NIA ENWL021

Value of Lost Load 2

Closedown Report

A Network Innovation Allowance Project

31 July 2020

VERSION HISTORY

Version	Date	Author	Status	Comments
V0.1	01/07/2020	Tracey Kennelly Customer Innovation Lead	Final	

REVIEW

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Lucy Eyquem	Innovation PMO Manager	28.07.20
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APPROVAL

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CONTENTS

GLOSSARY

BWS	Best-Worst Scaling
CBA	Cost benefit analysis
CNAIM	Common Network Asset Indices Methodology
CVM	Contingent valuation method
DNO	Distribution network operator
DUoS	Distribution Use of System charge
ENWL	Electricity North West Limited
ENWL010	Electricity North West's original Value of Lost Load NIA project
ENWL021	Electricity North West's follow-on VoLL2 NIA project
EV	Electric vehicle
GB	Great Britain
HILP	High impact, low probability events
IIS	Interruptions Incentive Scheme
LCNI	Low Carbon Networks and Innovation Conference
LCT	Low carbon technology
LSOA	Lower super output area
MWh	Megawatt-hour
NIA	Network Innovation Allowance
Ofgem	Office of Gas and Electricity Markets
PSR	Priority Services Register
RIIO-ED1	Electricity distribution price control 2015 to 2023
RIIO-ED2	Electricity distribution price control 2023 to 2028
RIIO-ED3	Electricity distribution price control 2028 to 2033
SME	Small to medium enterprise
VoLL	Value of Lost Load
WTA	Willingness to accept
WTP	Willingness to pay

1 EXECUTIVE SUMMARY

1.1 Aims

The Value of Lost Load (VoLL) is the economic metric of the value that customers place on the security of their electricity supply. There have been various methods used to calculate VoLL; the most accurate estimation is derived from the value that customers would be willing to accept in compensation if they were to experience an interruption. The current uniform VoLL established by Ofgem for RIIO-ED1 is £16,000/MWh, which was aligned to the Energy Not Supplied value used for RIIO-T1, set in 2011.

In Great Britain (GB) a single uniform VoLL is used to evaluate 'dis-benefit' to customers of a supply interruption of average duration. A uniform VoLL assumes that all customers are impacted equally as a consequence of the loss of power and attach the same value to their supply reliability. Investment in electricity networks is thereby, at least partly, driven by a factor that currently fails to recognise divergent customer need or valuation of service.

Electricity North West's previous Network Innovation Allowance (NIA) funded research, conducted in collaboration with project partner Impact Research (ENWL010), demonstrated that VoLL is now notably higher than observed in the last major GB study in this area, commissioned by Ofgem. This involved desktop research in 2012 ahead of RIIO-ED1, which, corroborated that the RIIO-T1 value was within the range established by the most recent international studies. This was followed by customer research, conducted by London Economics in 2013 which included stated preference methods. The original ENWL010 study which utilised a similar methodology, established that the VoLL value underpinning RIIO-ED1 incentive calibration is now outdated.

It also robustly concluded that the single value model is no longer appropriate since it takes no account of outages on different types of customers or reflect consumers' future needs as part of a low carbon future transition. The single estimate undervalues the needs of certain customer segments, whilst others are over represented, driving potentially inappropriate investments. An output of the original VoLL research was a recommendation for a new segmentation model that will enable Distribution Network Operators (DNOs) to make smarter investment decisions that more accurately reflect divergent customer needs.

To move towards the practical implementation of a differentiated VoLL, it was recognised that further detailed analysis was required to explore the requisite level of sophistication needed in a credible decision-making tool and the appropriate mechanism for practicable implementation, at scale. ENWL010 also highlighted the need for further empirical customer research to test the impact of different scenarios. This includes establishing the existence of a 'multiplier' effect on VoLL, relative to the scale and duration of an outage, when assessed on the basis of the entire community, rather than the individual. This understanding presents an opportunity for more sophisticated decision making, based on the relative value of proactive investment, aimed at preventing or minimising the severity of unplanned interruptions versus the ability to mitigate VoLL by deploying appropriate support mechanisms to manage the consequence of an event.

The VoLL2 project was established to address these issues and comprised two distinct elements of research:

Phase A - A strategic piece of statistical analysis and industry consultation to explore the practicalities and regulatory implications for implementation of a segmented VoLL model and its applicability.

Phase B - Further empirical research to provide insight into the existence of a multiplier effect and an evaluation of customer views on the fairness and acceptability of a variable VoLL model, including perceptions on cost socialisation linked to investment prioritisation. The customer research sought to answer the following three key questions:

1. What is the impact of a large event involving a significant number of customers on VoLL versus a smaller, localised interruption?
2. How does VoLL change over the duration of an event? Specifically, for longer durations over 12 hours, does VoLL per hour increase, stay the same, or reduce?
3. What are customer views on the fairness and equity of a variable VoLL, including attitudes on cost socialisation? Specifically, are customers willing to pay, through bill increases, for investment to reinforce areas where low carbon technology (LCT) uptake may be high versus, for example those living in fuel poverty?

1.2 Methodology

Phase A - Electricity North West tasked Frazer-Nash Consultancy (Frazer-Nash) with developing a methodology for a functional variable VoLL model. This was constructed through a combination of functions and customer data. The prototype model was developed using a supervised 'machine learning' model, which utilised training data derived from the ENWL010 customer survey and the segmented estimates of VoLL established in that study. Data-led research determined appropriate sample sizes for utilisation in the model, and which third-party data sources were incorporated. The methodology included a robust analytical approach for validating the accuracy and limitations of the tool. The analysis provides a basis for recommendations on the implementation of a variable VoLL model and factors that should be considered for such a model in RIIO-ED2 and beyond. Full details of the methodology are documented in the Modelling Approach Report, hereafter referred to as the MA Report, published on the project webpage on 23 January 2020.

Phase B - Electricity North West and its market research project partner, Impact Research, conducted qualitative and quantitative customer engagement to understand the multiplier effect and ascertain views relative to the fairness and equity of a variable VoLL model. The study involved a survey of 2,000 domestic and Small to medium enterprise (SME) customers from across GB. The main quantitative survey instrument contained a Contingent Valuation Method (CVM) exercise to deliver an understanding of which groups are considered most in need and/or deserving of additional support or investment, according to electricity customers' willingness to pay for it through higher annual bills. Questions were framed within in the context of prioritised supply restoration if this cost was socialised. This methodology was used as a representation of customers' acceptance of investment prioritisation and consequently perceptions around fairness of a variable model. The survey instrument also contained a stated preference Best-Worst Scaling (BWS) exercise used to evaluate the multiplier effect of VoLL relative to the scale, frequency and duration of outages. This research and its methodology built on previous studies in this area. Details of the research approach are fully set out in the VoLL2 Methodology Statement published on the VoLL2 project webpage on 8 May 2019, with further details of the Customer Survey Report.

1.3 Outcomes

Phase A - Frazer-Nash have developed a prototype variable VoLL model that estimates the VoLL for any given population containing at least two hundred individuals if the VoLL indicators, for the population are known. The model has been used to calculate the VoLL at a Lower Super Output Area (LSOA) level for all of GB, to demonstrate transferability of the approach and an example of the granularity at which VoLL can be calculated using the model.

The model utilised the customer survey data attained in ENWL010, to create a large number of artificial sample populations to train a prototype, using machine learning techniques.

The analysis suggests that the single most effective action that could be taken to improve the accuracy, and thus the fairness, of VoLL in investment decisions across GB is to update the current uniform value. However, if this simple approach was to be adopted in RIIO-ED2, consideration should be given as to whether the current assumption for the ratio of domestic to SME electricity consumption in GB is still appropriate.

There are significant benefits to be gained from the implementation of a variable VoLL model, and many of these benefits could be realised in the application of a relatively simple disaggregated model, which utilises a limited number of attributes identified as the key characteristics influencing VoLL in this study. Such a model provides a means of disaggregating the load-weighted sum of fixed values for urban and rural domestic and SME VoLL. The metric used to quantify the accuracy of the model is the root mean squared error (RMSE), In this case the error is the difference between the model predicted VoLL and the VoLL reported by the survey respondents.

Additional research into more complex models for either the domestic or SME VoLL that incorporate multiple VoLL indicators such as income, fuel poverty and electricity consumption may yield a better model that improves accuracy further still. Such a model for domestic VoLL was evaluated in the research. The RMSE of this domestic VoLL model is £6,109/MWh, which represents a 29.2% improvement over the current vanilla model employed by Ofgem (which has a RMSE of £8,624). The model also represents a 20.3% improvement, when assessed against the domestic VoLL of £17,481/MWh, as derived in ENWL010 (the RMSE in this instance is £7,667/MWh).

The analysis suggests that the accuracy of this domestic model can be improved further using a ‘cap’, to prevent the reporting of outlying statistics. When capped, the RMSE of the domestic model drops to £5,606/MWh.

It is possible that accuracy might be enhanced further still with additional research. This may necessitate more customer surveys and the project recommends that any additional research of this nature would benefit from a collaborative, joint DNO approach. However, a more complex model will incur additional overheads in model and data maintenance, and such considerations could be significant in determining the most appropriate objective for a re-evaluated VoLL and its practical application.

Phase B – This project has successfully established a multiplier effect and defined that effect by the geographic scale, frequency and duration of outages. The modelling validates the results of ENWL010 by identifying similarities in the findings and verifying earlier assumptions.

The analysis reveals the extent to which the ‘dis-benefit’ experienced by customers from an interruption of the type they are most likely to experience (e.g. in the range of 1 to 6 hours) could be multiplied to represent the effect of longer interruption times and wider geographical spread. The research identified that the length of interruption is the biggest factor in determining VoLL. For outages of more than 6 hours in duration, a 24-hour interruption (i.e. 18 hours longer than a 6-hour outage) has around twice the impact. A 3-day interruption (+66 hours) has about six times the impact when compared to a 12-hour interruption (+6 hours). This implies that VoLL per hour is lower beyond the 12-hour point, but then remains constant. This effect is the same for both domestic and SME customers and is consistent across most, but not all, sub-groups. These findings suggest that consideration should be given to how a more tailored VoLL might mitigate the increased disruption/impact and how this could be offset by deploying enhanced customer support strategies to better manage the consequences of power cuts.

The research also evaluated perceptions of fairness associated with the implementation of a differentiated VoLL model. This was achieved by inviting respondents to express their willingness to pay for investment in particular areas of the network, to support specific customer groups.

The study reveals that respondents generally supported socialised costs that would enable DNOs to proactively identify and contact customers eligible for priority services, when an interruption occurs. However, the results suggest a difference in the amount that customers would be willing to pay to reduce the restoration time for vulnerable groups (defined as the elderly, sick and disabled) versus. prioritised supply restoration. Domestic respondents were willing to pay an additional £10.86 to reduce the time it takes to restore power to vulnerable customers but only £9.71 to give them a priority service. The same pattern applies to SME respondents (£169.95 versus £143.74). This finding suggests that respondents are in principle supportive of vulnerable groups when it comes to restoring power, but less so when that support could be detrimental to others' experience.

Respondents appear to be willing to pay a similar supplement (in the region of £10 for domestic and £150 for SMEs) to prioritise restoring power to their own household or business, as they are to prioritise vulnerable customers.

Both domestic and SME respondents indicated that the amount they were prepared to pay to prioritise power restoration to customers living in fuel poverty was lower than for other vulnerable groups and there was considerably less appetite to prioritise supply restoration for LCT users.

1.5 Key Learning

Phase A - The aim of a variable VoLL model should be to deliver improvements in the accuracy and fairness of the various applications of VoLL when compared to the existing single value approach used within the RIIO-ED1 methodology.

This study presents an argument for the various approaches but recognises that a balance must ultimately be struck between the accuracy of the VoLL model, the complexity of methodology and how it can be practically implemented to the existing regulatory frameworks in a timely manner for RIIO-ED2. The study therefore suggests that a short-term position and long-term solution for the integration of a variable methodology within the regulatory framework is necessary and that an updated single macro value, along with a flexible disaggregated model may both have roles to play.

Based on the outputs of this analysis, it is concluded that introducing a variable VoLL into ED2 methodologies, specifically the Common Network Asset Indices Methodology (CNAIM) and Cost Benefit Analysis (CBA) model, should deliver significant improvements in accuracy. However, a disaggregated approach is not considered appropriate within the Interruptions Incentive Scheme (IIS) mechanism. Furthermore, a cautionary approach should be taken in the implementation of any solution, particularly in ensuring that there is a thorough understanding of the statistical uncertainties associated with model predictions.

Phase B - The key learning from the research is that large scale and lengthy interruptions have the potential to increase VoLL when compared to shorter limited scale outages, with duration playing the biggest part in determining VoLL. This validates the findings of ENWL010, which established that an outage incurs a higher VoLL the longer it lasts, but the marginal hourly value declines steadily. This project has observed a similar pattern demonstrating that VoLL per hour is lower beyond the 12-hour point, but then remains constant. This finding supports earlier assumptions as to the reasons for a flattening in the upward trajectory of VoLL associated with long duration interruptions, typically caused by extreme weather events; which is thought to reflect customers' awareness that these situations are outside the control of the network operator.

A stated preference technique was used to assess customers' acceptance of investment prioritisation and consequently, perceptions around fairness of a variable model. The findings demonstrate that customers generally accept prioritisation for certain groups but believe this ought to only be considered once the basic requirements of all customers are met first. The cost socialisation element of the research was difficult for customers to comprehend and the survey instrument used in the research required modification, to simplify the approach, following a cognitive pilot. As a result, the survey outputs were only able to provide a high-level assessment of perceptions on cost socialisation in respect of investment and charging prioritisation.

1.6 Conclusions

Phase - A - A variable VoLL model, as an alternative to the current single approach is attractive because it does not involve a significant change in the way that DNOs assess risk and benefits of investment relative to lost load mitigation, rather, it allows them to refine existing models to produce a more precise method for prioritising investment decisions, which incorporate a customer dimension that recognises the impact of decisions. The challenge of the project was to develop a model that could be practicably applied.

The research built on the learning derived from Electricity North West's original VoLL study and has delivered a comprehensive piece of analytical research to develop the simple 'VoLL Calculation Tool', originally proposed in ENWL010. The methodology utilised the segmented values of VoLL established in the original research to develop a functional variable VoLL model that could be practically applied in a manner that could be rolled out across GB.

Frazer-Nash achieved this by investigating how more complex comparisons of VoLL might be made across networks, with populations displaying multiple VoLL characteristics. The analysis evaluated the benefits, accuracy and shortcomings of relatively simple disaggregated models, which utilise a limited number of attributes, identified as the key VoLL indicators, versus more complex models that incorporate multiple characteristics that influence VoLL.

This project has made recommendations for a variable VoLL model which allows users to estimate the VoLL for any given population if the defining characteristics for that population are known. These indicators include the proportion of customers in fuel poverty, the electricity consumption of customers and the population rurality.

The model delivered by this project is a prototype designed to prove the concept and demonstrate to stakeholders the potential of a variable VoLL methodology. The research has culminated in recommendations for a disaggregated model, details of which are set out in the MA Report published on the project webpage on 23 January 2020. The research delivers a methodology that translates the empirical customer research gathered in ENWL010 into a useable tool that could be deployed within the RIIO-ED2 regulatory framework. The research concludes that there would be little difficulty introducing a variable VoLL into the CNAIM and CBA approaches, providing the model is simple to administer. The study recommends an early iteration of a variable methodology and suggests how this might be implemented within RIIO-ED2, with a view to perfecting its practical application for RIIO-ED3.

The study also identified several opportunities for further model refinement. Greater understanding and visibility of the model uncertainty is required to assess the robustness of a production-standard tool before it can be utilised in effective decision-making and fully implemented into regulatory mechanisms and BAU processes. It is therefore the intention of Electricity North West to pursue the independent development of a production standard model, with emphasis on how it can be used within CBA and CNAIM calculations to support specifically-targeted investment programmes in RIIO-ED2.

Phase B – Customer engagement in VoLL2 has successfully defined the multiplier effect on VoLL and has delivered an understanding of customer perceptions on the fairness and equity of a variable VoLL methodology. This has concluded that customers consider a variable approach desirable, thereby providing customer validation for the transition from a single value approach.

1.7 Closedown Reporting

Selected sections of this full Closedown Report (Sections 2-6, 7.1, 8.1, 9 and 11-14) are available via the Energy Networks Association's Smarter Networks learning portal at www.smarternetworks.org. This full version of the report provides additional information that is useful in understanding the project.

2 PROJECT FUNDAMENTALS

Title	

Project reference	ENWL 021
Funding licensee(s)	Electricity North West Limited
Project start date	November 2018
Project duration	18 months
Nominated project contact(s)	Tracey Kennelly (innovation@enwl.co.uk

3 PROJECT BACKGROUND

In Great Britain (GB) a single, uniform Value of Lost Load (VoLL) is used to evaluate dis-benefit to customers of a supply interruption of average duration. It can be expressed as the value that customers would be willing to pay to avoid an interruption or what they would be willing to accept in compensation if they experience an interruption. A uniform VoLL assumes that all customers are impacted equally by the loss of power and attach the same value to their supply reliability. Investment in electricity networks is thereby driven by a factor which currently fails to recognise any differentiation in customer need, or valuation of service.

Impetus for change

Recent NIA funded research conducted by Impact Utilities on behalf of Electricity North West (ENWL010) has demonstrated that VoLL is now notably higher than observed in the previous major GB study in this area, conducted by London Economics for Ofgem, in 2013. This increase is thought to reflect a greater dependency on electricity and changing customer needs and expectations. The study also robustly concluded that a uniform VoLL significantly undervalues the needs of certain customer segments, most notably the fuel poor and early adopters of LCTs; whilst others are over represented, driving potentially inappropriate investments. An output of the VoLL research is a new segmentation model, which will theoretically enable DNOs to make smarter investment decisions that are more reflective of divergent customer needs.

Implementation

To move towards the practical implementation of a differentiated VoLL it is recognised that further detailed 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. The previous Electricity North West study (ENWL010) also highlights the need for 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, i.e. assessing the overall impact of a large-scale outage affecting a significant number of people versus that of a smaller more localised interruption. This understanding will inform smarter decisions based on the relative value of proactive investment, aimed at preventing or minimising the severity of unplanned interruptions vs the ability to mitigate VoLL by deploying appropriate support mechanisms to manage the consequence of an event.

VoLL 2 comprised two distinct pieces of research:

- A strategic piece of statistical analysis and industry consultation to explore the practicalities and regulatory implications for implementation of an alternative, segmented VoLL model and its applicability (Phase A - strategy).

- Empirical customer research to provide insight into the multiplier effect and socialisation of cost arising from a revised model (Phase B - customer).

Phase A - strategy: Involved further detailed statistical analysis of the disaggregated VoLL indicators derived from the ENWL010 study to identify the key vectors influencing VoLL. This will determine the appropriate level of aggregation and sophistication required of a revised model to practicably implement at a national level. This analysis was expected to establish:

- How the range of factors that influence VoLL should be combined to guide an investment decision and how this understanding can be practicably utilised in more accurate decision-making tools.
- The optimum degree of complexity i.e. how sophisticated the approach might need to be and the advantages/disadvantages of a sophisticated, complex model (using an extensive range of indicator data) versus a simpler approach that utilises a limited set of readily available indicator data.
- The level of detail at which VoLL variables might be combined, relative to network parameters, e.g. substation, circuit, primary group.
- Forecasts and VoLL drivers from official, external (non-industry) sources that might be utilised to enhance the new model.
- The stability/variability of factors that influence VoLL.
- How investment models should account for large scale one-off events.

Phase B - customer: Involved exploratory customer research to address the following questions to support the practical application of the VoLL segmentation:

- What is the impact of a large event involving a significant number of customers on VoLL versus a smaller, localised outage
    - When assessing the aggregated impact at community level, can this change be simply summated i.e. is the relationship linear or non-linear?
    - How does VoLL change over the duration of an event? For longer interruptions over 12/18 hours does the rate of increase in VoLL per customer decelerate or plateau?
- How should investment models account for relatively low VoLL if values are influenced by greater resilience, brought about through customer's own proactive mitigation (e.g. medically dependent), or higher levels of tolerance as a result of repeated exposure to supply interruptions (e.g. worst-served customers)
- Are all customer segments able to accurately signal their true VoLL? What are the societal consequences if specific customer groups are unable to effectively signal true VoLL because the wider impacts are not necessarily recognised, i.e. costs which are not directly borne by the customer but are picked up by society elsewhere?
- Highlight, from a societal perspective, the unintended consequences of replacing one imperfect model with one that recognises divergence but may also be imperfect.

4 PROJECT SCOPE

Qualitative and quantitative research with a broad spectrum of DNO customers:

- Domestic (general, rural, urban, worst-served customers, vulnerable customers, fuel poor, adopters of LCT, experienced a lengthy interruption)
- SME customers from a range of market sectors (including but not limited to those heavily reliant on electricity / early LCT adaptors).

5 OBJECTIVES

Phase A – strategy:

- Optimise the VoLL decision-making tool by providing guidance on the appropriate combination of VoLL drivers and the requisite level of sophistication and aggregation.
- Identify, evaluate and incorporate appropriate forecasting features to future proof the model / demonstrate stability/variability over time.
- Deliver an understanding of the relative value of investment to prevent an event vs that of managing the consequence of the event.
- Undertake analytics to identify the appropriate network scale to which the differentiated VoLL value should be applied.
- Develop sample investment plans to understand options for implementation and potential impact on affordability and quality of outcomes for different customer segments.
- Engagement with key industry stakeholders to identify implications, formalise an appropriate VoLL decision-making tool and establish a strategy for transition to national implementation, identifying regulatory mechanisms currently or potentially driven by a VoLL function.

Phase B – customer:

- Determine the increased sense of equity and DNO service provision that can be achieved through implementation of a differentiated VoLL model.
- Quantify the impact of scale and duration of an outage on VoLL
- Deliver an understanding of the societal value of investment to prevent an event vs that of managing the consequence of the event
- Measure societal acceptance of a differentiated VoLL model, segmented by customer need
- Substantiate which segments are perceived by society to have the greatest need
- Quantify the likely effects of a differentiated VoLL investment model on society, now and in the future.

6 SUCCESS CRITERIA

The project success criteria are:

Phase A – strategy:

- Identification of key vectors influencing VoLL and the degree of sophistication requisite in a credible decision-making tool using a differentiated model.
- A preferred network scale of implementation following assessment of potential outcomes and data requirements.
- Sample investment plans to understand options for implementation and how that could impact affordability and quality of outcomes for different groups of customers.
- An understanding of the relative value of preventing an event vs managing the consequence of the event
- Consult key industry stakeholders to establish acceptability, regulatory and wider impacts.
- Establish required adjustments derived from learning in this project that key stakeholders support and can be implemented as a next step into our core processes.
- Establish implications for RIIO-ED2 and a strategy for national implementation.

Phase B – customer:

- Evaluation of potential social impacts of implementation of a future differentiated VoLL model by key customer and stakeholder groups.
- Deliver an understanding of the societal value of investment to prevent an event vs that of managing the consequence of the event
- A practical demonstration of how the VoLL model can help DNOs to more effectively plan investment levied in areas where the consequence of asset failure is much higher, in a manner which delivers greatest value to the DNO, and benefits those most impacted but which is fair to all.

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

7.1 Summary of performance

The VoLL2 project has successfully delivered against its original aims, objectives and success criteria. This section summarises the methodology used to meet the objectives specified in Section 5, the outcomes of the research and how the associated success criteria stated in Section 6 were met.

The VoLL2 study comprised two distinct pieces of research:

- Phase A (strategy). A data led piece of statistical analysis that culminated in recommendations for a proposed disaggregated VoLL model and an assessment of the regulatory implications associated with the adoption of such a model.
- Phase B (customer), which involved further exploratory customer research to expand on the learning delivered by ENWL010, address unanswered questions and provide customer validation for the adoption of a variable model.

Whilst there was some synergy in the outputs of these two discrete elements of the study, the research for each was conducted in isolation and is therefore clearly separated in the construction of this report. Details of project performance and outcomes for Phase A are expanded in Sections 8.2.1 to 8.2.6, listed by specific objective. Similarly, performance for Phase B, is reported in Sections 8.3.1 to 8.3.6.

The original Electricity North West NIA study into VoLL (which for the purpose of this Closedown Report is referred to by its ENA project reference: ENWL010), raised a number of fundamental questions which necessitated further investigation; therefore, this follow-on NIA project, VoLL2 (ENA reference ENWL021) was registered to address these issues.

Having quantified the variables that influence VoLL in ENWL010, this project sought to explore how decision-making methodologies and incentive mechanisms that form part of the existing DNOs' regulatory framework might be adapted to incorporate updated and potentially disaggregated VoLL values, which reflect diversity.

Phase A (strategy) was delivered in collaboration with Frazer-Nash, appointed as project partner via a competitive tender process.

In the move towards a variable model of VoLL, Frazer-Nash were tasked to:

- Explore the implementation of a disaggregated VoLL model that accounts for the variation in VoLL for different types of customers
- Determine demographic indicators that are correlated with VoLL;
- Implement a prototype disaggregated VoLL model;
- Gather VoLL indicator data for GB and use the prototype model to estimate the variation in VoLL across the UK; and,
- Visualise these estimates in the 'VoLL Visualisation Tool'.

The research culminated in recommendations for a disaggregated VoLL model, details of which are set out in the MA Report, which is referenced repeatedly throughout this Closedown Report and provides an overview of VoLL, its history, how it is currently used within the regulatory framework and how it aligns with the Energy Not Supplied scheme in Transmission. The MA Report also provides details of the mechanics associated with the development of a disaggregated model, along with the methodology for translating the empirical customer research gathered in ENWL010 into a useable tool that could be deployed within the RIIO-ED2 framework. The report explains the machine learning techniques and data validation approach used to determine appropriate sample sizes utilised in the model and sets out the third-party data sources that were incorporated. This includes an explanation of why specific VoLL attributes were selected for inclusion in the model and where there were limitations that had to be overcome with assumptions.

This phase of research concluded with an assessment of how a disaggregated VoLL could translate practically into current regulatory mechanisms, and how it might be practically implemented in a nationally applicable approach into the frameworks for RIIO-ED2 and beyond.

Phase B (customer) was delivered in collaboration with Impact Research. The purpose of the customer research in this project was to enhance the learning derived from ENWL010, clarify some earlier findings and address unanswered questions arising from the original study.

A key aim of the research was to establish the existence of a 'multiplier effect' for VoLL relative to the magnitude of an outage as a mechanism to extrapolate the customer impacts as expressed by an individual, to an understanding of the wider, aggregated effect on a community. This learning is expected to be beneficial in informing future strategies associated with risk management and impact mitigation during supply interruptions, particularly customer support strategies associated with High Impact Low Probability (HILP) events.

The research also sought to establish perceived social impacts and customer views on the fairness and acceptability of a variable VoLL model, specifically attitudes on targeted or priorities investment to negate the consequence of asset failure, where the customer impact is known to be greatest.

This engagement was considered necessary to provide customer validation for a shift from the single VoLL, currently used in investment decision-making, to a variable model more reflective of customer need and dependence.

The objectives and success criteria of the Phase B research were met predominantly by a large scale quantitative survey involving over 2,000 domestic and SME customers from across GB.

The survey design was informed by previous studies in this area and an initial piece of strategic qualitative market research carried out with an engaged customer panel (ECP). This comprised a diverse range of customers who met twice in a focus group setting. The ECP research was designed to explore initial perceptions of the VoLL multiplier, relative to frequency, duration and scale, in addition to attitudes concerning fairness and cost socialisation. This initial phase of customer engagement identified how best to contextualise and explain these complex concepts in the GB wide survey, to ensure the content of the questionnaire was fully understood by respondents and would deliver robust outputs that fully met its objectives.

Full details of the qualitative research approach, its results and lessons learned are disseminated in the ECP Report, published on the project webpage on 31 October 2019.

The large-scale customer survey commenced in January 2020 and was proceeded by a pilot study and peer review. Details of the survey design, along with the analytical and modelling approach and its outcomes are provided in Section 8.3 of this report and are fully documented in the .VoLL2 Customer Survey Report published on 15 May 2020.

8 THE OUTCOME OF THE PROJECT

8.1 Summary of outcome

As outlined above, the VoLL2 study comprised two separate pieces of research:

- Phase A (strategy)
- Phase B (customer)

Phase A comprised a strategic piece of analytical research and industry consultation which systemically explored the practicalities and regulatory implications of a segmented VoLL as an alternative to the existing single value approach. The study explored the extent to which a variable methodology would to improve planning models, to deliver more efficient investment decisions. This exploration considered customer impact, network resilience and regulatory mechanisms. The outcomes of this phase of the study are briefly summarised below and reported in greater detail, by specific project objective, in Sections 8.2.1 - 8.2.6).

Frazer-Nash were tasked with conducting a comprehensive piece of analytical research to further develop the simple segmented VoLL model proposed in ENWL010, on the basis of the values established in that study. Frazer-Nash achieved this by investigating how more complex comparisons of VoLL might be made across networks, with populations displaying multiple VoLL characteristics. The analysis evaluated the benefits and shortcomings of relatively simple disaggregated models, which utilise a limited number of attributes, identified as the key VoLL indicators, versus more complex models that incorporate multiple characteristics that influence VoLL.

This project has delivered recommendations for a variable VoLL model and describes how an early iteration of a variable VoLL approach might be implemented within RIIO-ED2, with a view to perfecting a practical methodology for RIIO-ED3.

Customer survey data obtained in ENWL010 was used to create a large number of artificial sample populations, each of which was able to be defined by values for a small number of VoLL indicators. This data set was used to train a prototype model that can predict the value of VoLL for any population for which the VoLL indicators are known. This VoLL model can be used to extrapolate predictions of VoLL outside of the survey population and has been used to make predictions of VoLL across the whole of GB, as part of this project.

The accuracy of this prototype model is assessed to be an improvement on the current approach, which uses a fixed, single VoLL, applied to investment decisions across the whole of GB. The research acknowledges that further work is required to improve and characterise a version of the model that could be implemented into regulatory mechanisms; however, the analysis suggests there are benefits to be realised from the application of a relatively simple disaggregated model and considers the practicalities of a rudimentary approach which brings investment targeting benefits without excessive complexity, versus a more complex model that incorporates multiple VoLL components.

The findings suggest that the simple prototype model suggested in this research which uses a load-weighted aggregation methodology (i.e. domestic and SME electricity consumption, by location) can estimate VoLL for a sample population with an accuracy approximately £2,000/MWh greater than the existing 'vanilla model' of £16.000/MWh, based on the fixed domestic/SME ratio used by Electricity North West (74:26) to reach the weighted average VoLL of £25,301/MWh (this ratio was used for parity with the LE Ofgem study for Ofgem in 2013). Slightly extending the complexity of this simple model, by increasing the two constant values (domestic and SME) to four parameters, to reflect the weighting of these customer groups by their domestic and rural situation improves the accuracy of the basic model by a further £1,000/MWh; demonstrating the benefits to be gained from a variable VoLL methodology.

The analysis goes on to demonstrate that an additional increase in accuracy can be achieved utilising a more complex disaggregated model which utilises multiple VoLL indicators. An example of such a model was established in this project for domestic VoLL.

The study presents an argument for the various approaches but recognises that a balance must ultimately be struck between the accuracy of the VoLL model, the complexity of methodology and how it can be practically implemented to the existing regulatory frameworks in a timely manner for RIIO-ED2. The study suggests that a short-term position and long-term solution for the integration of a variable VoLL model into the regulatory framework is necessary and that both an updated single macro value, along with a flexible disaggregated model may equally have roles to play

The research suggests that in the short term, the most effective single action that could be taken to improve the accuracy, and thus the fairness, of VoLL in investment decisions across GB is to simply update the current 'vanilla' value, which ENWL010 identified is now significantly higher than the value established for RIIO-ED1.

However, the analysis also concludes that incorporating a variable VoLL within the CBA model and the CNAIM will deliver more efficient and nuanced investment decisions, by including a dimension that reflects customer need.

The research also considered the most appropriate geographic granularity at which a variable VoLL model might be implemented and makes recommendations for application at Lower Super Output Area (LSOA). This approach is compatible with, and thus enables the use of, consistent, readily available open source data, allowing the model to be rolled out, industry wide, across GB. The model developed in this project is supported by an interactive Visualisation Tool, which allows the user to compare VoLL estimates across GB, calculated by LSOA. It is however acknowledged that the fundamental argument for a variable model is the ability to calculate the VoLL for a specific distribution network or network asset and the following sections of this document consider how the prototype model could be developed further to deliver more granular calculations, to inform particular investment decisions.

The conclusions presented in this study are caveated with recommendations for elements of additional research that are considered necessary to facilitate the efficient transition from a single, to variable model.

Phase B involved further exploratory customer research to build on the original ENWL010 study, conducted in collaboration with Impact Research. This was considered appropriate to address unanswered questions arising from the original project and provide customer validation for the adoption of a variable VoLL model. These outcomes are summarised below and reported in more detail, by project objective, in Sections 8.3.1 – 8.3.6.

ENWL010 defined the different impacts of supply interruptions across a diverse range of domestic and SME sub-groups and concluded that the weighted average VoLL is now notably higher than observed in the last major GB study for Ofgem. Ofgem established a value of £16,000/MWh for RIIO-ED1 based on desktop research conducted by Recon[1] in 2012, and subsequent customer research, undertaken by London Economics (LE) in 2013[2], which established a value of £16,940. In 2018 ENWL010 established an overall weighted average VoLL of £25,301/MWh, when research results were combined in the same way as the LE study. ENWL010 recognised that the 2013 LE value of £16,940/MWh would be approximately £18,500 in 2018, if adjusted for inflation[3]. The revised calculation, which has outstripped inflation represents a real movement of approximately 6,500/MWh. This highlights that over time VoLL is increasing and intuitively, this is thought to reflect greater dependency on electricity, evolving customer needs and higher expectations. This upward trajectory is expected to continue with increasing uptake in the electrification of transport and heating.

ENWL010 established disaggregated VoLL values by customer segment, which when translated into an appropriate model provides a mechanism for improved efficiency in the prioritisation of investment decisions, by ensuring those investments are based on a much richer and more representative understanding of customers' needs. However, ENWL010 was unable to definitively evaluate the impact of different scenarios including whether a 'multiplier effect' exists relative to the magnitude of an outage, specifically when VoLL is assessed on the basis of an entire community, rather than an individual. Whilst the original study robustly tested

[1] https://www.ofgem.gov.uk/ofgem-publications/47154/riioed1conresvoll.pdf
2 https://www.ofgem.gov.uk/ofgem-publications/82293/london-economics-value-lost-load-electricity-gbpdf
3 Based on Bank of England inflation figures averaged at 2.2% a year using the composite price index.

the effect of frequency and duration of outages on VoLL; it was unable to provide an extrapolated population measure based on the VoLL of each individual customer.

The VoLL2 project has successfully established a multiplier effect and defined that effect by the scale, frequency and duration of outages, including the overall combined effect. The modelling validates the results of ENWL010 by identifying similarities in the findings and verifying earlier assumptions. The analysis confirms that large scale and lengthy interruptions have the potential to increase VoLL, when compared to shorter, limited scale outages. These findings suggest that consideration should be given to how a more tailored VoLL might mitigate this increased disruption/impact and how this could be offset by deploying enhanced customer support strategies to better manage the consequences of power cuts, particularly those associated with HILP events.

The research also evaluated the social impacts/perceptions of fairness associated with the implementation of a differentiated VoLL model. Customers were asked detailed questions about their willingness to pay to support different customer segments within in the context of prioritised supply restoration, if this cost were socialised. This methodology was used as a representation of customers' acceptance of investment prioritisation and consequently, perceptions around fairness of a variable model. This found that customers are generally supportive of a disaggregated approach; however, it identified some disparity in overall appetite to prioritise investment towards certain customer groups known to have a higher than average VoLL, i.e. those that are most impacted by outages.

Customers were willing to pay more for some of these groups, including vulnerable customers, to be prioritised ahead of others. However, customers were also willing to pay more to have their own property or business premises restored before others. Vulnerable groups (defined as the elderly, chronically sick and disabled) were prioritised above those who are fuel poor. LCT users, defined as those who have electric vehicles and solar panels are considered to be lowest priority, unless the respondent is themselves an LCT user. These findings are documented in Section 8.3.5 and introduce pertinent questions that need to be considered in the wider debate on the appropriateness of a disaggregated VoLL and the appetite of customers to support a more sophisticated investment prioritisation tool which reflects customer need.

8.2 Outcomes - Phase A (strategy)

8.2.1 Optimise the VoLL decision-making tool by providing guidance on the appropriate combination of VoLL drivers and the requisite level of sophistication and aggregation

Electricity North West's original NIA project investigated the relative values of VoLL when making comparisons across single characteristics. This approach allowed VoLL to be determined for rural as opposed to urban customers or for male, compared to female customers etc. It demonstrated that VoLL varies substantially across different types of customers, and that these variations could be attributed to certain customer characteristics.

One of the outputs of ENWL010 was a simple VoLL calculation tool, which demonstrated how the aggregated VoLL of any particular asset might be calculated, utilising the segmented values established in that study (refer to Section 5 of the VoLL Recommendations Report, published on 5 October 2018).

However, the approach was limited in that it remained unclear how to calculate VoLL estimates for real customers, each of whom can be defined by multiple characteristics. The original study did not examine how to combine the estimates of VoLL for each of these individual characteristics to form an overall VoLL for the customer. The VoLL2 project drew on these findings and sought to overcome this challenge by defining a prototype model for a variable VoLL, and critically, the optimum level of sophistication required of the model for practical implementation across GB.

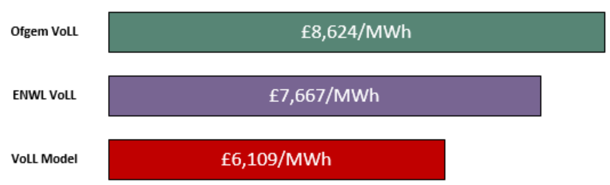
The prototype model, developed by Frazer-Nash, was constructed through a combination of functions and customer data, building on the empirical customer data collected in ENWL010. This model uses a subset of the possible VoLL indicators, limited in part by the availability of GB-wide data to facilitate predictions of VoLL across the whole of GB. The model was derived from many non-homogeneous populations containing respondents that display multiple characteristics including but not limited to: locality (rural vs urban), age, income, consumption, socio-economic status, vulnerability and electric vehicle (EV) ownership.

Using this data, a training data set of 100,000 sample populations, each comprising of 250 respondents was established. The VoLL was then calculated for each sample population. It is of note that the training data set was created using domestic customer survey data only. This decision was based on less available data for SME customers. This was because ENWL010 survey quotas were set to provide a statistically representative profile of customers across GB. There was also too much variation in market sectors for meaningful analysis. As a result, it was not possible to conduct detailed analysis for SME VoLL beyond the estimates for urban SME VoLL (£44,000/MWh) and rural SME VoLL (£68,500/MWh), as established in ENWL010. Therefore, only a model for domestic VoLL was created. This was separated into an urban and rural model for domestic VoLL. The rationale for this segmentation, and the approach for combining domestic VoLL with SME VoLL is explained in detail in Section 3.2.4 of the MA Report.

Several different types of machine learning options were trialled in the production of the model, as discussed in Section 3.2.3 of the MA Report. Of all the options considered, it was found that a linear model performed best when assessed for accuracy against a 'withheld test data set' which was used to validate the model's predictions. The relatively simple linear model also had the advantage of delivering results that are more intuitive than some alternative, more complex machine learning models.

The metric used for quantifying the overall assessed accuracy of the model was the root mean squared error (RMSE). In this analysis the error was the difference between the model predicted VoLL and the VoLL reported by the survey respondents in the original study (ENWL010). The approach to assessing and validating the model's accuracy is documented in Section 3.3 of the MA Report. The analysis has determined the accuracy of the domestic VoLL model developed in this study to be a RMSE of £6,109/MWh, for the 60 different models for which survey data was withheld. This represents a 29.2% improvement over the current 'vanilla model' employed by Ofgem in RIIO-ED1, in which a fixed value of £16,000/MWh is used across GB.

The following table also shows the error when compared to the ENWL010 derived value of £17,481/MWh for domestic VoLL (evaluated to have a RMSE of £7,667/MWh) and the relative improvement of the domestic VoLL model compared to this is over 20%.



The analysis established that some of the VoLL indicators in the sample populations were more significant than others; therefore, the characteristics that did not materially impact the accuracy of the model were omitted from the analysis at this prototype stage. Excluded indicators included population age, vulnerability, EV ownership, off gas status and previous experience of power cuts. The rationale for the selection/exclusion appears in Section 8.2.3 of the MA Report. The accuracy of results reported in Section 3.3 of the MA Report are for a version of the domestic VoLL model that include the following five key indicators:

- Rurality

- Income
- Electricity consumption
- Socio-economic status
- Fuel poverty.

A full description of all the data sources for each indicator, and a discussion of each indicator's impact on the model's accuracy, is provided in Annex A2 of the MA Report.

This prototype domestic VoLL model provides a mechanism to estimate VoLL for any given population, if these defining characteristics for the population are known. The model can therefore be used to extrapolate predictions of domestic VoLL outside of the survey population and has been used to make predictions of domestic VoLL across the whole of GB as part of this project. It is important to recognise that this model does not allow an estimation of VoLL for an individual but enables a calculation for a population of customers containing at least two hundred individuals. This limitation is a consequence of the Hierarchical Bayes analysis used in ENWL010. However, this is not believed to be a significant limitation to the approach because in most practical implications VoLL would involve estimations for populations of customers.

The model provides a mechanism to calculate VoLL at a Lower Super Output Area (LSOA) level for all of GB. This was performed to demonstrate the granularity at which VoLL can be calculated using the model.

The approach enables future enhancement of the model, enabling VoLL to be calculated across a range of different scenarios and alternative geographic boundaries i.e. customers living in a particular postcode area, or the households and businesses served by a particular network or network asset. The rationale for the LSOA approach is outlined in Section 8.2.4 and explained in detail in Section 4.2 of the MA Report.

This study has concluded that it is challenging to develop a model that can account for all the variability in VoLL. However, it does demonstrate that it is possible to develop a model that reflects some of this variability. The model developed in this project was designed to prove the concept and demonstrate to stakeholders the potential for a variable model, which allows VoLL figures to be established for a range of different customers, enabling more accurate information for different investment decisions.

The analysis shows that the variable model would be more accurate than the existing 'vanilla approach; however, the research also identifies the limitations as well as the advantages of this approach, with both being set out in Section 3.3 of the MA Report.

The study acknowledges that further work is required to improve and characterise a version of the model that could be implemented into regulatory framework and recognises that a variable model can only be applied in practice if 'hard coded' into these mechanisms for RIIO-ED2 and beyond, in common with the manner that the single VoLL is a construct of the RIIO-ED1 framework. The next steps in developing the prototype into a fully functional production version are discussed in Section 12 of this report.

8.2.2 Identify, evaluate and incorporate appropriate forecasting features to future proof the model / demonstrate stability/variability over time

The influence of the decarbonisation agenda and increasing adoption of LCTs is likely to increase the variation in VoLL across customer types and demographics.

The existence and availability of future forecasting data sets means that trends in VoLL indicators could be applied to a variable VoLL model to more accurately reflect the whole life and through life VoLL of an asset, for example, with greater penetrations of LCTs in a future zero carbon scenario. However, there are currently significant uncertainties about the general uptake of LCTs and regional patterns of adoption are particularly challenging to predict. The industry models future uncertainties against a range of assumptions underlying a number of scenarios.

The analysis used a stratified sampling approach, whereby sample populations on which the VoLL model was trained were created using different proportions of each indicator. However, it should be noted that there are limitations in the survey data - if the survey does not contain a sufficient volume of data on customers for particular VoLL indicators to create representative future populations, the model will remain untrained in this data space which could in turn compromise its accuracy.

EV ownership data is not readily available and therefore, for the purpose of evaluating its appropriateness as a VoLL indicator in this analysis; EV charging point locations were used as a proxy for ownership. The number of respondents owning an EV was approximately 70% of the sample population size used in the model. Stratified samples were created that contained differing percentages of EV owners ranging from 0-70%, however, no samples could contain between 70-100% of EV owners. This limitation means that a model incorporating EV ownership would be unexposed to this area of the sample space and predictions for samples containing these percentages could be less accurate. Section 8.3.5 also highlights considerations that should be noted concerning the LCT VoLL estimates derived from the ENWL010 survey.

This study highlights a key challenge in determining what timescales should be aimed for, to implement a variable VoLL, and whether both a short-term and long-term solution are appropriate, considering the ongoing decarbonisation and increasingly mixed electricity generation. The findings also recognise that LCT estimates of VoLL would benefit from further evaluation as adoption increases. Section 3.2.2 of the MA Report, explains why a model based on the data currently available may over-estimate VoLL for EV users. However, this difference is fractional and as EV ownership across GB currently represents a small overall percentage, it does not introduce significant inaccuracy. EV ownership was not included in the prototype version of the model and is therefore not included in the overall accuracy results reported in Section 3.3 of the MA Report; however, this indicator and any revised forecasting assumptions can easily be incorporated, pending further analysis.

When considering where forecasting should be applied, the CBA tool and CNAIM respectively consider the benefits and risks of an investment decision across the useful economic lifespan of an asset. Therefore, a VoLL forecast through time will introduce an improved level of accuracy in the overall assessment. However, the IIS which incentivises improved performance where it is most economically appropriate to do so, is concerned with rewarding and penalising DNOs in the present. For the CBA, consistency should be key for comparison and since all CBA projects are submitted in the same price control period they need to be based on comparable datasets. The research suggests a possible solution of denoting a VoLL ‘base year’ at the start of the price control with all options indexed from this. This leads to further implementation challenges, and whether separate VoLL values should be created for IIS, CNAIM and CBA. Furthermore, a challenge on implementation’s critical path is whether the VoLL for assets used in the CNAIM methodology can be calculated and verified in time for RIIO-ED2, as it is recognised the constrained timescales necessitate a model that must be simple to administer.

The details of any forecasting models, including where such forecasting should be applied, relative to a variable VoLL, need to be commonly agreed by industry stakeholders. The level of forecasting would also need to be explored to ascertain the most efficient and practical way to add-value to making investment decisions, acknowledging that all forecasting below the primary level is highly speculative.

8.2.3 Deliver an understanding of the relative value of investment to prevent an event vs that of managing the consequence of the event

ENWL010 established certain customer groups are significantly more impacted by outages than others, most notably households in fuel poverty, early LCT adopters, those in vulnerable circumstances and those served by rural networks. However, these variations are not acknowledged within the single uniform VoLL used in RIIO-ED1. VoLL inaccuracy has significant implications for vulnerable electricity consumers, especially the fuel poor. This research suggests that there is a need for a more precise VoLL to reflect groups with significant VoLL variation and the prototype model delivered by this project demonstrates the benefits to be gained from a tool that introduces a customer dimension into the decision-making process, to more accurately support investment plans and policies.

Section 2.6 of the MA Report provides a detailed summary of how VoLL is currently used within the regulatory framework and how a variable model might be applied within future methodologies. These mechanisms are summarised in Section 8.2.5 and 8.2.6 of this Closedown Report. This study suggests that a variable VoLL, if incorporated within the CBA and CNAIM methodologies will deliver more efficient investment decisions, informed by customer need.

ENWL010 also identified that proactive network investment, to reduce the duration and frequency of interruptions, will mitigate VoLL but it also established that a well-managed response to unplanned outages, in conjunction with appropriate customer support strategies, can provide an economically efficient means of reducing impact and consequently positively influence VoLL. The customer research element of VoLL2 (refer to Section 8.3.3) has determined that appropriate support strategies aimed at vulnerable customers are generally accepted and the research therefore suggests that it may be possible to utilise a variable model in establishing the relative value of condition-based risk of asset failure and appropriate non-network support strategies, tailored to manage the consequence of outages. This consideration is particularly pertinent to HILP events, also discussed in Section 8.2.

Customer vulnerability data (specifically penetrations of households with occupant/s on the Priority Service Register (PSR) and supply reliability data (experience of unplanned power cuts), which are both known to impact VoLL, were not included in the model. This data was omitted because it was sensitive and only available for the Electricity North West region - the purpose of the model was to demonstrate the practicalities and applicability of a variable approach that could be adopted on an industry wide basis.

The analysis also concluded that including vulnerability and reliability data and may not necessarily increase the model's accuracy by a significant order of magnitude. It is nonetheless recognised that inclusion of this data is likely to be attractive to both Ofgem and DNOs, as fundamental parameters reflective of customer need and dependence.

The proposed model was developed in a manner that easily enables these indicators to be included in a future version, should additional analysis suggest that there is merit in doing so, and suitable nationwide sources for the data are made available. However, adding fault history into the model would require additional analysis to explore if alternative models, trained with different sample populations, are able to make better predictions using outage data. If Ofgem were to recommend that a new VoLL model, adopted industry wide, would benefit from the inclusion of reliability data, then a collaborative, joint DNO approach that considers accurate fault data across GB is recommended.

8.2.4 Undertake analytics to identify the appropriate network scale to which the differentiated VoLL value should be applied

Section 8.2.1 outlines the analysis and recommendations for which VoLL indicators, based on the segmented values established in ENWL010, should be included in the prototype model (rurality, income, electricity consumption, socio-economic status and fuel poverty) and the reason for the selection. It also summarises the challenges of model development for SMEs.

This section considers the appropriate scale of the model, in terms of its complexity and the level of geographic granularity:

The study explored several options, each offering a solution with a varying degree of complexity. The analysis concludes that there are advantages replacing a single VoLL with a more nuanced, variable approach as demonstrated by the prototype model. However, the analysis suggests that many of the benefits could be realised from the application of a relatively simple disaggregated model, which utilises a limited number of attributes, identified as key characteristics influencing VoLL in ENWL010.

One example utilised constant values for domestic and SME VoLL but in such a manner that reflects the actual composition of specific areas by taking account the data used for the load-weighted aggregation (i.e. domestic and SME electricity consumption) by location. Analysis of this data suggests that this methodology would improve accuracy by approximately £2,000/MWh using such a disaggregated load-aggregation methodology.

It would then not be a significant further step to expand such an approach by using different constant values for domestic and SME VoLL in urban and rural areas. Instead of two constant values of VoLL (domestic and SME), there would be four (domestic urban, domestic rural, SME urban, SME rural). Analysis of the data suggests that this would improve the accuracy of estimations by a further £1,000/MWh.

Further improvements could then be derived from using a fully disaggregated model for either domestic or SME VoLL by incorporating VoLL indicators such as income, fuel poverty and electricity consumption.

The project created an example of such a model for domestic VoLL, which is described in Section 3.3 of the MA Report. This suggests that a capped domestic model (which removes outlying statistics to prevent very high or very low values of VoLL being reported) achieves an accuracy of £5,606/MWh, which represents an improvement of 35% when assessed against the Ofgem vanilla model. The study highlights limitations in the modelling associated with the data available and suggests that accuracy might be improved further with additional research involving more customer surveys and recommends that such research would benefit from a joint DNO collaborative approach.

The study also recommends that careful consideration is given to the relative advantages and costs of the various models for segmented VoLL - the more complex the model, the greater the volume of input data required. This will incur additional overheads in ongoing model and data maintenance, and such considerations could be significant in determining the most appropriate objective for a re-evaluated VoLL.

Geographic granularity

A fundamental consideration in the model development was the granularity of the geographic data used to derive it. Theoretically, greater granularity provides more flexibility and precision, but there are limiting factors associated with the level of individual household data that DNOs are/will be able to utilise within a RIIO-ED2 variable VoLL implementation.

Currently, low voltage circuit level (feeder) is the lowest point at which investment decisions are made and therefore it is logical for this to be the lowest level of connectivity at which VoLL is modelled. However, the study concluded that the level of accuracy of a variable VoLL model is unlikely to be so great that input data is necessary at a finer level of detail than LSOA. Furthermore, as open source data is readily available, in most cases, for the required inputs, this was considered the most appropriate level of granularity to use in VoLL2, to prove the concept of a variable model.

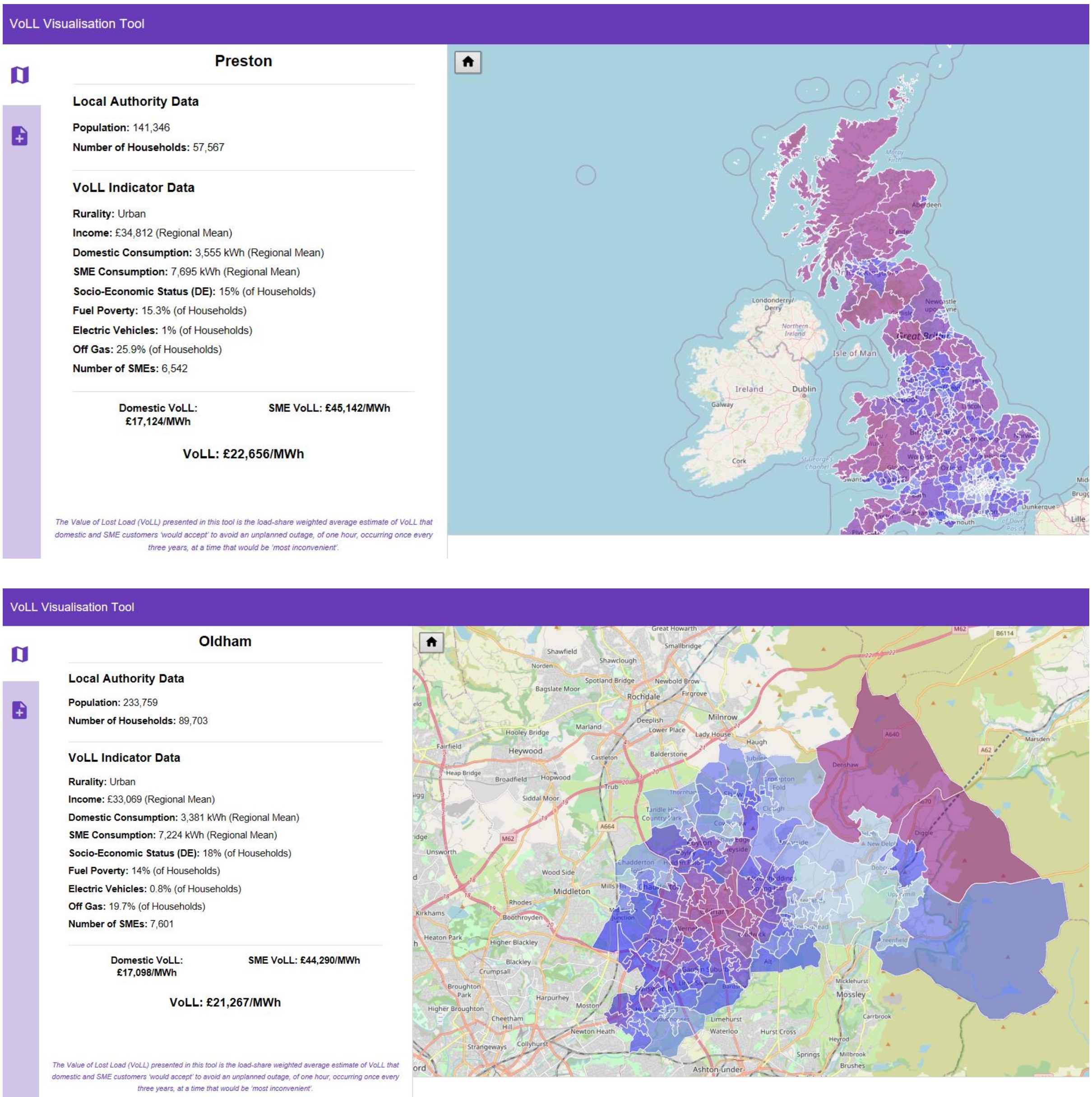
It is however acknowledged that the fundamental argument for a variable model is the ability to calculate the VoLL for a specific distribution network or asset. This could be achieved by calculating the VoLL at LSOA level, and simply applying the LSOA VoLL to all assets that sit within it. However, it is recognised that electricity networks are not aligned to LSOAs and this introduces geospatial complexities in the calculation, when assets serve customers across multiple LSOA's. In these circumstances to more fairly aggregate the VoLL, it would be necessary to either:

- Select an asset area using a variable VoLL calculation tool. This could be achieved by implementing a web application that includes point and click functionality to select an area, either as a point and radius or via drawing a freeform polygon. This would apply a load-weighted aggregation to the VoLLs for the households and SMEs in the area; or

- Use network connection databases to determine exactly which households and businesses are served by an asset, and then apply a load-weighted aggregation in a similar way.

To support the prototype model Frazer-Nash developed a VoLL Visualisation Tool, which displays predictions and allows the user to explore the variations in VoLL across an interactive map of GB. This tool was demonstrated on the Electricity North West stand at the LCNI in October 2019 and is illustrated in Figure 8.

Figure 8: Screenshots of the VoLL Visualisation Tool



The prototype Visualisation Tool, was developed purely to illustrate how the model could be practicably applied to stakeholders at the LCNI and includes indicators that are not included in model accuracy assessment documented in Section 3.3 of the MA Report. However, the tool demonstrates that additional indicators could be included in a future version, for example, the version illustrated in Figure 7 includes off-gas status and EV ownership.

8.2.5 Develop sample investment plans to understand options for implementation and potential impact on affordability and quality of outcomes for different customer segments

Implementation options for a variable VoLL and potential impacts are reported separately in this section.

Implementation options

The aim of a variable model should be to deliver improvements in the accuracy and fairness of the various applications of VoLL, when compared to the existing single value approach, used within the RIIO-ED1 methodology.

The following summarises how VoLL is currently used in three key areas of the RIIO-ED1 to guide network investment. This overview should be considered in conjunction with Sections 2.6 and 4.3.1 of the MA Report, which provides expanded detail on these mechanisms.

- Setting the Interruptions Incentive Scheme (IIS) incentive rate – VoLL is used as the parameter to set the marginal incentive rate for the frequency and duration of planned and unplanned supply interruptions within the IIS;
- Calibrating the Cost Benefit Analysis (CBA) model to evaluate customer performance benefit in the scrutiny of investment decision calculations;
- The network performance risk parameter within the Common Network Asset Indices Methodology (CNAIM) to derive the reference network performance cost of asset failure.

The study has concluded that a variable VoLL lends itself to the CBA and CNAIM methodologies but may not necessarily align with the IIS mechanism, as summarised below.

Interruptions Incentive Scheme

Since the introduction this regime in 2001 DNOs performance, judged against customer interruptions and customer minutes lost has improved significantly, demonstrating that a VoLL linked mechanism can have important, beneficial effects for consumers. The mechanism calibrates the marginal incentive rate to VoLL to reflect the value that consumers place on a secure supply, thus ensuring optimum investment to improve reliability. Consequently, the mechanism incentivises DNOs to improve performance where it is most economically appropriate to do so. A variable VoLL could therefore theoretically disadvantage customers on underperforming networks, who tend to have lower expectations of supply reliability and consequently, a lower VoLL, as established in ENWL010. This study acknowledges the potential for a variable VoLL to drive inappropriate behaviour within the IIS mechanism, which could lead to the prioritisation of investments in the wrong areas and worsen the divide between worst-served customers and those who value security of supply the greatest; for example, networks serving vulnerable populations, households in fuel poverty or early adopters of LCTs. For this reason, a variable VoLL may not be appropriate within the IIS and could be counterproductive. This study therefore suggests that simply updating the uniform macro VoLL, to reflect the weighted average value established in ENWL010, may be the most appropriate approach for the IIS mechanism in RIIO-ED2.

It is recognised that the IIS can be disadvantageous to those served by poorly performing networks, where costly investment may only deliver benefits to a relatively small number of customers. The worst-served allowance was included in RIIO-ED1 to counterbalance the IIS. Whilst VoLL is not explicitly part of the evidence required to receive funding under this regime, it is implied as part of the financial determinants contained within the mechanism. It is of note that the worst-served customer regime also recognises a need for DNOs to treat certain customer groups differently to deliver improvements in service, where customer and network performance benefits outweigh investment costs, but are unlikely to be reflected in a CBA. This acknowledgment provides early justification for a variable VoLL, which reflects the differing needs and impacts of certain customer groups.

Industry stakeholders must consider how a variable VoLL is applied within a successor worst served customer methodology, given this customer group has a lower VoLL than the average, which is thought to reflect lower expectations and greater resilience.

Common Network Asset Indices Methodology and Cost-Benefit Analysis Model

Analysis and stakeholder consultation suggest that the existing CBA and CNAIM methodologies lend themselves to a variable VoLL. For example, extending the base CBA engine, by replacing the fixed VoLL perimeter with a range of alternate factors, more attuned to the benefits of customers served by the asset, will inform more efficient investment decisions. The same principal applies to the assessment of costs when considering the failure of assets in the CNAIM. This mechanism provides a consistent way to evaluate the condition-based risk of failure of network assets and the consequence of failure across networks.

It is of note that the CNAIM already includes a ‘customer sensitivity factor’, which provides a mechanism for DNOs to make a basic adjustment to a calculation to reflect the sensitivity of customers served by a specific asset. The existence of this feature within the methodology implies an existing need for a variable VoLL; however, the methodology fails to provide guidance on which scenarios are relevant, nor the justification or evidence required to make the adjustment. This lack of clarity indicates that the sensitivity factor is currently not applied in a consistent manner, potentially leading to inefficiencies within investment decisions. Section 2.6 of the MA Report refers to Ofgem guidance that could potentially lead to similar inefficiencies in the CBA methodology.

The ultimate objective of a variable VoLL should be to inform decisions that better reflect consumers, provide increased consumer benefits and reduce the inefficiencies that exist within the RIIO-ED1 framework. Therefore, incorporating a variable VoLL that more accurately represents customer preferences into the CNAIM and CBA will facilitate consistently applied solutions that provide greater benefit to customers. The study concludes there would be little difficulty introducing a variable VoLL into these two methodologies, providing the model is simple to administer. However, a cautionary approach should be taken in the implementation of any solution, particularly in ensuring that there is a thorough understanding of statistical uncertainties associated with model predictions.

The key implementation challenges are a consensus on whether separate VoLL values should be created for IIS, and the CNAIM/CBA. Furthermore, a challenge on the implementation’s critical path is whether the VoLL for assets used in the CNAIM methodology can be calculated and verified in time for RIIO-ED2.

Section 8.2.4 discusses the merits of a simple disaggregated approach versus a more complex model that incorporates multiple VoLL indicators and Section 12 consider a way forward, by trialling an early iteration of a variable VoLL in RIIO-ED2, which provides an opportunity to refine the methodology and its application. The remainder of this section discussed potential impact on affordability and quality of outcomes for different customer segments.

Potential impacts

In addition to considering the practicalities and appropriateness of introducing a variable VoLL in the aforementioned methodologies, it is important to consider the impact, in terms of potential outcomes for different customer segments. For example, aligning the IIS with a variable VoLL may be counterproductive and result in greater inefficiency and negatively impact customers that are already poorly served.

ENWL010 established the impact of supply interruptions on VoLL; however, reliability data/fault history was not included in the variable model delivered by this project. The analysis recommends further exploration of the merits of including supply reliability data and acknowledges that Ofgem are likely to find the inclusion of this indicator attractive in a future model. Careful consideration needs to be given to how this characteristic could be appropriately incorporated, without unintended consequences, given that some values associated the experience of outages, as derived from the original study, initially appear counter intuitive.

The experience of both planned and unplanned outages has been demonstrated to impact VoLL and the original study reveals significant variations relative to the frequency, duration and type of power cuts. The VoLL2 customer research has established similarities with the earlier study. This focussed purely only on unplanned interruptions and has established a 'multiplier'. This suggests that disutility (for both domestic and SME customers) increases sharply for outages between 6 and 12 hours but then rises at a reduced rate above 12 hours, progressing steadily at that rate to where an outage lasts up to 3 days. This pattern is discussed further in Section 8.3.2.

The multiplier should be considered, alongside other indicators, in the evaluation of characteristics that are appropriate and improve overall accuracy in a future, production version of the model. However, further consultation is required to establish the merits of a methodology that takes account of long duration, widespread outages, sometimes referred to as High Impact, Low Probability (HILP) events, given that ENWL010 established the VoLL of customers with experience of at least one such event, is lower than the average.

Assumptions around these findings are thought to reflect customer acceptance that HILP events, often associated with extreme weather, are largely due to circumstances outside the control of DNOs and therefore less worthy of compensation. Anecdotal evidence suggests that impact, and consequently VoLL, might be mitigated with a well-managed response and good communications strategies. These assumptions are discussed in the VoLL Phase 3 Report.

These findings suggest that, in terms of how a variable VoLL might be incorporated into future regulatory mechanisms associated with the risk-based avoidance and consequence of HILP events, a non-network impact mitigation approach may be appropriate to best manage/respond to such eventualities.

Future scenarios

The potential impact on affordability and quality of outcomes was also considered in the evaluation of a model which incorporates early adopters of LCTs (who in the ENWL010 study were found to have higher VoLL than the average). Whilst further research is recommended to improve the accuracy of future electricity scenarios and forecasting models (see Section 8.2.2), it is of note that the customer research conducted in this study (Phase B) established that respondents were disinclined to prioritise investment in infrastructure to facilitate the transition towards decarbonisation, over investment benefitting other customer groups even though, anecdotally at least, they appear to recognise the need to do so, from an environmental perspective and a driver for wider societal benefits. It is also likely, as discussed in Section 8.3.5, that as the uptake of LCTs increases, so too will opinions, reflecting a heightened awareness of increased dependence.

Vulnerability

Vulnerable customers can voluntarily sign up to the priority services register (PSR) which enables DNOs to offer a range of free support services to mitigate the impact of an outage. This register makes it possible for each DNO to understand the penetration of vulnerability in a region by broad classification from a 'needs code' associated with the MPAN.

PSR data or other vulnerability indicators were not included as a VoLL characteristic in the prototype variable model and the reason was twofold. Firstly, PSR data, which is classified as personal and highly sensitive was not available to Frazer-Nash for the prototype model build. Secondly, the analysis, based on ENWL010 survey responses, suggests that including vulnerability only fractionally improved the accuracy of the model. (Appendix A.2.1.11 of the MA Report).

However, it is recognised that inclusion of vulnerability as a VoLL indicator, in a future model is likely to be attractive to both DNOs and Ofgem, in reflecting the dependence of customers in decision making processes. In common with the use of fault history/reliability data as a VoLL indicator, vulnerability is likely to be desirable, even where the complexity of including and maintaining a dynamic dataset, may only result in marginal improvements in the model's accuracy. Nonetheless, it is acknowledged that this indicator could be increasingly warranted in a future model, to deliver more nuanced calculations of VoLL, which recognise the customer impact of those decisions.

The use of the PSR to determine penetrations of vulnerability and the general nature of that vulnerability in the model also presents a challenge in so far as DNOs are aware that significant gaps exist in registrations, when compared to open source indices of vulnerability and deprivation. As such, it may be more appropriate to base a vulnerability indicator on public data sources in preference to the PSR. This study therefore recommends further analysis to support inclusion of vulnerability into a production model and establish the most accurate data set, with which to train the model. The modelling approach means that it would be relatively straightforward to incorporate this indicator, if the research demonstrates advantages in doing so.

Guaranteed Standards of Service

VoLL is not currently used within the Guaranteed Standards regime and as such the use of a variable VoLL within the regulation was not considered in this project. The ENWL010 Recommendations Report suggests that calibrating the regulation with a disaggregated VoLL would theoretically enable the mechanism to more accurately reflect the impact of interruptions, given the variability of VoLL by specific customer groups. However, any alignment of customer compensation strategies with VoLL introduces significant complexity and potential inequity, which are factors that the industry may wish to consider as part of the wider RIIO-ED2 consultation process.

Similarly, it is possible that other mechanisms, for example Black Start Policy and Low Frequency Demand Disconnection could be developed to reflect variations in VoLL, to mitigate the impact of network management activities associated with responses to HILP events. These mechanisms were not considered within the remit of this project.

The project has identified that whilst certain VoLL indicators may not easily fit within a variable model or materially improve its accuracy, they may nonetheless be influential in targeting non-network support strategies for certain customer groups.

8.2.6 Engage with stakeholders to identify implications, formalise a VoLL decision-making tool and establish a strategy for transition to national implementation, identifying regulatory mechanisms currently or potentially driven by a VoLL function.

Initial stakeholder consultation to identify implications

The Ofgem Reliability, Safety and Environment Working Group were regularly updated on the findings arising from ENWL010 and have continued to be engaged on the aims and outcomes of this follow-on study.

The research approach for the strategic element of VoLL2 (Phase A) was informed by the views of key stakeholders. The implications of a variable VoLL on price control regulation and investment decision making were discussed at a deliberative workshop hosted by Electricity North West in October 2019. This was attended by representatives of every GB DNO and Ofgem. A recording of the plenary session of this engagement is posted on the project webpage. Section 4.3 of the MA Report summarises the main discussion points and how views expressed at this event, along with subsequent feedback, influenced the development of the prototype model delivered by this project.

This consultation focussed on existing regulatory mechanisms that are driven by VoLL, those where VoLL is implied and areas where it might potentially be a feature of future methodologies, these topics are summarised in Section.8.2.5. This collaborative methodology was designed in recognition that a variable model can only be applied 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 that 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.

Stakeholder updates
Interim project findings were disseminated at one of the main breakout sessions (customer futures) during the Low Carbon Networks and Innovation (LCNI) Conference in Glasgow on 31 October 2019. A project factsheet was made available to industry stakeholders and the interactive, VoLL Visualisation Tool was demonstrated to delegates on the Electricity North West stand across the two days of the conference. In addition to the main breakout session, a stand presentation on VoLL2, which included a demonstration of the Visualisation Tool also took place.

On 14 November 2019, the project findings were presented to the Electricity North West Customer Engagement Group, an independent customer group with an overarching responsibility for scrutinising how the company engages with customers and stakeholder, ensuring their voices are heard and represented in its business plans.

The projects aims, objectives and early findings were disseminated in an advertorial published in networks online in December 2019.

In February 2020, during the 'validation' stage of the research, we shared our findings with key industry stakeholders (Ofgem all other DNOs), who were invited to review and challenge the recommendations contained in the MA Report, in relation to the suggested variable VoLL model and proposals for its implementation.

The results and implications of the findings were disseminated to industry stakeholders at the fifth Electricity Innovation Forum, hosted by the ENA on 21 February 2020.

The key findings from the VoLL2 project (specifically the strategic element of research - Phase A) and planned next steps were disseminated to Ofgem's Reliability, Safety and Environment working group on 31 May 2020. This meeting, debated how the learning should be used to inform improved decisions and the appropriateness and practicalities of incorporating a variable VoLL into the regulatory framework of future price control periods.

Periodic innovation updates have reported the progress made in VoLL research to industry stakeholders and Electricity North West's executive leadership team.

In line with the requirements of NIA governance and project commitments all outputs, learning attained, and materials generated by the VoLL2 research have been made available to DNOs and other stakeholders. Ongoing learning has been disseminated through an annual NIA project progress report and documented in a suite of key stage reports, all of which are available on the VoLL2 webpage.

Strategic engagement with key industry stakeholders concerning the appropriateness of a variable VoLL in RIIO-ED2 methodologies and a strategy for national implementation, is expected to continue as part of the wider RIIO-ED2 consultation process, beyond the date of this report. Proposed next steps and recommendations for planned implementation are discussed in Section 12.

8.3 Outcomes - Phase B (customer)

8.3.1 Determine the increased sense of equity and DNO service provision that can be achieved through implementation of a differentiated VoLL model.

This objective was achieved through a large scale quantitative customer survey of 2,054 electricity customers from across the whole of GB. 911 respondents were from within Electricity North West's operating region. A total of 1,545 of the surveys were conducted with domestic customers and 509 were completed by SME representatives, from a broad range of business sectors.

The survey contained a CVM exercise, which was designed to evaluate which customer groups are considered most in need and/or deserving of additional support or investment, according to respondents' willingness to pay for it through higher annual bills. The outputs were used as a proxy to assess customers' acceptance of investment prioritisation and consequently, perceptions around fairness of a variable model. Additional questions were included in the survey to support the CVM and explore perceptions on cost socialisation, in the context of capital investment and support strategies benefitting certain customer groups. This is a complex subject area and the rationale for the research methodology and outputs are summarised in Section 8.3.5 of this document (expanded in Section 3.1 of the Customer Survey Report).

In the evaluation of how DNOs fund network investment, respondents were asked questions that sought to uncover their views on how network costs are/should be apportioned and if costs should largely be proportional to consumption, as is currently the case, or based on alternative charging structures, such as a flat rate. Approximately half the respondents felt that proportional charging was fair, but the rest were ambivalent. When questioned about equitable charging, where costs fail to differentiate between the delivery of electricity to rural, as opposed to urban communities; more than half were uncertain about whether this is fair. However, when asked to choose between a range of possible network management approaches, most felt that all customers should receive the same level of reliability. This is consistent with a similar finding from the original VoLL study.

Overall most believe that the fairest approach to fund network investment from use of systems charges is a regime that encourages energy efficiency i.e. one based on a standard rate for everyone up to a certain limit, ensuring basic needs are covered, with subsequent unit rate increases, which ultimately result in heavy users paying proportionally more. More granular sub-group analysis is reported in Section 3.6 of the Customer Survey Report.

Survey findings were largely consistent with observations from the initial qualitative stage of research with an ECP, which established that whilst some participants accepted the value of using a differentiated VoLL to add a customer dimension into investment prioritisation methodologies, in practice they expected this vector to be secondary, with overall investment priorities determined by demand levels or the extent to which equipment is inadequate, or at risk of failure.

Analysis of the survey results demonstrate that certain customer groups are considered more deserving of investment and customers would therefore generally endorse a variable VoLL, which is considered more desirable than the current uniform value. However, this view is caveated by an expectation that investment prioritisation ought to only be considered once the basic requirements of all customers are met.

8.3.2 Quantify the impact of scale and duration of an outage on VoLL

ENWL010 established that an outage generally incurs a higher VoLL the longer it lasts, with the marginal hourly value declining steadily. It suggested there is a levelling out in the upward trajectory of VoLL for extremely long duration interruptions, typically associated with extreme weather events. However, ENWL010 concluded that additional research was required to understand how individual assignments of VoLL could be extrapolated to a community measure, relative to the frequency, duration and scale of outages.

This follow-on study involved a quantitative customer survey, designed to establish the degree to which the dis-benefit experienced by customers from an interruption of the type they are most likely to experience (in range of 1 to 6 hours) could be multiplied to represent the effect of longer interruption times and wider geographical spread.

The survey included a BWS choice exercise, which is a trade-off technique, to measure the relative importance that respondents attached to interruptions, defined in terms of length, and the extent to which this varies from a single property to a whole DNO region. In contrast to the main VoLL study, a price element was not included in the trade-off, as the aim was to encourage respondents to fully consider what extreme interruptions would mean to them in terms of how much worse these events are, when compared to short, relatively localised interruptions of the type they are more likely to experience. Including a price element would have introduced complexities associated with willingness to pay (WTP) studies.

For the BWS modelling, coefficients were standardised against the disutility of a '6-hour interruption' versus the base level of 'up to 1-hour interruption'. This allowed interpretation of the results for large scale interruptions to be expressed in terms of a 'multiplier' against this base level of disutility and allowed the results for all customer groups to be compared on a common basis.

Analysis of the VoLL2 survey substantiates the findings of ENWL010, by demonstrating that large scale and lengthy unplanned interruptions have the potential to increase VoLL, when compared to shorter, limited scale outages.

The research established that the duration of an interruption was the biggest factor in determining VoLL, relative to the multiplier. For interruptions that last more than 6 hours, a 24-hour interruption has approximately twice the impact. A 3-day interruption has about six times the impact of a 12-hour interruption. This implies that the VoLL per hour is lower beyond the 12-hour point, but then remains constant. This effect is the same for both domestic or SME customers and is consistent across most other sub-groups. There were small sub group differences, reported in Sections 2.3 and 2.4 of the Customer Survey Report.

Figure 8.1 summarises the overall results for domestic and SME customers. These results are standardised against the disutility of moving from an interruption of up to 1 hour to an interruption of 6 hours. This provides a basis for comparing the impact of longer interruptions and the geographical scale of supply interruptions across customer groups.

Figure 8.1: Results for total sample (indexed)

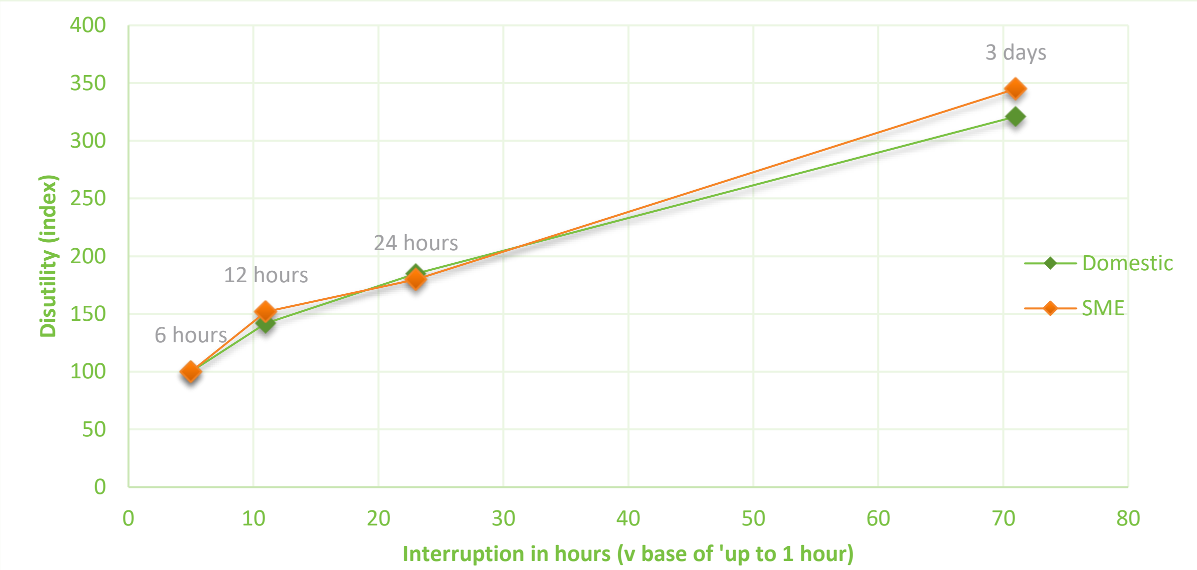
Attribute level		Domestic (all) N=1,545	SMEs (all) N=509
Length of supply interruption	Up to 1 hour (Base)	0	0
	6 hours	100	100
	12 hours	142	152
	24 hours	185	180
	3 days	321	345
Scale of interruption	Just my property (Base)	0	0
	My street or several local streets	7	-32
	My town/village and surrounding areas	18	35
	The whole of [REGION]	43	69
Frequency of interruption	Once every three years (Base)	0	0
	Once per year	22	39
	Several times per year	142	221

Full details of how the multiplier effect was evaluated can be found in Sections 2 of the Customer Survey Report. This explains how the multiplier was measured, modelled and can be applied to the monetary values of VoLL established in ENWL010. The main findings are illustrated below:

Duration of supply interruption

These standardised model results suggest that disutility increases at a reduced rate above a 12-hour interruption but then progresses steadily at that rate up to a 3-day interruption. This pattern, shown in Figure 8.2 is similar for domestic and SME customers. This is consistent with the pattern observed in the earlier VoLL study (ENWL010).

Figure 8.2: The multiplier effect of large interruptions



Scale of supply interruption

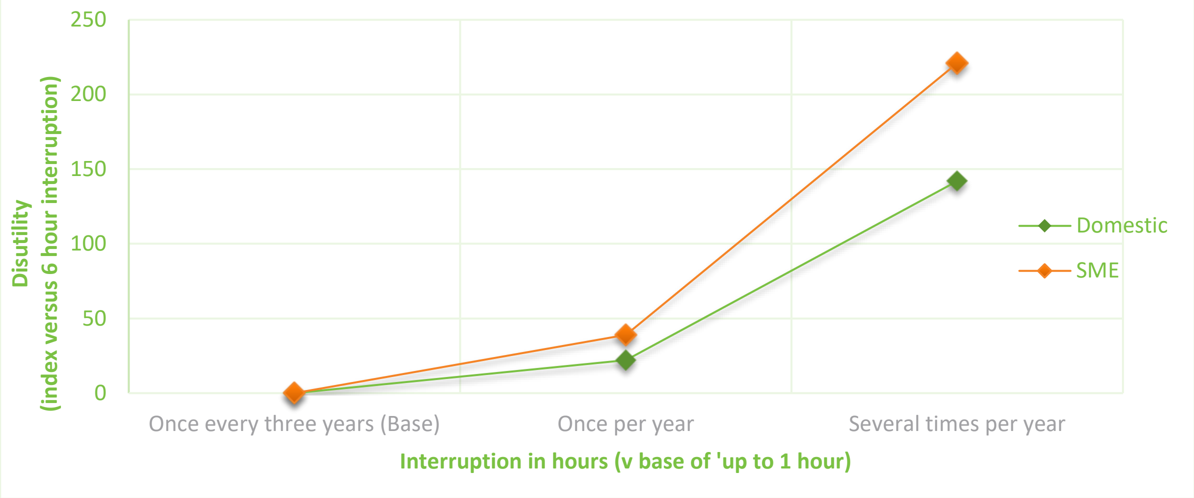
The standardised model results suggest that disutility resulting from the scale of an interruption is different for domestic and SME customers, as illustrated in Figure 8.3. Domestic customers register a relatively modest increase in disutility as the scale moves from 'just my property' to 'my town/village/area', where it then doubles if it moves to the whole of their region. SME customers show a similar pattern for town/village/area and whole region but are least concerned if it occurs at the level of 'my street / local'.

Figure 8.3: The multiplier effect of the geographical scale of an interruption

Frequency of supply interruption

The standardised results suggest that disutility resulting from the frequency of an interruption is broadly similar for domestic and SME customers, though more pronounced for the latter, as illustrated in Figure 8.4. Experiencing more than one interruption a year increases the disutility dramatically for both customer groups. This effect was also observed in ENWL010, indicating further similarity between the results of this study and the earlier work.

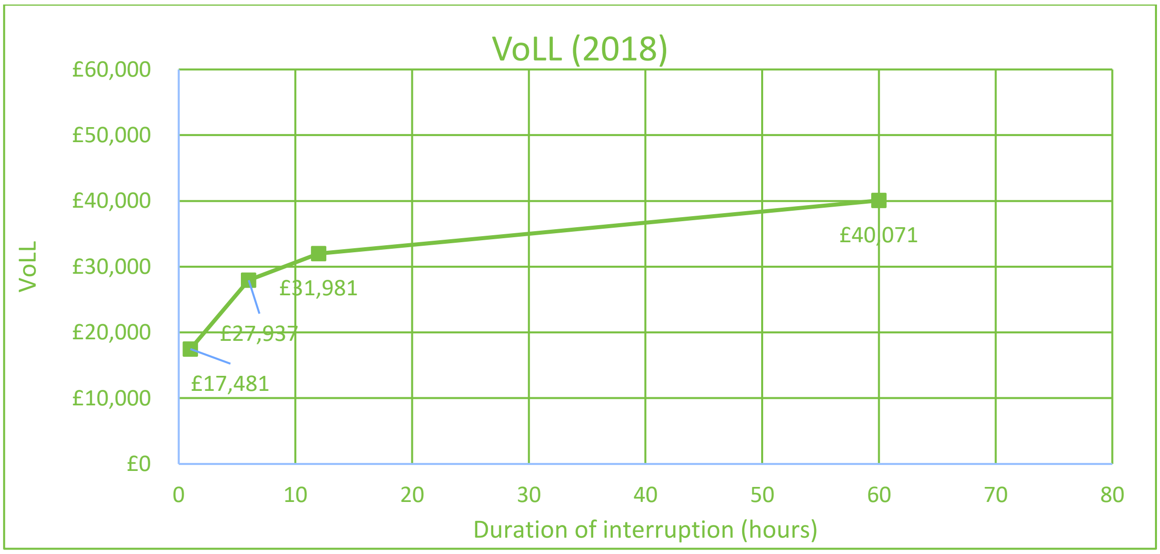
Figure 8.4: The multiplier effect of the frequency of an interruption



The analysis indicates the potential 'multiplier' effect that large-scale interruptions could have on VoLL. The analysis assumes that the relationship between utility and value established in ENWL010 hold for these results, meaning they can be used to transform the standardised utility estimates into an equivalent monetary measure.

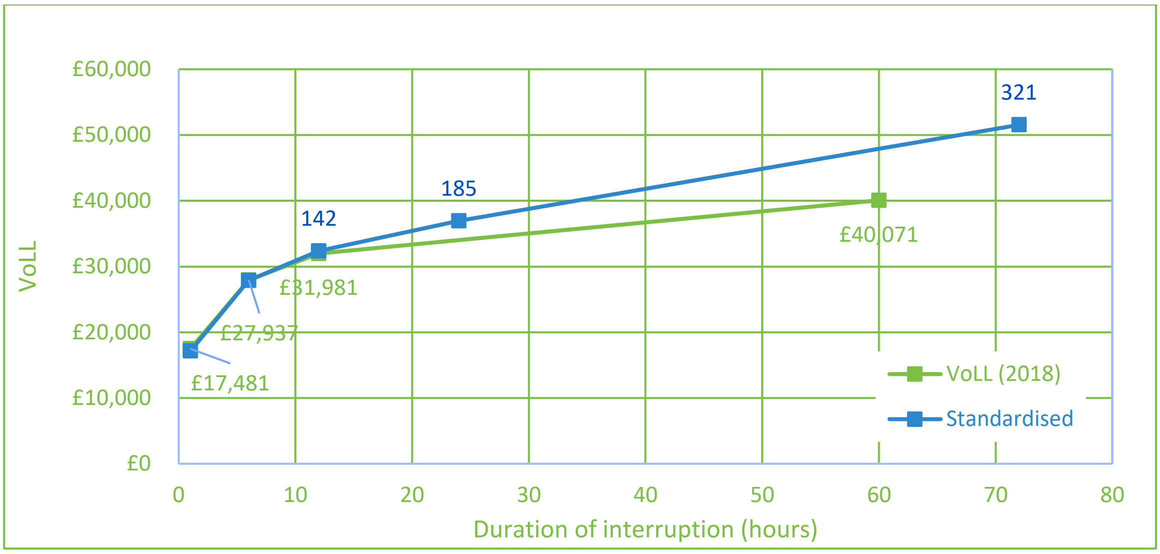
In ENWL010 a relationship between VoLL and duration of interruption was established, as shown in Figure 8.5.

Figure 8.5: The relationship between VoLL and interruption duration (domestic customers)



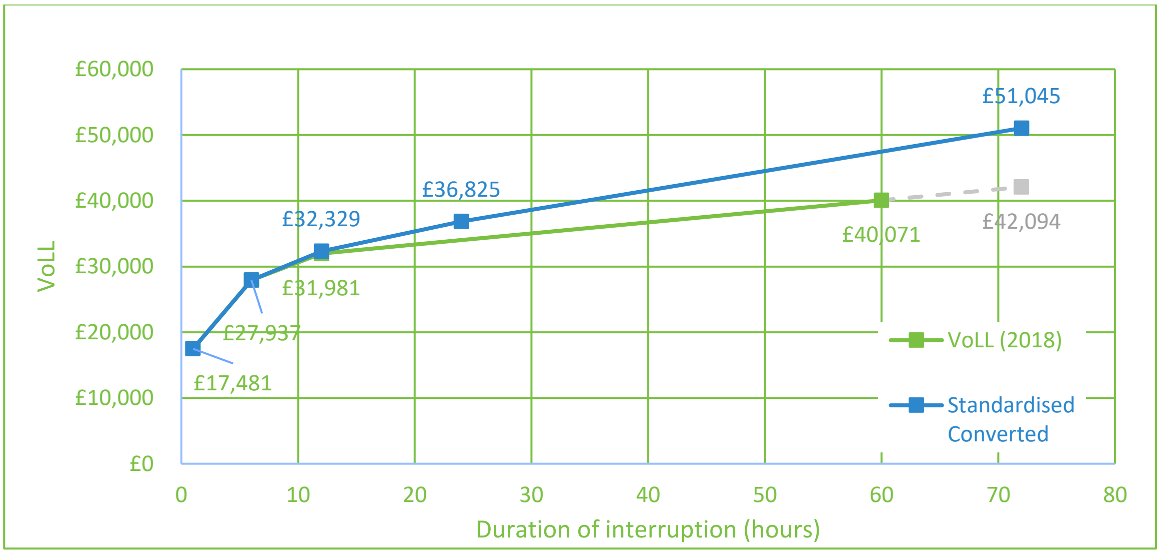
The standardised values (indexed against the dis-utility of the change from 'up to 1 hour' interruption to a 6 hour interruption), established in this study can be "overlaid" onto Figure 8.5, as shown in Figure 8.6.

Figure 8.6: New standardised results overlaid on VoLL (domestic customers)



The standardised result of 100 for 6 hours versus ‘up to 1 hour’ is then assumed to be equivalent to a mean value £10,456 (this the £27,937 mean value for 6 hours minus £17,481 mean value for 1 hour), as taken from the earlier VoLL research. This conversion (£104.56 = 100 standardised units) is then applied to the other standardised values to give the values shown in Figure 8.7. In addition, the value of VoLL (2018) for a 3-day interruption (72 hours) is extrapolated from the 12 hours to 60 hours results to give an approximate comparator value.

Figure 8.7: New results overlaid on VoLL (domestic customers)



The implication here would be that the monetary value for VoLL progresses at a lower rate than the ‘pure’ multiplier effect measured in the current study. Figure 8.8 shows a similar relationship for SMEs, also suggesting a similarly lower value. However, in both cases the confidence intervals around these point estimates suggest that the difference is unlikely to be statistically significant.

Figure 8.8: New results overlaid on VoLL (SME customers)

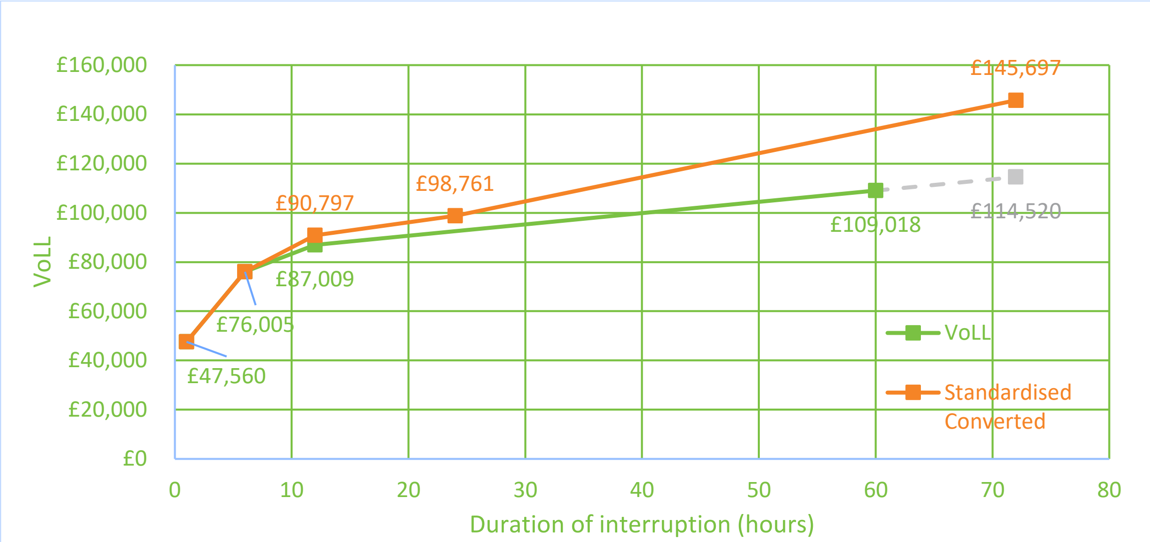


Figure 8.9 indicates the implied increase in VoLL when the scale of a 3-day interruption is beyond 'just my property'. As these figures are based on simple point estimates of VoLL, they should only be considered as indicative.

Figure 8.9: Potential Impact of large scale, 3-day service interruption on VoLL

3 day interruption in …	**Domestic**		**SME**	
	Standardised Value	Extrapolated VoLL	Standardised Value	Extrapolated VoLL
Just my property	321	£42,094	345	£114,520
Town / area	349	£45,766	380	£126,138
Whole region	364	£47,733	414	£137,424

The research shows that customers identify a multiplier effect for the dis-benefit of a large service interruption and that this relates both to the length of the interruption and the geographical scale of the interruption. Figure 8.10 summarises the implied multipliers that can be applied to the VoLL for a six-hour interruption (based on Figure 8.1, illustrated above).

Figure 8.10: Results for total sample (additive)

Attribute level		Domestic	SMEs
Length of supply interruption	6 hours	0.0	0.0
	12 hours	0.4	0.5
	24 hours	0.9	0.8
	3 days	2.2	2.5
Scale of interruption	Just my property (Base)	0.0	0.0
	My street or several local streets	0.1	-0.3
	My town/village and surrounding areas	0.2	0.3
	The whole of [REGION]	0.4	0.7
Frequency of interruption	Once every three years (Base)	0.0	0.0
	Once per year	0.2	0.4
	Several times per year	1.4	2.2

*For example, A six-hour interruption that only affected a customer's property, with a domestic VoLL of £42k based on the main VoLL study, implies a value of (£42k + £42k * (0.9 + 0.2) = £88k for a 24-hour interruption (0.9) that affected the town/village and surrounding areas (0.2)*

8.3.3 Deliver an understanding of the societal value of investment to prevent an event vs that of managing the consequence of the event

ENWL010 highlighted the need for further empirical customer research to test the impact of different scenarios. This included a requirement to establish the effect of an outage's magnitude on VoLL, when assessed at community level, rather than the individual, i.e. assessing the overall impact of a large-scale event affecting a significant number of people versus that of a smaller, more localised interruption. This learning is summarised in Section 8.3.2.

Electricity North West's original study, now substantiated by VoLL2 research, established that the number and frequency of outages increases VoLL and consequently, investment to reduce the likelihood of asset failure will mitigate VoLL. The prototype model developed by Frazer-Nash has proven there are benefits to be gained from the implementation of a variable approach within the CNAIM and CBA methodologies that introduce a customer dimension into condition-based risk and cost benefit calculations.

Furthermore, understanding the 'multiplier' by customer segment and sub-segment is expected to inform an assessment of the appropriateness of incorporating supply reliability/historic fault data as a VoLL indicator in a production-standard version of the model. Theoretically, this learning could deliver more sophisticated and nuanced calculations, resulting in greater efficiency in investment decision making. However, as outlined in Sections 8.2.3 and 8.2.5, including reliability data as a vector in the model will require careful consideration to ensure this does not incentivise inappropriate decisions; for example, in the case of poorly served customers, who tend to have a lower VoLL, which is thought to reflect the lower expectations of those more accustomed to a less reliable supply. Therefore, a supply reliability indicator will be subject to additional analysis, to determine the practicability of inclusion and the extent to which this improves the model's accuracy.

This research does however provide insight on how a variable VoLL might be considered in the evaluation of the relative value of proactive capital investment, aimed at preventing or minimising the severity of unplanned interruptions versus the ability to mitigate VoLL by deploying appropriate non-network and welfare strategies to support customers during a fault scenario, to best manage its consequences.

A range of support mechanisms were assessed relative to their impact on VoLL in ENWL010. This established that a well-managed response to unplanned outages, in conjunction with appropriate customer support strategies, most notably good communication, can provide an economically efficient means of positively influencing VoLL. These findings are documented in Section 2.8 of the VoLL Phase 3 Report, which summarised the outputs of the original research

The VoLL 2 study also examined the relative importance that customers place on restoring power to different customer groups, known to be negatively impacted more than most during a power cut. This revealed that customers generally support socialised costs that enable DNOs to proactively identify, contact and support vulnerable customers in an outage. The research suggests that customers generally advocate the prioritisation of supply restoration to communities with a high incidence of vulnerability, in the context of the elderly sick and dissabled.

This learning is expected to be important in developing more sophisticated investment decision methodologies and tailoring effective customer service, support and welfare strategies. This understanding also has implications for business plan development and is likely to be relevant to future policies associated with HILP events and a successor worst-served customer regime in RIIO-ED2

8.3.4 Measure societal acceptance of a differentiated VoLL model, segmented by customer need

The social costs of outages are multi-faceted, vary significantly depending on scale, duration and frequency, and the communities affected. These impacts were explored in the initial qualitative phase of research, as documented in the ECP Report. Social impacts are notoriously hard to measure, and it is equally challenging to evaluate perceptions on the fairness of socialising out the cost of investment, specifically investment prioritisation aimed at mitigating the risk of outages and their impacts on particular communities.

A key objective of this project was to explore this complex concept to establish whether customers were willing to pay for investment to reinforce networks most likely to benefit certain customer groups i.e. where there is a need to facilitate LCT uptake, versus areas with a high incidence of vulnerability or fuel poverty.

In contrast to the main element of the survey, which used a BWS technique to establish the VoLL multiplier; societal acceptance of a variable model was evaluated using a CVM technique, explained in Section 8.3.5. The CVM incorporated a price component to assess the acceptability of a range of possible annual bill increases, linked to five different scenarios. The financial component ranged from between 50p to £20 for domestic customers, and 0.5% to 10% of the annual electricity bill for SME customers.

In this way, the CVM outputs were used as a proxy to assess customers' acceptance of investment prioritisation and consequently, views on the fairness of a variable VoLL. This was considered the most appropriate mechanism for establishing perceptions on the basis that asking customers to respond directly to research of this type, which specifically refers to company investment decisions, is far too complex a proposition and introduces significant bias that would be unable to produce meaningful results. A peer review of the method is summarised in Appendix 3 of the Customer Survey Report and concluded that the approach achieved this objective from a methodological and statistical perspective.

The CVM provided over 48,000 data points to construct a standardised statistical model, which allowed the results for all customer groups to be compared on a common basis.

The use of WTP measures within the CVM, was evaluated alongside responses to several deliberative survey questions that were designed to elicit views on a range of charging scenarios.

The analysis suggests that customers are generally supportive of approaches that prioritise the needs of vulnerable customers even where this means that other customers/communities that are also experiencing an interruption, may be without power for longer. However, the WTP research reveals this level of support extends only to vulnerability, in the context of customers that are elderly, chronically ill or disabled. Respondents do not necessarily endorse the same level of prioritisation towards areas of social deprivation, where fuel poverty is prevalent. However, both of these groups take precedence over the needs of LCT users, where an increase in bills to prioritise supply restoration is considered less acceptable.

The study also suggests support for those served by poorly performing networks. These findings imply that there is generally societal acceptance of a differentiated VoLL, segmented by customer need. However, the results also indicate that the level of acceptance is not consistent across all customer groups.

The general customer view appears to be that sufficient investment should be made to meet the needs of vulnerable customers and to this extent, a mechanism that enables this (i.e. variable VoLL) is supported. Yet this must not be at the expense of adequate investment for everyone else.

8.3.5 Substantiate which segments are perceived by society to have the greatest need

The ENWL010 study, robustly demonstrated that a 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 a broad range of customer types.

VoLL2 sought to investigate both the technical application of a variable VoLL within future regulatory mechanisms, but also evaluate if customers believe that it is right for the industry to consider the unique needs of different customer groups in decision making processes.

Whilst ENWL010 clearly evidenced that the impact of outages varies significantly across different customer groups; VoLL2 aimed to definitively establish if customers nevertheless believe that these differences should be reflected in investment decisions or whether the status quo should be maintained, with all customer groups continuing to be treated equally.

As explained in Section 8.3.4, this element of the research involved a CVM technique, the outputs of which were used as a proxy to assess customers' acceptance of investment in specific areas of the network to support particular customer groups.

Figures 8.11 and 8.12 show the five WTP scenarios presented to respondents and illustrates consistent agreement across domestic and SME customers on the order that different groups should have power restored to them, representing those perceived by society as having the greatest need.

Figure 8.11: Domestic customers: – Order of importance of each scenario

Order	Scenario	Description	% of 897 sub-groups who agree with the order
1	1	Scenario 1 – restore power to vulnerable customers sooner	97% (out of 897 sub-groups)
2	2	Scenario 2 – prioritise your household	55% (40% rated as 3rd most important
3	3	Scenario 3 – prioritise vulnerable customers	56% (41% rated as 2nd most important
4	5	Scenario 5 – prioritise fuel poor customers	94%
5	4	Scenario 4 – prioritise EV or solar panel users	98%

Figure 8.12: SME customers: – Order of importance of each scenario

Order	Scenario	Description	% of 212 sub-groups who agree with the order
1	1	Scenario 1 – Restore power to vulnerable customers sooner	83% (out of 212 sub-groups)
2	2	Scenario 2 – Prioritise your business	70% rated as 2nd most important
3	3	Scenario 3 – Prioritise vulnerable customers	58% rated as 3rd most important
4	5	Scenario 5 – Prioritise fuel poor customers	72%
5	4	Scenario 4 – Prioritise EV or solar panel users	84%

The findings imply that customers are willing to pay more for some groups, including vulnerable customers (the elderly, sick and disabled), to be prioritised ahead of others. However, customers were also willing to pay more to have their own property, or business premise, restored before others.

The reasons why fuel poor households/communities are regarded as less deserving than other vulnerable groups are not completely clear, but it is possible that society may perceive that those who are struggling with fuel poverty already receive public support and that the responsibility for supporting this group lies with the government or other agencies, and less so with themselves.

This highlights a dichotomy that conflicts with the ENWL010 findings, which clearly established that fuel poor customers have a significantly higher VoLL than the average domestic customer. It is generally accepted this is because these customers are least able to cope, having limited residual income to manage the effects and consequences of outages, as discussed in detail in Section 6.6 of the VoLL Phase 3 Report. By implication, this suggests that it would be efficient for DNO's to prioritise investment to mitigate the risk of asset failure on networks in socially deprived regions, serving a high proportion of households in fuel poverty. VoLL2 however highlights that as investment costs are socialised via the Distribution Use of System (DUoS) charge; society is less supportive of investment prioritisation towards networks serving fuel poor customers, above those where a high proportion of vulnerability exists, defined in terms of elderly customers and those with chronic or serious health conditions. It is of note that

ENWL010 established that VoLL for vulnerable customers (when adjusted for income) was above the average but significantly lower than the value assigned by fuel poor customers.

This finding reveals important insights about how vulnerability is defined more broadly by society and specifically, which classifications of vulnerability are considered more deserving, when the cost of delivering support is socialised.

Figures 8.11 and 8.12 show that the scenario perceived to have the greatest importance is 'getting power restored to vulnerable groups' – scenario 1. However, it is of note that when the term "priority" is introduced (scenario 3) WTP generally decreases. This demonstrates that respondents are in principle supportive of vulnerable groups when it comes to restoring power, but less so when that support could be detrimental to their own experience. The analysis reveals that respondents were willing to pay similar amounts of money to prioritise the restoration of power to their own household/business, as they are for prioritisation targeted at vulnerable groups.

Customers that use electricity to charge their electric vehicles or have solar panels are considered to be lowest priority (unless the customer is themselves a member of this group). This finding, whilst not completely unexpected, highlights important questions concerning investment prioritisation to facilitate transition towards a decarbonised economy. ENWL010 established that early adopters of LCT have a VoLL approximately 10% higher than that of the average domestic customer, with EV users expressing a VoLL almost 25% above the average.

It is of note that ENWL010 established that 'non-users' of LCTs find it challenging to envisage how the adoption of new technologies might fundamentally change the overall impact of supply interruptions and therefore, they struggle to recognise that investment to facilitate LCT uptake will increase future supply reliability. Therefore, VoLL estimates were calculated only for current users of LCTs, on the basis that early adopters are most reflective of the future scenario. It is also important to consider that this survey was conducted in 2017/18 and estimates derived from ENWL010 are therefore reflective of the VoLL of relatively early adopters, whose perspective may have been ahead of the general curve. EV sales have risen dramatically over the last few years and further research may be required to re-validate LCT VoLL estimates as adoption enters the mainstream, to support predictions relating to future scenarios. Section 8.2.2 highlights current limitations with the sufficiency of data for certain VoLL indicators to create representative future populations in the model developed by Frazer-Nash that would benefit from such additional customer research.

This study indicates that at present, unless customers are themselves LCT users, they are disinclined to support the prioritisation of investment to meet the increasing growth in these technologies. Nonetheless, anecdotally at least, there is evidence that customers recognise the need for DNOs to facilitate LCT uptake and are cognisant of the wider environmental benefits of doing so. The VoLL2 survey provides insight that supports this premise, with over 10% of respondents including optional verbatim comments which reference the need for change to meet GBs aspirations for carbon neutrality.

It is important to recognise that whilst there currently appears to be limited overall customer appetite to support the prioritisation of investment for LCT intensive networks through increases in bills; it is likely, as the use of LCT progresses, the opinions of individuals will change to become more aligned with the views of current LCT users. In this study these respondents assigned greater significance towards prioritisation of LCT users and by default, an implied acceptance of investment to facilitate increased LCT uptake.

Figure 8.13 illustrates the amount that domestic and SME respondents were willing to pay to support the four customer groups represented in the five scenarios.

Figure 8.13: Willingness to pay to support different customer segments

Respondent customer type	Scenario 1 Restore power to vulnerable customers sooner	Scenario 2 Prioritise your household/ business	Scenario 3 Prioritise vulnerable customers	Scenario 4 Prioritise EV or solar panel users	Scenario 5 Prioritise fuel poor customers
Domestic (n=1,545)	**£10.86** (£10.17-£11.54)	**£9.71** (£9.02-£10.39)	**£9.71** (£9.01-£10.41)	**£5.67** (£5.06-£6.28)	**£8.67** (£7.97-£9.38)
SME * (n=449)	**£169.95** (£153.44-186.46)	**£155.78** (£139.61-171.74)	**£143.74** (£127.62-159.86)	**£117.18** (£102.52-131.83)	**£136.26** (£120.77-151.75)
SME % increase	**4.2%** (3.8%-4.6%)	**3.8%** (3.4%-4.2%)	**3.6%** (3.2%-4.0%)	**2.9%** (2.5%-3.3%)	**3.4%** (3.0%-3.8%)

* Only those SME respondents who provided an estimate of their annual electricity bill were included in the analysis.
All figures in brackets are the low-high estimates produced by the Turnbull method. Figures in bold are the average.

The findings indicate a difference in acceptance, based on the values expressed, between reducing restoration times for vulnerable groups and prioritising restoration. Domestic respondents were willing to pay an additional £10.86 to reduce the time it takes to restore power but only £9.71 to prioritise supply restoration for vulnerable customers. The same pattern applies to SME respondents (169.95 versus £143.74: a 4.2% versus 3.6% increase, where WTP values were expressed as a percentage of the customers annual bill). This finding suggests that respondents are in principle supportive of vulnerable groups when it comes to restoring power, but less so when that support could be detrimental to others' experience.

Respondents appear to be willing to pay a similar supplement (in the region of £10 for domestic and £150 for SMEs) to prioritise restoring power to their own household/business (scenario 2) as they are to prioritise vulnerable customers (scenario 3).

The WTP value for prioritising power restoration to customers living in fuel poverty (scenario 5) was lower than for vulnerable customers in scenario 3: £8.67 versus £9.71 for domestic; £136.26 versus £143.74 (3.4% versus 3.6%) for SMEs. This may reflect some respondents considering that these customers already receive support from government and that the responsibility for supporting this group lies with the government and less so with themselves.

There was considerably less WTP to support LCT users who are users of EVs or have solar panels installed (scenario 4). Here the average WTP is £5.67 for domestic (£5.09 for non-LCT users); £117.18 / 2.9% for SMEs (£94.86 / 2.4% for non-LCT users). This may reflect a perception that LCT users are generally more affluent and therefore not a priority group.

Detailed sub group analysis (documented in Section 3.4 of the Customer Survey Report), reveals that some customer groups are willing to pay more than others, for example, those who use LCTs/EVs/solar panels have greater willingness to pay. This partly reflects a relationship with income where, perhaps unsurprisingly, those with higher incomes and those who do not tend to struggle with paying bills are willing to pay more. However, other groups also express a higher willingness to pay for priority power restoration: the youngest consumers, those living in urban areas, those with children in the household, and those on the Priority Service Register (PSR).

ENWL010 established that LCT users, vulnerable customers and those aged 30-44 (i.e. the age group most likely to have children at home) have a higher VoLL than average and their greater WTP, particularly in relation to prioritisation of restoration to the most vulnerable and their own household, may reflect the importance they place on a secure electricity supply.

The younger population of respondents (18-29 years) appear to be more socially aware than other groups, and willing to pay an additional £12.12 per year to reduce the time it takes to restore power to vulnerable customers.

Perhaps unsurprisingly, WTP is reflective of financial circumstance; those in socio-economic segment DE, possibly having less disposable income and most likely to experience fuel poverty, have WTP levels lower than average. This group would be most impacted by any increase in bills and as such, the sub-group analysis may under-represent the amount this group would pay, if they had the means to do so.

8.3.6 The likely effects of a differentiated VoLL investment model on society, now and in the future.

A key objective of ENWL010 was to define how VoLL might change in a low carbon future. That research used stratified random sampling to ensure that a cross-section of early LCT adopters were included in the survey population. The VoLL for current domestic users of LCTs have a higher VoLL than the average for all domestic customers

LCT users were compared with the VoLL assignment of all domestic customers and revealed the potential change in VoLL associated with increased LCT adoption. This is an important consideration given the anticipated increase in LCT adoption and hence, customers' greater dependency on electricity. This will be a critical factor influencing future VoLL and consequently, will have significant implications for DNOs' long-term investment strategies and pivotal in informing issues such as network reliability standards and design policy for LCT intensive networks.

However, as reported in Section 8.3.5, this study highlights a disconnect in the higher VoLL associated with the needs and expectations of this group and a general customer/societal acceptance of prioritising investment to facilitate the predicted levels of uptake. Nonetheless the analysis provides clear evidence that customers believe investment prioritisation should be considered in the context of all customers receiving adequate levels of investment. By extension, this implies that it would be unacceptable for the supplies of customers on LCT intensive networks to be detrimentally impacted as a consequence of a DNOs failure to adequately invest, to meet the needs of customers served by such networks.

Furthermore, anecdotal evidence from ENWL010, the VoLL2 ECP and indeed the verbatim justification for choices made in the cost socialisation element of the VoLL2 survey, clearly indicate a wider recognition of the need for the electricity industry to invest strategically to accommodate LCTs, and electric vehicles in particular. This understanding is not explicitly expressed by respondents in the context of avoidance of network constraints but in more generalised terms relating to the 'climate emergency'. Responses suggest an understanding of wider environmental benefits and positive societal outcomes, e.g. an overall improvement in air quality associated with a reduction in emissions from combustion engines.

Section 8.2.2 discusses how the availability of future forecasting data will allow LCT vectors to be incorporated into a variable VoLL model, thereby informing a more accurately reflection of the whole life and through life VoLL for a given asset or network. However, it also acknowledges that there is uncertainty about the general level of uptake and regional patterns of adoption and therefore VoLL, relative to future scenarios, requires further research to ascertain the most efficient and practical way to add-value, in investment decision strategies. Section 8.3.5 highlights why further empirical customer research would benefit any wider research to re-calibrate and validate the VoLL estimates of LCT users, as adoption levels increase.

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

There were no modifications in the planned approach to Phase A (strategy) of the project. Minor modifications were required in the approach to Plan B (customer) in respect of the design of the customer survey, specific to cost-socialisation questions

This aspect of the survey sought to establish if customers are willing to pay (through bill increases) for investment to reinforce areas where LCT uptake may be high, for example versus networks with high levels of customer vulnerability to determine whether a variable VoLL approach was considered fair.

This is a complex subject and the initial stage of customer research with an ECP highlighted the need for clear explanations in the customer survey, to ensure that participants were able to comprehend the subject matter and provide informed opinions.

The survey instrument was therefore peer reviewed and quantitatively tested in a cognitive pilot study, prior to its roll out. Unlike the pilot survey, which was administered face-to-face, the main survey was conducted primarily online, and several modifications were required to ensure it could be understood and answered by previously unengaged respondents, via an online platform.

To prevent respondent fatigue, questions and educational content were simplified. Questions that had originally been included to enhance the research were removed, if they were not considered critical to the study.

The basis for the changes and lessons learned are summarised in Section 11.2. The survey instrument tested in the pilot is published on the project webpage and can be compared with the final survey instrument, published on 13 January 2020.

Analysis of the full survey results, as documented in the Customer Survey Report, suggests that these modifications were appropriate and have successfully delivered an instrument containing concise and relevant questions, supported by the optimum amount of education for comprehension and meaningful responses.

10 PROJECT COSTS

Item	Category	Estimated costs (£k)	Final costs £k (rounded)	Variance
1	Project Management	20,000	9,880	-10,120
2	Research/Consultancy	380,000	277,919	-102,081
	Total	**400,000**	**287,799**	**-112,201**

11 LESSONS LEARNT FOR FUTURE PROJECTS

This project has fully delivered against all of its objectives and no significant issues were encountered with the research methods utilised in the study. Full details of learning outcomes from the strategic (Phase A) of this project are summarised in Section 11.1 and documented fully in the MA Report. Details of the learning from the customer research component of the project (Phase B) are summarised in Section 11.2 with details of the key learning documents, pertinent to each stage of the research are tabulated in Figure 11. Project-related materials generated during the research can be found on the project webpage. Learning dissemination associated with this project is reported in Section 8.2.6.

11.1 Phase A (strategy):

The variable VoLL model delivered by this project is a prototype designed to prove the concept and demonstrate to stakeholders the potential for such a model. The research involved the evaluation of various models and implementation options as summarised in this document. The findings acknowledge that it is as important to understand the limitations as well as the advantages of a relatively simple model versus a more complex approach. The learning also suggest that a segmented model may not necessarily align with all regulatory mechanisms and that both a short and long-term approach to implementation. Learning delivered by this research has resulted in a recommendation for elements of additional, targeted research to develop the proposed model further, along with a trial implementation period, to credibly test whether logical 'good decisions' are appropriate across the whole regulatory framework and deliver economically efficient investment decisions within business case proposals.

The strategic element of the research culminated in a detailed report that comprehensively documents the methodology used in the development of the prototype model delivered by this project, which includes an evaluation of the accuracy and uncertainty achieved by the model. This study was not intended to create a fully functional production model, rather it sought to provide sufficient learning to facilitate informed discussion and further the debate, with key industry stakeholders, on the appropriateness of a variable VoLL and whether further work is required to implement such a model within regulatory mechanisms.

11.2 Phase B (customer):

Lessons learned in the development, roll out and analysis of the GB wide VoLL2 customer survey that can be exploited to support replication in similar future projects are signposted below:

The customer research element of the project encompassed five distinct stages as set out in the Methodology Statement. informed by a comprehensive Literature Review. The VoLL2 ECP report, published on the project webpage on 31 October 2019 disseminates the learning from Stage 2 (qualitative exploration), which formed the initial stage of direct customer engagement. Lessons learned for future innovation projects, requiring a similar approach to meet its objectives are summarised in Section 5 of the Engaged Customer Panel Report.

Learning from Stage 3 (quantification) associated with the design and administration of the customer survey are documented in the Pilot Survey Report 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 research, involving complex concepts of the type considered in this study.

The following summarises the key lessons learned from this study:

Lesson: *Socialisation of costs is a complex topic for customers to comprehend, particularly when introduced in a survey format.*

The customer research objective in respect of establishing a VoLL modifier were fully met; however, the cost socialisation element of the research, designed to evaluate perceptions on the fairness and equity of a variable model to replace a single value was more challenging. The concept was particularly difficult for customers to comprehend in a questionnaire and the research approach required modification. Following a pilot of the survey instrument it was re-designed and significant content omitted. The questionnaire was optimised, using shorter descriptions and more succinct education materials. As a consequence, the survey outputs were only able to provide a high-level assessment of perceptions on cost socialisation in respect of investment and charging prioritisation. Providing detailed education, to scaffold more focussed questions, with the aim of informing more granular views on prioritisation, was found to be counter-productive, as respondents became confused.

Should more detailed information be required on customers views relative to fairness and the socialisation of costs, it is recommended that in-depth qualitative engagement should be undertaken, focused purely on this topic. In this format, education materials can be discussed at length, questions asked, and interviewers can easily identify where customers struggle to comprehend the subject and/or associated materials.

Lesson: *Simple choice exercises are beneficial for respondent comprehension, data quality and clarity of analysis*

The pilot study highlighted areas in the choice exercise (trade-off technique) where service levels for the attributes being tested could be consolidated, or wording simplified/clarified. These changes meant less information for the respondent to process. The descriptions used to define a region (in the assessment of scale/magnitude of an outage) were less informative but had enhanced differentiation which limited the potential for misinterpretation during administration and analysis.

12 PLANNED IMPLEMENTATION

This study concludes that it is challenging to develop a model that can account for all of the variability in VoLL. However, it demonstrates that it is possible to develop a model that reflects some of this variability, and such a disaggregated model would be more accurate than the existing uniform approach.

The variable model developed in this project by Frazer-Nash was designed to prove the concept and demonstrate to stakeholders the potential to estimate VoLL for any sample population, to provide more accurate information for different investment decisions.

Section 8.2.4 discusses the benefits that could be derived from merely updating the existing 'vanilla model' from the current figure of £16,000/MWh, which underpins the RIIO-ED1 framework, to the revised average value of £25,300/MWh, established in ENWL010. The 2013 LE derived value of £16,940/MWh would have been approximately £18,500 in 2018 if adjusted for inflation[4], representing a real movement in the combined overall VoLL of approximately £6,500/MWh. VoLL2 also considers the merits of a relatively simple disaggregated model versus a more complex approach and recognises that a pragmatic strategy is required to establish a balance between the accuracy of the model, its complexity and how it can be practically implemented within existing regulatory methodologies.

The analysis and model delivered by this project support the transferability and scalability of a variable VoLL across GB; however, such a model can only be applied in practice if 'hard coded' into the regulatory mechanism for RIIO-ED2 and beyond, in common with the manner that the single VoLL is a construct of the RIIO-ED1 framework. As such, it will need to be adopted on an industry wide basis and be agreed by Ofgem. Section 8.2.6 summarises the engagement with key industry stakeholders that has taken place in this regard and these discussions will continue beyond the date of this report as part of the RIIO-ED2 consultation process.

The study concludes that a single value and flexible disaggregated model may both have roles to play in forthcoming price controls. This research suggests that a uniform macro VoLL may remain appropriate for the IIS framework. However, there are significant benefits to be gained from incorporating a variable model into the CNAIM and CBA approaches, to support more effective investment decision making.

ENWL010 demonstrated that VoLL is now notably higher than the value underpinning RIIO-ED1 and has outstripped inflation. The study therefore suggests that updating the macro VoLL value used to set the IIS incentive rates would be a sensible initial step and could be achieved without introducing any additional complexity into the existing methodology. However, the temporal impact should be considered in such an approach i.e. if VoLL continues to rise faster

[4] Based on Bank of England inflation figures averaged at 2.2% a year using the composite price index

than inflation, with the increasing electrification of heat and transport, then a projected RIIO-ED2 mid-period re-calibration of the single VoLL for IIS may be appropriate.

The key timing challenge to implementation is whether the VoLL for assets used in the CNAIM and CBA methodologies can be calculated and verified in time for RIIO-ED2. At the date of this report, DNOs are in early stage consultation with Ofgem on the approach to setting the electricity distribution price control for RIIO-ED2 and the development of their respective business plans. Within this constrained timescale, the introduction of a variable VoLL for RIIO-ED2 must be relatively simple to implement, allowing DNOs to format the components of their business plans with ease. Therefore, a recommendation of this project is that an early iteration of a variable VoLL methodology could be trialled within RIIO-ED2 with the view of perfecting a practical methodology for RIIO-ED3. This approach would provide sufficient time for additional research to refine the model.

For instance, VoLL trials working in parallel with the day-to-day RIIO-ED2 calculations utilising an updated single VoLL, would allow each variable VoLL methodology for CNAIM, CBA and IIS to be perfected, balancing ease of use with improvement. Alternatively, a variable VoLL could be used by DNOs to test hypothetical or previous CBA investment decisions, to refine the methodology and application.

It is also recommended that the learning derived from this study is considered in the RIIO-ED2 consultation process, in relation to how a disaggregated VoLL might be utilised to inform a successor approach to the current worst-served customer mechanism.

The study identified a number of opportunities for further model refinement. These findings and recommendations were presented at the Ofgem Safety, Reliability and Resilience Working Group in March 2020. Whilst the collaborative, joint DNO approach to furthering the research, as recommended by this project is not expected to be delivered in RIIO-ED1, Electricity North West recognise that there is a need to integrate the VoLL model into its internal systems and processes and this will require a follow-on phase of work. As such It is the intention of Electricity North West to pursue the independent development of a production standard model, with emphasis on how it can be used within CBA and CNAIM calculations.

This work is expected to be funded outside the NIA and will form part of Electricity North West's RIIO-ED2 business plan development strategy. However, in the spirit of the NIA, continued learning on the model's development will be disseminated to Ofgem and other interested stakeholders at pertinent industry working groups.

The project will refine the model, statistically characterise the uncertainty associated with the prototype delivered in this project and develop a robust production-standard version. This is expected to demonstrate that the tool can be utilised in effective decision-making in the North West and will provide a test-bed to enable subsequent implementation into regulatory mechanisms and BAU processes.

This follow-on study will determine the most appropriate scale of deployment, expanding on the outputs of this project, which derived a methodology for calculating VoLL at LSOA. This work will examine the benefits of an approach that facilitates the calculation of VoLL for a flexible geographic region, a more granular area aligned to specific networks or a particular network asset.

The work will also address other opportunities to improve the accuracy of the model and reduce uncertainty. The merits of a simple first version will provide a benchmark to measure the benefits that could be derived from a model that introduces additional complexity. The work will therefore include further exploration of the extent to which overall performance could be improved by including additional VoLL indicators and forecasting capability. The analysis will consider the results of the empirical research generated by this project, specifically in relation to the multiplier. The research is expected to utilise network data and other datasets for the North West, as opposed to nationally available data, as was required in VoLL2 to demonstrate 'proof of concept' for a GB wide approach.

The customer research element of this project has demonstrated that a variable model is generally positively perceived by customers and considered fair in informing the prioritisation of investment relative to the needs of certain customer groups. However, this is rooted within the context that DNOs should adequately invest to meet the needs of all customers and prioritisation should not be at the expense and detriment of others.

Further research is recommended beyond this project to explore the apparent dichotomy of views associated with investment to support users of, and the uptake of LCT. At the present time, it appears that most customers do not support prioritised supply restoration for LCT intensive networks, when compared to other groups. Customers do nevertheless appear to be supportive of LCT to deliver environmental benefits and by inference, recognise the need for appropriate investment to facilitate greater LCT uptake to meet carbon reduction targets and tackle climate change. It is also important to recognise that customers' views are likely to change to reflect those of current LCT users who have a higher VoLL than the average and are more inclined to support the prioritisation of investment to facilitate the transition to decarbonisation. Further research could help to determine how this possible transition in priorities might take place and with which customers.

Whilst ENWL010 demonstrated that individuals from households in fuel poverty have a significantly higher VoLL than other domestic customers, respondents in this study did not consider that this customer group were as deserving of precedence over other vulnerable groups. The reasons for this are not straightforward and may indicate a lack of understanding about the extent to which customers in fuel poverty are negatively impacted by outages; equally, the findings could reflect assumptions about whose responsibility it is to support these households. Further research is recommended to provide greater insight.

In the evaluation of the appropriateness of including the multiplier within a functional variable model, additional exploration would be beneficial to better understand the needs of rural communities. Both SME and domestic customers gave less weighting to interruptions that affected their surrounding area, when compared to an outage affecting only their own property. This may reflect a sense of being less connected to the area and services around them and/or a belief that their individual needs are unique to them (e.g. farms and remote rural industry).

13 DATA ACCESS

Electricity North West's Privacy Policy and Innovation Data Sharing Policy can be found on our website. A Data Protection Impact Assessment was developed for VoLL2 prior to any form of customer engagement taking place.

14 FOREGROUND IPR

There is no foreground IPR associated with this project.

15 FACILITATE REPLICATION

Full details of the methodology applied in the development of the prototype VoLL model delivered by Phase A (strategy) of this project are documented in the MA Report, published on the project webpage on 23 January 2020.

The methodology for the customer research (Phase B) in VoLL2 was jointly designed by Electricity North West and its market research partner, Impact Research. Full details of the approach, to facilitate project replication are set out in the Methodology Statement, published on the project webpage on 8 May 2019. This encompassed five key stages of customer and stakeholder engagement:

- Stage 1: Desk research and stakeholder engagement
- Stage 2: Qualitative exploration
- Stage 3: Quantification
- Stage 4: Implementation scale analysis
- Stage 5: Validation.

The research approach and learning outcome associated with each stage of engagement are documented in key learning reports published on the project webpage.

Stakeholder engagement in Stage 1 of the customer research involved consultation with expert advisors, most notable representation from Scottish and Southern Energy Networks. Valuable insights associated with the learning from its SAVE project informed the customer research methodology.

The physical components required to replicate Stage 2 (qualitative exploration) were consistent with the components of the original VoLL study, as referenced in Appendix 4 of the ENWL010 Engaged Customer Panel Report, published on the VoLL webpage dated 23 August 2016. The learning associated the qualitative research is disseminated in the VoLL2 ECP Report and the discussion guides used to facilitate the two rounds of focus group meetings are published on the project webpage dated 15 and 29 August 2019. The stimulus information used to support the ECP discussions is also published. The pilot survey instrument that was developed and tested in Stage 3 is published, as is the final version of the survey that forms the basis of the research and analysis summarised in this Closedown Report.

16 OTHER COMMENTS