



The future

The Value of Lost Load Methodology Statement

5 February 2016



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VERSION HISTORY

Version	Date	Author	Status	Comments
1	28 January 2016	Impact research	Draft	
2	5 February 2016	T. Kennelly/ K. Quigley	Version 1	

GLOSSARY

Abbreviation	Term
CE	Choice experiment
CV	Contingent valuation
DECC	Department of Energy and Climate Change
DG	Distributed generation
DNO	Distribution network operator
ECP	Engaged customer panel
EV	Electric vehicle
GB	Great Britain
LCN Fund	Low Carbon Networks Fund
LCT	Low carbon technology
MRS	Market Research Society
NEA	National Energy Action
NGET	National Grid Electricity Transmission
NHH	Non-half hourly
Ofgem	Office of Gas and Electricity Markets
PSR	Priority service register
RIIO-ED2	Electricity distribution price control 2023 and beyond
SME	Small and medium enterprises
SMS	Short message service
VoLL	Value of Lost Load
WTA	Willingness to accept
WTP	Willingness to pay

FOREWORD

This report seeks to re-examine the existing model used by distribution network operators (DNOs) to place a value on the loss of electricity supply to customers. Electricity North West and its project partner, Impact Research, will conduct extensive customer and stakeholder engagement to understand how the existing model used to calculate the Value of Lost Load (VoLL) is assessed by different customer segments and how this might change in a low carbon future.

The research aims to deliver a comprehensive assessment of customer impacts associated with the loss of electricity supply, how this is valued by specific customer groups and how this might change with the adoption of low carbon technologies (LCTs). It will also examine if VoLL could be influenced by adopting different approaches to managing outages.

At present in Great Britain (GB), a single VoLL is used to evaluate what customers would be willing to pay to avoid a supply interruption. The value of loss can be expressed as a customer damage function (CDF) relative to the duration, season, time of day and notice of an outage. Previous research has identified that VoLL varies significantly among three distinct customer groups: residential, small/medium commercial and industrial enterprises (SMEs) and large commercial/industrial users. The value may also vary considerably within each of these groups, for example rural and residential customers. The existing single VoLL is aggregated to provide an overall estimate of the value given to loss across all customer segments.

This project will investigate if a single uniform VoLL, applied to all customer segments, remains appropriate as Great Britain moves towards an economy increasingly reliant on electricity, driven by a decarbonisation agenda. Extensive customer research will build on previous research in this area to determine if a revised VoLL model would benefit customers.

This project is funded by the [Network Innovation Allowance \(NIA\)](#), introduced as part of the RII0-ED1 price control, which provides an allowance for RII0 network licensees to fund projects which have the potential to improve network operation, maintenance and deliver financial benefits to the licensee and its customers.

This research project is due to commence in January 2016 and will be conducted over an 18-month period. It will culminate in a comprehensive assessment of how VoLL should be defined across a range of customer segments and ultimately inform a potential revised model to help DNOs better plan their network investment and customer strategies.

1 BACKGROUND

1.1 Definition of the Value of Lost Load

Electricity supply interruptions ('lost load') have financial and social impacts on customers.

The Value of Lost Load (VoLL) is defined as:

“A measure of the economic value given to an amount of electricity that is prevented from being delivered to consumers (ie is 'unserved') as a result of a planned or unplanned outage of one or more components of the electricity supply chain.”¹

This measure of economic value can take a number of forms:

- The amount that customers are willing to pay in order to avoid an outage

¹ Electricity Authority – Te Mana Hiko, 2012, Investigation into the Value of Lost Load in New Zealand – Summary of Findings.

- The amount they wish to be compensated in the event of an outage
- The actual financial cost they incur as a consequence of an outage.

1.2 Why measuring VoLL is important: the problem

Improving or maintaining reliability of supply to customers requires significant and continuous investment in distribution assets. Supply interruptions have financial and social impacts on customers, which vary by season, time of day, customer load and customer type. Research into VoLL has previously been undertaken and has identified such differences. However, it is still the practice to use a single uniform VoLL based on existing customer energy usage and assigned value. Existing research identified a range of possible values (£4,300 – £22,000/MWh) to use as an incentive for operators to reduce lost load. Ofgem settled on a value of £16,000/MWh but recognised that this could be changed in the light of further research².

As Great Britain (GB) decarbonises heat and transport, customers will become more reliant on electricity for their energy needs and hence it is likely that the VoLL may change. This future VoLL is important in informing issues such as network reliability standards, design policy for low carbon technology intensive networks and service standards. VoLL may also have significantly different values across the various segments of the customer base; for example rural customers compared to urban or worst served customers compared to the average. Understanding the VoLL by segment will be an important factor in forming DNO policies and investment plans for RIIO-ED2 and beyond.

While VoLL is reflected in various incentive rates such as IIS, it may not necessarily follow that incentive rates should also be segmented. Differential VoLL rates may be more appropriate in investment decisions where relative customer needs can be considered.

1.3 Measuring VoLL: best practice

Unlike large commercial/industrial users, SMEs and domestic electricity customers cannot influence the reliability of their power supply by paying for additional network assets or installing alternate supplies such as generators. These customers may have widely varying assessments of VoLL but importantly are able to effectively influence their security of supply. As such and subject to stakeholder endorsement, this class of customer will not be included in the research work. Customer research designed to measure VoLL in this way has been undertaken in a number of countries and utility sectors, most notably for Ofgem and the Department of Energy and Climate Change (DECC) in 2013³. This study observed how the value can vary by season, time of day, customer load and customer type (for example, urban/rural, worst served). As the first part of the literature review in Section 3 will show, this historic body of work established a guide on how current VoLL can best be measured via customer surveys.

The biggest challenge for this project, and possibly its most significant contribution to understanding VoLL, is how to measure the likely changes in VoLL in the future, particularly in relation to the adoption of LCTs. This change in customer use, and hence dependency on electricity, is a critical factor in influencing the future VoLL and hence long-term decision making in investment planning. The method for making this calculation is described in Section 11.3.

1.4 Project objective

The aim of the Project is to quantify VoLL to customers by customer segment, now and in the future. This will be achieved by answering the following research questions:

² Ofgem, March 2011, Strategy for the next transmission price control - RIIO-T1: Outputs and incentives, Supplementary Annex, p 42

³ London Economics, 2013, The Value of Lost Load (VoLL) for Electricity in Great Britain, Final Report for OFGEM and DECC.

1. What is the impact on customers of lost load?
2. What is the value of this impact, expressed as the financial and social cost to customers in £ per kWh?
3. How does this vary by customer type?
4. How can Electricity North West and key stakeholders mitigate the cost of lost load to customers?
5. How will this vary with LCT adoption?

1.5 Project success criteria

The research will deliver the following outputs:

- An understanding of customer impact, how value is defined and how this might be influenced (eg better communications)
- A credible segmentation and future VoLL model by key customer groups to guide investment decisions
- A demonstration of how these values would help Electricity North West and other DNOs to better plan their network investment strategy
- Guidance on customer compensation strategies.

2 SUMMARY OF THE APPROACH

The method will encompass three phases of customer and stakeholder engagement to acquire a comprehensive understanding of VoLL over time and by customer segment.

2.1 Phase 1: Understanding the problem

Phase 1 comprises the following activities:

- Review of published literature on the measurement of VoLL. This literature will identify the best methods of evaluation among customers and established methods of VoLL calculation drawing on previous international work. The review is published in Section 3
- A peer review of the proposed methodology. An executive summary of this is published in Appendix B
- Consultation with key stakeholders (Ofgem, DECC, Citizens Advice) to outline the approach and integrate feedback into the proposed method. The research will also be shaped through engagement with suppliers, National Energy Action and other parties with a vested interest, as directed by key stakeholders.

2.2 Phase 2: Refining the approach

Phase 2 will comprise focus groups and depth interviews with a cross-section of customers, and with stakeholders likely to be in contact with customers during a supply interruption. This includes, but is not limited to: domestic customers, SMEs (with a focus on sectors heavily reliant on continuous electricity provision), hospitals, care homes, British Red Cross, Age UK and communications companies. Customers interviewed will include those that have recently endured high impact, low probability events such as storm damage in Lancaster and Rochdale. These customers will be able to discuss recent experiences of a supply interruption and the impact on their household or business.

This research will explore:

- How reliability of supply is defined by customers
- How customers and businesses prepare, if at all, for supply interruptions
- Differing expectations for planned outages versus unplanned interruptions associated with faults
- How different customer groups value reliability of electricity supply in differing ways

- The financial impact of lost load (particularly to SME customers and service organisations). This will consider customer perception around costs associated with their own resilience measures, insurance cover for loss resulting from outages and uninsured losses
- The social impact of lost load (particularly in relation to domestic customers) including the impact on communications and vital services
- Expectations around communication and support from Electricity North West and other stakeholders during a supply interruption and to what extent enhanced support would mitigate their assessment of VoLL. Optimised customer communications could provide a financially efficient means of mitigating power loss compared with network reinforcement
- Key attributes of supply interruptions such as frequency, duration, time of day and financial impact
- How customer and stakeholder views may change with future decarbonisation of heat and transport
- How VoLL might vary in relation to the scale of a supply interruption/event and the number of customers experiencing the loss of supply within a community. For example, where a major incident affects a large population, as was the case in Lancaster in December 2015, as a result of flooding). This research will consider the extent to which VoLL varies when demand on vital services increases to support entire communities
- If there is a 'tipping point' in the VoLL for customers, when measured against investment in reinforcement to improve network resilience to mitigate against lost load.

Each issue will be investigated by engaging with separate groups of customers, likely to have shared experiences (eg SMEs, worst served customers and vulnerable customers). An engaged customer panel (ECP) represented by domestic and SMEs sectors will be convened. Focus groups are proven to be a suitable ECP platform to explore complex concepts and encourage informed discussions. Key stakeholders will be interviewed individually to understand their unique position between Electricity North West and their own customers.

The main quantitative survey described in Section 2.3 will be piloted in phase 2, with the ECP and a wider audience of domestic customers and SMEs.

2.3 Phase 3: Measuring VoLL

A large-scale quantitative survey will be conducted to provide answers to the following research questions:

- Does VoLL vary by customer segment and what are their relative value assignments?
- How will VoLL vary with LCT adoption?
- How would the level of incentives tested for demand side response in other Low Carbon Networks (LCN) Fund trials compare to future VoLL?
- Which segments, if any, would support a strong VoLL and hence potentially higher investment?
- How does the scale and duration of an interruption affect VoLL? Is there a tipping point at which investment to mitigate against supply interruptions becomes the most financially viable option to customers, particularly during extremely infrequent, lengthy and widespread outages (as seen across the UK during exceptional flooding events in the winter of 2015/16)?

The survey will include a stated preference choice experiment (CE), identified in the literature review in Section 3 as the most robust technique for measuring VoLL. This will involve asking customers to trade off different levels of supply reliability in exchange for an incentive (financial or otherwise). The worst served customer sample will be key to this element of the research, having a poorer experience of supply interruptions than the average customer and thereby a more informed opinion.

VoLL will be measured both in terms of customers' willingness to accept (WTA) compensation for lost load and willingness to pay (WTP) for avoidance of lost load. This is based on previous research, which has demonstrated quite different results from these two approaches, with WTP values being notably lower than WTA values.

3 PHASE 1: LITERATURE REVIEW

This literature review covers published work relating to the measurement of VoLL and, specifically, the methods considered most suitable for that calculation. This review draws on the comprehensive work undertaken by London Economics for Ofgem and DECC in 2013⁴. This study made extensive use of stated preferences (what people say they will do) when measuring VoLL for domestic and SME customers. As noted in Section 3.3, the use of revealed preferences (what people *actually* do) would be the ideal information on which to estimate VoLL, but the lack of such data justifies the use of stated preferences in its place.

3.1 Factors influencing VoLL measurements

There are significant challenges for researchers to determine the most effective method for measuring VoLL:

“Even if VoLL offers the opportunity of expressing the value of power supply security in monetary terms, there is no market on which power interruptions can be traded, which is why VoLL cannot be directly derived as market performance. Consequently, VoLL must be determined by using scientific measuring techniques.”⁵

Studies conducted on how to measure VoLL fall into two broad types: a macro-economic approach (where the actual costs to customers and wider society are estimated) and WTP (derived from stated preferences gathered from customer surveys). A review of studies that have sought to measure VoLL is listed in Appendix C.

The main observations that have been drawn from this review are:

- There is a wide diversity of VoLL values, ranging from a few €/kWh to as much as €45/kWh for private households and €250/kWh for industrial and commercial customers.
- For private households, the VoLL values derived from WTP studies are generally significantly lower than those derived from macro-economic studies; for industrial and commercial customers they are generally higher.
- The extent to which region is broken down influences the level of differentiation in VoLL values.

The result is that it is difficult to make meaningful comparisons across countries. To develop a uniform framework, Schröder and Kuckshinrichs recommend the following:

- Employ one single method (macro-economic or WTP).
- Clearly define the framework of the outage; the factors from Figure 3.1 must be given equal consideration.
- Co-ordinate the breakdown of the industrial sectors both with respect to their delimitation and the degree of differentiation.

Inclusion of the factors listed in Figure 3.1 in the research will ensure a full understanding of how VoLL varies by the nature of the interruption and the situation of the customer.

⁴ London Economics, 2013, The Value of Lost Load (VoLL) for Electricity in Great Britain, Final report for OFGEM and DECC

Figure 3.1: Factors influencing power interruptions

Technical factors	Load-side factors	Social factors
Duration	Type of electricity customer	Special cultural and social features
Region	Number of customers affected and level of dependence on electricity	
Frequency	Degree to which process steps can be substituted	
Time	Existence of standby power supply	
Dimension		
Advance warning		
Accustomed level of supply security		

Source: Rabatha et al, 2013⁶ and adapted by Schröder and Kuckshinrichs, 2015⁷

Consideration will be given to the best method for presenting and analysing region. The third recommendation is of less relevance as it applies to industrial and commercial customers, not covered in this project.

3.2 Overall VoLL and variations by time and segment

A figure of £16,940/MWh was established by the London Economics work as the overall national average VoLL for domestic and SME customers. This is close to the value of £16,000/MWh established for RIIO by Ofgem⁸.

While the research suggested that VoLL remains consistent with the length of outage (ie the £/min is similar for a 20-minute outage as for a four-hour outage), it varies by time of day, day of the week and season of the year. It was also a lot higher for SME customers. These values are shown in Figure 3.2.

Figure 3.2: VoLL by time

		Winter			Summer		
		Peak	Off-peak	Weekend	Peak	Off-peak	Weekend
Residential	WTA	£10,289	£9,100	£10,982	£9,257	£6,957	£9,550
	WTP	£208	£315	£2,240	£105	£101	£2,766
SME	WTA	£35,488	£39,213	£44,149	£33,358	£36,887	£37,944
	WTP	£21,685	£21,325	£26,346	£20,048	£19,271	£21,864
Total	WTA	£11,874	£12,144	£13,884	£11,036	£10,822	£12,070
	WTP	£5,082	£5,053	£6,827	£4,713	£4,556	£6,141

Source: Results of the London Economics report summarised in Royal Academy of Engineering, Nov 2014, *Counting the Cost: The Economic and Social Costs of Electricity Shortfalls in the UK*, A report for the Council for Science and Technology.

This suggests VoLL is highest in winter at the weekends and lowest in summer off-peak. A single annual estimate should therefore represent a weighted sum of these values by

⁶ Ratha, A., Iggland, E., and Andersson, G. (2013). "Value of lost load: how much is supply security worth?," in Power and Energy Society General Meeting (PES), 2013, (Vancouver, BC: IEEE), 1–5.

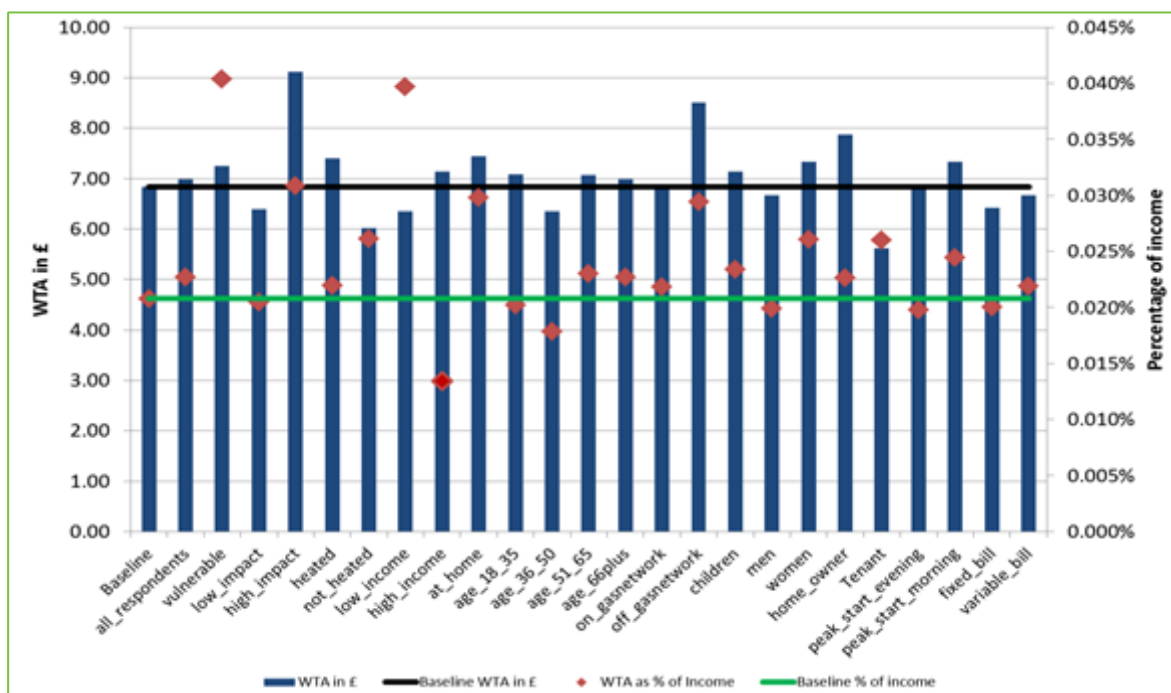
⁷ Schröder and Kuckshinrichs, December 2015, Value of Lost Load: An efficient economic indicator for Power Supply Security? A Literature Review, *Frontiers in Energy Research*

⁸ Ofgem, March 2011, Strategy for the next transmission price control - RIIO-T1: Outputs and incentives, Supplementary Annex

outages experienced at these times over the year, in addition to an appropriate mix of domestic and SME customers.

VoLL is also seen to vary by customer type, as shown in Figure 3.3. This indicates that absolute WTA values are greatest for heavier consumers of electricity ('high impact' groups and those not connected to a gas network). The absolute WTA values for vulnerable customers and those on low incomes are near to values for the overall population ('baseline'), but when expressed as a proportion of their income, they are the highest (and correspondingly low for the higher income groups). This raises the issue of how to interpret VoLL in terms of social equity. Use of the absolute values could lead DNOs to focus on maintaining the reliability of supply for heavier consumers of electricity (generally more affluent users); use of values standardised against income reverses the picture.

Figure 3.3: VoLL by customer type



Source: London Economics, 2013, *The Value of Lost Load (VoLL) for Electricity in Great Britain, Final Report for OFGEM and DECC*.

3.3 Willingness to pay and willingness to accept

In research conducted on VoLL, customers consistently portray very different values according to whether this represents the WTA value for experiencing an outage, or the WTP value to avoid an outage. In the UK, WTA values can be five to ten times larger than WTP values⁹.

In the UK, very high reliability of supply is the norm and VoLL is being measured in the context of existing supply provision. Based on this high expectation of reliability, previous research indicates that survey respondents object to having to pay more to improve the service they currently receive. However, they expect substantial compensation when that perceived reliability is reduced.

Both results reflect an inherent customer bias to maintain the status quo. Most studies have included both measures and presented them as upper and lower bounds within which the

⁹ London Economics, 2013, *The Value of Lost Load (VoLL) for Electricity in Great Britain, Final report for OFGEM and DECC*, p xi.

actual VoLL is likely to sit. A further consideration is whether the mean or median is the most appropriate reporting value, the former being the most common but the latter being advised where the distribution of individuals' values is skewed¹⁰.

3.4 'Stated preferences' are the appropriate measure

'Stated preference' measures are market research techniques that present customers with a hypothetical market choice where it is possible to measure a trade-off between monetary measures and specific events (eg "pay £500 to avoid a one-hour peak outage"). Indirect methods, where respondents are not required to explicitly state a monetary value, but infer it through their choices, can provide a precise estimate of the monetary value of these events. These choices are entirely hypothetical; nevertheless, surveys that use carefully designed indirect methods are considered to give plausible and robust results, and their use is advocated by influential institutions such as the Council of European Energy Regulators¹¹.

The alternative to 'stated preference' measures are 'revealed preferences', in which the economic value of non-market goods can, in theory, be derived from individuals' or businesses' choices in the real world or responses to realistic experiments. In practice, it is very difficult to obtain data that sufficiently defines the true economic value of a particular event, such as an electricity outage. In the UK, for example, the majority of customers experience very few outages so data on their response is limited.

Even where data on such events is available, customers on a particular network cannot choose different service levels. Each customer is non-excludable and therefore susceptible to the same number of outages of the same duration although their experience of service reliability varies.

Hence, despite variations in the service experienced, there is no true revealed preference information on the *value* to customers of changes in the frequency of supply interruptions and in the duration of outages.¹²

A Royal Academy of Engineering report on the costs of electricity outages and how to measure VoLL¹³ expressed the desirability of basing VoLL on revealed preferences and other 'real world' measures, but appreciated the difficulties involved in this. It noted that "VoLL is not a value-neutral measure; it is a measure of people's perception of the value of a unit of electricity". The report recognised that the work undertaken by London Economics was rigorous, but pointed to the potential for "moving from stated preference methods for estimating VoLL to a combination of stated and revealed preferences, using data about how people actually act in the market for electricity security."

It is therefore reasonable to conclude that the limited availability of suitable revealed preference data makes the stand-alone use of stated preference methods the most practical option for measuring VoLL, with the caveat that careful consideration is given to their application. This is reflected in the decisions taken by Ofgem in 2014:

"We have determined VoLL administratively (starting at £3,000/MWh and set to rise to £6,000/MWh by early winter 2018/19). This administrative VoLL is lower than the average domestic VoLL, average weighted SME and domestic VoLL and marginal SME VoLL according to the study we commissioned from London Economics, and therefore would not represent an appropriate cap."¹⁴

¹⁰ London Economics, 2013, Value of Lost Load Literature Review and Macroeconomic Analysis, prepared for ERCOT, p20.

¹¹ Council of European Energy Regulators (CEER), Dec 2010, Guidelines of Good Practice on Estimation of Costs due to Electricity Interruptions and Voltage Disturbances, Ref: C10-EQS-41-03.

¹² Information is available for a few industries on the value they place on supply interruptions, through their expenditure on replacement electricity, eg some London theatres have emergency generators in case of a supply interruption.

¹³ Royal Academy of Engineering, Nov 2014, Counting the Cost: the Economic and Social Costs of Electricity Shortfalls in the UK, A Report for the Council for Science and Technology.

¹⁴ Ofgem, May 2014, Electricity Balancing Significant Code Review – Final Policy Decision, p44.

3.5 Choice experiments are the preferred survey method

There are several consumer research techniques that have been used to measure ‘stated preference’¹⁵:

- Contingent valuation (CV) methods – respondents are asked directly about their WTP or WTA energy supply with a specific hypothetical reliability
- Direct worth – respondents are asked about the costs they estimate they would incur in particular scenarios
- Preparatory action method – respondents are asked to select from a list of options, which actions they would choose to mitigate the effect of a particular interruption
- Conjoint analysis – respondents are asked to choose between alternative scenarios of energy reliability, with each scenario having a specific cost associated with it.

Direct questioning, as represented by CV and direct worth techniques, does not generally work well with domestic customers. These techniques may require customers to make decisions about subjects with which they are unfamiliar and feel unqualified to take. The preparatory action technique, which involves questioning respondents about their behaviour in the event of an interruption, provides useful context and may be valuable in relation to future behaviour (see Section 10.3). However, the general practice in previous studies has been to ask customers to focus on the worst possible experience when considering outages, thus yielding potentially inflated VoLL values that might not be accurately representative of VoLL overall.

As a result, conjoint analysis, in the form of choice experiments (CE), is the method that is widely recommended and applied in the measurement of VoLL among domestic customers. This technique is considered most appropriate because it simply invites individuals to choose between competing alternatives, which is a type of decision that customers make on a regular basis in other markets¹⁶. Some SME customers may feel qualified to answer the direct questioning of CV, but the preference in the literature reviewed advocates using CE.

An example of a CE scenario from the London Economics study is given in Figure 3.4:

Figure 3.4: Example of a CE scenario

	Option A	Option B
It lasts for:	20 minutes	Four hours
At this time of year:	Not winter	Winter
At this time of the day:	Off peak (10pm to 2pm)	Peak (3pm to 9pm)
On a:	Weekend/bank holiday	Weekend/bank holiday
The one-off payment you pay to avoid this happening	£15	£1

Please choose the option you prefer: Option A; Option B; Don't know

Source: London Economics, 2013, The Value of Lost Load (VoLL) for Electricity in Great Britain, Final Report for Ofgem and DECC.

The study described in this paper will use a similar stated preference (CE) methodology to the approach used by London Economics. This will ensure that results are comparable, based on an established and approved methodology. The work will build on the learning

¹⁵ See Reckon, May 2012, Desktop Review and Analysis of Information on Value of Lost Load for RIIO-ED1 and Associated Work, p10.

¹⁶ Ibid, p10.

related to VoLL derived from stated preferences, including the stability of results over time (2016 v 2013) and variations by geography and customer type.

4 PHASE 1: INTERVIEWS WITH KEY STAKEHOLDERS

The results from this project should make it possible to predict future changes to VoLL, as LCTs are adopted onto the network. Stakeholders likely to make use of the information and adopt any new values must be engaged in the early stage of the project to help shape the research, if the findings are to be used to their full potential.

It is anticipated that these stakeholders will be engaged at several stages during the project. **Error! Reference source not found.** An initial, depth interview will be conducted with individual stakeholders to understand their views on the proposed approach and capture any concerns they may have regarding the methodology, results and subsequent implementation. This feedback will be used to refine the approach, if necessary, before the main research phases of the project.

On completion of the project, the stakeholders will be provided with advanced notice of the summary results and the implications for implementing a revised VoLL model.

The project team will be available to answer questions from these stakeholders throughout the life of the project.

5 PHASE 2: CUSTOMER ENGAGEMENT TO GUIDE SURVEY DESIGN

To measure VoLL accurately, the customer survey must examine all of the main factors that adversely impact customers as a direct and indirect result of lost supply. To ensure that no elements are missed, exploratory research will be conducted among key customer groups who have specialist requirements, or suffer lost load more frequently than average customers. This engagement will be influential in establishing customer experience of negative impacts associated with the loss of supply.

5.1 Engaged customer panel

An ECP will be convened ahead of the main customer survey data collection stage.

The ECP will comprise four focus groups, each representing a key customer segment:

- Urban domestic
- Rural domestic
- Worst served customers
- SMEs (particularly from industries heavily reliant on electricity).

Ten customers, representative of each segment, will be recruited to reflect an appropriate balance of demographics such as age and gender. Each group will meet twice before the start of the quantitative research. The ECP will explore:

- How reliability of supply is defined by customers
- How customers and businesses prepare, if at all, for supply interruptions
- Differing expectations for planned outages versus unplanned interruptions associated with faults
- How different customer groups value reliability of electricity supply in differing ways
- The financial impact of lost load, and customer perception specific to their own resilience costs, insured and uninsured losses (particularly in relation to SME customers and service organisations)

- The social impact of lost load (particularly in relation to domestic customers) including the impact on communications and vital services
- Expectations around communication and support from Electricity North West and other stakeholders during a supply interruption and to what extent enhanced support would mitigate their assessment of VoLL. Optimised customer communications could potentially provide a financially efficient means for DNOs to mitigate the impact of power loss, when compared with the cost of network reinforcement
- Key attributes of supply interruptions such as frequency, duration, time of day and financial impact
- How customer and stakeholder views may change with future decarbonisation of heat and transport
- How VoLL might differ in relation to the scale of a supply interruption/event and the number of customers experiencing the loss of supply within a community. For example, where a major incident affects a large population, as was the case in the Lancaster flooding incident in December 2015. This research will consider the extent to which VoLL varies when demand on vital services increases to support entire communities
- If there is a 'tipping point' in the VoLL when measured against investment in reinforcement to improve network resilience to mitigate against lost load.

To meet these research objectives, ECP meetings will cover the subject areas shown in figure 5.1.

Figure 5.1: ECP meetings

ECP Meeting	Date	Research objective
ECP Meeting 1	April 2016	<ul style="list-style-type: none"> • Introduce Electricity North West, its role as a DNO in the electricity industry and its relationship to National Grid and suppliers • Establish customer perception and impact of VoLL on their household/business
ECP Meeting 2	May 2016	<ul style="list-style-type: none"> • Evaluate draft survey instrument, in particular the attributes and levels to be used in the choice based conjoint, with regards to effectiveness and accuracy of data collection

The draft materials for the customer survey research will be developed between two meetings of each ECP group. These materials will incorporate the factors identified as adversely impacting customers as a result of lost supply. These materials will be evaluated at the second focus group meeting, and further refined before launching the survey instrument (refer to Section 7.2).

5.2 Customer and stakeholder depth interviews

In addition to the ECP, up to ten depth interviews will be conducted with difficult-to-reach customers and particular stakeholders. These will include:

- Vulnerable customers listed, or eligible to be, on the priority service register (PSR)
- Key stakeholders such as hospitals, care homes and charities such as British Red Cross, Age UK and communications companies who are actively involved in supporting customers in the event of a supply interruption
- Customers affected by large scale supply interruptions such as those seen in Lancaster and Rochdale in winter 2015 to 2016.

The topics covered will be the same as those discussed in the ECP. Individual depth interviews will be conducted by phone or face-to-face, depending on participants' preferences. These one-to-one interviews are likely to be more convenient for vulnerable customers, who may be unable to travel long distances or be too geographically dispersed to

attend a focus group. Key stakeholders will be interviewed individually, to understand the unique position between Electricity North West and their customer base. Relevant customer insights will be integrated in the design and administration of the customer survey.

6 PHASE 2: CUSTOMER SURVEY INSTRUMENT DESIGN

The main customer survey will be conducted using a combination of online and telephone research to maximise response numbers, particularly from difficult-to-reach groups such as vulnerable customers. The full breakdown of the target sample is detailed in Section 8.1. The survey instrument will be tailored to fit the response method; however the content will be similar.

The survey instrument will initially be designed by Impact Research in conjunction with Electricity North West to ensure it is able to robustly address the objectives of the research set out in Section 1.4. The draft survey will then be introduced to the ECP to test and refine its content. The survey instrument will test the following hypotheses:

- Does VoLL vary by customer segment and what are their relative value assignments?
- How will VoLL vary with LCT adoption?
- How would the level of incentives tested for demand side response in other LCN Fund trials compare to future VoLL?
- Which segments would support a strong VoLL and hence potentially higher investment?
- How does the scale and duration of an interruption affect VoLL? Is there a tipping point at which investment to mitigate against infrequent, lengthy and widespread interruptions (as seen across the UK during exceptional flooding events in the winter of 2015/16) becomes the most financially viable option to customers?

To ensure the survey is not too onerous to complete, thus maximising potential participation among all customer segments, it is expected to take approximately 20 minutes and will include the following sections:

- Demographic information such as age, gender, customer vulnerability, business type, geographical location, electricity consumption (including use of LCT), energy affordability
- Experience of unplanned and planned interruptions in last year
- Duration of interruption/s
- Context of the interruption/s, for example, localised fault or outage caused by severe weather events, including storms and flooding
- Satisfaction with power quality
- Perception of past supply interruptions experienced
- Future expectations of unplanned interruptions
- Stated preference scenarios, where customers will trade off varying levels of reliability of supply in exchange for a customer incentive (financial or otherwise).

The ECP will be influential in refining the draft survey instrument, particularly the stated preference scenarios. The scenarios will include several key factors that contribute to customer perception of VoLL. Participants in the survey will be presented with key attributes and a series of choices.

The analysis of this decision making process will inform our understanding of the levels of acceptability for each. For example, loss of supply at a specific time of day is a key attribute to measure. The levels within the attribute might be morning, middle of the day, late afternoon, evening and night time. The ECP will utilise a deliberative approach to establish the list of attributes and levels, based on the ECP's experiences and expectations of planned and unplanned interruptions. The draft survey instrument will be evaluated by the ECP in

terms of its content, terminology, clarity and coverage. The instrument will be revised as necessary before being piloted and peer reviewed, before the main customer survey phase.

This well established approach to survey design allows for the comprehensive testing and refinement of the instrument before a pilot (refer to Section 7). Any required adjustments highlighted at the pilot stage ensure that the survey instrument is thoroughly optimised before the actual customer survey takes place.

7 PHASE 2: CUSTOMER SURVEY PILOT

A pilot will be conducted with a small group of customers to review the survey instrument and any supporting materials before it is rolled out more widely. This is a direct learning from previous customer engagement projects and ensures that the final survey instrument can be correctly understood and will provide accurate and relevant data.

7.1 Sample size and method

All ECP members (up to 40 customers) will complete a pilot version of the quantitative customer survey after any refinements are made following the second ECP meeting. They will be asked to complete the survey online and then contacted by phone and asked for constructive feedback.

As the ECP will have been educated about VoLL and background context, its members are likely to give more considered responses than typical customers. Therefore, a further 130 pilot interviews will be conducted to thoroughly test the survey instrument.

These interviews will comprise 100 domestic and 30 SME customers. Among the domestic sample, 50 interviews will be conducted with customers from Electricity North West's region, with a focus on the key customer groups of interest (as referenced in Section 8.1).

The composition and administration of the pilot will reflect that of the final survey. The majority of domestic and SME quantitative interviews will be conducted online. Face-to-face and telephone interviews will be offered as an alternative, and surveys will be specifically administered in this manner when targeting the vulnerable and worst served group of customers.

7.2 Actions from the pilot

The final survey instrument will be reviewed and refined following feedback from the pilot before launching the customer survey. It is not envisaged that major amendments will be required following the pilot. However, should this be the case, a further pilot will be conducted to test the updated instrument prior to launching the full survey.

A peer review of the survey instrument will be undertaken to evaluate its ability to provide accurate quantitative research and to achieve the research objectives. The peer review is intended to maintain standards of quality, improve performance, and provide credibility.

8 PHASE 3: QUANTITATIVE SURVEYS

8.1 Sample selection

A total of 5,000 surveys will be completed by customers from Electricity North West's operating region and from other GB DNOs. This will include 4,300 interviews with domestic customers and 700 interviews with SMEs heavily dependent on a continuous and reliable supply of electricity.

The approach for classifying SMEs as being heavily reliant on continuous and reliable supply provision will be developed in consultation with stakeholders, the ECP and pending a peer review. Existing research has categorised respondents who indicate that an electricity outage, (eg of a one-hour duration) would have a 'high impact' on their organisation's business-as-usual operations, as having a heavy reliance. Customers are likely to quantify the impact on their organisation in different ways (eg productivity) and be influenced by any mitigation already in place to enhance the organisation's resilience. Therefore, an understanding of customer impact will primarily inform the way in which heavy reliance is defined.

The interviews will be conducted in two phases in June and December 2016, with 50% for each customer type being completed in each phase. The 700 interviews with SMEs will be conducted across GB, via an online survey approach, with 350 interviews per fieldwork period.

The online survey will include a nationally representative sample of domestic customers, covering a variety of rural and urban locations. A minimum number of 250 interviews will be conducted by domestic customers within each DNO region. Demographic quotas will be set in relation to age, gender and social grade to ensure results are representative of the total population. Following consultation with key stakeholders and agreement of the methodology; DNOs will be sent written notice of proposed engagement with customers in their operating regions, before the initial phase of customer survey fieldwork in June 2016. DNOs will also be provided with the project methodology statement.

As set out in Section 8.2, the majority of customers are expected to respond online, but face-to-face or telephone surveys will be available for those for whom this is more appropriate.

To guarantee sufficient data from key customer groups and to permit sub-analysis by each of these segments, 2,500 interviews will be targeted at the following subgroups in the Electricity North West region:

- Worst served customers, including:
 - Customers affected by large scale supply interruptions during adverse weather in winter 2015 to 2016
- Vulnerable customers
- Customers in fuel poverty
- Off gas network customers
- Early adopters of LCTs
- Heavy users of electricity.

It is expected that identification of some customers falling into these subgroups will be naturally apparent in the national survey sample; in which case, their data will also be included in the subgroup analysis.

The proposed sample structure is outlined in Figure 8.1 below for domestic customer interviews (including key customer groups of interest).

Figure 8.1: Quantitative sample structure for customer interviews

Cell	Recruitment/ survey method	Total interviews	
		North West	Rest of GB
Population density			
Rural	Online	280 (13%)	430 (20%)
Urban	Online	1870 (87%)	1720 (80%)
Region			
Electricity North West	Online, F2F and Tel	2150	
Scottish and Southern Energy	Online		Minimum 250
SP Energy Networks	Online		Minimum 250
Northern Ireland Electricity	Online		Minimum 250
Northern Powergrid	Online		Minimum 250
Western Power Distribution	Online		Minimum 250
UK Power Networks	Online		Minimum 250
Faults			
Worst served	F2F in region, GB Online	430 (20%)	Natural fall out
Experienced large scale, lengthy supply interruption in last six months	F2F in region, GB Online	100 (5%)	
Sensitivity			
Vulnerable	F2F in region, GB Online	667 (31%)	Natural fall out
Fuel poverty	Online	323 (15%)	
Off gas network	Online	Natural fall out	

8.2 Survey approach

The nature of the sample to be interviewed requires a tailored survey approach to ensure the best responses from key customer groups.

The customer survey will mostly be conducted through online panels of respondents, pre-registered and open to research of this kind. This cost-effective approach provides for the targeted selection of rural and urban customers from across GB, ensuring the sample is representative of the national population, with quotas on key demographics such as age, gender and social grade. It also allows for quotas by DNO, energy consumption and customers off main gas networks.

The stated preference scenarios can be viewed on screen to inform the trade-off decisions, and the survey can be completed at a time and place convenient to the participant.

Subject to formal acceptance of the VoLL customer engagement plan (CEP), subgroups described in Section 8.1 will be identified and targeted from Electricity North West's customer database. Although it would be preferable to approach customers in these groups GB-wide, this would require other DNOs to provide customer information to Impact Research. This is likely to be problematic for a number of reasons and impractical within the constraints of time and budget allocated for this project. Therefore, targeting a representative sample of customers from all segments within Electricity North West's region will be sufficient to draw conclusions about the application of VoLL to these subgroups nationwide.

These customers will be approached by phone or face-to-face and offered an incentive to the value of £10 to participate in the survey. These methods have consistently been proven to obtain a higher response rate than online recruitment alone and will ensure samples that are statistically robust for the required analysis. Additionally, the presence of an interviewer enables customers to ask questions or clarify survey content as necessary.

8.3 Seasonal variation and timings

Customer perception of VoLL is likely to vary by the season in which a supply interruption occurs, as indicated by previous research. Customer experience will be affected differently dependent on daylight hours and whether heating is required, as discussed in Section 3.1. Seasonal perception of VoLL is also expected to vary among users of different LCTs ie early adopters of electric heat pumps (EHP), electric vehicles (EV) and those with photovoltaic systems (PVs) (refer to 10.3).

It is recognised that VoLL will vary by season. It is also accepted that only a proportion of customers interviewed might be expected to have recently experienced a supply interruption. However, conducting surveys in two phases will be used to identify any changes in perception of VoLL during the season in which the interviews take place, and how this varies within each segment dependent upon recent experience of an outage.

Previous research has identified that planned interruptions are generally more acceptable to customers during warm summer months but extraordinarily disruptive in winter. By comparing customer perception of VoLL over summer and winter, the extent of the seasonal impact will be quantified. While it may be more challenging to gauge perception of VoLL based on past events, these experiences will be influential when customers are considering future, hypothetical situations (refer to 8.4).

For the purposes of this research, it will be sufficient to control the seasonal variation in the analysis by collecting survey data across two seasons – midsummer and midwinter – and deriving average values of VoLL across these likely extremes in perception. Any seasonal considerations will be controlled in the scenarios presented, for example, by presenting attributes that relate to heating and lighting requirements at the time of the interruption. Irrespective of whether a customer completes a survey in summer or winter, they will be presented with scenarios that include variables relating to all four seasons. It is possible that respondents will find it more straightforward to provide VoLL perceptions relative to the season during which they complete the survey. For example, customers may find it more difficult to consider the impact of fewer hours of daylight, or several hours without heating in winter, when responding to these scenarios at the height of summer. However including a comprehensive seasonal question set in the survey instrument, and conducting interviews during the two seasonal extremes, will ensure the analysis is sufficiently robust to determine the scale of any changes in perception of VoLL by season.

8.4 Past experience of supply interruptions

Past experience of supply interruptions is an influencing factor on VoLL perception. The type of bias this might introduce will be explored with the ECP and measured in the customer survey. The customer survey data will be analysed according to experience of supply interruptions.

Experience of supply interruptions can broadly segment customers into four groups:

- Customers who have historically experienced very few, if any, supply interruptions
- Customers who have had repeat exposure to supply interruptions (largely urban, 80% of the volume)
- Customers who have experienced supply interruptions of a relatively longer duration (increased customer minutes lost, rural)

- Customers who have experienced large scale supply interruptions as a consequence of severe weather events ie storms and flooding.

The worst served customers, described in Section 8.1, comprise segments two and three described above. Although they are described as one group, it will be interesting to understand how VoLL perception varies between the two types of worst served customer and this will be included in the results analysis.

8.5 Measuring customer perception of VoLL

Choice experiments (CE), as referenced in Section 3.4, will be integrated into the customer survey instrument. This section is likely to be one of the longest to complete and will demand concentration and the complete engagement of the participant. As such, it will be included as close to the beginning of the survey as possible, after any essential demographic or screening information is captured.

The CE design for this research will be broadly similar to the approach taken by the London Economics study for Ofgem and DECC. However, this research does not propose to cover all the attributes included in that study, for two reasons:

- It is not necessary to capture the same granularity of detail regarding time of day/day of week/season because a robust measure of these variations was achieved in that study
- Omitting most of these variations will provide capacity in the design to include other attributes not previously tested.

The key attributes of duration and amount to pay or accept will be the same as in the London Economics study. That is, durations of 20 minutes, one hour and four hours and domestic one-off payment values of £1, £5, £10, £15 (for SMEs these will be replaced with bill reductions of 1%, 5%, 10% and 15%, to reflect the greater diversity of bill values in this group).

The results from the ECP and consultations with stakeholders will guide which other attributes are included. At this early stage it is proposed that the following could be tested however, the value of including these elements will be determined by the stakeholders:

- Alternative channels through which notification and information on the outage could be given: eg none, short message service (SMS), phone, letter
- Amount of advance warning: eg none (unplanned), 24 hours, two days, one week (planned)
- Level of assistance for vulnerable customers: eg none, helpline, named support contact.

All of these measures are means by which VoLL could be reduced through communication and customer support.

To provide a reference point for the scenarios, the average occurrence of an interruption of this type will be used as a constant across all the scenarios. This provides a realistic context while avoiding the complexities associated with this measure¹⁷. It is recognised that many survey participants, particularly the worst served sample, are likely to have experienced a greater frequency of interruptions than the average and as such, the CE will be introduced with explanatory text to place the statistic into context.

¹⁷ For a justification as to why frequency of outages is not included, see London Economics, 2013, The Value of Lost Load (VoLL) for Electricity in Great Britain, Final report for OFGEM and DECC, p7.

Figure 8.2: Example of how a CE scenario (WTA) could look to respondents

	Option A	Option B
It lasts for:	20 minutes	Four hours
Notification	None	By SMS 24 hours before No indication of how long
Customer assistance	General helpline	A named support contact
The one-off amount you are offered for this happening	£15	£1
<input type="checkbox"/> Option A	<input type="checkbox"/> Option B	<input type="checkbox"/> Don't know

The inclusion of a ‘no choice’ option in the form of a ‘don’t know’ response avoids forcing a choice with an inherent biasing effect on the results. In the WTP version, respondents will be shown “The one-off amount you pay to avoid this happening”.

The scenarios will be constructed using established statistical design principles. Each respondent will see two CEs per screen, one presenting WTP and the other WTA; the order of these will be randomised. Each exercise will comprise 12 scenarios for each respondent¹⁸. Full instructions for completion of this slightly unusual questioning technique will be included before the exercise and evaluated during the pilot.

9 CUSTOMER ENGAGEMENT PLAN

This section provides a summary of the customer engagement strategy that will be adopted during the project. A full customer engagement plan and data privacy statement will be submitted to Ofgem and engagement with relevant customers will begin only after the requisite approval has been granted (refer to Section 9.4). These documents will be published on Electricity North West’s [website](#) in early 2016.

This project will not directly affect customer power quality or supply, as it does not involve physical changes to the distribution network, customers’ private installations or any other aspect of supply provision. The research is based purely on assessing the perception of customers across GB, in regards to the impact of lost load on themselves, their households or business.

The objective of this research is to understand VoLL by customer segment, at the present time and how this might change in the future. This will ultimately inform DNO policies and investment plans for RIIO-ED2 and beyond.

The VoLL project will generate outputs and learning in a number of key areas. These will be of particular interest to other DNOs, Ofgem and DECC. In addition to specific customer and stakeholder engagement activities, the project team will provide and share relevant learning from VoLL with stakeholders.

¹⁸ All these elements of the design are consistent with the London Economics, 2013 report for Ofgem and DECC, pp4-9.

9.1 Customer engagement activities

The customer engagement plan sets out the approach and activities that will be undertaken to engage customers and stakeholders throughout the VoLL project. The plan covers the following activities, described in detail in Sections 6 to 12:

- Establishing which customers need to be engaged
- Developing and implementing engagement plans
- Planning customer selection and approach for focus group and customer survey participation
- Bringing customers into the project
- Keeping customers engaged in the project
- Managing customers' enquiries
- Incorporating learning from Electricity North West's previous LCN funded projects, specifically in relation to customer survey activities.

9.2 Project partners

Electricity North West will work closely with Impact Research who will provide dedicated support to the VoLL project in convening the ECP, customer and stakeholder interviews, customer survey and analysing the results.

9.3 Quality assurance of customer engagement outcomes during the project

The VoLL project is internally supported by Electricity North West's executive leadership team, who have ultimate oversight of its strategic direction and will receive bi-monthly updates on its progress.

Key stakeholders such as Ofgem, DECC, and Citizens Advice, will be consulted during interviews at the outset of the project, to guide its direction.

The project will be undertaken in accordance with Electricity North West's governance and project management approach. This will ensure that the deliverables are of the highest quality and that any deviation is quickly rectified.

9.4 Feedback and review

In accordance with Sections 4.6 to 4.10 of the Electricity Network Innovation Allowance Governance Document, a comprehensive CEP and DPS will be submitted to Ofgem in compliance with customer protection requirements. These documents will specify how Electricity North West and its project partners will interact with, or impact upon, relevant customers where any form of engagement is undertaken as part of the project. The following sections briefly summarise the communication that will take place. All project partners will adhere to the CEP and its basic principles; however, there may be a need to review the plan as the project progresses to reflect feedback and lessons learned.

Details of engagement with specific groups are set out below:

Customers

Throughout the project the VoLL team will seek feedback on customers' perception and experiences. Customers will be able to use a range of methods to contact the project team. The project team may use the results of the feedback to amend processes.

Priority services register customers

Electricity North West appreciates that some of its customers have additional requirements due to disability, being elderly, having a chronic illness or other forms of vulnerability. The company has a strong history of promoting safety and security at the homes of these vulnerable customers. Among other things, the company maintains a PSR of customers who

have special requirements or who may be vulnerable during a power outage. The register enables the company to provide prompt assistance to these customers if required.

The project team will use this register to identify vulnerable customers willing to participate in this research. These customers (or persons nominated by the vulnerable customer to act on their behalf) will be contacted by telephone, as outlined in Section 7.1. Appropriate measures will be adopted in all engagement with vulnerable customers to ensure the project is suitably introduced, its aims fully explained, and critically, these customers perceive no undue pressure to participate in any element of the research. A full suite of supportive and explanatory information will be produced and will be available in alternative formats such as audio, large print, Braille or minority languages on request.

Throughout the VoLL project any potential effects on vulnerable customers will be kept to a minimum. Interviewers will have access to details of PSR services available to customers and details of how to contact the VoLL project team with any queries or concerns. Survey materials will also include similar information. Customers will not experience any changes to their power quality or reliability as a result of this research. As such, there are no plans to contact PSR customers as part of a general awareness campaign or to discuss their special requirements, other than to determine how these uniquely influence their VoLL.

DNOs, project partners and interested stakeholders

Electricity North West will work with its partners and key suppliers to disseminate the learning outcomes from the project and seek feedback from interested stakeholders. Full details of project dissemination are included in Section 12.

Stakeholder consultation

Electricity North West has consulted its project partners, relevant internal departments and will engage with external stakeholders such as Ofgem, DECC and Citizens Advice to develop the project's CEP. Key stakeholders were previously engaged to gauge support for the VoLL project during its scoping and preparation stages.

9.5 Engaged customer panel and customer depth interviews

An ECP will be convened in advance of the customer survey, comprising a cross-section of electricity consumers reflecting the demographic profile of the domestic and SME customer base across GB. This approach has been used successfully in previous engagement activity with Electricity North West customers. The ECP will consist of four focus groups, each one representing a key customer group.

Certain customers, such as those who are vulnerable or already use specific LCTs, will be more directly engaged and interviewed by phone or face-to-face. This approach will enable the recruitment of a suitable survey population among these key segments. It will also mitigate against problems associated with the geographical spread of these customers and access difficulties impeding the attendance of focus group meetings in central locations.

The ECP and customer interviews will influence the design of the customer survey instrument and their test and pilot of the instrument will ensure it is refined to maximise its effectiveness and clarity.

9.6 Customer survey

A customer survey is required to measure VoLL accurately, examine variations by customer group and model the likely changes to VoLL as LCTs are adopted onto the network. Customers will therefore be recruited to participate in a customer survey conducted over two seasons as part of the VoLL Project.

A representative sample of customers will be surveyed in Electricity North West's operating region and across the wider GB population. There are particular customer groups which are likely to exhibit greater variation in VoLL than other customers:

- Worst served customers
- Vulnerable customers
- Customers in fuel poverty
- Off gas network customers
- Adopters of LCTs
- Heavy users of electricity
- SMEs with a heavy reliance on electricity.

The subgroup sample population will be specifically targeted to ensure sufficient interviews are completed to accurately assess the calculation of their VoLL.

A total of 5,000 customers will be surveyed across two interview periods in June and December 2016. Customers will predominantly respond online. In line with the ECP methodology, customers who may be more difficult to engage will be offered a telephone or face-to-face interview, to maximise their potential to respond and allow them to ask questions. An appropriate financial incentive will be offered to customers who complete the survey.

The survey will take approximately 20 minutes, irrespective of the contact method. Before taking part, customers who agree to participate will be fully informed about how their data will be used and shared. They will be asked to sign a consent form and by doing so, will agree to their information being used for the stated purposes. This process will be clearly defined in the DPS.

Impact Research will also inform customers that their personal data will not be included or shown (in a disaggregated manner) in any customer trial analysis.

The survey instrument must be focused, engaging and easily understood, to maximise the data collection opportunity, guaranteeing accuracy of results and a successful output. This will be achieved by repeated engagement with the ECP, who will be instrumental in providing feedback on the survey instrument's overall content and wording. The survey instrument will be piloted with a small group of customers before the main customer survey. This approach is a direct learning from previous customer engagement projects and will provide a suitably robust survey instrument with which to accurately measure VoLL.

9.7 Incorporating learning from previous customer engagement

The techniques that will be used to engage with customers during this project draw heavily on Impact Research's experience from previous Electricity North West customer engagement activities. Based on this experience, the project team is confident that it can successfully explain the DNO's role within the electricity industry and introduce relevant concepts which will enable customers to fully engage in this process and make an informed evaluation on project materials. The insight developed from previous experience in this sector will ensure the question set presented in the survey will derive the most accurate results to measure VoLL.

10 ANALYSIS

10.1 Modelling stated preferences

Statistical models will be used to examine the decision making process of customers and quantify the influence of each attribute in the choice between two options presented in each scenario of the CE. This produces a measure of the value placed by customers on each

attribute. The ratio of each non-monetary attribute to the monetary attribute gives an inferred WTP or WTA value.

Further detail on this process is provided in Appendix A.

10.2 Segmentation by customer groups

The WTP and WTA values will be estimated for each respondent. This allows the responses to be grouped in two ways:

- By predefined customer subgroup (eg early LCT adopters, vulnerable customers)
- As clusters of individuals with similar preferences as expressed in the CEs.

This second part of the analysis could identify new subgroups within the predefined subgroups or across the wider survey population.

Vulnerability and affordability

The analysis will assess VoLL in the context of the DNO's social responsibility to its vulnerable customers by examining the value placed on the loss of supply within this customer segment. Variations in VoLL among customers categorised with different definitions of vulnerability, based on information voluntarily provided in the survey, may be identified. These results are expected to be influential in the DNO's policy decisions aligned to social obligations, customer vulnerability strategies and interventions to address fuel poverty.

10.3 Forecasting LCT adoption and other future behaviour

Early adopters

One way of identifying how VoLL might change with the adoption of LCTs is to compare the responses of current LCT users with those of comparable customers who are not yet users of these technologies. The VoLL for customers with electric vehicles (EVs), photovoltaic systems (PVs), or electric heat pumps (EHPs) will be compared with the VoLL of comparable customers of a similar demographic profile who currently do not use these technologies.

Customers can be broadly identified as early, mid, late and non-adopters of LCTs, using direct questions in the survey that measure the propensity to take up such technologies.

Forecasting LCT adoption

The latest forecasts for LCT adoption will be used to estimate how the overall VoLL is expected to change in the future as the mix of LCT owners/non-owners changes over time. For example, the UK government aspires to 100% of all new car sales being ultra-low emission vehicles by 2040¹⁹.

11 IMPLEMENTATION OF FINDINGS

Objective four, as referenced in Section 1.4 considers:

'How can Electricity North West and key stakeholders mitigate the costs of lost load to customers?'

¹⁹ Brook Lyndhurst, August 2015, Uptake of Ultra Low Emission Vehicles in the UK: A Rapid Evidence Assessment for the Department for Transport.

The Royal Academy of Engineering suggests that “there are a number of relatively low cost measures that can be taken to mitigate economic and social costs of [electricity] shortfalls.”²⁰

These include:

- Improved communication with customers, both in content and technology
- Improved planning and phasing of outages, particularly in the avoidance of peak load times
- Demand side response
- Use of communities and social networks to mitigate impacts.

This study provides the opportunity to explore customer perception around the acceptability of such measures and to examine how VoLL could vary relative to individual circumstances. For example, VoLL may be influenced by customers’ familiarity with and preference for different communication channels.

It is expected that the research will identify distinct customer groups who vary in their VoLL, and may also respond differently to various DNO strategies intended either to reduce lost load or mitigate its effects. The results of this research will be published and disseminated via appropriate channels to key stakeholders (refer to Section 12). The final report will focus on the following topics:

- Marketing and the management of customer expectations regarding supply interruptions
- Effective customer communication channels during and after supply interruptions, and prior to planned outages
- Local asset replacement in worst served areas
- Changing Electricity North West’s investment strategy in relation to asset refurbishment and replacement
- The wider implications for Ofgem and GB DNOs in planning their future investment strategy.

12 DISSEMINATION OF FINDINGS AND LESSONS LEARNED

Following successful completion of this project, the fundamental driver in the adoption of a revised VoLL model will be the dissemination of findings to all key electricity industry stakeholders in an appropriate manner. There will be several reporting deliverables to share the result of the analysis and demonstrate achievement of the following success criteria:

- An understanding of customer impact, how value is defined and how this might be influenced (eg better communications)
- A credible segmentation and future VoLL model by key customer groups to guide investment decisions
- A demonstration of how these values would help Electricity North West to better plan its network investment strategy
- Guidance on customer compensation strategies.

²⁰ Royal Academy of Engineering, Nov 2014, Counting the Cost: the Economic and Social Costs of Electricity Shortfalls in the UK, A Report for the Council for Science and Technology, p3.

The project findings, lessons learned and implementation recommendations will be shared as follows:

When	Criterion	Required evidence
Phase 1	Literature review, research approach and CEP	Publish the methodology statement by end January 2016
	Inform DNOs of the project aims and customer impact	Circulate methodology statement to DNOs by end March 2016
	Draft the CEP and DPS by January 2016	Send the CEP and DPS to Ofgem, for approval, by end January 2016
Phase 2	Executive summary (PowerPoint presentation) of ECP and key customer depth interviews	Publish executive summary of ECP and key customer depths interviews by end July 2016
Phase 3	Executive summary (PowerPoint presentation) of customer survey and VoLL model analysis	Publish key analysis from model in final report by March 2017
	Annual NIA progress report	Submitted to Ofgem July 2016 and 2017
	Final survey report including lessons learned	Submit the final report to Ofgem for publication on the NIA portal by April 2017
Stakeholder updates	Update reports to key stakeholders and Electricity North West's executive leadership team	Quarterly email updates sent directly to stakeholders throughout project at key project milestones Dissemination events held for key stakeholders at project milestones by webinar or in person

13 APPENDICES

Appendix A: Choice modelling and the estimation of WTA/WTP

In a stated preference study, such as a choice experiment (CE), it is assumed that individuals are rational, know their own preferences and, are able to choose that which offers them the highest utility. Thus, if an individual n is assumed to choose alternative i over alternative j , if the utility derived from attribute bundle i is greater than the utility derived from attribute bundle j ; i.e. if $U_{ni} > U_{nj}$, where U_{ni} is the total utility associated with alternative i and U_{nj} is the total utility associated with alternative j . The utility function for respondent n related to alternative i is specified as:

$$U_{ni} = \beta_n x_{ni} + \varepsilon_{ni}$$

Where $\beta_n x_{ni}$ is the systematic (non-stochastic) utility function observed by the analyst because it is linkable to the attribute levels of each alternative (e.g. electricity service attributes, etc.) and ε_{ni} is a random component, which is known to the individual, but remains unobserved to the analyst. This random component (ε_{ni}) arises either because of randomness in the preferences of the individual or the fact that the researcher does not have the complete set of information available to the individual (Train, 2003).

A mixed logit (MXL) model will be used in the analysis, because unlike conventional logit models, it expresses choice probability as the probability that person n chooses alternative i , conditional on β_n . This is the standard logit formula:

$$L_n(\beta_n) = \exp(\beta_n x_{ni}) / \sum_j \exp(\beta_n x_{nj})$$

Where L is the likelihood of respondent n choosing option i and j is all the alternative options. However, since β_n is random and not known, the (unconditional) choice probability is the integral of this logit formula over the density of β_n :

$$P_{ni} = \int L_{ni}(\beta) \cdot f(\beta) \cdot \theta \cdot d\beta_n$$

Hierarchical Bayesian analysis will be used to estimate the parameters of the MXL model. It is hierarchical because the approach has two levels. At the higher level, it is assumed that individuals' part worths are described by a multivariate normal distribution. At the lower level, it is assumed that, given an individual's part worths, his/her probabilities of choosing particular alternatives are governed by a multinomial logit model.²¹

Once the mixed logit model is estimated, the marginal WTA and WTP estimates are computed directly from the model specified. The ratio of the following two coefficients yields the WTA for the attribute 'i':

$$WTA_{\text{Attribute } i} = \beta_i / \beta_{\text{price}}$$

This assumes a linear-in-the-parameters model with no interactions, otherwise more complex calculations apply.

²¹ The Sawtooth CBC/HB package will be used to estimate the model parameters for this study.

Appendix B: Executive summary of peer review

To follow.

Appendix C: Sources

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VoLL studies 2004-2014 – an overview

Study	State/Region	Base Year	Method/Scenario	Focus
Chowdhury et al.(2004)	USA – Midwest Region	2002	Willingness to pay: differentiation according to event, 2 s, 1 min, 20 min, 1 h, 4 h, 8 h	Industry, commercial users, private users, organisations
Bliem (2005)	Austria	2002	Macroeconomic approach: regional differentiation (federal states), consideration of different points in time (weekday/Sunday)	Industry (six sectors), private households
Centolella et al. (2006)	USA – Midwest Region	2005	Direct cost survey: differentiation into larger (>1 million kWh/a) and smaller (<1 million kWh/a) industrial and commercial users; determination for an interruption of 1 h, 2 h, 3 h,Willingness to pay	Industry (nine sectors), private households
Tol (2007)	Ireland	2005	Macroeconomic approach: for 2005, calculation differentiated according to 19 sectors; calculation of industrial VoLL from 1990 to 2005, but average values for industry broken down according to time of day/ week/year	Industry (19 sectors), private households
de Nooij et al.(2007)	The Netherlands	2001	Macroeconomic approach: differentiation according to regions, broken down according to days of the week (weekday/Saturday/Sunday) and time of day (day/evening/night)	Industry (six sectors), government, private households
Baarsma and Hop (2009)	The Netherlands	2003-2004	Willingness to pay: differentiation according to event: 1 event/a lasting 0.5 h,1 h, 4 h, 8 h, 24 h, and a 2-h event 1, 2, 4, 6, or 12 times/a year	Industry, private households
Sullivan et al. (2009)	USA	2008	Willingness to pay: a metadatabase was compiled from 28 studies (surveys on willingness to pay between 1989 and 2005); differentiation into large (>50,000 kWh/a) and smaller (<50,000 kWh/a) industrial and commercial users; differentiation according to length of event: short-term, 30 min, 1 h,4 h, 8 h; calculation for different points in time (summer/winter; weekday/weekend; mornings/daytime/evenings)	Industry (nine sectors), private households
Praktiknjo et al. (2011)	Germany	2002	Macroeconomic approach: combined with a Monte Carlo simulation	Industry (four sectors), private households
Leahy and Tol (2011)	Ireland / N Ireland	2008/2010	Macroeconomic approach: differentiated consideration of Ireland and Northern Ireland; period from 2000 to 2007, consideration of average values for industry broken down according to weekday/weekend; day/evening/night; spring/summer/autumn/winter	Industry, services, private households
Carlsson et al. (2011)	Sweden	2004	Willingness to pay: distinction between planned and unplanned; differentiation according to event 1 h, 4 h, 8 h, 24 h, consideration of the influence of socioeconomic factors; comparison before and after actual power interruption	Private households
Lineares and Rey (2012)	Spain	2008	Macroeconomic approach: for 2008, calculation differentiated according to 15 sectors; calculation of industrial VoLL from 2000 to 2008, but average values for industry for five sectors; differentiated according to Spanish regions for 2008	Industry (15 sectors), private households
Zachariadis and Poullikkas (2012)	Cyprus	2009	Macroeconomic approach: differentiated according to seasons; weekday/weekend; time of day (hours); only industrial / commercial / private users are considered in the temporal differentiation	Industry (15 sectors), private households

Reichl et al. (2013)	Austria	2009	Macroeconomic approach: 12-h interruption in summer Willingness to pay: 12-h interruption in summer; consideration of the influence of socioeconomic factors	Industry (15 sectors), private households
Growitsch et al. (2013)	Germany	2007	Macroeconomic approach: results differentiated according to federal state and sector; overall costs determined for a period of 1 h for the federal states	Industry (15 sectors), private households
Röpke (2013)	Germany	2008-2010	Macroeconomic approach	Industry (five sectors), private households
Piaszeck et al. (2013)	Germany	2010	Macroeconomic approach: regional subdivision on the level of local districts; breakdown into time of day/course of the week	Industry (six sectors), private households
New Zealand Electricity Authority (2013)	New Zealand	2010	Willingness to pay: differentiation into small/medium-sized/large enterprises; regional differentiation; differentiation and event, 10 min, 1 h, 8 h; scenarios according to time of day and season	Industry, private households
Schubert et al. (2013)	Germany, Munich	2012	Willingness to pay: investigation of a blackout on 15 November 2012, duration 4 h	Private households
London Economics, (2013b)	UK	2011	Willingness to pay: differentiation into small and medium-sized enterprises/industrial and commercial enterprises; scenarios according to season and working day/weekend	SMEs, industrial and commercial enterprises I&C), private households
Praktiknjo (2014)	Germany	2011	Willingness to pay: combined with a Monte Carlo simulation; blackout scenarios lasting 15 min, 1 h, 4 h, 1 day, 4 days	Private households
Kim et al. (2014)	South Korea	2010	Willingness to pay: differentiation according to event (1 s, 3 s, 1 min, 20 min, 1 h, 2 h, 4 h, 8 h, 1 day, 3 days); at the same time socioeconomic factors also surveyed	Industry, private households

Source: Schröder and Kuckshinrichs, December 2015, Value of Lost Load: An efficient economic indicator for Power Supply Security? A Literature Review, *Frontiers in Energy Research*

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