IMPACT

FROM INSIGHT TO INFLUENCE

Value of Lost Load to Customers (VoLL2)

Literature Review

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electricity north west

Bringing energy to your door

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Name	Role	Date
Tracey Kennelly	Innovation Customer Delivery Lead	01 April 2019

GLOSSARY

Abbreviation	Term
ACER	Agency for the Cooperation of Energy Regulators (EU)
BEIS	The UK government Department for Business, Energy and Industrial Strategy
DNO	Distribution network operator
DSO	Distribution system operator
ECP	Engaged customer panel
GB	Great Britain
GDN	Gas distribution network
NIA	Network innovation allowance
SME	Small and medium enterprise
ToU	Time of use
VoLL	Value of lost load
WTA	Willingness to accept
WTP	Willingness to pay

FOREWORD

In Great Britain (GB) a single, uniform Value of Lost Load (VoLL) is used to evaluate ‘disbenefit’ 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 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 which currently fails to recognise any differentiation in customer need, or valuation of service.

Recent NIA funded research conducted by Impact 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 low carbon technologies; 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.

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. ENWL010 also highlighted the need for further empirical customer research to test the impact of different scenarios. This includes 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 versus the ability to mitigate VoLL by deploying appropriate support mechanisms to manage the consequence of an event.

This follow up project will comprise two distinct elements 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; and empirical customer research to provide insight into the multiplier effect and socialisation of cost arising from a revised model.

The key findings set out in this report, which is one of a series of project dissemination documents, specifically reference the learning from a literature review of existing research on the ‘multiplier’ effect and the impact of longer duration interruptions. Also referenced is previous learning on cost socialisation and investment prioritisation.

1 EXECUTIVE SUMMARY

1.1 Summary of key findings

1.1.1 The multiplier effect

One of the main findings of Electricity North West's initial VoLL study (ENWL010) was that duration was a key factor in determining the magnitude of disruption experienced.[1] The interruption durations examined were: up to one hour, six hours and more than six hours. A similar effect was found in an EU-wide survey, which tested interruptions of 20 minutes, two hours and two days[2].

There appears to be little relevant research for durations longer than this, or for interruptions affecting much wider communities, although reports exist relating to major, unplanned interruptions in Cyprus and Italy within the last 20 years[3]. One possible reason for this absence of data is that, because of the rarity and uniqueness of such events, it is difficult for survey participants to envisage the impact or value of lost load in such circumstances. The economic impact of lengthy, large scale interruptions is also extremely hard to calculate with any accuracy and, would depend on specific situations, which could include a range of 'knock-on effects' not present in localised interruptions. Consequently, the customer research phases of this project will need to ensure that participants have sufficient education and context to allow them to fully consider the myriad impacts of a wide-scale outage before completing Willingness to Accept (WTA) trade-off exercises.

It is noted that DNOs will play a greater role in black start planning, as the route to the network for operators of local, low-carbon distributed generation, which is increasingly being incorporated into black start procedures (see section 2.6).

An online tool called blackout-simultor.com does provide WTA/VoLL values for regional supply interruptions across the EU, but the underlying data on which its calculations are based inevitably suffer from the difficulties outlined above.

1.1.2 Cost socialisation and investment priorities

Changes in the nature of electricity consumption and generation, and greater visibility of consumption data raise challenging questions about the fairest way to pass distribution costs on to the new generation of 'prosumers'. This debate is central to the DNOs transition to distribution system operator (DSO) and their need to play a more sophisticated role in the capacity balancing market, where providers can sell flexibility making innovative charging models possible. Although a reasonable body of literature exists on the options that might be adopted along a spectrum from full cost-reflection to full socialisation, the views of customers in this area are not clear.

The water industry in England and Wales prioritises charging measures that encourage the effective use of water. The industry is currently in a lengthy transition phase as water meters are rolled out; currently around half of domestic properties have meters, but their distribution is somewhat skewed towards those with low water usage, leading to cross-subsidisation. There is some similarity between

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[1] Value of Lost Load to Customers: Conclusions and recommendations – Executive summary report (October 2018) https://www.enwl.co.uk/globalassets/innovation/enwl010-voll/voll-general-docs/voll-recommendations-report.pdf

[2] Study on the Estimation of the Value of Lost Load of Electricity Supply In Europe (July 2018) https://www.acer.europa.eu/en/Electricity/Infrastructure_and_network%20development/Infrastructure/Documents/CEPA%20study%20on%20the%20Value%20of%20Lost%20Load%20in%20the%20electricity%20supply.pdf

[3] Estimating the socio-economic costs of electricity supply interruptions (November 2014), http://www.innoenergy.com/wp-content/uploads/2016/03/INSIGHT_E_RREB_2_FINAL_2.pdf

this situation and electricity where distribution charges are calculated differently for customers with smart meters on half hourly-settled tariffs compared with those not on these tariffs[4].

There are considerable direct and indirect benefits to society of ensuring that as great a proportion of the population as possible live in warm homes. Using the new segmented VoLL model derived in Electricity North West's initial VoLL project (ENWL010) it is possible to introduce a customer dimension to investment decisions and prioritise networks where there is a higher reliance on electricity for heat. However, there are a range of diverse and complex factors, outside the scope of DNOs that contribute to fuel poverty in households that are not adequately heated.

DNOs and gas distribution networks (GDNs) have a number of initiatives in place to support fuel poor customers. However, there is little published research showing customer support for a small premium on energy bills to reduce the fuel poverty gap for the most impoverished in society.

One particular issue currently affecting DNOs is how connections, including new, low-carbon generation connections, should be most fairly charged. DNOs are also adopting new strategies to ensure that access to the network is fair for a range of applicants, including community-based projects in poorly-served areas.

1.2 Next steps

A research methodology for the customer engagement phase of this research project will be produced and peer-reviewed, taking into account the findings of this literature review.

2 THE MULTIPLIER EFFECT

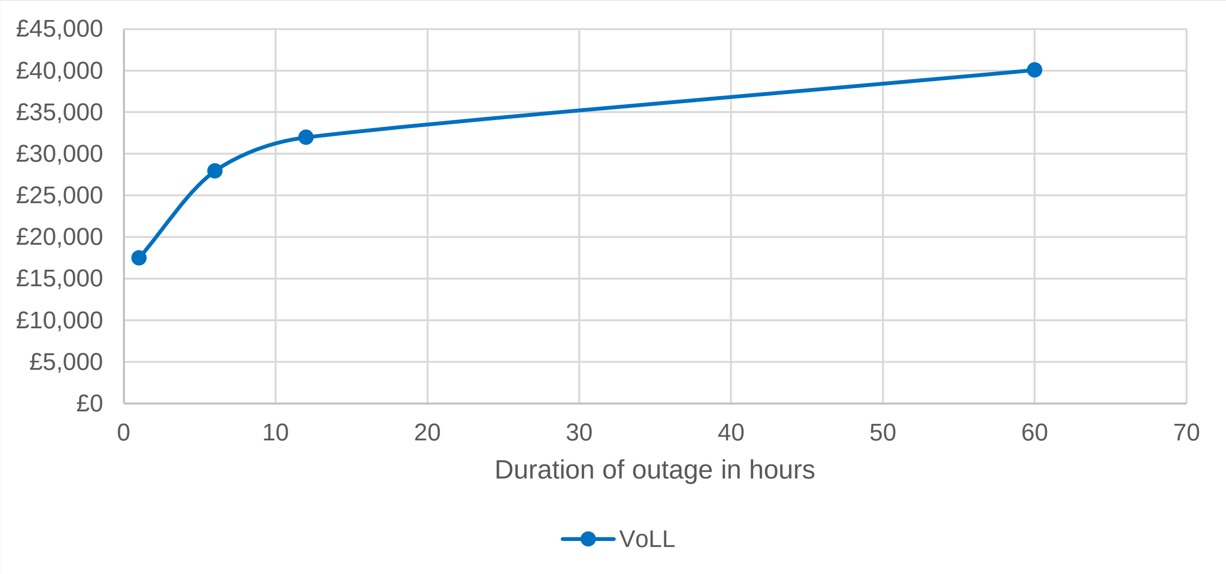
2.1 The impact of interruption duration on VoLL

ENWL010 found that an outage generally incurs a higher VoLL the longer it lasts. However, the marginal hourly value declines steadily; there is a levelling out in the upward trajectory of VoLL for extremely long duration interruptions typically associated with extreme weather events. This is likely to reflect an awareness that such incidents are largely outside the control of the DNO and therefore less worthy of additional compensation.

For domestic customers who experience one unplanned outage in a three-year period, VoLL increases by 60% when the duration rises from one hour to six hours and 83% when it rises to 12 hours. The chart below shows how the marginal increase in VoLL reduces with duration.

Figure 2.1: VoLL versus duration of outage

[4] Smarter, Fairer? Cost-reflectivity & socialisation of costs in domestic electricity prices (March 2016), http://www.sustainabilityfirst.org.uk/images/publications/other/Sustainability_First_-_Discussion_Paper_by_Jon_Bird_-_Smarter_fairer__Cost-reflectivity_and_socialisation_in_domestic_electricity_prices_-_FINAL.pdf



There is also a significant increase in VoLL when the number of outages experienced in a three-year period exceeds six. The VoLL for planned interruptions is substantially less than for unplanned outages, but this reduction diminishes as frequency increases.

For small and medium enterprise customers (SMEs), a similar pattern is observed for unplanned and planned outages. However, there is a suggestion that while there is tolerance for limited planned work requiring outages, acceptance diminishes after more than three planned interruptions lasting a full day over a three-year period. This demonstrates the importance of a cohesive approach to construction and maintenance strategies, and the need to consolidate planned work where possible.[5]

Although this study did not investigate whether the value that an individual places on an outage at their property remains the same when the entire community is affected, anecdotal evidence gathered during the research suggests that widespread outages often foster increased societal cohesion when a community recognises that 'we're all in it together' and take measures to support each other, particularly those less able to cope. This is supported by a lower VoLL observed in this study for those who stated they had experience of such events. Elsewhere, high levels of customer satisfaction have been reported when there is recognition that a prolonged outage is the result of conditions outside the control of the DNO, specifically extreme weather related events. See Appendix 5.1 and 5.2 for detailed VoLL values for domestic and SME customers relating to supply interruptions of one hour, six hours and more than six hours.

The overall findings of a report for the European Agency for the Cooperation of Energy Regulators (ACER)[6] were similar. The report begins with a literature review of several studies from 2005-2013 which consider the impact of outage duration on VoLL for domestic and service sector SME customers, although using inconsistent methodologies, and relating to a variety of outage durations. This concluded, "Overall, the majority of studies found that marginal WTP/WTA decreases with duration. Intuitively, this is because as duration increases, the relevance of the initial 'annoyance factor' decreases and consumers are better able to engage in other activities which are less dependent on electricity (the 'adaptation effect')."

The ACER study's own survey, which considered supply interruptions lasting 20 minutes, two hours and two days, concluded that, "Willingness-to-accept (WTA) a financial amount in response to a

[5] Value of Lost Load to Customers Customer: Survey (Phase 3) Key Findings Report (October 2018) https://www.enwl.co.uk/globalassets/innovation/enwl010-voll/voll-general-docs/voll-phase-3-report.pdf

[6] Study on the Estimation of the Value of Lost Load of Electricity Supply In Europe (July 2018) https://www.acer.europa.eu/en/Electricity/Infrastructure_and_network%20development/Infrastructure/Documents/CEPA%20study%20on%20the%20Value%20of%20Lost%20Load%20in%20the%20electricity%20supply.pdf

hypothetical supply interruption increases with the duration of the interruption, but that the marginal WTA (per hour) decreases… The WTA per hour for a **twenty-minute** outage is 128% of that for an outage lasting **two hours**. WTA for a **two-day outage** is only 43% of that for a two-hour outage." It interpreted this finding as being due to, "An initial 'annoyance factor' and damage costs which decrease (relatively speaking) as consumers become better able to adapt with increasing duration of the outage." Amongst non-domestic customers, who had a higher VoLL than domestic customers, it noted that WTA for longer durations increases less steeply than for domestic.

It should be noted that this survey used a much smaller sample size (892 customers of which 124 were non-domestic, across all 28 EU states) than ENWL010 (6008 interviews of which 4968 were domestic and 1040 were non-domestic). The maximum duration which the ACER study asked customers to consider was two days because this was considered to be the longest outage likely to occur, while observing that such a long duration is statistically very unlikely to happen based on past occurrences. Even in cases where serious damage to generation, transmission or distribution infrastructure occurs, which cannot be repaired within two days, some level of supply may nevertheless be restored by backup generators or other means.

Both ENWL010 and the ACER studies noted that giving notice of the interruption mitigated its effects and thus reduced VoLL.

2.2 Likelihood of large scale, long duration supply interruptions

A 2014 report by the Royal Academy of Engineering[7], designed to build on the 2013 London Economic study, asserts that the stated preference method [used in ENWL010], "Only has utility up to around 24 hours of outage; beyond this, people's experience is too limited. It is therefore worth noting that the maximum 'acceptable' duration is entirely dependent upon people's perceptions, communication (before, during and after the outage) and on how the issue is framed in society and in the media."

While admitting that, "People generally appear to cope fairly well with short duration disruptions," it continues, "A nationwide outage lasting for longer than 48 hours could, however, have a severe impact on society; however, this type of scenario is so unlikely in the UK that the actual impacts are impossible to model with any degree of robustness."

It adds a further note of caution with regards WTA VoLL figures, stating that, "Experience of interruptions affects WTA," (which was also observed in ENWL010). It also suggests that people tend to over-estimate the negative impact of a power cut (especially if they have no experience of one), and that WTA/WTP do not value security of supply but the RIGHT to security of supply, and that WTA is artificial as customers are not actually compensated for short losses of supply. This should be considered when using VoLL to inform investment decisions because, "The costs of some measures to mitigate capacity shortages are very high, meaning that the price of getting a cost-benefit analysis wrong is potentially serious."

These conclusions appear to cast doubt on the practicality of conducting further customer research into the multiplier effect, and the accuracy of values it would produce. However, the practical challenges can be mitigated by carefully designed deliberative programmes that support survey respondents in thinking deeply about the context of a major disruption and specifically, all of the effects such an event would have on them and the wider community before making their trade-off decisions in a WTA exercise. The impact of individuals' own 'coping' actions should also be explored carefully in the design of the research. It is also important to note that whilst WTA is undoubtedly an artificial model, there is no better alternative.

[7] Counting the cost: the economic and social costs of electricity shortfalls in the UK: A report for the Council for Science and Technology (November 2014) https://www.raeng.org.uk/publications/reports/counting-the-cost

The Royal Academy of Engineering report also observes that traditional distinctions between domestic and service industry workplace use may no longer be appropriate due to the rise in the number of people working from home; which means the presumption that residential areas generate less economic wealth is increasingly inaccurate, and this should be taken into account for investment decisions.

Analysis published by the TUC in 2018[8] indicates that 1.6 million people (1 in 16 or 6.1% of the workforce) regularly worked from home in 2017. The practice was most common in the South West where 9% of employees worked from home. Although the proportion of 'tele-commuters' had risen considerable since 2005 when 5.1% of the population regularly worked from home, it had not changed since 2016, suggesting that the practice was no longer growing, although other figures published in the analysis suggest that there is some scope for further increases.

2.3 Socio-economic impacts specific to large-scale, long-duration interruptions

The Royal Academy of Engineering report made the following points regarding the impact of longer, community-wide interruptions:

- Perceptions of a lack of energy security could deter investment in GB by global corporations. This includes even short-term "voltage sags".
- During widespread, longer duration outages, the overriding theme of anecdotal evidence is of "Co-operation rather than unrest. One respondent characterised this by noting that during an incident such as an outage, people change from being 'consumers' to 'citizens'." This is supported in other research conducted by Electricity North West as part of Project Avatar[9], where customers impacted by flooding in Lancaster in 2017 reported wide spread community cohesion and support, with local residents acting as ambassadors to spread communications and ensure those most vulnerable received the support they needed.
- "There is evidence that outages lead to considerable knock-on effects between sectors, especially as economies are now so interconnected. However, the knock-on effects are dependent on value chains; the higher up the value chain, the greater the impact to the economy as a whole."
- Long interruptions could see additional impacts after four days such as back-up generators running out of fuel and a lack of cash in circulation because ATMs will have been out of use. In Project Avatar (referenced above) customers with experience of prolonged power outages, associated with severe weather events, report a reliance on alternative forms of communication, such as radio broadcasts (using wind up radios), when unable to access information via traditional means ie cordless landlines, mobile phones, other web based media channels and TV.
- Security of supply may increasingly be a factor when organisations decide where to invest in new premises.
- Although the isolated cost of a widespread, long-duration interruption may be high, the overall long term cost is relatively low because of the rarity of these events.
- There can be an increase in emergency services calls as a result of fires caused by the use of candles, and intruder alarm systems being triggered.
- Crime tends to be lower during power cuts. However, in prolonged outages the opposite can be the case, despite increase community cohesion. The media reported that extra security

[8] Growth in home working has stalled (May 2018) https://www.tuc.org.uk/news/growth-homeworking-has-stalled

[9] Project Avatar https://www.enwl.co.uk/zero-carbon/smaller-projects/network-innovation-allowance/enwl018---avatar/

was required in the aftermath of Storm Desmond in Carlisle in 2016 to prevent looting[10], with a suggestion that criminals from outside the region had exploited the dire circumstances and targeted communities at their most vulnerable.

The report notes that, "The UK's history of high security of supply over the past four decades means that UK consumers are especially vulnerable to outages, as most will not have contingency measures in place." This was also evident in the qualitative engagement conducted with worst served customers as part of ENWL010[11]. Typically, urban customers who had never experienced an outage, or had done so very infrequently, were far less likely to have considered preparing for these eventualities:

In contrast, customers residing or operating businesses in rural locations, particularly those identified as worst-served, were significantly more prepared and had well developed contingencies.

A 2014 report[12] estimating the socio-economic costs of electricity supply interruptions, prepared by a think tank informing the European Community, included case studies of major supply interruptions. The wider impacts included:

- Political decisions being made to prioritise hospitals, the tourism sector and large industrial users.
- Political (not technical) decisions being made in Austria that small hydro-electric generation plants would be used to supply local premises rather than contribute to the national grid in the case of a generation problem.
- People being stuck in underground trains and lifts.

2.4 Challenges surrounding the use of VoLL for large scale, long duration interruptions

The largest scale and longest duration supply interruptions in Britain in the 21st century are generally unplanned and associated with extreme weather [13] such as the exceptional flooding events which occurred in the Electricity North West region as a result of Storm Desmond in the winter of 2015/16. Community-wide outages can also occur as a result of inadvertent damage to cables, an example of which occurred in the Electricity North West region, in October 2018, when a third party severed underground cables that delivered power to 22,000 homes.

While DNO investment can improve the resilience of the network for example, by undergrounding overhead cables so they are not brought down by falling trees during storms, the extent to which preventative measures can avert outages, can only be partial. Understanding VoLL for large scale, long duration interruptions may be of less relevance to investment decisions than having an accurate set of VoLL values for more common types of supply interruptions.

2.5 Blackout simulator

Blackout-simulator.com is an online tool co-funded by the European Commission, designed to enable users to assess the socio-economic effects of power outages from one to 48 hours in the European Union. It utilises an econometric modelling approach based on businesses' production data and data from a willingness-to-pay (WTP) survey covering more than 8,300 households.

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[10] BBC News Storm Desmond: Thousands of people flooded out of homes https://www.bbc.co.uk/news/uk-35023558

[11] The Value of Lost Load (VoLL) Phase Two: Refining the Approach https://www.enwl.co.uk/globalassets/innovation/enwl010-voll/voll-ecp-and-survey/voll-ecp-report.pdf

[12] Estimating the socio-economic costs of electricity supply interruptions (November 2014) http://www.innoenergy.com/wp-content/uploads/2016/03/INSIGHT_E_RREB_2_FINAL_2.pdf

[13] http://www.rmduk.com/news-and-blog/news-press/102-7-of-the-worst-power-outages-in-the-uk

Registered users can set region, time of day, date and duration variables for which a damage cost is returned. The purpose of the tool is to provide, "A rationale for electricity supply security enhancing investments and energy policy decisions."

As the tool only operates at a regional level, and the original WTP data on which it is based appears not to be available, it cannot, as it stands, be used to analyse VoLL for very localised supply interruptions or the perceived impact of much larger and longer duration events.

2.6 Black start

Black start is, "The procedure to recover from a total or partial shutdown of the National Electricity Transmission system which has caused an extensive loss of supplies. This entails isolated power stations being started individually and gradually being reconnected to other power stations and substations in order to restore the interconnected system."[14] In future the generation mix providing services to National Grid is likely to look very different from today as more conventional power stations close.

These closures will mean that new black start service providers may be required to ensure adequate levels of black start service provision into the future. National Grid is also investigating alternative approaches to future system restoration. Such alternative approaches include local generation points which are connected to the network by DNOs, a change from the model hitherto where generation was connected first to the transmission system. DNOs would therefore have a different role to play in black start, and the importance of local generation is also increased.

3 COST SOCIALISATION AND INVESTMENT PRIORITISATION

3.1 New options for cost socialisation

A 2016 paper[15] published by the environmental think-tank Sustainability First and written by John Bird, a former Head of Sustainability at Northern Powergrid, sets out a detailed discussion on this subject, which is summarised here.

The introduction of smart meters and the development of domestic micro-generation and battery storage are opening up new models for cost socialisation in electricity distribution. (Note: it is important to be clear about the difference between costs charged to customers, which will be described as 'charges' hereafter, and actual distribution costs to DNOs.)

Traditionally, distribution charges have been based on their customers' total energy throughput, but this has not necessarily reflected the cost of distributing supply to the customer, leading to cross-subsidisation between segments. Throughput-based charging does not take peak usage into account, for example, yet it is the peak load on substations that may require them to be expensively reinforced.

Such charges have also not been area-specific (within each DNO region), leading to urban customers cross-subsidising rural dwellers in terms of distribution costs, and off-gas customers with higher electricity consumption paying larger distribution costs than dual-fuel customers. However, charges do vary between DNO regions.

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[14] Black Start: Frequently Asked Questions (2016) https://www.nationalgrideso.com/sites/eso/files/documents/Black%20Start%20Frequently%20Asked%20Questions.pdf

[15] Smarter, fairer? A discussion paper on cost-reflectivity and socialisation of costs in domestic electricity prices (March 2016) http://www.sustainabilityfirst.org.uk/images/publications/other/Sustainability_First_-_Discussion_Paper_by_Jon_Bird_-_Smarter_fairer__Cost-reflectivity_and_socialisation_in_domestic_electricity_prices_-_FINAL.pdf

Many GB consumers are on legacy time of use (ToU) tariffs (which encourage the use of electricity at times when it is available more cheaply) and new ToU tariffs are emerging with the smart meter roll out, using captured data and half hourly settlement. This is expected to lead to a demand-side response by customers who are encouraged to reduce their peak usage, although this paper warns against the assumption that behaviour observed amongst customers on a trial, who are by nature engaged, is indicative of how a wider population will behave over time. It should also be noted that a number of studies have observed that both peak and overall consumption varies considerably between households. Further, limited customer understanding on how ToU tariffs work can reduce their effectiveness. Research conducted by Citizens Advice in 2018 found just less than half (49%) of customers on ToU tariffs actively trying to change their energy use to avoid peak charges, often attributed to confusion over when their off-peak time was[16]. Any reduction in peak load could, though, be reflected in distribution charges and actual lower costs distribution costs (assuming the avoidance of network reinforcement is not counterbalanced by an increase in the administration costs of more complex billing).

However, the smart meter rollout could lead to unintended adverse consequences for some customer segments such as those who are off-gas, or in certain vulnerable circumstances (which make it hard for them to reduce peak usage), or electricity-intensive industrial customers who have limited capacity to reduce their consumption. The report notes that “socialisation of charges is a blunt tool” and suggests that support for such groups might be more effectively provided in other ways.

Another challenge in moving towards cost-reflectivity and away from cost socialisation in distribution is that DNOs/DSOs would need to accurately distinguish between fixed distribution costs, throughput-related costs and peak load costs to create three-part tariffs[17]. Again, the work involved in this may be cost prohibitive.

As DNOs transition to DSOs, new models will need to be found for the fair charging of customers with their own PV or solar thermal panels, heat pumps or other forms of micro-generation and possibly domestic battery storage. Such customers are often described as ‘prosumers’ because they both produce and consume electricity. Currently, as their distribution charges are based purely on the supply they draw from the network, which can be considerably less than that consumed by a similar conventional household, their distribution charges are low. While these reflect the throughput costs of distribution, they do not reflect either the peak or fixed costs, the cost of the DSO accepting feed in to the grid, or the impossible-to-quantify benefit of the availability of full grid supply to such households should their own equipment fail. This, it should be noted, could happen with no warning of a sudden increase in load demand being available to the DSO, as would be the case with a mainstream generator. One option for such households would be ‘behind the meter’ charging where distribution charges are based on consumption plus generation, a model which socialises charges to these customers and is not cost-reflective.

The report states that, in principle at least, it is possible to identify the relevant charges and costs in respect of each customer. It further sets out that, “A strict cost-reflective approach would look at the level of spare capacity at each location (node) on the network and set prices according to the marginal cost of supplying additional load at that location. This would mean, for example, in areas where load was declining and reinforcement investment is unlikely to be needed, charges would be lower. Instead however, prices are based on the long-run marginal cost of a hypothetical significant increase in load on the network. The stated reason for this is that customers are benefiting from the maintenance of the electricity distribution network as a whole and charges are a system cost.”

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[16] False Economy (2108) https://www.citizensadvice.org.uk/about-us/how-citizens-advice-works/media/press-releases/time-of-use-tariff-lessons-must-be-learned-says-citizens-advice/

[17] The impact of PVs and EVs on Domestic Electricity Network Charges: a case study from Great Britain, University of Cambridge Energy Policy Research Group (2018) https://www.eprg.group.cam.ac.uk/wp-content/uploads/2018/05/1814-Text.pdf

A similar point is made in a 2015 briefing by Frontier Economics Limited[18] which explains, "Traditional methods for recovering the cost of large network investments have historically been relatively simple. But those methods are breaking down as countries pursue decarbonisation policies. The energy sector is characterised by high sunk costs (costs associated with decisions which, once taken, cannot be reversed) … Particularly in the electricity sector, the cost of subsidies to low carbon generation to ensure that renewables targets are met (so-called "policy costs") are a growing source of sunk costs which need to be recovered… Electricity demand has been largely insensitive to price. Therefore, charging electricity customers extra on their bill (eg a constant €/kWh "levy") hardly affects their future consumption of electricity. Sunk costs in this sector have therefore typically been "socialised", or recovered from the generality of customers in a way which has been perceived to be fair… At around today's levels of overall cost per MWh, there are credible economic options for customers of all sizes to reduce their net consumption by generating their own power, and so customers will look to do so. This means that attempts to socialise increasing levels of sunk cost across electricity demand may result in a reduction in (net) consumption of electricity from the grid. This creates a vicious circle. With a reduced base of demand over which to recover network costs, the per unit socialised charge to recover a given level of cost increases, which encourages more on-site generation, which reduces demand further. There is a risk that a small number of customers end up bearing a very high socialised charge: unfair if these are voters, uncompetitive if these are industrial customers."

Frontier Economics proposes, "A different form of socialised charge may be an alternative… A per kW charge may work better than per kWh levies. However, a per kW charge will focus cost recovery more on customers with 'spiky' consumption, including households. A per customer charge would also be possible, though it is not clear whether this would be perceived as resulting in equitable burden sharing between domestic and industrial customers."

Another 2015 paper[19], relating to the socialisation of electricity transmission costs in the US where cost allocations must be 'just and reasonable', underlined this same point, explaining costs can only be allocated directly to consumers for improvements to the electric grid if the consumer benefits from that improvement. It continues, "Conversely, the socialization methodology of cost allocation is allowed where all grid users will benefit from a transmission upgrade, such as a reliability upgrade. This method assumes that all system users enjoy increased reliability to the grid due to the new transmission facility. Moreover, this method is supported by the logic that since the beneficiaries of the transmission system change over time as load configurations change, all users should pay because they will eventually benefit from the facility." It concluded, "Socialized cost allocation is the best method of allocating the costs of these facilities because it most closely matches how consumers on an interconnected grid use and benefit from grid improvements over time."

Another option for socialising the 'cost' of network reinforcement is avoiding it through customer behaviour change; in this case it is customer effort which is socialised as those who make little or no effort to change poor behaviour will benefit so long as others do. A 2014 report from the Customer-Led Network Revolution project[20] noted, "Households involved in the CLNR project have shown that they can be flexible in their electricity use. Participants who have trialled a time of use tariff have shown sustained shift in their electricity use in the early evening peak period together with an overall reduction in electricity use." Unsurprisingly, the survey found, "From our research we suggest that the practices of most direct interest in terms of their potential ability to play a part in demand side management of the electricity distribution network are household chores, cooking and dining,

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[18] That Sinking Feeling: Problems On The Horizon For Network Cost Recovery (2015) https://www.frontier-economics.com/media/2464/frontier-briefing_that-sinking-feeling.pdf

[19] Jordan A. Smith, *Socialized Is Not a Dirty Word: The Only Just and Reasonable Method for Assigning the Costs of High-Voltage Interstate Transmission Lines Is to Socialize Them*, 56 B.C.L. Rev. 841 (2015), http://lawdigitalcommons.bc.edu/bclr/vol56/iss2/10

[20] Customer-Led Network Revolution: Durham University Social Science Research (2014) http://www.networkrevolution.co.uk/wp-content/uploads/2014/05/CLNR-L052-Social-Science-Report-April-2014_2.pdf

laundry and dish washing. Electronic entertainment and cooking, although often undertaken in the evening peak period, either have low electrical intensity (entertainment), or are perceived by respondents to be less flexible (both)."

Similarly, Electricity North West's Power Saver Challenge[21], which ran from 2013-2016 found that households could be encouraged to change their energy usage behaviour and their attitude towards energy consumption, both during the trial and after it had ended, and saw a 5.8% reduction in peak energy consumption across the lifespan of the project. Participants in the national EcoTeams[22] project that ran in 2005-2008 saw their electricity consumption drop by 7%.

In another example, US company Opower provides consumers with a Home Energy Reporting Program, which includes information showing how their energy use compares with similar neighbours. At least nine independent evaluations have demonstrated consistent average energy savings in the order of 2-3%. The 'injunctive norm' (provided in a 'How you're doing' box - in this case a smiley face) provided a social appraisal of the household's relative performance. Injunctive norms appear to be critical in mitigating a 'boomerang effect' (whereby social norms could cause relatively low energy consumption households to increase energy use), whilst encouraging energy-efficient users to continue to outperform the average.[23]

Most DNOs have run initiatives of this type, both as one-off research and business-as-usual programmes. However, the Sustainability First report warns about reading too much into trial participants' short-term behaviour changes, and the period covered by these trials tends to be a year at most for funding reasons. Consequently, there is limited proof that the headline reductions are sustained over the longer term, although it is likely that some impact will remain.

3.2 Socialisation versus cost-reflection of retail prices in other markets

The Sustainability First report briefly notes the charging models used in other markets with a utilitarian nature:

- Postage: The universal postal service obligation represents total socialisation in terms of national geography.
- Insurance premiums are totally cost-reflective, although Government policy has led to some socialisation: for example, gender can not now be used for car or life insurance. Another example is Flood Re (a reinsurance scheme, making home insurance in flood-risk areas more affordable, particularly for those in lower council tax bands), which covers some of the impact of flooding.
- Water uses a hybrid model with charges to metered customers reflecting the cost of supply more than unmetered customers. More details of charging in the water industry are set out below.

3.3 Socialisation of cost in the water industry

The Sustainability First paper contains a useful summary of how the socialisation of consumer charges in the water industry have changed with the introduction of water meters.

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[21] Power Saver Challenge: Project Closedown Report (2017) https://www.enwl.co.uk/globalassets/innovation/power-saver-challenge/power-saver-challenge-closedown-report.pdf

[22] https://www.thensmc.com/resources/showcase/ecoteams

[23] Behaviour Change and Energy Use (2011), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/48123/2135-behaviour-change-and-energy-use.pdf

Traditionally, water bills, which charge customers for both the supply and delivery of water, were based on the rateable value of the property, leaving considerable scope for a disconnect between consumption and charge, and consequent cross-subsidy between customers.

Another feature of the water industry is that each regional water company has a different cost base, which has to be passed on to its customers.

From 1990, all new homes have had to have water meters installed as a mandatory requirement and since then meters have also been retro-fitted voluntarily when customers request one, compulsorily in areas of water shortage, and when the occupancy of a property changes. Aside from the fact that such a piecemeal approach is not a cost-efficient way of 'metering' the entirety of GB's domestic housing stock, this has led to a mixed market where some customers bills are based on consumption (which is reasonably, though not entirely cost-reflective) whilst others' bills remain socialised. The proportion of customers who opted voluntarily to have a meter fitted were generally those with below-average consumption for the size of their home, who therefore had an expectation that their water bill would reduce. While there have been complaints from some customers who did not realise the expected reduction, from opting for a meter; in general, bills have tended to reduce for metered customers and consequently, have risen for those who remain unmetered, shifting the market distortion so that the 'unfairness' of the old model moved from those with below-average consumption to all others.

3.3.1 Fairness

An independent review of water charges requested by the Government and published in 2011[24] concluded that fair charges should [amongst other things – not all are relevant to electricity]:

- Incentivise the efficient use of water (to conserve it).
- Be based on the use made of the system (which includes waste water as well as water supply).
- Be affordable to those on low income.
- Be fair to companies.
- Be fair to future generations.
- Be simple and transparent to customers.
- Not be too expensive to administer.

These requirements can sometimes conflict and so an order of precedence is necessary. For example, the report dismissed the argument that as water is an essential of life, it should be charged on a customer's **ability to pay** and therefore charged progressively [ie the more you earn the more you pay] on the basis that it does not incentivise efficient usage. Similarly, customer concerns about **regional charging** were also dismissed because there are real regional differences in costs and "local ownership of these costs encouraged greater efficiency" and that prices were being averaged at an appropriate geographic scale.

The report concluded that usage-based charging was the fairest approach as it incentivised efficient use of water.

These are matters which DNOs may need to consider in the transition to DSO, with further exploration of the appropriateness of socialising the recovery of investment driven, in part, by a customer dimension. This introduces important questions about the fair apportionment of charges for customers who are unable to benefit from providing the DSO with emerging flexibility and balancing services.

[24] The Independent Review of Charging for Household Water and Sewerage Services (the 'Walker Report') (2011)
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69459/walker-review-final-report.pdf

3.4 Measuring the societal impact of network activities

In October 2017 Northern Powergrid (a DNO), Northern Gas Networks (a gas distribution network) and two water companies commissioned research to explore how the societal impact of network interventions could be better understood.[25]

In an interim report[26] on the progress of this project, Northern Gas Networks explained that, "With such a wide range of activities, locations and communities, there is no off-the-shelf tool to fully assess all social impacts. But by placing ten network activities in logical causal chains – a clear way of setting out each step of each process and showing its effects – the impact of each and who it affects can be mapped thoroughly and consistently. This allows quantification, and where that is not possible, qualitative evaluation means mitigation can be planned if the effects are negative." A final report recommending use, development and next stages required to complete a framework is currently being compiled.

3.5 Societal benefits of smart meters

The adoption of smart meters provides societal benefits that go further than simply reducing consumers' bills; by encouraging them to reduce the usage of appliances which consume the most electricity, and for those on a ToU tariff, shift peak usage. Consequent reductions in overall load generate network benefits, and reduce environmental impact: Smart Energy GB, states that "When everyone is using a smart meter and keeping an eye on the energy they use, the collective CO2 savings would be like planting more than 10 million trees a year until 2030 or taking a total of 600,000 cars off the road by 2030." and, "If the whole nation got a smart meter we could save the same amount of energy as it takes to power every household in Aberdeen, Cardiff and Manchester for a year."[27] Reducing peak load also helps DNOs to delay or avoid expensive, carbon-intensive network reinforcement.

3.6 Socio-economic class and fairness

There are a number of areas of electricity costs and charges that vary with socio-economic status. These include:

- The proportion of **household income spent on energy**: this is around 10% for the poorest households but only 3% for the most affluent[28], although the absolute value of the bill for the latter is higher. As the network cost element of a bill is partly dependent on absolute consumption levels, this means that more affluent bill-payers are effectively subsidising the network for those with smaller homes and bills, and activities to alleviate fuel poverty. This could be considered unfair as all customers derive utility from it, although it is in line with the income tax approach in the UK.
- The uptake of **PV installations** is greater in more affluent households[29] which reduces the proportion of their income spent on energy further, although only after a significant capital expenditure.

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[25] Measuring the Societal Impact of Network Activities - Northern Gas Networks and Northern Powergrid (NIA_NPG_013) (presenter at 2018 LCNI by Dean Pearson) https://www.northernpowergrid.com/news/northern-powergrid-part-of-pioneering-cross-utility-research-to-assess-true-impact-of-utilities-on-society

[26] Northern Gas Networks: Network Innovation Allowance Annual Summary 2017-18 (page 19) https://www.northerngasnetworks.co.uk/wp-content/uploads/2018/07/Innovation-report-2018.pdf

[27] Benefits for Britain (downloaded February 2019) https://www.smartenergygb.org/en/smart-meter-benefits/benefits-for-britain

[28] How should we share the benefits of the low carbon transition? Oxford Martin School (2018) https://www.oxfordmartin.ox.ac.uk/opinion/view/429

[29] Ibid.

- Previous Energy Company Obligation (ECO) schemes (a government energy efficiency scheme in GB to help reduce carbon emissions and tackle fuel poverty) is reported not to have appropriately targeted those most in need of **home insulation**. The Institute for Public Policy Research (IPPR) estimate that only 30 per cent of funds are likely to be spent on fuel-poor consumers.[30]
- Increased numbers of **electric vehicles** (EVs) in use is placing new demands on the network. EV ownership is skewed towards more affluent households[31] as these vehicles are more expensive to buy than equivalent cars with a standard combustion engine, although it has been suggested that the monthly cost of 'owning' an EV on finance (as it is likely the majority of early adopters do), is similar[32]; charging is much easier for (more affluent) households with off-road parking; and there is low availability of second hand EVs because the market is relatively immature, thus putting them out of reach of those who cannot afford a new car. Therefore, if DNOs invest to upgrade particular networks to facilitate this demand, it can be argued that they would be socialising the cost of a direct benefit to affluent socio-economic groups across the general population. However, if DNOs fail to invest in networks with existing or forecasted high EV penetration, all customers in these areas could quickly become poorly-served as interruptions associated with degradation of assets increase because peak throughput is reached more often. This reduction in service standards would seem particularly unfair on arguably a majority of customers served by the network, who do not own EVs.
- Whilst a range of customer champions and advocacy organisations represent/offer support to marginalised and impoverished members of society for a variety of reasons, it is generally recognised that more affluent socio-economic groups tend to have a **louder voice** and are often better able to vocalise their changing needs and expectations (eg in relation to EVs). However, no specific research has been uncovered in relation to this. Conversely, poorer customers, especially the older generation who may have lived through shortages and adversity can be extremely resilient and accept the temporary hardship caused by supply interruptions that leave them without a warm home (refer to Section 3.6.1) or hot food with **stoicism.** Therefore, not only do their WTA responses indicate a lower VoLL but their VoLL is unlikely to reflect unconsidered, wider social costs, for example impact on the NHS of treating health problems created or exacerbated by a short or medium-term supply interruption, which are likely to be greater if a whole community is affected. Using a segmented VoLL where one group **over-reports** WTA and another **under-reports** could therefore lead to unintended consequences and investment decisions which are as flawed as those based on a single, uniform VoLL applied to all customer segments. There are also anecdotal reports, but little formal research, citing a reluctance of some vulnerable customers to reach out for help and support due to the 'stigma' associated with doing so.
- Although concerned that electricity distribution charges are **fair**, Ofgem, "Aims to reflect the full economic costs in the network in ways that give incentives to customers to use the network **efficiently**.[33]"

3.6.1 The health benefits of warm homes

In October 2017 the BEIS-led initiative "Under One Roof: Preventing cold-related ill health, winter deaths and reducing health inequalities through joint working" reported that, "Fuel poverty and cold homes negatively impact on physical and mental health," and that there could be long-term, though hard-to-quantify societal impacts of this including poor educational achievement by children who

[30] Ibid.
[31] House of Commons Business, Energy and Industrial Strategy Committee, Electric vehicles: driving the transition (2018) https://publications.parliament.uk/pa/cm201719/cmselect/cmbeis/383/383.pdf
[32] What is it really like to own an electric car? (2018) https://www.telegraph.co.uk/cycling/tour-of-britain-2018/what-its-like-owning-an-electric-car/
[33] The impact of PVs and EVs on Domestic Electricity Network Charges: a case study from Great Britain, University of Cambridge Energy Policy Research Group (2018) https://www.eprg.group.cam.ac.uk/wp-content/uploads/2018/05/1814-Text.pdf

miss school through cold-related illness and who, separately, are more likely to suffer from cognitive delay if they live in a cold home. Warm homes can also support earlier hospital discharge (reducing healthcare costs), and prolong the time that the elderly and vulnerable can spend in their own home (again reducing costs to other services). The long-term impacts associated with cold homes and prolonged health conditions do differ from the effects of comparatively short term interruptions. However, these findings highlight the importance of DNOs providing a range of appropriate mitigating support to those most in need during an interruption, which can play a part in preventing further burden on the NHS and other social support services.

In 2018, Age UK noted that Office for National Statistics figures showed that there were nearly 46,000 excess deaths among people aged 65 and over during the winter of 2017-2018. The Charity's director said, "A toxic cocktail of poor housing, high energy prices and ill health can make winter a dangerous time for many older people, and tragically it is the oldest old and those who are the most vulnerable who particularly suffer the consequences. We know such high levels of excess winter deaths are not inevitable. As a country we are not doing enough to ensure our older population stays warm and well throughout the harsh winter months."

The BEIS presentation notes that reducing health inequalities requires a focus on addressing health consequences for the most disadvantaged groups to reduce the gap between most and least advantaged. A segmented VoLL allows a customer dimension to be incorporated into investment decisions, reflecting the fact that rural domestic customers, those in fuel poverty and domestic customers who are off the mains gas network have above-average VoLL[34]. This insight and its relevance for DNOs' investment and customer vulnerability strategies should mean that decisions about networks serving these demographics are more nuanced than possible when using a model based on a single VoLL.

3.7 Supporting fuel poor customers

Fuel poverty in England is measured using the Low Income High Costs (LIHC) indicator. Under the LIHC indicator, a household is considered to be fuel poor if:

- They have required fuel costs that are above average (the national median level)
- Were they to spend that amount, they would be left with a residual income below the official poverty line

The level of fuel poverty in England is highest in the private rented sector (21.3 per cent of households that are private rented are in fuel poverty) compared to those in owner occupied properties (7.4 per cent of households in fuel poverty). Those in the private rented sector also tend to be deeper in fuel poverty, with an average fuel poverty gap of £410, compared to £175 for those in local authority housing. [35]

BEIS state that there are three important elements in determining whether a household is fuel poor; household income, household energy requirements and fuel prices. Those with electricity as their main source of heating are more likely to be fuel poor.

A report produced by Citizens Advice[36] stated that fuel poverty and its consequences are largely preventable through the right policy interventions, including action on energy prices, direct financial support to relevant households and energy efficiency schemes. It concluded that improving energy

[34] See Appendix 5.3.
[35] Annual fuel poverty statistics report 2017 (2015 data), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/639118/Fuel_Poverty_Statistics_Report_2017_revised_August.pdf
[36] Beyond ECO: the Future of Fuel Poverty Support (2018), https://www.citizensadvice.org.uk/about-us/policy/policy-research-topics/energy-policy-research-and-consultation-responses/energy-policy-research/beyond-eco-the-future-of-fuel-poverty-support/

efficiency was the most cost-effective and sustainable approach to reducing fuel poverty. However, a report produced by the University of East Anglia's (UEA) Centre for Competition Policy, following a two-and-a-half-year project as part of the UK Energy Research Centre (UKERC) research programme, stated "The current focus of fuel poverty policy on improving the energy efficiency in households does not address all the factors leading to energy affordability difficulties".[37]

DNOs and GDNs do have some provisions in place to provide support for fuel poor customers. For GDNs this typically includes the provision of grants or financial support for funding connections to main gas, whereas DNOs can offer additional support offered in the event of a supply interruption and are increasingly providing energy efficiency and bill advice, often in the form of targeted initiatives, such as Northern Powergrid's 'Green Doctor' fuel poverty assistance programme[38].

This literature review found limited published evidence that the general UK population would, or would not, support a small premium on energy bills to reduce the fuel poverty gap. GDNs and DNOs conducted customer research to understand investment priorities ahead of RIIO-1 and the Stakeholder Engagement and Customer Vulnerability Incentive is driving best practice amongst DNOs ahead of RIIO-2. Customers generally prioritised reliability and safety ahead of social obligations which cover support for all forms of vulnerable customers, including those in fuel poverty. Western Power Distribution (WPD), in conjunction with UK Power Networks and National Grid, have conducted a dedicated piece of research to understand customers' perceptions of value for money in regards to support provided for vulnerable customers. This research revealed that in 2016 in the area of 'fuel poverty', customers most valued doubling the number of fuel poor customers supported (up to 12,500).[39]

There is also some discussion about what support DNOs *should* provide for fuel poor customers. In 2016 Citizen's Advice published its Networks' Good Intentions report[40], which recommended that networks should only deliver social obligations where they are best placed to cost effectively improve outcomes for energy consumers. For example, supporting vulnerable consumers in a power cut, but not taking responsibility for clearer billing. The report states that network operators may be best-placed to meet social obligations, because these need to be delivered to all customers across a particular geographic area, but DNOs should not stray into providing services that are the remit of another party, such as Social Services.

There are a range of organisations, both local and national, designed to support those in fuel poverty. One key organisation is the National Energy Action (NEA) that assists households in fuel poverty through:

- Sessions in schools to educate children on the importance of energy efficiency;
- Research into the causes and extent of fuel poverty;
- Managing demonstration projects which show innovative ways of tackling fuel poverty;
- Training for individuals and community groups;
- Advice and support for fuel poor households; and
- Campaigns to increase assistance for vulnerable groups.

There are also a range of organisations who seek to measure societal benefits such as Big Society Capital (social investment bank), Social Enterprise UK (industry body) and UK Social Audit Network.

[37] Fairness in Retail Energy Markets? Evidence from the UK (2018), https://www.uea.ac.uk/about/-/report-examines-fairness-in-uk-retail-energy-market-and-fuel-poverty
[38] https://www.northernpowergrid.com/news/results-from-the-green-doctor-pilot-programme
[39] WPD: Ofgem Stakeholder Engagement & Consumer Vulnerability Incentive 2016/17, Consumer vulnerability outcomes (2017), https://www.westernpower.co.uk/downloads/614
[40] Networks' Good Intentions A report on how energy networks' social obligations are delivered (2016), https://www.citizensadvice.org.uk/Global/CitizensAdvice/Energy/Networks'%20Good%20Intentions%20-Final%20Paper.pdf

Outside of the energy sector, social tariffs in water are available from most Water Operating Companies to support low income customers or those receiving specific benefits. For example, South Staffordshire Water offer the Assure[41] tariff "available to customers who have been identified by the Company or a third party debt advice agency as needing additional support. Financial circumstances of customer is 'means' assessed considering income, expenditure and other supporting evidence".

In 2019 Westminster Council asked households in the highest council tax band to voluntarily pay an extra £833 (double the normal amount) to help rough sleepers in the area. 644 elected to do so, raising £600,000. A small number donated up to £10,000[42].

3.8 Connections

Requests for new connections to the electricity network have predominantly been from developers of domestic and commercial properties. However, both house builders and new manufacturing facilities often now include renewable energy sources in their designs and consequently the traditional connections process has become more complex. In addition, local distributed generation facilities, for example on farm-based sites, are seeking connection to the network to benefit from commercial export opportunities. These connections can offer synergy benefits to network operators, particularly in relation to supply reliability in rural areas.

With a consequent increase in both connections and quotations for connections, which are time-consuming for DNOs to provide, the most appropriate and fair model for socialising the cost of all aspects of the connection process are being re-evaluated.

A 2016 paper by the European Wind Energy Association[43] recommended that, "The financing of grid reinforcements needs to be considered in the broader context of the development of the internal electricity market. Therefore, the benefits of grid development should not be related to an individual project or technology. Grid development benefits all producers and consumers and, consequently, its costs and benefits should be socialised." It also proposed that:

- First-connectors should not bear the whole cost of grid reinforcements arising from their marginal contribution to the power system (compared with existing generation plants).
- Locational and power based 'G charges'[44] tend to penalise wind power plants. Therefore, G-charges should be energy-based and abstain from a general inclusion of locational signals. Locational signals should instead be provided by efficient congestion management.

Another substantial question in this area is who should pay for the increasing number of connection applications which are not implemented. A 2017 BEIS impact assessment[45] states, "The primary policy objective is to allow for a fairer allocation of costs by ensuring that customers who do not accept connection offers contribute to, or entirely pay for, the costs of assessing their applications. A secondary objective is to ensure efficiency in the connections market by potentially reducing the number of non-accepted/potentially speculative connection applications and helping to ease

[41] https://www.ccwater.org.uk/households/help-with-my-bills/south-staffordshire-water-assure/
[42] https://www.independent.co.uk/news/uk/home-news/homeless-crisis-rough-sleeping-fund-donation-westminster-council-london-a8765556.html
[43] EWEA position paper on network tariffs and grid connection regimes (revisited) (2016), http://www.ewea.org/fileadmin/files/library/publications/position-papers/EWEA-position-paper-on-harmonised-transmission-tariffs-and-grid-connection-regimes.pdf
[44] "Measurement Class G charges apply to Exit/Entry Points at non-domestic premises with whole current Metering Systems where half hourly metering is used for Settlement," Electricity North West Use of System Charging Statement (2018), https://www.enwl.co.uk/globalassets/about-us/regulatory-information/documents/current-charging-information/enwl--use-of-system-charging-statement--april-2018.pdf
[45] Impact assessment: Allowing up front Assessment and Design (A&D) fees to be charged (2017) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/684183/Assessment___Design_fees_Final_Impact_Assessment.pdf

pressure on distribution networks." Some non-accepted connections arise because community schemes can only establish the cost of a new connection by first making an application. If this is felt to be beyond the scheme's resources, it is revised and a new application is made. This iterative use of the full application process is inefficient.

A further complication in this area is that when there is limited network capacity for new generation connections, organisations with the greatest ability to pay the cost of the connection can secure that capacity, but this mean that community-based schemes which may deliver much greater social benefits in rural areas, may be 'priced out' of the market.[46] DNO are now developing strategies to actively engage with community and local energy groups to advise and better support them in the development of smart, flexible networks.[47]

4 CONCLUSIONS AND NEXT STEPS

4.1 Conclusions

Large-scale, long-duration supply interruptions are extremely rare in GB, and as a result potential research subjects have little or no experience of them and find them hard to envisage. In addition, it is in the nature of such interruptions that each one is unique to its location and circumstances in its features and impacts. These factors combine to make it much harder to develop robust WTA-based VoLL models for such interruptions, compared with short-term, individual experiences.

The previous VoLL research (ENWL010) provided a richer understanding of customer needs to help guide network investment and customer compensation strategies. More research is required on customer acceptability of DNOs informing investment, in part by the differing needs of specific customer groups, and the associated societal and economic impacts this has. The opportunities provided by a segmented VoLL model introduces questions of appropriateness and fairness, which need to be more fully considered against the single VoLL approach, which forms part of the Network Output Measures (NOMs) framework, that ensures Transmission owners are targeting investment in the right areas to manage network risk effectively.

Changes in the nature of electricity consumption and generation, and the data available about consumption raise new questions about the fairest way to pass distribution costs on to the new generation of 'prosumers', and also make innovative charging models possible. Although a reasonable body of literature exists on the options that might be adopted, the views of customers in this area are not clear.

One further issue is how connections are most fairly charged, including generation connections as well as supply connections, and how network reinforcement costs to support LCT uptake should be socialised.

4.2 Next steps

Following on from this review of existing literature on cost socialisation and investment prioritisation, the project team will formalise the best methods of evaluating fairness and the efficiency of alternative investment models, and produce a detailed methodology document which will be academically peer reviewed and critiqued by key stakeholders before any customers engagement.

[46] Farm generation – who pays for connections (2015). https://www.fwi.co.uk/business/gridlock-get-fair-deal-green-grid-connection

[47] https://www.enwl.co.uk/zero-carbon/community-and-local-energy/

5 APPENDICES

Appendix 5.1: Domestic VoLL by frequency and duration of outages (unplanned)

Domestic WTA unplanned						Confidence interval (95%)	
Frequency	**Duration**	**WTA**	**Lower**	**Upper**	**VoLL**	**Lower**	**Upper**
Once every 3 years	1 hour	**£7.87**	***£7.30***	***£8.44***	**£17,481**	***£16,209***	***£18,753***
2-3 times every 3 years	1 hour	£9.61	*£8.96*	*£10.26*	£21,333	*£19,887*	*£22,779*
4-6 times every 3 years	1 hour	£10.52	*£9.82*	*£11.21*	£23,354	*£21,813*	*£24,895*
7-14 times every 3 years	1 hour	£15.86	*£14.88*	*£16.84*	£35,213	*£33,037*	*£37,388*
15+ times every 3 years	1 hour	£16.78	*£15.75*	*£17.81*	£37,259	*£34,966*	*£39,552*
Once every 3 years	6 hours	£12.58	£11.66	£13.50	£27,937	£25,903	£29,970
2-3 times every 3 years	6 hours	£15.35	£14.31	£16.39	£34,092	£31,781	£36,404
4-6 times every 3 years	6 hours	£16.81	£15.70	£17.92	£37,322	£34,859	£39,785
7-14 times every 3 years	6 hours	£25.34	£23.78	£26.91	£56,273	£52,797	£59,750
15+ times every 3 years	6 hours	£26.81	£25.16	£28.46	£59,544	£55,879	£63,208
Once every 3 years	12 hours	**£14.40**	***£13.35***	***£15.45***	**£31,981**	***£29,654***	***£34,309***
2-3 times every 3 years	12 hours	£17.58	*£16.38*	*£18.77*	£39,028	*£36,383*	*£41,674*
4-6 times every 3 years	12 hours	£19.24	*£17.97*	*£20.51*	£42,726	*£39,906*	*£45,545*
7-14 times every 3 years	12 hours	£29.01	*£27.22*	*£30.80*	£64,421	*£60,441*	*£68,400*
15+ times every 3 years	12 hours	£30.70	*£28.81*	*£32.59*	£68,165	*£63,969*	*£72,360*

Once every 3 years	2-3 days	**£18.04**	***£16.73***	***£19.36***	**£40,071**	***£37,154***	***£42,987***
2-3 times every 3 years	2-3 days	£22.02	*£20.53*	*£23.51*	£48,901	*£45,586*	*£52,215*
4-6 times every 3 years	2-3 days	£24.11	*£22.52*	*£25.70*	£53,533	*£50,000*	*£57,065*
7-14 times every 3 years	2-3 days	£36.35	*£34.10*	*£38.59*	£80,716	*£75,730*	*£85,702*
15+ times every 3 years	2-3 days	£38.46	*£36.09*	*£40.83*	£85,406	*£80,150*	*£90,663*

Appendix 5.2: SME VoLL by frequency and duration of outages (unplanned)[48]

SME WTA unplanned						Confidence Interval (95%)	
Frequency	**Duration**	**WTA**	**Lower**	**Upper**	**VoLL**	**Lower**	**Upper**
Once every 3 years	1 hour	£158	£151	£165	£46,972	£44,833	£49,110
2-3 times every 3 years	1 hour	£158	£151	£165	£46,972	£44,833	£49,110
4-6 times every 3 years	1 hour	£288	£277	£298	£85,621	£82,428	£88,814
7-14 times every 3 years	1 hour	£302	£291	£313	£89,854	£86,536	£93,173
15+ times every 3 years	1 hour	£403	£389	£417	£119,919	£115,773	£124,065
Once every 3 years	6 hours	£252	£241	£264	£75,065	£71,649	£78,482
2-3 times every 3 years	6 hours	£252	£241	£264	£75,065	£71,649	£78,482
4-6 times every 3 years	6 hours	£460	£443	£477	£136,831	£131,728	£141,934
7-14 times every 3 years	6 hours	£482	£465	£500	£143,597	*£138,294*	*£148,899*
15+ times every 3 years	6 hours	£644	£622	£666	£191,643	*£185,017*	*£198,268*
Once every 3 years	12 hours	**£289**	**£276**	**£302**	**£85,934**	***£82,022***	***£89,845***
2-3 times every 3 years	12 hours	£289	£276	£302	£85,934	*£82,022*	*£89,845*

[48] The values quoted for SMEs are those reported in the main VoLL report (ENWL010) entitled Value of Lost Load to Customers: Conclusions and recommendations – Executive summary report (October 2018) https://www.enwl.co.uk/globalassets/innovation/enwl010-voll/voll-general-docs/voll-recommendations-report.pdf. Further modelling based on additional surveys produced slightly higher values for SME VoLL, but the relationship between VoLL and frequency of outage remained very similar (for more details please see NIA (ENWL010) Value of Lost Load to Customers: Customer Survey (Additional Interviews) Report on Revised Results (February 2019) https://www.enwl.co.uk/globalassets/innovation/enwl010-voll/voll-general-docs/voll-additional-sample-report.pdf.

4-6 times every 3 years	12 hours	£526	£507	£546	£156,642	*£150,800*	*£162,484*
7-14 times every 3 years	12 hours	£552	£532	£573	£164,387	*£158,317*	*£170,458*
15+ times every 3 years	12 hours	£737	£712	£763	£219,389	*£211,805*	*£226,974*
Once every 3 years	2-3 days	£362	£345	£378	£107,670	£102,769	£112,571
2-3 times every 3 years	2-3 days	£362	£345	£378	£107,670	£102,769	£112,571
4-6 times every 3 years	2-3 days	£659	£635	£684	£196,264	£188,944	£203,583
7-14 times every 3 years	2-3 days	£692	£666	£718	£205,968	£198,362	£213,574
15+ times every 3 years	2-3 days	£924	£892	£955	£274,883	£265,379	£284,386

Appendix 5.3: Domestic VoLL (WTA) by sub-groups

Domestic WTA unplanned	n	WTA	Lower	Upper	VoLL	Confidence Interval (95%) Lower	Upper	Index v Total
Total	3381	**£7.87**	£7.30	£8.44	**£17,481**	***£16,209***	***£18,753***	100
Female	1791	**£8.26**	£7.33	£9.18	**£18,432**	***£16,373***	***£20,490***	105
Male	1510	**£7.62**	£6.89	£8.36	**£16,891**	***£15,272***	***£18,510***	97
Age: 18 – 29	702	**£7.50**	£6.02	£8.98	**£16,516**	***£13,252***	***£19,779***	94
Age: 30 – 44	770	**£8.95**	£7.60	£10.31	**£20,042**	***£17,017***	***£23,066***	115
Age: 45 – 59	844	**£7.59**	£6.72	£8.46	**£16,921**	***£14,973***	***£18,869***	97
Age: 60+[49]	994	**£7.80**	£6.66	£8.94	**£17,237**	***£14,719***	***£19,755***	99
AB	835	**£8.13**	£6.93	£9.32	**£17,867**	***£15,241***	***£20,493***	102
C1	1040	**£9.05**	£7.97	£10.12	**£20,053**	***£17,667***	***£22,439***	115
C2	569	**£8.54**	£6.95	£10.14	**£19,217**	***£15,634***	***£22,801***	110
DE[50]	843	**£6.15**	£5.16	£7.13	**£13,667**	***£11,479***	***£15,855***	78
Rural	1023	**£9.63**	£8.29	£10.96	**£21,314**	***£18,361***	***£24,268***	122
Urban	2353	**£7.16**	£6.55	£7.77	**£15,934**	***£14,572***	***£17,295***	91
Electricity North West	969	**£6.46**	£5.39	£7.52	**£14,080**	***£11,752***	***£16,409***	81
Scottish and Southern Energy	294	**£10.60**	£7.88	£13.32	**£22,702**	***£16,880***	***£28,523***	130

[49] Unadjusted for income (adjusted WTA = £19,372 (Index 111)
[50] Unadjusted for income (adjusted WTA = £20,501 (Index 117)

Domestic WTA unplanned	n	WTA	Lower	Upper	VoLL	Confidence Interval (95%) Lower	Upper	Index v Total
SP Energy Networks	308	**£6.69**	£5.02	£8.36	**£14,707**	***£11,033***	***£18,380***	84
Northern Powergrid	378	**£8.01**	£6.35	£9.66	**£18,012**	***£14,283***	***£21,742***	103
Western Power Distribution	646	**£8.36**	£7.12	£9.60	**£18,285**	***£15,578***	***£20,991***	105
UK Power Networks	690	**£8.38**	£7.21	£9.54	**£19,289**	***£16,607***	***£21,971***	110
Worst served	163	**£3.16**	£1.07	£5.24	**£6,894**	***£2,345***	***£11,442***	39
Vulnerable[51]	1951	**£8.54**	£7.56	£9.51	**£19,632**	***£17,388***	***£21,875***	112
Fuel poverty[52]	239	**£17.52**	£15.25	£19.80	**£32,470**	***£28,256***	***£36,683***	186
Off-gas	721	**£7.13**	£5.61	£8.65	**£18,543**	***£14,598***	***£22,489***	106
LCT users	960	**£8.69**	£5.38	£12.00	**£18,973**	***£11,743***	***£26,203***	109
Domestic - Electric vehicle (EV)	275	**£9.20**	£0.54	£17.85	**£21,493**	***£1,264***	***£41,722***	123
Domestic - Solar panels (PV)	538	**£8.42**	£3.57	£13.28	**£17,884**	***£7,580***	***£28,189***	102
Domestic - Heat pump (HP)	428	**£8.98**	£2.52	£15.44	**£19,911**	***£5,578***	***£34,243***	114
Low usage	1216	**£7.26**	£6.44	£8.09	**£16,371**	***£14,510***	***£18,231***	94
Medium usage	1752	**£8.53**	£7.62	£9.44	**£18,768**	***£16,762***	***£20,774***	107
High usage	328	**£7.60**	£5.97	£9.24	**£16,504**	***£12,952***	***£20,056***	94

[51] Adjusted for income (unadjusted WTA = £16,941 (Index 97)
[52] Adjusted for income (unadjusted WTA = £21,646 (Index 124) 22 Adjusted for income (unadjusted WTA = £13,487 (Index 77)

Domestic WTA unplanned	n	WTA	Lower	Upper	VoLL	Confidence Interval (95%) Lower	Upper	Index v Total
MDE (medically dependent)[22]	310	**£6.15**	£4.34	£7.96	**£18,013**	***£12,711***	***£23,315***	103
Want to keep bills constant	1265	**£7.19**	£6.36	£8.02	**£15,863**	***£14,024***	***£17,702***	91
Want to keep reliability	963	**£7.85**	£6.80	£8.90	**£17,745**	***£15,368***	***£20,121***	102
Want to improve worse served	651	**£7.74**	£6.48	£9.00	**£17,261**	***£14,447***	***£20,075***	99
Want to improve supply	431	**£11.28**	£8.56	£13.99	**£25,334**	***£19,240***	***£31,429***	145
Low vulnerable[53]	872	**£8.63**	£7.25	£10.01	**£19,175**	***£16,115***	***£22,235***	110
Medium vulnerable[54]	397	**£8.99**	£6.78	£11.19	**£21,106**	***£15,929***	***£26,284***	121
High vulnerable[55]	417	**£7.09**	£5.20	£8.98	**£18,313**	***£13,427***	***£23,198***	105
No experience of power cuts (planned or unplanned)	1178	**£8.63**	£7.42	£9.83	**£19,221**	***£16,534***	***£21,908***	110
Experience of power cuts (either planned or unplanned)	2203	**£7.57**	£6.93	£8.22	**£16,802**	***£15,376***	***£18,228***	96
Experienced four or more unplanned power cuts	464	**£6.42**	£5.30	£7.54	**£14,233**	***£11,751***	***£16,714***	81
Experienced two or three unplanned power cuts	847	**£8.65**	£7.35	£9.96	**£18,780**	***£15,957***	***£21,603***	107
Experienced one unplanned power cut	723	**£8.85**	£7.46	£10.24	**£19,755**	***£16,646***	***£22,865***	113
Experienced no unplanned power cuts	1200	**£7.23**	£6.36	£8.10	**£16,093**	***£14,159***	***£18,028***	92

[53] Adjusted for income (unadjusted WTA = £17,447 (Index 100)
[54] Adjusted for income (unadjusted WTA = £16,608 (Index 95)
[55] Adjusted for income (unadjusted WTA = £15,211 (Index 87)

Domestic WTA unplanned	n	WTA	Lower	Upper	VoLL	Confidence Interval (95%) Lower	Upper	Index v Total
Experienced planned power cuts	859	**£7.30**	£6.05	£8.55	**£16,161**	***£13,395***	***£18,928***	92
Experienced large scale interruption in last 12 months	377	**£5.82**	£3.67	£7.96	**£12,140**	***£7,660***	***£16,619***	69
Impact of power cut – low	1442	**£8.83**	£7.88	£9.79	**£19,737**	***£17,605***	***£21,869***	113
Impact of power cut – medium	507	**£7.87**	£6.45	£9.28	**£17,316**	***£14,208***	***£20,423***	99
Impact of power cut – high	166	**£6.40**	£2.89	£9.91	**£13,613**	***£6,147***	***£21,078***	78

Grey font indicates small sample size, interpret with caution

Appendix 5.4: SME VoLL (WTA) by sub-groups

SME WTA Unplanned	n	WTA	Lower	Upper	VoLL	Confidence Interval (95%)		Index v Total
						Lower	Upper	
Total	615	**£160**	£152	£167	**£47,560**	*£45,289*	*£49,830*	100
Rural	118	**£217**	£184	£249	**£68,452**	*£58,201*	*£78,703*	144
Urban	489	**£152**	£144	£160	**£43,885**	*£41,680*	*£46,090*	92
Electricity North West	325	**£186**	£175	£198	**£47,466**	*£44,561*	*£50,371*	100
Scottish and Southern Energy	34							
SP Energy Networks	22							
Northern Powergrid	44							
Western Power Distribution	77							

SME WTA Unplanned	n	WTA	Lower	Upper	VoLL	Confidence Interval (95%)		Index v Total
						Lower	Upper	
UK Power Networks	106	**£144**	£125	£164	**£59,762**	*£51,572*	*£67,951*	126
Experienced large scale interruption L12M	87							
Off-gas	316	**£152**	£144	£161	**£49,056**	*£46,406*	*£51,706*	103
No power cuts	239	**£147**	£137	£157	**£38,167**	*£35,648*	*£40,686*	80
Power cuts	376	**£153**	£143	£163	**£51,341**	*£47,981*	*£54,701*	108
Impact of power cut – Low	161	**£114**	£101	£127	**£42,375**	*£37,455*	*£47,296*	89
Impact of power cut – Medium	149	**£131**	£113	£150	**£36,629**	*£31,458*	*£41,801*	77
Impact of power cut – High	68	**£146**	£126	£166	**£48,005**	*£41,454*	*£54,555*	101
Want to keep bills constant	188	**£144**	£132	£155	**£45,823**	*£42,297*	*£49,349*	96
Want to keep reliability	141	**£124**	£109	£139	**£38,564**	*£33,832*	*£43,296*	81
Want to improve worse served	116	**£233**	£196	£269	**£63,896**	*£53,833*	*£73,958*	134
Want to improve supply	161	**£131**	£119	£142	**£32,919**	*£30,044*	*£35,793*	69
Winter	319	**£73**	£66	£81	**£19,099**	*£17,079*	*£21,119*	40
Summer	287	**£229**	£216	£241	**£77,843**	*£73,572*	*£82,115*	164
Experienced planned power cut	185	**£232**	£215	£248	**£58,227**	*£54,077*	*£62,377*	122

Grey font indicates small sample size, interpret with caution