either to allow the start-up of a backup generator or to enable an orderly shutdown of operations.[41]

It can be safely assumed that customers incur the expenses because the avoided loss is greater than the cost of defensive expenditure. Hence, defensive expenditure may result in a lower bound estimate of VCRs; it does not reflect customers' full extent of WTP.

Making assessments based on the data collected about defensive expenditure requires some important considerations. First, improving reliability may be only one of many factors taken into consideration when making an investment decision. Also, some customers do not invest in any equipment. This does not, however, mean that the value they place on reliability is zero; it simply

[39] This method is different from the 'direct worth' or 'direct cost' methods in which customers are asked to estimate the expenses they incur due to a hypothetical or experienced outages. Usually several scenarios are presented and customers have to specify the economic costs according to predefined categories. For example, households categories may include the value of lost food in their freezer and lost computer data. For industrial customers categories may include damage to equipment or costs of penalty payment due to lost production.

[40] See Values of Customer Reliability Consultative Committee (VCRCC) Meeting Minutes, 7 February 2019, p. 2.

[41] Some UPS systems are designed to offset or filter out electricity with poor power quality and thus they offer additional benefits beyond reliability. Depending on how the UPS system is set up, these power quality benefits may be provided continuously and not just at times of supply outages. Therefore, investments in UPS systems may have been motivated by multiple objectives such as achieving improved power quality and reliability.

means that their WTP is below the cost of acquiring the equipment. Similarly, for customers that do incur defensive expenses, all that their spending reveals is that their values are at or above the expense. It is important to properly consider both the lack of transactions relating to defensive expenditure for some customers and the observable transactions for some other customers. [42]

Reliability is likely to exhibit 'diminishing marginal returns' and thus customers are likely to be willing to pay less for additional units of reliability as reliability levels increase. That is, customers are likely to value the existing level of reliability higher than improved levels of reliability. For this reason, defensive expenditures are likely to result in estimates at the lower end of the spectrum.

7.1 Advantages and disadvantages of defensive expenditure methods

Advantages	Disadvantages
• The choices observed are real choices in which consumers have considered real trade-offs relative to status quo. • Relatively easy to collect data, available market data can be used. • Real market behaviour, not hypothetical. • Can be used to estimate values of a range of customer types, including business and direct connect customers. • Regarding residential customers, the data collection about DER uptake and costs may need to be accompanied with a survey to help establish the extent that customers' DER purchases were motivated by concerns for reliability. • May augment other types of estimation methods. • The DSP Information database is likely to provide some insight in terms of the number and kind of businesses that have invested in DERs (generators, solar PVs, batteries). • May be less resource intensive as a direct cost method and may only require businesses' accounting staff to help out.	• It provides a lower bound for the customers' costs, not a precise estimate. It can only be established that the customer's costs associated with the outage are at least as high as the defensive expenditure. For customers who have not chosen to install a backup solution, the backup costs may be seen as an upper bound on their WTP. • There is limited or consideration of attributes of outages (duration, timing, etc). • May be difficult to convert the results to estimates in the form of "kWh interruption avoided". • May be difficult for residential and some business customers to quantify expenses.

[42] In terms of data collection, customers without any investment will return a 'zero' value, whereas those with some investment will return the cost (the market price) of their investment. Both values are likely to underestimate the customers' true VCRs.

8. Hedonic pricing methods

In this section two possible hedonic pricing avenues are explored for assessing customers' VCRs. The first considers the value of reliability as it may be reflected in house prices. The second considers the effect of reliability related attributes as they may be reflected in battery storage prices.

The value of reliability as reflected in house prices

The hedonic pricing method uses a regression analysis to model the impact of relevant characteristics (explanatory variables) on the prices paid for the product or service (dependent variable).

One of the areas where hedonic pricing has been applied is the area of house prices.[43] Two types of variables are typically included as explanatory variables in the hedonic housing price functions:

- Characteristics of the individual house
- Characteristics of the neighbourhood.[44]

Characteristics relating to reliability may enter the regression analysis at both the individual house and the neighbourhood level, and these may not be independent of each other.

Everything else being equal, a house that has solar PVs and a battery installed is likely to fetch higher prices than the same house without the solar PVs and the battery. Similarly, everything else being equal, houses in a neighbourhood with a more reliable power system are likely to fetch higher prices than houses in a neighbourhood with less reliable power. The household may in fact have installed the solar PVs and the battery due to the inferior reliability characteristics of the neighbourhood.

There are some challenges associated with this method. First, reliability of power supply from the network (a potential explanatory variable that may influence house prices) cannot readily be "observed" prior to the purchase of the property. Second, house prices are dependent on many different characteristics (number of rooms, condition, distance from amenities, etc) some of which may be difficult to obtain. If important characteristics of the properties or the neighbourhood are not reflected in the hedonic pricing model, there is a risk that 'omitted variables' may be driving the outcome of differences in property prices.

Given that neighbourhood reliability cannot easily be assessed by customers, an option is to compare properties when there are noticeable and known differences between service quality.

[43] For example, one of the frequently used applications of hedonic pricing includes measuring the extent that air pollution or noise pollution influence property prices.

[44] The 'neighbourhood' is a shorthand for an area and how it is defined is dependent on the purpose of the study. Neighbourhood may be defined as a collection of houses connected to the same substation or located within the same region.

Subject to overcoming data challenges, the hedonic pricing methods have several advantages. For example, hedonic pricing provides estimates that reveal how much customers are willing to pay for an incremental change in reliability relative to a chosen 'baseline'.

A similar problem exists in the area of building energy efficiency. Property buyers have difficulty ascertaining the energy efficiency of buildings at the point of sale. In order to overcome the information problem, a complex measure was developed that maps different thermal-performance characteristics of the building into an 'energy efficiency rating'. Box 7. below provides an example how this metric has helped establish values that customers associate with energy efficiency, using hedonic pricing methods.

Box 7. Case study: Hedonic pricing study on the energy efficiency rating in the Australian Capital Territory

The mandatory energy efficiency rating disclosure program in the Australian Capital Territory (ACT) is one of the longest running residential disclosure programs globally. One of the earliest studies of the effects of energy efficiency rating on house prices in the residential sector was conducted by the Australian Bureau of Statistics (ABS) using 2005 (n = 2385) and 2006 (n = 2719) property sales transactions. Besides information on prices and energy efficiency ratings, the study also included data collected from building certificates. The study used standard hedonic modelling and identified a price premium of 1.2% in 2005 and 1.9% in 2006 for each half-star increase in energy efficiency in the ACT.

Another study by Fuerst and Warren-Myers (2018) analysed 42,000 property sales transactions in the ACT between 2011 and 2016. This study also used a comprehensive hedonic model including neighbourhood and individual property level characteristics. This study also found that energy efficiency ratings are reflected in house sale prices. For example, a 7-star rated home attracted a sales premium of 9.4% when compared with the 3-star (reference) level.

The authors also used another variation of the hedonic model that omitted the energy efficiency ratings and instead only used variables such as solar PV, solar hot water, and double glazing. This model specification allowed it to test whether property prices reflect the relevant property characteristics even if they are provided outside the context of the mandatory energy efficiency rating. As an example, properties with solar PVs attract about 2% price premium when compared with similar households. Other results were also consistent with the model that included energy efficiency ratings as explanatory variables.

Source:
Fuerst, F., & Warren-Myers, G. (2018). Does voluntary disclosure create a green lemon problem? Energy-efficiency ratings and house prices. Energy Economics, 74, 1-12.

This method clearly relies on extensive data collection. This is likely to be challenging. Even if data on reliability is available there may still be an issue with insufficient variation in the data. In particular, there may not be enough variation in reliability that is independent of location, another key determinant of property prices. For example, reliability may be higher in metropolitan areas, and so are house prices. Without a sufficiently large number of property sales across a variety of locations and reliability levels, it would be difficult to isolate the impact of reliability from the value of the location.

There could be some areas where there may be some known large variation in reliability levels that could be used to identify the incremental value in going from one reliability level to another. However, this may still be stymied by the relatively lower number of property sales in these regions and difficulties in establishing exactly what reliability is available in each property.

The value of reliability as reflected in battery prices

One option for using hedonic pricing in the context or reliability is to use battery storage prices, together with information about the characteristics of the battery storage systems to examine how the characteristics of the batteries are valued. Using data on battery prices a regression model can be used to determine the effect of various characteristics of batteries on the battery prices.

As in the hedonic property pricing of the previous section, data requirements could be challenging. First, the analysis is limited to batteries that are currently being offered in the market. Currently, there appears to be only a limited number of batteries that are offered with characteristics that may help with reliability. An underlying assumption in the hedonic pricing method is that the prices reflect a competitive market outcome. If batteries with reliability benefits are only offered by one (or a few) providers, it may be the case that the prices do not only reflect customers' WTP but also the unique market position (power) of the seller.

8.1 Advantages and disadvantages of hedonic pricing methods

Advantages	Disadvantages
• May be a low cost 'no regrets' approach if a database relating to properties and neighbourhood characteristics has already been established. Existing data could be extended to include reliability variables. • Study may be well suited for situations when there are well-known, persistent reliability issues.	• Highly challenging at a practical level. • Data may be restricted and may be difficult to isolate 'reliability' from other factors that property prices may depend on. • Difficult to apply to business customers. • Will only capture valuation of reliability if people are aware of the level or reliability at the time of purchasing the property. • The interpretation of results is challenging, as coefficients are understood in relation to a 'standard' level.

9. Conclusion

The Revealed Preference approaches discussed in this study have theoretical appeal. Economists often instinctively reach for Revealed Preference information in the form of market based prices. Unfortunately, in the context of electricity supply reliability, no such market exists that may be used for the purpose of this study.

Experimental markets provide a practical and robust alternative to real markets. There are several experimental market designs that may be used, ranging from a simple 'take it or leave it' to a more complex 'choose one or none' design. Given the complexities that arise from the factorial designs that may need to be considered, Stated Preference methods may be combined with Revealed Preference methods to 'enrich' the data while ensuring that Revealed Preference approach grounds the VCR estimates in reality.

A defensive expenditure approach may be increasingly relevant as more and more households and businesses equip themselves to avoid the costs of potential outages. As for hedonic pricing methods, the data requirements appear likely to be too onerous to be applied using property prices. With the increasing uptake of batteries, a study that uses battery prices to establish customers WTP for characteristics of the battery that provides reliability could also be a viable option.

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Appendix 1. Sample instructions – "take it or leave it" offer

We are trialling an electricity interruption program whereby residential households are offered payments for accepting some interruptions to their electricity supply. Taking up this offer is entirely voluntary. If you decide to accept this offer, you will receive $X paid to your account upon returning the signed agreement.

This contract will not affect your normal electricity retail contract that you have with your retailer. Accepting this offer will not impact the rates or discounts that you may be entitled to.

If you accept the offer, your electricity supply may be interrupted by us for a period of X hours, during the period specified below, see *Specification of offer section.*

Important things to note:

- **All your electricity use will be affected:** If the interruption happens, it will affect all your electricity use during the period. That is, none of your appliances (fridge, freezer, electric cooktop, lights, air-conditioner, computer, TV) will be powered. The electricity supply will be restored by us, immediately after the interruption period.
- **No prior notice of interruption is provided:** If the interruption occurs, we will not be able to provide a notice to you prior to the interruption.
- **No opt-out:** Although accepting the offer is voluntary, once you have opted-in the program, you will not be able to opt-out at a later stage.
- **The time of the year, frequency, and length of interruption:** The interruption relates to the period specified in this agreement, that is it is not an annually recurring or ongoing program. The interruption may occur the number of times and for the length of time each time, during the period specified below.
- **Unconditional offer:** The payment to you will be upon receiving your signed agreement. The payment to you does not depend on whether the interruption occurs or not.
- **Eligibility:** You do not need to be the owner of the house where you live. You only need to be responsible for paying the retail contract at the premise to be eligible to participate.

Specification of offer

SERVICE INTERRUPTION CONTRACT	DO NOT ACCEPT
Unannounced, no notice given	
Full outage, all load impacted	
Externally controlled by an operator	
No opt-out	
During peak hours (sometime between 4-8pm)	
Once in the summer period	
In the summer	
On weekday	
1-3 hours long interruption	
$ 50 PRICE	

Appendix 2. Sample instructions – "battery bulk purchase"

We are trialling an electricity supply 'reserve service' program. As part of the program we are bulk purchasing batteries and are installing these at households that are willing to pay for them. You are invited to place an offer for one of these batteries. If your offer is higher than the price at which we will be able to buy these batteries, we will order one for you and install it at your premise.

We will only charge you if and when we have managed to negotiate a deal on your behalf at or below your nominated offer price.

Submitting an offer is entirely voluntary. If you decide to make an offer, and the offer price is below the price at which we are able to secure the batteries, you will receive the battery. Once you have signed the agreement and made an offer, you will not have an opportunity to opt-out of the program at a later stage.

This contract will not affect your normal electricity retail contract that you have with your retailer. Accepting this offer will not impact the rates or discounts that you may be entitled to.

Important things to note:

- All your electricity use will remain uninterrupted: The service we provide will leave all your energy use uninterrupted during times of outages that may occur to others that do not have this service. That is, you will continue to be able to enjoy all of your appliances (fridge, freezer, electric cooktop, lights, air-conditioner, computer, TV) as these will remain to be powered.
- The service will be seamless: When outage may occur elsewhere, your service will remain unaffected. There is nothing for your to do, this will happen 'automatically'.
- Unconditional offer and no opt-out: Although making an offer by you is voluntary and the offer you make is entirely up to you, you will not be able to opt-out at a later stage. We will bulk purchase the reserve service batteries for all households who indicated that the price they are willing to pay is above the price that we have negotiated on behalf of the households. If the price we are able to negotiate is below your nominated price, you will be charged your nominated price and you will receive the battery.
- Single purpose batteries: Please note that the batteries installed will only operate during times of outages. You will not be able to use the batteries any other time or for any other purpose. These batteries will not help you to reduce your normal retail bills.
- No need for solar panels or alternative source of power: You do not need to have solar panels or backup generators installed at your premise. These batteries will provide the reserve service without an alternative source of supply.
- Technical features: The maximum length of time that the battery will provide service without you changing your normal energy use is X hours. You may be able to extend the

length of time that the battery lasts by switching off some appliances. That is entirely up to you. Our service is for the minimum length of time of X hours.

- Changes to normal electricity supply service contract: Accepting this reserve service will not impact your normal electricity supply service. You will not be more likely to experience outages as a result of taking up this service.
- Unconditional offer: The payment to you will be upon receiving your signed agreement. The payment to you does not depend on whether the interruption occurs or not.