electricity north west

Bringing energy to your door

NIA ENWL010
Value of Lost Load to Customers
Closedown report

A Network Innovation Allowance Project

31 July 2019

VERSION HISTORY

Version	Date	Author	Status	Comments
V0.1	31 May 2019	Tracey Kennelly Customer Innovation Lead	Final	

REVIEW

Name	Role	Date
Lucy Eyquem	Innovation PMO Manager	26 June 2019
Paul Turner	Innovation Manager	12 July 2019

APPROVAL

Name	Role	Signature & date
Steve Cox	Engineering & Technical Director	29 July 2019

CONTENTS

GLOSSARY

Abbreviation	Term
CBA	Cost benefit analysis
CE	Choice experiment
CNAIM	Common Network Asset Indices Methodology
DNO	Distribution network operator
DSR	Demand side response
DUoS	Distribution use of system
ECP	Engaged customer panel
ELT	Executive leadership team
EV	Electric vehicle
GB	Great Britain
HB	Hierarchical bayesian
I&C	Industrial and commercial customers
LCNI	Low carbon networks and innovation conference
LCT	Low carbon technology
NIA	Network Innovation Allowance
NOMs	Network Output Measures
NPV	Net present value
Ofgem	Office of Gas and Electricity Markets
PPR	Annual NIA project progress report
PSI	Planned supply interruption
RIIO-ED2	Electricity distribution price control 2023 to 2028
SME	Small to medium enterprise
SMS	Short message service
VoLL	Value of Lost Load
WSC	Worst-served customers
WTA	Willingness to accept
WTP	Willingness to pay

1 EXECUTIVE SUMMARY

1.1 Aims

Electricity supply interruptions have financial and social impacts on customers that vary by season, time of day, customer type and customer load. Understanding the Value of Lost Load (VoLL) is important for distribution network operators (DNOs) when determining network planning and investment strategies. This will become increasingly important as customers grow more reliant on electricity in the low carbon future. At present in Great Britain (GB), a single uniform VoLL is used to provide an overall estimate of the value given to loss by domestic and business customers. This single measure is used to evaluate the amount that customers would be prepared to accept to avoid a supply interruption of average duration. A VoLL of £16,000/MWh was established for RIIO ED1 by Ofgem and this figure is used to represent the economic measure of a supply interruption: It acts as a price signal for the adequate level of supply security in GB and is a useful guide for determining how much should be spent to deliver security of supply.

Previous research has identified that VoLL varies significantly among three distinct customers groups: residential, small/medium commercial and industrial enterprises (SMEs) and large commercial/industrial users. The value also varies considerably within each of these groups, for example, between rural and urban customers, different income groups and those in vulnerable circumstances.

The VoLL project sought to deliver a comprehensive assessment of customer impacts associated with the loss of electricity supply, the relative importance of various supply interruption characteristics e.g. frequency and duration, how these components are valued by specific customer groups and how this might change with the adoption of low carbon technologies (LCTs). The research also examined if, and to what extent, VoLL could be influenced by adopting different approaches to mitigating the impact of outages.

1.2 Methodology

The project sought to establish if the current single uniform VoLL applied to all customer segments remains appropriate as GB moves towards an economy increasingly reliant on electricity driven by the decarbonisation agenda. To this end, Electricity North West and its market research project partner, Impact Research, conducted extensive qualitative and quantitative customer and stakeholder engagement to understand how VoLL is assessed by different customer segments and how this might change in a low carbon future. The study involved a survey of over 6,000 domestic customers and SME representatives from across the whole of GB.

This research and its methodology built on previous studies in this area to determine if a revised VoLL model would benefit customers. Details of the research approach are set out in the detailed project methodology statement published on the VoLL webpage on 29 July 2016. This document is supported by a literature review, peer review and a summary of stakeholder consultation, which informed the method. The customer research activities were underpinned by a comprehensive customer engagement plan and data privacy statement.

1.3 Outcomes

Previous VoLL research has identified that estimates vary significantly among three distinct customers groups: residential, SMEs and large industrial/ commercial (I&C) customers. This study has further demonstrated the extent to which VoLL also varies considerably within each of these groups, across many customer segments, for example there are significant differences between rural and urban customers, those in vulnerable circumstances and users of low carbon technologies. While this divergence is recognised, it is not reflected in the current single VoLL model. This research provides robust evidence that the existing ‘vanilla’ VoLL fails to reflect the

significant variation that exists in the financial and social impact of supply interruptions across different customer types.

1.4 Key learning

This project study has demonstrated that VoLL is now higher than when estimated during the last major study for Ofgem in 2013. VoLL estimates are substantially higher for less affluent groups, particularly those classified as 'fuel poor'. When adjusted to reflect income, the VoLL of customers with vulnerabilities is also well above the average. This finding demonstrates that Ofgem's focus on identifying and tackling consumer vulnerability in the energy market is justified. VoLL was also found to be higher than the average in the 30-44 age group, which is likely to reflect the greater impact of interruptions on families with children. Predictably VoLL was higher than average for customers without a mains gas supply, where electricity is the primary source of energy.

VoLL estimates vary significantly relative to the scale and duration of an outage. The study also demonstrated that it is possible to mitigate the impact of an outage and lower VoLL by offering various support mechanisms to customers.

One of the key objectives of this study was to investigate potential changes in VoLL in a low carbon future. The analysis established that VoLL for domestic customers using LCTs is significantly higher than the average and this was particularly apparent for users of electric vehicles (EVs) who expressed a VoLL of almost 25% above the average. This is a significant finding and has important implications for future network investment strategies and design policy as it suggests that VoLL is set to increase in line with the projected uptake of LCTs.

1.5 Conclusions

The results of this study provide evidence that a single uniform VoLL may no longer be appropriate and the research allows a much more representative VoLL model to be established. This more sophisticated approach will significantly improve efficient targeting of investments and ensure those investments are based on a much richer and more representative understanding of customers' needs.

The research demonstrates the different impacts of supply interruptions across a range of domestic and SME sub-groups. It reveals that the range of values is almost double when considering the lowest to highest estimates reported.

This study concludes that the current universal VoLL undervalues the needs of certain customers, for example those dependent on LCTs, off-gas customers and the fuel poor. Similarly, it may over-represent the needs of other customer groups.

The Conclusions and Recommendations Report published on 5 October 2018 makes suggestions for how the revised VoLL might be applied, summarises the standard industry data used in the study and provides details of other external data sources that could be exploited to enhance the proposed VoLL calculation tool.

In summary, a revised, segmented VoLL model is attractive because it does not involve a significant change in the way that DNOs assess the benefits of lost load mitigation. Rather, it allows them to refine their models to produce a more precise method for prioritising investment strategies which focus on the impact of decisions. This alternate approach would enable DNOs to re-distribute investment without increasing customers' bills to deliver the greatest value now and into the future. This will ensure bills remain affordable and investment decisions to deliver improvements in service are informed by those most impacted by outages. These findings are likely to have an impact on Electricity North West's social obligations and influence how the company adapts its response to customers on the priority services register and its approach for addressing fuel poverty.

2 PROJECT FUNDAMENTALS

Title	Value of Lost Load to Customers
Project reference	NIA_ENWL010
Funding licensee(s)	Electricity North West Limited
Project start date	October 2015
Project duration	36 months
Nominated project contact(s)	Tracey Kennelly (innovation@enwl.co.uk)

3 PROJECT BACKGROUND

Improving and/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 the Value of Lost Load (VoLL) has previously been undertaken; however, this resulted in a single uniform VoLL based on existing customer energy usage and assigned value. As GB decarbonises heat and transport customers will become reliant on electricity for new needs and hence it is likely that the VoLL will change. This future VoLL is important in informing issues such as network reliability standards, design policy for LCT intensive networks and service standards. In addition VoLL may have significantly different value for sub segments for the customer base, for example rural customers versus urban, worst served customers versus average etc. Understanding the VoLL by segment will be an important factor informing DNO policies and investment plans for ED2 and beyond.

To facilitate a comprehensive understanding of VoLL over time and by customer segment, the method will encompass three key stages of customer and stakeholder engagement.

Phase 1:

- Desk research to gain contextual understanding, comprehensively reviewing previous research on VoLL (including the London Economics survey conducted for VoLL and DECC). Reviews of published literature on the subject of VoLL primarily in GB but also abroad, and information available from GB DNOs on efforts to measure the VoLL.
- Formalisation of best methods of evaluative procedures among customers and optimal methods of VoLL calculations - proposed methodology document produced and peer reviewed. Meetings with key stakeholders (Ofgem, DECC, Citizens Advice Bureau) to outline proposed approach and obtain buy in.
- Finalisation of research questions that will be explored.

Phase 2:

Qualitative research in the form of focus groups and in depth interviews with customer groups, including but not limited to: domestic customers; SMEs (with a focus on industries heavily reliant on electricity); stakeholders e.g. hospitals, care homes, age UK etc., and customers.

This research will explore:

- How reliability and quality of supply is defined by customers
- Explore how customers and businesses prepare, if at all, for faults
- Differing expectations for planned versus unplanned faults
- How different customer groups value reliability of electricity supply in different ways
- The financial impact of lost loads (particularly to SME customers and service organisations)
- The social impact of lost loads (particularly to domestic customers)
- Expectations around communications and support during a supply interruption from Electricity North West and other stakeholders
- Key attributes of a supply interruption such as frequency, duration, time of day, financial impact etc that will determine the attributes and levels for scenario testing during the quantitative phase.
- How these views may change with decarbonisation of heat and transport

These issues will be explored for groups of customers likely to have shared experiences (e.g. SMEs, worst served customers, vulnerable customers). Key stakeholders will be interviewed individually, to understand their unique position between Electricity North West and their customer base. Engaged customer panels (ECPs) will be formed for domestic and SMEs, given the complexity of the survey topic, to facilitate informed discussions. The main quantitative survey will be piloted in phase 2, among the ECPs and a wider audience of Domestic and SME customers

Phase 3:

Large scale robust quantitative survey amongst customers, designed to test the following hypotheses:

1. Does VoLL vary by customer segment and what are their relative value assignments?
2. How will VoLL vary with LCT adoption?
3. How would the level of incentives tested for demand side response in other LCNF trials compare to future VoLL?
4. Which segments would support a strong VoLL and hence potentially higher investment?

The survey will include stated preference scenarios, where customers are asked to trade off varying levels of reliability of supply in exchange for a customer incentive (financial or otherwise). It is proposed that the worst served customers are key to this research, as these customers are the most likely to have experienced interruptions and thereby have a recent benchmark. The survey will be conducted over two fieldwork periods, one winter and one summer to understand the variations in VoLL by season. The survey and associated analysis will quantify the VoLL and produce curves for relevant customer groups that identify the optimal levels of investment.

4 PROJECT SCOPE

The scope involved research across the full range of distribution network operator (DNO) customers including:

- Domestic customers (qualitative ECP and quantitative research); general, worst-served customers, vulnerable customers, fuel poor, adopters of low carbon technologies (LCTs), heavy users (targeted by tariff type)
- Small to medium enterprises (SMEs) (qualitative ECP and quantitative research); targeted at industries with heavy reliance on electricity*
- Stakeholders (qualitative depth research): Ofgem, DECC, Citizens Advice Bureau, local government (resilience forums), charities (such as British Red Cross), police, fire brigade,

housing associations, emergency services, hospitals, care homes, airports and other transport hubs.

** Large I&C customers were not a focus of this study. Whilst it is recognised that these customers may have widely varying assessments of VoLL they are considered more able to effectively influence the security of their supply and have provision in place for dealing with lost load.*

5 OBJECTIVES

This research aims to quantify the value of dead load/loss of supply to customers. This will be achieved by answering the following research objectives:

- What is the impact on customers of lost load?
- What is the value of this impact – financial and social costs to customers in £ per kW?
- How does this vary by customer type? Currently all customer types are treated uniformly
- How can Electricity North West and key stakeholders mitigate the costs of lost load to customers?
- How will this vary with LCT adoption?

6 SUCCESS CRITERIA

The project success criteria were:

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

7 PERFORMANCE COMPARED TO THE ORIGINAL PROJECT AIMS, OBJECTIVES AND SUCCESS CRITERIA

7.1 Summary of performance

The VoLL project has successfully delivered against its original aims, objectives and success criteria. The following section summarises the methodology used to meet the objectives specified in Section 5, the outcome of the research and how the associated success criteria stated in Section 6 were met.

The research methodology was designed to analyse VoLL at a much more granular level than in previous studies by taking account of more detailed customer information. The objective of achieving an enhanced, disaggregated understanding of VoLL was to allow DNOs to consider their investment strategies in a more informed and targeted manner; however, prior to undertaking the research, there were no presuppositions about how VoLL might be segmented or how this information could be utilised by DNOs.

The objectives and success criteria of this project were met predominantly by a large scale quantitative survey involving over 6,000 customers across GB. The survey design was informed by previous studies in this area and by extensive customer and stakeholder engagement conducted

as part of this project. Before the survey was implemented it was subject to peer review and a robust piloting phase.

The main component of the survey instrument was a 'stated preference choice experiment' (CE) which is widely accepted as the strongest technique for measuring metrics such as VoLL. Respondents were presented with a series of scenarios and asked to trade off different levels of supply reliability and possible support mechanisms available during an interruption in exchange for a hypothetical financial incentive or penalty. For parity of approach with previous studies VoLL was measured in terms of customers' willingness-to-accept (WTA) a payment for an outage and willingness-to-pay (WTP) to avoid an outage.

For parity with previous studies it was necessary to test both WTA and WTP values and in common with earlier research WTA estimates were significantly higher than comparable WTP estimates, for the reasons outlined in Section 7.3. The WTA values established in this study are used to make comparisons across the customer groups because this is the metric used in previous studies and it gives an average value across domestic and SME customers that is closest to the value currently used by Ofgem.

VoLL was initially analysed by means of a high level and simplistic, domestic and SME classification and then segmented further by key demographic, socio-economic, geographic, attitudinal, behavioural and event-based information collected during the survey. A multinomial logit econometric estimation method was utilised to convert the CE results into £/MWh VoLL figures and confidence intervals.

Analysis of survey responses revealed significantly different impacts of supply interruption across a range of domestic and SME sub-groups, which has the effect of large variations in the segmented assignment of VoLL. It also established an average 'group level' WTA estimate for domestic customers as £17,481. The comparable group level estimate for SME customers was £47,560[1].

The analysis also revealed that the overall estimate of VoLL has risen since the last major study in 2013. When average group level results for domestic and SME customers are combined in a weighted average in the same manner as the London Economics study; we established a combined value of £25,301 MWh. This compares to the London Economics' 2013 figure of £16,940 (which would now be closer to £18,500 if adjusted for inflation). This finding suggests that over time VoLL is increasing and intuitively this reflects higher levels of customer dependency and expectations.

The research considered the impact of, and duration and frequency of, outages on VoLL and found that an interruption generally incurs a higher VoLL the longer it lasts, but the marginal hourly value declines steadily. There is a levelling out in the upward trajectory of VoLL for extremely long duration interruptions typically associated with extreme weather events.

The study revealed that current domestic users of LCTs have a higher VoLL than the average, with EV users expressing a VoLL almost 25% above the average. This finding is important given the anticipated increase in LCT adoption and hence customers' greater dependency on electricity. LCT adoption will be a critical influencing factor in customers' future assignment of VoLL and consequently will have significant implications for DNOs' long-term investment strategies as GB transitions to a low carbon economy.

[1] The average consumption for domestic customers is 0.00045 MW per hour. An average WTA value of £7.87 per hour (range £7.30 - £8.44) was obtained for all domestic customers, giving a MWh value of £7.87/0.00045 = £17,481 (range £16,209 - £18,753). The average consumption for SME customers is 0.00336 MW per hour. An average WTA value of £160 per hour (range £152 - £167) was obtained for all SME customers, giving a MWh value of £160/0.00336 = £47,560 (range £45,289 - £49,830). The actual calculations were based on numbers to 16 decimal places.

These results provide robust evidence that the existing single 'vanilla' VoLL, applied to all customer segments, fails to adequately reflect the significant variation that exists in the financial and social impact of supply interruptions across the full spectrum of customer types.

The research has delivered a set of VoLL estimates that reflect the varying needs of different customer groups far more accurately than the single-value approach currently used. Analysis and modelling allows a much more representative VoLL model to be established. This more sophisticated approach could significantly improve efficient targeting of investments and ensure those investments are based on a much richer and more representative understanding of customers' needs.

Disaggregated VoLL variables have been incorporated into a prototype calculation tool, which demonstrates how DNOs could assess the collective VoLL of all customers served by specific assets.

This revised model does not replace the cost benefit framework principles and calculation methodologies embedded within the regulatory framework to evaluate investment decisions, i.e. the Common Network Asset Indices Methodology (CNAIM) which considers the condition-based consequence of failure. Rather, it provides an additional customer-driven dimension to improve the sophistication of the decision-making process.

The new model is attractive because it does not involve a significant change in the way that DNOs assess the benefits of lost load mitigation, but refines existing models to produce a more precise method for prioritising investments which focus on the impact of decisions.

A segmented VoLL model would enable DNOs to re-distribute investment without increasing customers' bills to deliver the greatest value from finite resources now and into the future. This approach ensures DNOs target investment in the right areas to manage network risk effectively and continue to deliver their primary outputs in the future.

These results are significant and have wider implications for Ofgem and GB DNOs in planning their future investment and customer strategies which might need to consider issues of equity as well as efficiency when it comes to policy design and implementation. These findings suggest that the industry may need to consider more nuanced customer service standards to reflect the personal and societal impact of supply interruptions on specific groups such as rural customers, LCT users, the fuel poor and customers in vulnerable circumstances. The relative high weighted VoLL of vulnerable and low income groups is significant and demonstrates that Ofgem's focus on identifying and tackling consumer vulnerability in the energy market is correct.

As such, it is anticipated that the values for segmented VoLL, calculated as part of this study, will have important regulatory implications and be influential in informing DNO policies and investment plans for RIIO-ED2 and beyond.

Details of how the objectives and success criteria were met are reported in Sections 7.2 to 7.7 of this report. These outputs are more thoroughly documented in the main Customer Survey (Phase 3) Report (which will hereafter be referred to simply as the 'Phase 3 Report'). This document is supported by a detailed Technical Appendix and a Conclusions and Recommendations Report, which makes suggestions for a VoLL calculation tool and outlines the network and customer benefits of using a more sophisticated model to assist DNOs in better planning network investment and customer strategies.

7.2 What is the impact on customers of lost load?

A detailed understanding of the impact of loss of supply on a wide range of domestic and SME customers was derived from a phase of qualitative research. This comprised a series of meetings with an engaged customer panel (ECP) and 17 'depth' interviews.

Participants in the ECP represented four key customer segments: urban and rural domestic customers, worst-served customers and SMEs. The depth interviews provided learning from customers who were more difficult to engage in a focus group environment, these included: those in vulnerable circumstances; off-gas customers; those affected by large-scale supply interruptions; LCT users; SME customers that are heavily reliant on electricity; opinion leaders and relevant stakeholders.

The detailed findings from this phase of research are documented in the ECP and Depth Interviews Reports, published on the VoLL webpage on 23 and 31 August 2016. The following summarises the key findings:

- Supply reliability was defined by the ECP as the continuous availability of electricity with no interruptions.
- Infrequent planned supply interruptions (PSI) or unplanned outages do not adversely affect customers' perception of reliability and the impact is further diminished when the reason for an interruption is explained.
- Tolerance of interruptions was generally high, particularly among rural customers who have greater experience of both planned and unplanned outages.
- Rural and worst-served domestic customers perceive that all customers should expect the same level of reliability and DNOs should invest accordingly to achieve this.
- Duration was a key factor in determining the magnitude of impact but the time of the interruption was also important, particularly if it disrupted the preparation of hot meals.
- Customers are more tolerant of PSIs than unplanned interruptions, because the notice requirement allows them to prepare in advance, thereby mitigating the impact.
- Supply interruptions are more disruptive to vulnerable customers who should potentially be prioritised in:
    - Decisions influencing security of supply
    - Restoration following an interruption
    - Provision of a temporary support during an interruption (i.e. generator).
- The most valuable support from DNOs during an unplanned interruption is accurate, up-to-date information about the restoration time and regular progress updates during longer outages.
- All customer groups believe that DNOs have a social obligation to offer limited support to vulnerable customers; however, there was an expectation that those who rely on electricity for essential medical equipment should bear some responsibility for their own contingency plans.

Success criterion for objective 1 (what is the impact on customers of lost load?):

Demonstrated by criterion 1: *'An understanding of customer impact, how value is defined and how this might be influenced'.* This was met by providing an understanding of:

- Factors that affect the impact of loss of supply on customers
- How customers define reliability
- The general importance of communication to customers both before a PSI and during an unplanned interruption.

7.3 What is the value of this impact – financial and social costs to customers in £ per kWh?

The value of the financial and social impact on customers was established in a quantitative phase of research. This comprised a large-scale survey of 6,000 domestic and SME customers from across the whole of GB.

This research provides evidence that the existing single 'vanilla' VoLL, applied to all customer segments, fails to adequately reflect the significant variation that exists in the financial and social impact of supply interruptions across the full spectrum of customer types.

The study shows that domestic customers' willingness-to-pay (WTP) to avoid loss of supply is approximately £2,000 per MWh and the equivalent measurement for SMEs is £17,500[2].

Customers' willingness-to-accept (WTA) compensation for lost load is much higher than the comparable WTP figures for both segments. For domestic customers it is £17,500 and for the SME segment it is £47,500. Refer to Figure 7.3.1.

Figure 7.3.1: Overall VoLL in £/MWh among domestic and SME segments*

VoLL measure	Domestic	SME
Willingness to pay (£/MWh)	£2,000	£17,500
Willingness to accept (£/MWh)	£17,500	£47,500

**Figures rounded to nearest 100*

This finding was anticipated. It is consistent with previous studies in this area and is attributed to the psychological sense of loss from giving something up which feels greater than the gain from retaining it. This illustrates that customers are generally far less willing to accept a decrease in supply reliability than pay for an improvement. WTA assignments are considered to be most appropriate estimates to value security of supply for electricity and further information about the use of WTA can be found in Section 2.1 of the Phase 3 Report.

The WTP value cited in Figure 7.3.1 for domestic customers is comparable to the figure reported by London Economics in 2013[3] (£2,000 versus £2,000) while the one-off 'compensation' payment expected by customers to accept a decrease in service (WTA value) is higher (£17,500 v £12,000).

Success criterion for objective 2 (what is the value of this impact – financial and social costs to customers in £ per kWh?):

Demonstrated by criterion 2: *'A credible segmentation and future VoLL model by key customer groups to guide investment decisions'.* This was met, as outlined in the above findings.

7.4 How does this vary by customer type and supply interruption components?

Currently all customer types are treated uniformly; however, as explained in Section 7.3, VoLL differs substantially between domestic and SME customers, with the VoLL of commercial customers being significantly higher.

VoLL for domestic customers was found to be higher in summer than winter and this unexpected finding was consistent but more pronounced in the SME sample. Intuitively VoLL might be expected to be higher in winter than summer, given that the impact of an interruption is likely to be greater. However, unlike the London Economics research, where respondents were presented with seasonal attributes; this study asked participants to express their VoLL in relation to the 'worst possible time'. So in principle, the timing of the survey should not have had a large effect, which appears to be the case for domestic sample.

[2] Based on one hour of unplanned lost supply, every three years. All figures rounded to nearest £100.
[3] London Economics, 2013. The Value of Lost Load (VoLL) for Electricity in Great Britain, Final Report for Ofgem and DECC.

The study identified significant variations in VoLL across the broad customer spectrum sampled, influenced by socio-economic, demographic, geographic, attitudinal, behavioural and event-based factors. For example, a relatively high VoLL was identified in domestic customers aged 30-44, those in rural locations and those who want to see an improvement in supply. The VoLL of vulnerable customers is also high when adjusted to reflect income, and it is substantially higher for less affluent groups, e.g. those classified as 'fuel poor'. There are also significant differences within domestic and SME sub groups.

Figure 7.4.1 below demonstrates the variations in VoLL (WTA estimates) by domestic customer segment, based on analysis of the main survey. These values are for the baseline scenario of ***an unplanned outage of one-hour duration, once every three years, occurring at a time that would be most inconvenient***.

The VoLL results for domestic customers, for different frequency and duration of outage, are summarised later in this section and fully reported in Section 6.3 of the Phase 3 Report.

Figure 7.4.1: Domestic VoLL (WTA) by sub-groups[4] ***(main sample only)***

(Grey font indicates small sample size, interpret with caution)

Domestic WTA unplanned	Sample number	WTA	Lower	Upper	VoLL	Confidence interval (95%) Lower	Confidence interval (95%) Upper	Index v total
Total	3381	**£7.87**	£7.30	£8.44	**£17,481**	***£16,209***	***£18,753***	100
Female	1791	**£8.26**	£7.33	£9.18	**£18,432**	***£16,373***	***£20,490***	105
Male	1510	**£7.62**	£6.89	£8.36	**£16,891**	***£15,272***	***£18,510***	97
Age: 18 – 29	702	**£7.50**	£6.02	£8.98	**£16,516**	***£13,252***	***£19,779***	94
Age: 30 – 44	770	**£8.95**	£7.60	£10.31	**£20,042**	***£17,017***	***£23,066***	115
Age: 45 – 59	844	**£7.59**	£6.72	£8.46	**£16,921**	***£14,973***	***£18,869***	97
Age: 60+[5]	994	**£7.80**	£6.66	£8.94	**£17,237**	***£14,719***	***£19,755***	99
AB	835	**£8.13**	£6.93	£9.32	**£17,867**	***£15,241***	***£20,493***	102
C1	1040	**£9.05**	£7.97	£10.12	**£20,053**	***£17,667***	***£22,439***	115
C2	569	**£8.54**	£6.95	£10.14	**£19,217**	***£15,634***	***£22,801***	110
DE[6]	843	**£6.15**	£5.16	£7.13	**£13,667**	***£11,479***	***£15,855***	78
Rural	1023	**£9.63**	£8.29	£10.96	**£21,314**	***£18,361***	***£24,268***	122
Urban	2353	**£7.16**	£6.55	£7.77	**£15,934**	***£14,572***	***£17,295***	91
Electricity North West	969	**£6.46**	£5.39	£7.52	**£14,080**	***£11,752***	***£16,409***	81
Scottish and Southern Energy	294	**£10.60**	£7.88	£13.32	**£22,702**	***£16,880***	***£28,523***	130

[4] The average consumption for domestic customers is 0.00045 MW per hour. An average WTA value of £7.87 per hour (range £7.30 - £8.44) was obtained for all domestic customers, giving a MWh value of £7.87/0.00045 = £17,481 (range £16,209 - £18,753). The average consumption for SME customers is 0.00336 MW per hour. An average WTA value of £160 per hour (range £152 - £167) was obtained for all SME customers, giving a MWh value of £160/0.00336 = £47,560 (range £45,289 - £49,830). The actual calculations were based on numbers to 16 decimal places.
[5] Unadjusted for income (adjusted WTA = £19,372 (Index 111)
[6] Unadjusted for income (adjusted WTA = £20,501 (Index 117)

Domestic WTA unplanned	Sample number	WTA	Lower	Upper	VoLL	Confidence interval (95%) Lower	Confidence interval (95%) Upper	Index v total
SP Energy Networks	308	**£6.69**	£5.02	£8.36	**£14,707**	***£11,033***	***£18,380***	84
Northern Powergrid	378	**£8.01**	£6.35	£9.66	**£18,012**	***£14,283***	***£21,742***	103
Western Power Distribution	646	**£8.36**	£7.12	£9.60	**£18,285**	***£15,578***	***£20,991***	105
UK Power Networks	690	**£8.38**	£7.21	£9.54	**£19,289**	***£16,607***	***£21,971***	110
Worst served	163	**£3.16**	£1.07	£5.24	**£6,894**	***£2,345***	***£11,442***	39
Vulnerable[7]	1951	**£8.54**	£7.56	£9.51	**£19,632**	***£17,388***	***£21,875***	112
Fuel poverty[8]	239	**£17.52**	£15.25	£19.80	**£32,470**	***£28,256***	***£36,683***	186
Off-gas	721	**£7.13**	£5.61	£8.65	**£18,543**	***£14,598***	***£22,489***	106
LCT users	960	**£8.69**	£5.38	£12.00	**£18,973**	***£11,743***	***£26,203***	109
Domestic - Electric vehicle (EV)	275	**£9.20**	£0.54	£17.85	**£21,493**	***£1,264***	***£41,722***	123
Domestic - Solar panels (PV)	538	**£8.42**	£3.57	£13.28	**£17,884**	***£7,580***	***£28,189***	102
Domestic - Heat pump (HP)	428	**£8.98**	£2.52	£15.44	**£19,911**	***£5,578***	***£34,243***	114
Low usage	1216	**£7.26**	£6.44	£8.09	**£16,371**	***£14,510***	***£18,231***	94
Medium usage	1752	**£8.53**	£7.62	£9.44	**£18,768**	***£16,762***	***£20,774***	107
High usage	328	**£7.60**	£5.97	£9.24	**£16,504**	***£12,952***	***£20,056***	94
MDE (medically dependent)[9]	310	**£6.15**	£4.34	£7.96	**£18,013**	***£12,711***	***£23,315***	103
Want to keep bills constant	1265	**£7.19**	£6.36	£8.02	**£15,863**	***£14,024***	***£17,702***	91

[7] Adjusted for income (unadjusted WTA = £16,941 (Index 97)
[8] Adjusted for income (unadjusted WTA = £21,646 (Index 124)
[9] Adjusted for income (unadjusted WTA = £13,487 (Index 77)

Domestic WTA unplanned	Sample number	WTA	Lower	Upper	VoLL	Confidence interval (95%) Lower	Confidence interval (95%) Upper	Index v total
Want to keep reliability	963	**£7.85**	£6.80	£8.90	**£17,745**	***£15,368***	***£20,121***	102
Want to improve worse served	651	**£7.74**	£6.48	£9.00	**£17,261**	***£14,447***	***£20,075***	99
Want to improve supply	431	**£11.28**	£8.56	£13.99	**£25,334**	***£19,240***	***£31,429***	145
Low vulnerable[10]	872	**£8.63**	£7.25	£10.01	**£19,175**	***£16,115***	***£22,235***	110
Medium vulnerable[11]	397	**£8.99**	£6.78	£11.19	**£21,106**	***£15,929***	***£26,284***	121
High vulnerable[12]	417	**£7.09**	£5.20	£8.98	**£18,313**	***£13,427***	***£23,198***	105
No experience of power cuts (planned or unplanned)	1178	**£8.63**	£7.42	£9.83	**£19,221**	***£16,534***	***£21,908***	110
Experience of power cuts (either planned or unplanned)	2203	**£7.57**	£6.93	£8.22	**£16,802**	***£15,376***	***£18,228***	96
Experienced four or more unplanned power cuts	464	**£6.42**	£5.30	£7.54	**£14,233**	***£11,751***	***£16,714***	81
Experienced two or three unplanned power cuts	847	**£8.65**	£7.35	£9.96	**£18,780**	***£15,957***	***£21,603***	107
Experienced one unplanned power cut	723	**£8.85**	£7.46	£10.24	**£19,755**	***£16,646***	***£22,865***	113
Experienced no unplanned power cuts	1200	**£7.23**	£6.36	£8.10	**£16,093**	***£14,159***	***£18,028***	92
Experienced planned power cuts	859	**£7.30**	£6.05	£8.55	**£16,161**	***£13,395***	***£18,928***	92
Experienced large scale interruption in last 12 months	377	**£5.82**	£3.67	£7.96	**£12,140**	***£7,660***	***£16,619***	69
Impact of power cut – low	1442	**£8.83**	£7.88	£9.79	**£19,737**	***£17,605***	***£21,869***	113
Impact of power cut – medium	507	**£7.87**	£6.45	£9.28	**£17,316**	***£14,208***	***£20,423***	99
Impact of power cut – high	166	**£6.40**	£2.89	£9.91	**£13,613**	***£6,147***	***£21,078***	78

[10] Adjusted for income (unadjusted WTA = £17,447 (Index 100)
[11] Adjusted for income (unadjusted WTA = £16,608 (Index 95)
[12] Adjusted for income (unadjusted WTA = £15,211 (Index 87)

The main study also identified significant differences amongst SME customers. However, given the diversity of the SME sample in relation to size, economic activity and consumption profile, an additional 400 surveys were conducted following the publication of the main survey to deliver more robust and nuanced insights and allow further sub-segment analysis.

The effect of incorporating data from the 400 additional SME interviews into the original model was to increase the overall VoLL estimate for SMEs from £47,560 MW/hr (as evidenced in the Phase 3 Report) to £50,584 MW/hr.

The difference between this new figure (based on a sample size of 1003) and the value obtained in the main study (sample of 615) is not statistically significant[13]; suggesting that the result obtained from the larger sample does not make a case for changing the VoLL for all SMEs. This rationale is discussed in Section 4.1 of the Additional Survey Report, published on the VoLL webpage on 8 February 2019. However the result does suggest that, directionally at least, the VoLL for SMEs could be higher.

The values reported in Figure 7.4.2 are WTA values, by SME sub-groups and represent the analysis of the combined SME sample (main survey plus additional 400 surveys). For comparison, the SME values estimated from the main study only are shown in Appendix 1).

The values shown below in Figure 7.4.2 are for the baseline scenario of ***an unplanned outage of one-hour duration, once every three years, occurring at a time that would be most inconvenient***. The SME VoLL results for different frequency and duration of outage are summarised in Section 3.2 of the Additional Sample Report.

[13] A range of £49,006 to £52,162 at the 95% level of confidence versus £45,289 to £49,830 in the previous study results. The overlap, with £49,830 > £49,006 indicates that they are not significantly different, but the result is border-line.

Figure 7.4.2: SME VoLL (WTA) by sub-groups ***(main survey plus additional sample)***

SME WTA unplanned	Sample number	WTA	Lower	Upper	VoLL	Confidence interval (95%)		Index v total	
						Lower	Upper	Main + additional	Main only
Total	1003	**£170**	*£165*	*£175*	**£50,584**	*£49,006*	*£52,162*	**100**	*100*
Rural	202	**£198**	*£182*	*£214*	**£71,433**	*£65,635*	*£77,232*	**141**	*144*
Urban	699	**£160**	*£154*	*£166*	**£45,453**	*£43,792*	*£47,115*	**90**	*92*
Electricity North West	712	**£175**	*£169*	*£182*	**£40,160**	*£38,744*	*£41,576*	**79**	*100*
Off-gas	483	**£218**	*£211*	*£225*	**£54,283**	*£52,627*	*£55,939*	**107**	*103*
LCT users	254	**£32**	*£22*	*£41*	**£13,081**	*£9,320*	*£16,842*	**26**	
No power cuts (either planned or unplanned)	391	**£186**	*£177*	*£195*	**£49,472**	*£47,120*	*£51,823*	**98**	*80*
Power cuts (either planned or unplanned)	596	**£161**	*£155*	*£168*	**£54,999**	*£52,639*	*£57,359*	**109**	*108*
Impact of power cut – low	283	**£125**	*£118*	*£133*	**£48,796**	*£45,918*	*£51,675*	**96**	*89*
Impact of power cut – medium	209	**£164**	*£149*	*£179*	**£51,613**	*£46,884*	*£56,342*	**102**	*77*
Impact of power cut – high	116	**£190**	*£171*	*£208*	**£60,396**	*£54,547*	*£66,244*	**119**	*116*
Want to keep bills constant	312	**£185**	*£175*	*£195*	**£55,868**	*£52,880*	*£58,857*	**110**	*96*
Want to keep reliability	249	**£145**	*£135*	*£154*	**£47,783**	*£44,652*	*£50,913*	**94**	*81*
Want to improve worse served	202	**£183**	*£168*	*£198*	**£53,859**	*£49,554*	*£58,165*	**106**	*134*

SME WTA unplanned		Sample number	WTA	Lower	Upper	VoLL	Confidence interval (95%)		Index v total	
							Lower	Upper	Main + additional	Main only
Want to improve supply		230	**£134**	*£126*	*£142*	**£33,033**	*£30,998*	*£35,069*	**65**	*69*
Winter		707	**£122**	*£117*	*£127*	**£30,957**	*£29,711*	*£32,204*	**61**	*40*
Summer		287	**£229**	*£217*	*£240*	**£81,628**	*£77,540*	*£85,717*	**161**	*164*
Experienced planned power cut		302	**£157**	*£147*	*£167*	**£64,611**	*£60,459*	*£68,764*	**128**	*122*
Experienced four or more unplanned power cuts		124	**£191**	*£177*	*£206*	**£80,081**	*£73,844*	*£86,319*	**158**	
Experienced two or three unplanned power cuts		240	**£131**	*£120*	*£142*	**£44,852**	*£41,094*	*£48,610*	**89**	
Experienced one unplanned power cut		197	**£179**	*£168*	*£190*	**£45,163**	*£42,422*	*£47,905*	**89**	
Experienced no unplanned power cuts		397	**£175**	*£167*	*£182*	**£43,325**	*£41,499*	*£45,150*	**86**	
Sector Group	Utilities, manufacturing, construction, retail, transport	296	**£177**	*£165*	*£189*	**£73,703**	*£68,846*	*£78,561*	**146**	
	Accommodation, information, finance, professional	189	**£63**	*£58*	*£68*	**£23,045**	*£21,064*	*£25,026*	**46**	
	Admin, education, health, arts	209	**£171**	*£155*	*£188*	**£76,763**	*£69,390*	*£84,136*	**152**	
	Other services	141	**£229**	*£209*	*£249*	**£48,083**	*£43,892*	*£52,273*	**95**	
	Other	243	**£234**	*£221*	*£247*	**£64,497**	*£60,940*	*£68,053*	**128**	
Public		259	**£43**	*£36*	*£50*	**£18,839**	*£15,774*	*£21,905*	**37**	
Not public		725	**£198**	*£191*	*£204*	**£55,544**	*£53,712*	*£57,376*	**110**	

To understand how VoLL varies by supply interruption component, the study also sought to understand:

The impact of the scale and duration of a supply interruption on VoLL

The research established that an outage generally incurs a higher VoLL the longer it lasts. However, the marginal hourly value declines steadily; there is a levelling out in the upward trajectory of VoLL for extremely long duration interruptions typically associated with extreme weather events. This is likely to reflect an awareness that such incidents are largely outside the control of the DNO and therefore less worthy of additional compensation.

For domestic customers who experience one unplanned outage in a three-year period, VoLL increases by approximately 80% when the duration rises from one hour to 12 hours. There is also a significant increase in VoLL when the number of outages experienced in a three-year period exceeds six. The VoLL for planned interruptions is substantially less than for unplanned outages, but this reduction diminishes as frequency increases.

For SMEs a similar pattern is observed for unplanned and planned outages. However, there is a suggestion that while there is tolerance for limited planned work requiring outages; acceptance diminishes after more than three planned interruptions lasting a full day over a three-year period. This demonstrates the importance of a cohesive approach to construction and maintenance strategies and the need to consolidate planned work where possible.

Success criterion for objective 3 (how does this vary by customer type and supply interruption components?):

Demonstrated by criterion 2*: 'A credible segmentation and future VoLL model by key customer groups to guide investment decisions'.* This was met by:

- Demonstrating how VoLL varies by customer segment
- Building the values derived into a VoLL calculation tool, which allows DNOs to identify VoLL for any customer type.

Success criterion 3 *'A demonstration of how these values would help Electricity North West and other DNOs to better plan their network investment strategy'* has been met by:

- Demonstrating how DNOs could utilise the new tool to calculate the collective VoLL of customers served by specific assets, to attain a greater understanding of need and dependence when prioritising investment decisions.

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

The research identified two main ways to mitigate the costs of loss of supply to customers:

Proactive network investment, to reduce the duration and frequency of supply interruptions

The research established that because VoLL increased as the duration and frequency of interruptions increased, network investment designed to reduce interruptions would mitigate the costs of lost load to customers. The earlier qualitative phase of research corroborates that the impact of loss of supply was perceived to be higher for unplanned interruptions, emphasising the value of proactive network reinforcement.

Effectively communicating with customers during supply interruptions to provide accurate information about when power will be restored.

The research identified that proactive network investment, to reduce the duration and frequency of interruptions, will mitigate VoLL. However, in addition to testing the core set of supply interruption attributes the study also explored:

- Levels of additional assistance available for vulnerable customers
- Communication channels via which information about the supply interruption can be proactively provided
- Quality of information provided.

Targeted customer communications, such as telephone calls made directly to domestic customers are more than three times as effective in mitigating the impact of a supply interruption as updates through social media. In the case of proactive telephone calls the analysis suggests that these can directly mitigate the loss of supply for up to five minutes in an hour (refer to Appendix 6.5 in the Phase 3 Report).

The implication suggested by these findings, is that offering support to customers could provide an economically efficient means of reducing the impact of lost supply and consequently positively influence VoLL.

Priorities were similar for SME customers, for whom the most important components were: updates sent via SMS, proactive telephone calls and accurate information about supply restoration.

The research also exposes significant differences in the value placed on various support and communication strategies by those aged 18-29, where greater value is placed on information relayed via social media (Twitter, Facebook etc), suggesting that effective communication and support strategies must evolve to reflect diversity and the changing needs/expectations of customers.

It is also worth noting that social media platforms are more important for SME customers. It is reasonable to assume that this is because of the value that business customers place on instantaneously updated information is now an expectation rather than an aspiration.

Further details about VoLL mitigation are provided in Section 2.8 of the Phase 3 Report

Success criterion for objective 4 (how can Electricity North West and key stakeholders mitigate the costs of loss of supply to customers?):

Demonstrated by criterion 1 '*An understanding of customer impact, how value is defined and how this might be influenced (e.g. better communications)'* was met by:

- Providing a detailed understanding of the methods of communication that may reduce VoLL
- Demonstrating that VoLL is mitigated by the effective management of customer expectations regarding and during supply interruptions.

These findings also met success criterion 4 -*'Guidance on customer compensation strategies' by:*

- Demonstrating how current customer compensation strategies might be reviewed with consideration given to the personal and societal impact of supply interruptions on specific groups, especially fuel poor, vulnerable and those living in rural areas who have a higher VoLL.
- Section 2.5 of the Phase 3 Report discusses the impact of scale and duration on outages on VoLL. The present 12 hour qualifying period for an electricity guaranteed standard (EGS)[14] payment negates the large increase in VoLL for an unplanned interruption when the duration

[14] RIIO-ED1 regulatory instruction and guidance: Annex 7 - Interruptions

increases from one hour to six hours. The high magnitude of increase is apparent across the various frequencies tested for both domestic and SME customers, with a subsequent lower hourly rate incurred the longer the outage lasts

- There is a marked difference in VoLL between planned and unplanned interruptions, with a significantly lower VoLL for planned outages. Currently customers are entitled to a payment when the DNO fails to provide the required notice. Given the impact of effective communication in mitigating VoLL, future compensation strategy may need to reflect the importance of adequately communicating with those most impacted during unplanned outages.

These observations and inferences are discussed in more detail in the Conclusions and Recommendations (Executive Summary) Report, published on the project webpage on 5 October 2018.

7.6 How will VoLL vary with low carbon technology adoption?

The electricity industry accepts that there will be fundamental changes in customer behaviour associated with the widespread adoption of LCTs. As a consequence it is considered likely that current estimates of VoLL will significantly change. A key objective of this study was to investigate the potential changes and the impact on VoLL assignment, to ensure that future policy is driven by evolving customer needs.

The qualitative and pilot phases of the research identified that current non-users of LCTs found it difficult to envisage how the adoption of new technologies might change the impact of lost supply in the future. Therefore, to estimate how values will vary with increased LCT adoption, VoLL estimates were calculated for current users of LCTs, as these early adopters are most reflective of the future scenario.

The VoLL of domestic customers using LCTs, who, as a consequence, have an increased dependency on electricity, is +9% higher than the average for all domestic customers. VoLL for users of heat pumps is higher at +14% and increases further for EV users at +23%. This is a significant finding for determining future network investment needs and standards driven by VoLL as LCT adoption is projected to increase.

Given the anticipated increase in LCT adoption and hence customers' future greater dependency on electricity, the expected increase in VoLL has significant implications for DNOs' long-term investment strategies. Further details about VoLL relative to LCT adoption are outlined in Section 2.2 of the Phase 3 Report.

The main survey identified a similar difference among SME customers; however, the sample size was insufficient to draw any meaningful conclusions. The additional SME surveys conducted in October 2018, provided an enhanced WTA sample of SME LCT users, made up of 254 respondents. Analysis of this sub-segment unexpectedly revealed a very low VoLL compared to the average for all SME customers, around a quarter of the value. However, differences in the profiles of SME LCT users versus non-users, suggests that the difference in VoLL is unlikely to be a result of LCT adoption and more a reflection of the different types of business that are likely to use LCTs.

Success criterion for objective 5 (how will VoLL vary with low carbon technology adoption?):

Demonstrated by: criterion *2 'A credible segmentation and future VoLL model by key customer groups to guide investment decisions'.* This was achieved by:

- Providing an assessment of VoLL for current LCT users, who represent the best practicable means of understanding likely changes in future VoLL, on the basis that these customers' most accurately reflect evolving needs and expectations.
- Including data for this segment in a prototype VoLL calculation tool which demonstrates a mechanism for DNOs to identify the future VoLL for any customer type.
- Increasing the size of the SME sample to provide more nuanced insights concerning LCT adoption in this segment.

7.7 Summary of additional outcomes

In meeting the above objectives the study also sought to answer the following hypothesis:

How would the level of incentives tested for DSR in other LCN Fund trials compare to future VoLL?

The Capacity to Customers (C2C) study carried out in 2015 by Electricity North West, sought to obtain a price per MW of demand response from industrial and commercial (I&C) customers. One of the key objectives of C2C was to establish an optimal price point at which commercial customers are willing to 'trade', i.e. to accept a short-term detriment in service in return for an incentive. While at first inspection the VoLL and the price to purchase demand side response appears to represent a similar customer valuation of a supply interruption, research has shown these values to be very different. Although conceptually the trade-off associated with C2C was comparable to the VoLL WTA, there were important differences between the two studies which meant that comparison of the results was not possible.

8 THE OUTCOME OF THE PROJECT

8.1 Summary of outcome

The project developed a credible methodology to estimate VoLL across a diverse range of customers. An extensive programme of engagement has delivered a comprehensive understanding of VoLL over time and by customer segment.

The research has defined the different impacts of supply interruptions across a diverse range of domestic and SME sub-groups. It reveals that the range of values is almost double when considering the lowest to highest estimates reported. This suggests that the current VoLL model undervalues the needs of certain customers, for example those dependent on LCTs, off-gas customers and the fuel poor; however, it may over-represent the needs of other customer groups.

The study demonstrates how VoLL is influenced by frequency and duration. It also reveals that the overall estimate of VoLL has risen since the last major study conducted by London Economics in 2013, suggesting increasing customer dependence and expectation.

This project has provided clear evidence that a single 'vanilla' VoLL applied to all customer segments, may no longer be appropriate. The findings allow a much more representative VoLL model to be established. This more sophisticated approach could significantly improve efficiency in the targeting of investments, and ensure that those investments are based on a richer, more representative understanding of need, by adding a customer driven dimension to the decision-making process.

As a result, the project has delivered a prototype VoLL calculation tool and made recommendations for how this might be applied to help guide future investment decisions.

This research approach is set out in the detailed methodology statement (version 2) published on the VoLL webpage on 29 July 2016. This document is supported by a literature review, peer review and a summary of stakeholder consultation which informed the method. The customer research activities were underpinned by a comprehensive customer engagement plan and data privacy statement.

Key findings are documented in the Phase 3 Report, published on the VoLL webpage in October 2018. This document is supported by an extensive Technical Appendix. A separate Conclusions and Recommendations Report was produced to support the Phase 3 Report which was also published in October 2018. This presents an argument for adopting a segmented VoLL model and suggests a framework for developing the VoLL calculation tool.

The following sections summarise the main outcomes associated with each phase of the project:

8.2 Phase 1: Understanding the problem

Phase 1 of the study was devoted to gaining a contextual understanding of VoLL and formalising the optimal method to obtain accurate segmented VoLL estimates. The VoLL methodology statement (version 2), along with three supporting addendums (a literature review, peer review and stakeholder consultation) were produced in phase 1 and these were published on the VoLL webpage on 29 July 2016.

8.3 Phase 2: Refining the approach

Phase 2 of the study comprised:

- Focus group meetings with an engaged customer panel (ECP)
- Depth interviews with a cross-section of difficult-to-reach customers, and with stakeholders likely to be in contact with customers, or support customers, during supply interruptions
- Design, evaluation and pilot of a survey instrument.

A comprehensive customer engagement plan and a data privacy statement were developed before any form of customer engagement took place. These documents were submitted to Ofgem for approval on 9 February 2016 and confirmation of approval was received on 14 April 2016.

Direct customer consultation explored the needs and expectations of a diverse range of customers served by different types of networks, with varied experiences of supply interruptions. Stakeholder consultation was valuable in gaining a wider societal and industry perspective which guided refinements to the overall research approach. The objectives and outputs of this phase of the study were summarised in the first annual VoLL Project Progress Report (PPR), published on 22 July 2016. Key findings and lessons learned from consultation with the ECP were published on the project webpage on 23 August 2016 and learning from the depth interviews was published on 31 August 2016.

Relevant customer insights from the focus group meetings and depth interviews were integrated into the design and administration of the customer survey. The resulting questionnaire was subject to a peer review and a robust pilot before being fully launched. These activities were summarised in the second annual PPR, published on 31 July 2017 and are fully documented in the peer review report dated 30 August 2016 and the Pilot Report dated 30 November 2016, both of which are published on the project webpage.

8.4 Phase 3: Measuring VoLL

8.4.1 Seasonal survey

The final stage of direct customer engagement was to administer the large-scale quantitative survey, designed to provide insight into the following research questions:

- Does VoLL vary by customer segment and what are the relative value assignments of these segments?
- 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?

A total of 6,000 customer surveys (comprised of 5,000 domestic customers and 1,000 representatives of small to medium enterprises), were completed during this phase of the study. The surveys were carried out in two distinct seasonal phases between 2016 and 2017, as reported in the third annual VoLL PPR, published on the project webpage on 31 July 2018.

The survey included a 'stated preference choice experiment' (CE) which is widely accepted as the most robust technique for measuring metrics such as VoLL. This involved asking customers to trade off scenarios which presented different levels of supply reliability and support, in exchange for a hypothetical payment or penalty.

The choices made by respondents inferred their willingness to pay (WTP) higher prices for a better service, or their willingness to accept (WTA) compensation for a loss in service. This approach is generally considered to provide more objective measures of WTP and WTA than direct questioning.

The analysis provides clear evidence of the different impact of a supply interruption across a range of domestic and SME sub-groups, which has the effect of large variations in the assignment of VoLL. These results are summarised in Section 7.4 above, and fully documented in the Phase 3 Report. These findings demonstrate how understanding relative VoLL components at a much more granular level, provide an opportunity for improvements in DNOs' current cost-benefit analysis models, which would deliver greater efficiency in future investment decisions.

These findings support the project's primary research objective that a single uniform VoLL, applied to all customer segments, which assumes that all customers are equally impacted, may no longer be appropriate.

8.4.2 Further modelling and reporting

Independent peer reviews were conducted to substantiate the findings before dissemination to key stakeholders. These critiques recommended more detailed modelling to provide like-for-like comparisons with the results of the original London Economics study, along with more detailed reporting around specific 'treatments', i.e. to compare planned versus unplanned outages, WTA versus WTP values, and domestic versus SME results etc.

The original approach to the analysis of the CE which formed part of the survey was a hierarchical bayesian (HB) method, designed to estimate values for individual respondents. However, in response to the critique a multinomial logit econometric estimation method was utilised to convert the CE results into £/MWh VoLL figures and confidence intervals. This allowed more direct comparison with the earlier London Economics study.

The results of this analysis are documented in the main Phase 3 Report and its accompanying Technical Appendix, which describes the rationale for the CE and modelling approach. These documents are accompanied by a Recommendations Report, also published on 5 October, which suggests a framework for a credible VoLL calculation tool and how this might be applied to help guide future investment decisions.

8.4.3 Supplementary surveys – winter 2018

The re-modelling exercise outlined above resulted in the separation of the WTP/WTA analysis into two separate exercises (WTP only and WTA only), which effectively halved the number of observations on which the final modelling was based. This affected the stability of results for sub-groups with small sample sizes; therefore, to strengthen results in these areas an additional 500 customer surveys were conducted, this:

- Provided more robust analysis of worst-served customers (WSC); and
- Increased the sample size of SMEs such that more nuanced sub-group analysis could be conducted.

This additional research revealed some small differences in point estimates of WTA reported in the new samples compared to the main study; however, the peer review concluded that there was not sufficient statistical evidence to claim any meaningful difference for either the WSC or SME samples. Nonetheless some interesting details did emerge which are summarised in Section 9.2.3 of this document and reported in detail in the VoLL Additional Sample Report, published on the project webpage on 8 February 2019.

8.4.4 Stakeholder updates

VoLL findings were presented to Ofgem's Network Output Measures (NOMs) cross-sector working group by Electricity North West's Head of Asset Management on 19 February 2018. Project outcomes were disseminated further to Ofgem in September 2018 and the results of research to date and planned next steps were presented to Ofgem's Reliability, Safety and Environment working group on 23 May 2019.

The results and implications of VoLL findings were disseminated to industry stakeholders at an innovation and learning event hosted by Electricity North West on 4 July 2017. The findings were subsequently shared with a broad and inclusive range of relevant stakeholders at the Affordability and Sustainability Advisory Panel workshops in July 2018, during which stakeholders endorsed additional research into fairness, the socialisation of costs and the practicalities of adopting an alternative model.

Interim VoLL findings were disseminated at the Low Carbon Networks and Innovation (LCNI) Conference in Telford on 7 December 2017 and a project factsheet was made available to industry stakeholders at the LCNI in October 2018.

In addition, regular Innovation updates have reported the progress made in VoLL research to industry stakeholders and Electricity North West's executive leadership team (ELT) in: July 2016, October 2016, February 2017, November 2017, January 2018, August 2018 and March 2019.

All outputs and learning attained from the VoLL study have been made available to other DNOs. All materials developed and learning derived from this project are publicised on the VoLL webpage.

8.5 Opportunities for future projects to develop learning further.

To move towards the practical implementation of a differentiated VoLL, it is recognised that further analysis is required to explore the requisite level of sophistication needed in a credible decision

making tool and the appropriate mechanism for practicable implementation at scale, refer to Section 12 which discusses planned implementation.

Stakeholder feedback also recommended further empirical customer research to test the impact of different scenarios, including the 'multiplier' effect on VoLL of scale and duration, when assessed on the basis of the entire community, rather than the individual.

This project was unable to provide an extrapolated population measure based on the actual VoLL of each individual customer, but concluded that a good approximation could be obtained by using the mean VoLL from groups of customers (as derived from the survey), based on their characteristics. In this way, the single VoLL calculated from the values derived for each group will give a more representative overall estimate.

To meet these requirements, supplementary research will be conducted under Electricity North West's Network Innovation Allowance (NIA) portfolio. The follow on project was registered on the ENA Smarter Networks Portal in October 2018, entitled VoLL2 (ENWL021). Please refer to the VoLL2 project registration document for further details.

9 REQUIRED MODIFICATIONS TO THE PLANNED APPROACH DURING THE COURSE OF THE PROJECT

9.1 Phase 1 & 2: Understanding the problem/refining the approach

9.1.1 Adaptation of proposed methodology

Based on the learning from phases 1 and 2 of the study, a far more complex research methodology than had been originally anticipated was necessary in phase 3. This could not have been anticipated in advance of the study and resulted in a divergence from the proposed approach, which was to replicate the core principles of the VoLL study, conducted by London Economics for Ofgem in 2013. The project team is confident that the resulting methodological changes were justified to deliver robust and credible results at a granular level.

The required modifications to the planned approach arising in phases 1 and 2 were summarised in the second annual PPR, published on 31 July 2017.

9.1.2 Expansion of the role of the engaged customer panel (ECP)

In response to feedback from the former Department of Energy and Climate Change in 2016 (during phase 1), the role of the ECP was to be expanded to include a customer evaluation of the research findings and implications.

It was intended that focus group meetings would be held following publication of the learning outcomes in the Phase 3 and Recommendation Reports (as reported in the third VoLL PPR dated 31 July 2018). However, in view of stakeholder feedback advocating further empirical evidence to better understand the multiplier effect and gauge customer perceptions about fairness; a follow up study was recommended. As outlined in Sections 8.5 and 12, this supplementary research will also be conducted under Electricity North West's NIA portfolio.

9.2 Phase 3: Measuring VoLL

9.2.1 Winter survey

Following a peer review of the survey instrument and the pilot survey, a number of refinements were made to the questionnaire and accompanying educational materials before launching the full

survey. These modifications were summarised in the second annual PPR dated 31 July 2017 and are fully documented in the Peer Review Report dated 30 August 2016 and the Pilot Report dated 30 November 2016.

No subsequent changes were required to the main survey instrument or its administration.

9.2.2 Analysis and reporting

The stated preference CE scenarios used in the customer survey were designed to follow a similar format to the earlier London Economics study for compatibility. However, the content of Electricity North West's CE and its analytical approach differed in a number of respects to derive more robust, granular VoLL assignments by distinct customer segment.

Interim analysis identified significant variations in VoLL across a range of customer segments and these results were externally peer reviewed by two independent academic experts. In light of the deviation from the original methodological approach, the critique recommended further modelling to substantiate the findings and compare attribute definitions with the earlier London Economics study in 2013.

The original approach to the analysis of the 'discrete choice experiment' (CE), which formed part of the survey was a HB method, designed to estimate values for individual respondents. However, in response to the critique, a multinomial logit econometric estimation method was utilised to convert the CE results into £/MWh VoLL figures and confidence intervals. This allowed more direct comparison with the earlier London Economics study and a basis for comparing and contrasting the final HB results at the aggregate level. The final results were subject to further peer review by Professor Iain Fraser from the School of Economics, University of Kent.

This modification delivered:

- More detailed modelling of data to demonstrate compatibility and continuity with the previous study.
- Further advanced analytics to validate the granular outputs and evaluate the range of certainty around these values. This analysis is documented in the Phase 3 Report, published on the project webpage on 5 October 2018. This is supported by a detailed Technical Appendix, which describes the rationale for the CE and modelling approach.
- Enhanced reporting and further external validation to add credibility to the overall findings and satisfy industry stakeholders that best practice methods were implemented.

This change could not have been anticipated in advance of the study. The variation extended the proposed project end date and increased the estimated budget to £731,000

9.2.3 Follow on customer research to supplement the main study

The change to the originally proposed analytical model (as outlined in Section 9.2.2) resulted in the separation of the WTP/WTA analysis into two separate exercises (WTP only and WTA only). This effectively halved the number of observations on which the modelling of the duration and frequency was based. This affected the stability of results for sub-groups with sample sizes of less than 200.

In light of the above, the academic peer review identified a need for supplementary surveys to strengthen the results of the WSC and SME sample. These surveys were carried out under the VoLL2 project, the results of which can be found in the Additional Sample Report, published on both the VoLL and the VoLL2 project webpages on 8 February 2019. These findings are also referenced in the first VoLL2 PPR, published in July 2019. However, as these research results strengthen the overall learning of the main VoLL study, the rationale and key findings are briefly summarised below:

- It was not possible in the main study to provide a definitive explanation for the directionally lower VoLL expressed by domestic customers classified as 'worst served', because of the relatively small 'WTA' sample size of this group and the mix of 'objective' and 'self identified' definitions. The main VoLL study suggested that customers served by poorly performing networks have a lower reference state than those used to a higher level of service. Therefore further research was recommended to increase the sample size with 'objectively-defined' customers only, i.e. those served by networks meeting the Ofgem classification of 'worst served'.

  Analysis of the larger sample, which included 100 additional surveys, identified that the VoLL for objectively-defined WSCs (£13,736) is largely the same as VoLL for the average domestic customer served by Electricity North West's network (£14,080), as estimated in the main study. This figure is lower than the value of £17,481 MW/hr for all domestic customers, GB-wide.

- Given the diversity of the SME sample in relation to size, economic activity and consumption profile, additional 'WTA' surveys were recommended to deliver more nuanced insights of VoLL assignments of SME customers, across a range of industry sectors.

  Analysis of the overall SME VoLL, based on a larger WTA sample (1,003 versus 615), did not significantly change the average SME estimate of £47,560 MW/hr, as measured in the main study. However, the directional finding suggests that this value could be slightly higher than originally reported (with an average of £50,584 MW/hr based on the larger SME sample).

9.2.4 Further research to support the main study (VoLL2)

The VoLL study successfully established the value that different customer groups place on the value of the electricity supply; however, it also introduced a number of questions which our stakeholders believe warrant further investigation. Therefore, a follow-up study, VoLL2 (ENWL021) will be conducted under the NIA. The VoLL2 project was registered in October 2018 and details of the research are contained in the registration document.

10 PROJECT COSTS

Final project costs came in under budget as per the table below:

Figure 10: Cost variance table

Item	Category	Estimated costs (£k)	Final costs £k (rounded)	Variance
1	Project management	214,804	146,349	-68,455
2	R&D (Impact Research)	516,196	516,196	0
	Total	**731,000**	**662,545**	**-68,455**

11 LESSONS LEARNT FOR FUTURE PROJECTS

This project has delivered a credible segmentation of VoLL and demonstrated significant variations across different domestic and business sub-groups. The project has also demonstrated how VoLL can be estimated for customers defined by multiple characteristics (i.e. more than one household attribute). This involved testing accuracy using the multiplicative model, which concluded that the most accurate method for deriving VoLL for complex households is to obtain these for only two

sub-groups at a time. However, it was recognised that further detailed analysis of the key VoLL drivers will be required to determine the optimum level of complexity in a disaggregated model for its practical implementation (refer to Section 12).

The follow on study (VoLL2) will consider the impact of a more sophisticated approach on the CBA/lifetime costing of investment decisions. This analysis will also assess the stability and variability of VoLL characteristics over time. This project will involve consultation with key industry stakeholders to consider the most practicable mechanism for a disaggregated model at scale, along with the regulatory implications and practicalities of national implementation of a new tool, which maintains the principals of the CNAIM and NOMs.

The lessons learned from this project and the additional learning expected from VoLL2 will ensure DNOs continue to target investment in the right areas to manage network risk effectively and will continue to deliver their primary outputs in the future.

Lessons learned that will influence the approach and administration of future research, of a similar nature, are summarised below.

11.1 Phase 1: Understanding the problem

Lessons learned during phases 1 and 2 are referenced in the 2016 and 2017 PPRs. The latter report also includes early lessons learned from phase 3, specifically concerning the administration of the winter survey. The following represents lessons learned from the summer and final phase of customer survey fieldwork and the subsequent analysis:

11.2 Phase 3: Measuring VoLL

11.2.1 Customer survey and fieldwork

The benefit of a comprehensive pilot survey, followed by thorough analysis of responses, cannot be underestimated. There should be scope to conduct small or large scale changes at this early stage to benefit the overall research.

Early analysis of the winter survey confirmed that amendments made to simplify the CE, following the pilot survey, had a positive impact on respondents' ability to comprehend the exercise in the main survey. Refinements made following the pilot ensured there was greater parity in the trade-off scenarios which meant that it was easier for respondents to make considered choices when stating a preference. Analysis of a second pilot was conducted before proceeding to the main survey. This found that respondents provided more complete information than in the initial pilot, even though the time taken to complete the CE was shorter. These findings were confirmed in the main seasonal survey. The enhancements made are summarised as follows:

- Splitting the CE so that respondents only ever traded off planned or unplanned scenarios. For example, planned attributes and levels were evaluated alongside other planned attributes and levels. This approach was clearer for respondents, allowing them to consider more meaningful comparisons. The approach also provides greater insight in customer attitudes towards planned versus unplanned outages.

- Removing some of the levels in the CE for attributes found to have a linear relationship (duration, frequency and cost). Analysis confirmed that this did not negatively impact the ability to calculate VoLL.

Respondents may not read communications materials embedded into a survey; they may be unwilling to spend time sourcing accurate information (in this instance from electricity bills) and are sometimes reluctant to provide information that could identify them.

Analysis of responses to 'open questions' contained in the main seasonal survey revealed the following:

- Customers found it difficult to identify their DNO with 35% selecting 'don't know' even when provided with a map clearly defining regional boundaries. It is therefore useful to collect postcode information when conducting a GB-wide survey, to validate both domestic and commercial respondents' DNO/IDNO.

- Despite the provision of clear instruction SME customers found it difficult, or were unwilling, to provide their meter point administration number (MPAN), further validating the need to collect postcode, address, or company information, where required to substantiate key responses.

- Domestic and SME customers are more inclined to provide postcode information when its purpose is clearly explained; however, it should be recognised that a proportion of respondents will actively safeguard their anonymity and purposefully omit data which links them to their residence or place of work. Appropriate mitigation should be incorporated into similar survey instruments to minimise the potential for erroneous entries.

- Actual electricity consumption data was obtained from meter readings with the explicit consent of respondents. This was achieved by using the MPAN, postcode and address details provided, to retrieve records held in the Distribution Use of System (DUoS) and Associated Distribution Systems national database. However, the data contained some anomalies and it was necessary to develop a tool to calculate annual consumption for the purpose of the analysis. This took into consideration: meter changes; multiple readings associated with 'multi rate differential tariffs'; erroneous readings; and those where an incorrect number of digits were recorded.

- When questioned about LCTs, customers are generally familiar with (and can therefore make informed decisions about) solar panels and EVs; however, the pilot research identified that this does not apply in the case of electric heat pumps. The majority of respondents had limited understanding or were completely unaware of what heat pumps are and, consequently, required additional educational information and context before they could make reasonably informed choices in response to the presented scenario questions. The additional communication materials introduced in the main seasonal surveys led to a significant decrease in the proportion of customers reporting that they did not know whether their heating and/or hot water was supplied by a heat pump.

11.2.2 Analysis and critique

Sufficient time and financial contingency should be factored into projects to accommodate the implementation of pertinent recommendations that arise when outputs are subject to independent critique.

In view of the deviation from the original methodological approach and the industry interest generated by this research project, it was considered prudent to conduct a more extensive critique of the general approach and findings than was anticipated at the outset. This recommended further modelling to validate the findings and compare attribute definitions with a previous study conducted for Ofgem.

Consultation with experts involved in previous studies and direct comparison of analytical methods, to provide like-for-like comparisons in results, is recommended in future projects. This will underpin findings arising from methodological divergence, particularly where industry implications are significant and outputs are likely to be subject to high levels of scrutiny.

11.2.3 Requirement for additional research – integration of findings

Similar research should anticipate the variability of results in key customer groups to ensure sufficient quotas are attained. The effect and implications of incorporating supplementary research into an existing model (particularly where the approach deviates from the original method) can be significant and introduces a risk of compromising the original findings.

As outlined in Sections 9.2.3 and 11.2.2, an additional 500 surveys were conducted in the latter part of 2018 to strengthen the results of the domestic WSC and SME sample. The survey instrument developed for the main study was used as the vehicle to obtain the supplementary sample, but respondents were only asked to considerer scenarios framed in a 'willingness-to-accept' (WTA) context for 'unplanned' outages in the choice experiments (CEs), to ensure the activity was efficient and cost effective. To maintain consistency with the earlier research the same statistical model specification was used to examine all of the additional survey data. The method for incorporating these results into the model was robustly debated, and was subject to academic challenge to ensure the most appropriate mechanism was adopted. This is discussed in Appendix 4 of the VoLL Additional Sample Report, published on the project webpage on 8 February 2019.

12 PLANNED IMPLEMENTATION

Historically VoLL has been set as a single figure and applied at a national level. This figure has been derived from previous customer surveys and desktop research.

This project has identified that:

- There is major diversity around the average VoLL which needs to be reflected in investment decision-making if infrastructure operators are to truly reflect customer valuation of service.
- The overall VoLL value currently used may be understated given changes in customer usage of electricity with the increasing adoption of LCTs.

However, this empirical research can only be applied in practice if it is integrated into the relevant regulatory mechanisms, which in RIIO-ED1 includes a 'hard coded' approach to VoLL in the investment decision models DNOs use as an industry standard. As a result, any new VoLL approach will need to be adopted on an industry wide basis and be agreed by Ofgem.

DNOs use a range of decision support models in their investment decision making; and Ofgem use the concept of VoLL to calibrate regulatory incentives on network performance. At present, these models use the single national standard figure for VoLL which is also aligned to the equivalent in the Transmission price control (RIIO-T1).

Ahead of the next round of price controls for the DNOs (RIIO-ED2, running from April 2023 to March 2028), Electricity North West is embarking on an exploration of how these decision-making approaches and incentives should be adapted to incorporate disaggregated VoLL values, which reflect diversity, as evidenced by this research. This research is being conducted in a follow-up study under Electricity North West's NIA portfolio (VoLL2 – ENWL021).

In order to be adopted as a new nationally-applicable approach, the variable VoLL concept needs to be adapted into the regulatory framework and current 'business as usual' approaches. As such, the scope of VoLL2 is to:

- Review the relevant regulatory mechanisms which use the current VoLL value and identify how these can be adapted in the future.

- Based on research published under this project, explore, assess and identify the appropriate scale of deployment in each case identifying a practical approach that brings investment targeting benefits without excessive complexity / investment management cost; and
- Build or adapt models as appropriate to demonstrate how this would work in practice.

One application of VoLL for example, is use of the current single value as the parameter to set the marginal rate at which consumers' value avoiding power cuts within the RIIO Interruptions Incentive Scheme (IIS). This rewards or penalises DNOs for deviations in power cut performance against pre-set targets. As a result, it is also used in models which evaluate the potential risks and benefits to the DNO of changes in power cut performance as a consequence (either primarily or incidentally) of investment. In Ofgem's RIIO-ED1 Cost Benefit Analysis (CBA) model, it is the defined calibration of the customer performance benefit and in the CNAIM; it is used as the monetised definition of the network performance risk parameter.

This integrity between regulatory incentivisation and assessment of both risks and benefits is seen as a strength of the current framework that needs to be preserved.

The empirical customer research carried out as part this project has explored a wide range of variables around an average VoLL figure and identified the most significant. These can be applied at a range of scales from a national re-assessment of contemporary VoLL, through to a VoLL specific to each individual customer.

Clearly the data requirements increase significantly with further disaggregation and the VoLL Recommendations Report, published on 5 October 2018, discusses data restrictions in some detail as part of its early model build work. Therefore, the VoLL2 project will establish the appropriate level of augmentation of a more disaggregated VoLL, within existing decision making frameworks, to deliver the original premise of more value-reflective decision making; whilst ensuring that the solution can be practically applied to current decision making models by all DNOs.

The VoLL2 project will also involve further empirical customer research to gain a better understanding of the 'multiplier' effect on VoLL relative to the magnitude of an outage, when assessed on the basis of the entire community, rather than the individual, which was outside the scope of the original project. The main study robustly tested the effect of scale and duration on VoLL; however, it was not feasible to provide an extrapolated population measure based on the actual VoLL of each individual customer. A good approximation can be obtained by using the mean VoLL from groups of customers as derived from the main survey based on their characteristics. In this way the single VoLL calculated from the VoLLs derived for each group, will give a more representative overall value. However, stakeholder feedback has recommended further research in this area to better understand extrapolated VoLL values at community level, relative to the magnitude of outages.

This empirical customer research will also consider cost socialisation and evaluate perceptions, by key customer groups, around the fairness and legitimacy of a more disaggregated VoLL model. It is anticipated that these findings will support the more strategically focussed element of VoLL2, which considers the practicalities of incorporating a more disaggregated VoLL into the existing regulatory framework.

13 DATA ACCESS

Electricity North West's privacy policy can be found on Electricity North West's website.

In the main survey, conducted during the winter of 2016/17 and summer 2017, the average annual electricity consumption of survey participants was calculated using meter readings held in the DUoS and Associated Distribution Systems database. This activity was conducted in accordance

with the VoLL data privacy statement, which was submitted to Ofgem for approval on 9 February 2016 (confirmation of approval was received on 14 April 2016). Consumption data was obtained with the explicit consent of respondents who provided their MPAN and/or postcode and address, specifically for this purpose.

The EU General Data Protection Regulation (GDPR) was introduced in May 2018, following completion of the main survey but before the additional survey of SME and WSC (as referenced in Section 8.4.3). To comply with GDPR, any of the additional 500 survey respondents who were unable or unwilling to share actual consumption data or an MPAN/address, and provide their consent for Electricity North West to obtain this data, could not be excluded from taking part in the survey. As a consequence, most of the additional sample respondents could not be identified for the purpose of establishing their actual consumption data. As such, the consumption ratios for the additional sample SME and WSC respondents are not considered sufficiently accurate and therefore, the ratios used to model the larger sample (which incorporate the 500 additional surveys), are based solely on data from respondents who completed the main study.

No personal data collected during this study will be retained by either Electricity North West or its project partner, Impact Research, beyond the life of this project. Only anonymised technical data has been retained.

14 FOREGROUND IPR

There is no foreground IPR associated with this project.

15 FACILITATE REPLICATION

- The engaged customer panel – the ECP report, published on 23 August 2016 disseminates learning associated with the initial stage of direct customer engagement, which took place in phase 2 of the project. Lessons learned for future innovation projects are summarised in Section 3 of that report and Appendix 4 (project replication) specifically references the physical components required to repeat this activity.

- The lessons learned during the design and administration of the survey (also part of phase 2 - refining the approach), are documented in the Pilot Survey Report, which was published on the project webpage on 30 November 2016. This report focuses on describing how DNOs and their stakeholders can capitalise on a robust piloting process to identify and respond to challenges that may arise in future customer engagement, of a similar nature. The lessons learned are documented specifically in Section 5 of that report.

- The lessons learned from the main phase of the survey that support replication in future projects, are reported in Section 3 of the main Phase 3 Report published on 5 October 2018.

- Interim results and lessons learned were presented collaboratively by Electricity North West and its market research partner, Impact Research, at the LCNI on 7 December 2017, held in Telford.

- VoLL findings were presented to Ofgem's NOMs cross-sector working group on 19 February 2018. Project outcomes were disseminated further to Ofgem in September 2018 and the results of research to date and planned next steps were presented to Ofgem's Reliability, Safety & Environment working group on 23 May 2019.

- The results and implications of VoLL findings were disseminated to industry stakeholders at an innovation and learning event hosted by Electricity North West on 4 July 2017. The findings were subsequently shared with a broad and inclusive range of relevant stakeholders at the Affordability and Sustainability Advisory Panel workshops in July 2018.

- Regular update reports were sent to industry stakeholders and Electricity North West's ELT in: July 2016, October 2016, February 2017, November 2017, January 2018, August 2018 and March 2019.

- All outputs and learning attained from VoLL customer engagement activities will continue to be made available to other DNOs. Specifically, materials developed and learning derived from this project are publicised on the VoLL webpage and follow-on research will be published on the VoLL2 webpage.

APPENDICES

Appendix 1: SME VoLL (WTA) by sub-groups (main survey only), as reported in Section 6 (Figure 6.9) of the Phase 3 Report.

These estimates are shown in comparison to the WTA values reported in Section 7 (Figure 7.4.2) of this report, which represent the analysis of the combined SME sample (main survey, as per the values stated below, plus an additional 400 SME surveys). These values are for the baseline scenario of ***an unplanned outage, of one-hour duration, once every three years, occurring at a time that would be most inconvenient.***

SME WTA unplanned	Sample number	WTA	Lower	Upper	VoLL	Confidence interval (95%)		Index v total
						Lower	Upper	
Total	615	**£160**	£152	£167	**£47,560**	*£45,289*	*£49,830*	**100**
Rural	118	**£217**	£184	£249	**£68,452**	*£58,201*	*£78,703*	**144**
Urban	489	**£152**	£144	£160	**£43,885**	*£41,680*	*£46,090*	**92**
Electricity North West	325	**£186**	£175	£198	**£47,466**	*£44,561*	*£50,371*	**100**
Scottish and Southern Energy	34							
SP Energy Networks	22							
Northern Powergrid	44							
Western Power Distribution	77							
UK Power Networks	106	£144	£125	£164	**£59,762**	£51,572	£67,951	126
Off-gas	316	**£152**	£144	£161	**£49,056**	*£46,406*	*£51,706*	**103**
Want to keep bills constant	188	**£144**	£132	£155	**£45,823**	*£42,297*	*£49,349*	**96**
Want to keep reliability	141	**£124**	£109	£139	**£38,564**	*£33,832*	*£43,296*	**81**

SME WTA unplanned	Sample number	WTA	Lower	Upper	VoLL	Confidence interval (95%)		Index v total
						Lower	Upper	
Want to improve worse served	116	**£233**	£196	£269	**£63,896**	*£53,833*	*£73,958*	**134**
Want to improve supply	161	**£131**	£119	£142	**£32,919**	*£30,044*	*£35,793*	**69**
Winter	319	**£73**	£66	£81	**£19,099**	*£17,079*	*£21,119*	**40**
Summer	287	**£229**	£216	£241	**£77,843**	*£73,572*	*£82,115*	**164**
No power cuts (either planned or unplanned)	239	**£147**	£137	£157	**£38,167**	*£35,648*	*£40,686*	**80**
Power cuts (either planned or unplanned)	376	**£153**	£143	£163	**£51,341**	*£47,981*	*£54,701*	**108**
Experienced planned power cut	185	**£232**	£215	£248	**£58,227**	*£54,077*	*£62,377*	**122**
Experienced large scale interruption L12M	87							
Impact of power cut – low	161	**£114**	£101	£127	**£42,375**	*£37,455*	*£47,296*	**89**
Impact of power cut – medium	149	**£131**	£113	£150	**£36,629**	*£31,458*	*£41,801*	**77**
Impact of power cut – high	68	**£146**	£126	£166	**£48,005**	*£41,454*	*£54,555*	**101**

(Grey font indicates small sample size, interpret with caution).