VENICE

Understanding Vulnerability and Energy Usage Report

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Glossary of Terms

Fuel poverty	Where a household has a low income in a home which cannot be kept warm at reasonable cost.
Fuel poverty gap	The reduction in fuel costs needed for a household to not be in fuel poverty (BEIS, 2021c).

Table of Acronyms and Abbreviations

BREDEM	BRE Domestic Energy Model
DME	Durable Medical Equipment
DNO	Distribution Network Operator
Frazer-Nash	Frazer-Nash Consultancy
LILEE	Low Income Low Energy Efficiency (fuel poverty)
Ofgem	Office of Gas and Electricity Markets
PSR	Priority Services Register
SMIP	Smart Meter Implementation Program
VENICE	Vulnerability and Energy Networks, Identification and Consumption Evaluation
WPD	Western Power Distribution
WREN	Wadebridge Renewable Energy Network

1 Executive Summary

1.1 Background

Frazer-Nash Consultancy (Frazer-Nash) have carried out research on behalf of Western Power Distribution (WPD) as part of project VENICE (Vulnerability and Energy Networks, Identification and Consumption Evaluation). Frazer-Nash's contribution was focussed on establishing the potential use of smart meter data to better support vulnerable consumers. To address this, an approach combining the technical and behavioural sciences was adopted. This report covers the full methodology, findings, and conclusions of the behavioural science elements of the project, which were used to support data scientists in developing a model to identify vulnerability.

1.2 Technical Approach

The behavioural research consisted of two phases. First, a literature review, which covered academic and grey literature relating to vulnerability in the energy sector. The purpose of this was to consider how vulnerability had been defined in previous research, and to take into account the myriad of factors affecting vulnerable consumers and circumstances. Second, a series of stakeholder workshops with WPD and charities or support organisations were carried out. This consultation enabled a wide range of expert opinions to be gathered, helping to verify and complement findings from the literature review relating to factors affecting vulnerability, and how these might manifest within energy usage. Project researchers comprised of behavioural scientists with experience in conducting literature reviews, stakeholder workshops and applied data analysis. The research was conducted between October 2021 and February 2022.

1.3 Key Findings

Within the literature review, existing definitions and a number of vulnerability factors were identified. Definitions of vulnerability within the energy sector were found to account for a breadth of potential vulnerable circumstances. However, current approaches to managing vulnerable consumers (e.g. the Priority Services Register) may not acknowledge the full range of vulnerability factors, particularly those relating to mental health. This review outlined a number of factors relating to vulnerability, including:

- Finance- (e.g. fuel poverty)
- Health- and- capacity (e.g. physical health, engagement with the energy supplier)
- Geographic- and location-based (e.g. rurality, household composition).

It was found that there were complex relationships and correlations between vulnerability factors, and that vulnerability can generally be considered along a continuum rather than as a category.

The stakeholder workshops were attended by individuals from a range of UK charities and support organisations, and served to confirm and extend some of the literature review findings. Attendees highlighted the fluctuating nature of vulnerability and how it may differentially affect certain individuals. Additionally, the workshops drew out those vulnerabilities thought to be most (e.g. fuel poverty) and least (e.g. English as a second language) noticeable through energy usage, along with potential appliances (e.g. medical devices) and usage patterns (e.g. night-time usage) that might portray vulnerability. A consumer questionnaire was also developed following the review and workshops, which can be used to establish energy usage patterns and household vulnerability.

1.4 Implications

This research has implications for the way in which vulnerability is defined and approached within the energy sector. It may be necessary to consider the *degree* to which an individual or household may be in vulnerable

circumstances to allow for targeted support (‘worst first’). There is a need for further research to understand the complex relationships and correlations between vulnerability factors, and their relative impact across households. Furthermore, effort should be put into effectively combining data sources to allow for improved understanding of vulnerable consumers and circumstances. This is necessary to continue to better identify vulnerabilities less noticeable within energy usage, and would also support in the development of a continually-evolving predictive model of vulnerability, as more and better quality information becomes available.

1.5 Conclusions

Several overarching conclusions were drawn as a result of this research effort:

1. The use of a probabilistic model of smart meter data for the purposes of predicting vulnerability was supported, given the complex and transient nature of vulnerability.
2. The impact of vulnerability is likely to vary greatly across households and time, and certain vulnerabilities may be more detectable than others.
3. Data gathered from smart meters should be considered in conjunction with other sources of available information, such as account history and known household characteristics. Triangulation is likely to improve the quality of predictions relating to vulnerability, and crucially, smart meter data seems likely to be capable of providing incremental utility to the accuracy of that prediction.
4. It was suggested that the use of smart meter data for the proposed purposes would be of benefit for consumers, suppliers and network operators. A case could be made for operators to independently have access to such data, to allow them to understand, support and anticipate consumer circumstances and energy demands during the transition to NetZero.

2 Introduction

2.1 Context

The rollout of smart meters in the UK represents a major shift in the energy economy. Through access to more accurate and timely data, the Smart Meter Implementation Program (SMIP) has the potential to empower consumers to make informed decisions about energy usage, to allow suppliers to manage demand and billing more effectively, and for widescale improvements to be made to national infrastructure. While SMIP is not without its challenges (Sovacool, Kivimaa, Hielscher & Jenkins, 2017), operation of smart meters in domestic properties continues to increase, standing at 46% of all domestic meters as of June 2021 (Department for Business, Energy & Industrial Strategy [BEIS], 2021a). Accompanying such a technological shift are concerns that certain groups of consumers may be left behind or may not be able to realise the benefits of smart meters, such as those in rural areas, the elderly or those whose native language is not English (Citizens Advice, 2017). Meanwhile, there is recognition that the use of consumers' smart meter data has great potential, both in identifying and supporting such groups (Chalmers, 2017), and in supporting wider energy saving and emissions objectives (Deloitte, 2020). Indeed, the Office of Gas and Electricity Markets (Ofgem) Consumer Vulnerability Strategy report (2019) highlighted 'improved use of data' as one of its five areas where strong improvements for consumers in vulnerable situations could be made. It is within this realm – improving the effective use of smart meter data for identifying vulnerable consumers – where the present research lies.

2.2 Background

As part of the commitment to achieving Net-Zero, Western Power Distribution (WPD) launched an industry leading-innovation project to support vulnerable customers. In partnership with Frazer-Nash Consultancy (Frazer-Nash), Wadebridge Renewable Energy Network (WREN) and Frontier Economics, project VENICE (Vulnerability and Energy Networks, Identification and Consumption Evaluation) aims to use innovation to identify vulnerability and ensure no customers are left behind in the transition to a smarter, greener network. The approach taken to the project incorporates three projects designed to identify ways in which WPD are able to identify and support their vulnerable consumers.

The first project, for which this report relates to, is led by Frazer-Nash Consultancy, and aims to explore whether smart meter data can be used to identify vulnerable consumers and subsequently create a vulnerability prediction model. The model would be used to determine if a consumer's energy usage exhibits vulnerability markers. Such a tool could enable electricity operators like WPD, in collaboration with other stakeholders, to target investment and support at communities where they would be most effective in tackling vulnerability. The second project is led by Wadebridge Renewable Energy Network (WREN) and focuses on a Net Zero Community at Wadebridge in Cornwall. That project will establish how net zero is likely to impact upon fuel poverty as growing numbers of people switch to electrical transport and heat. WREN will then consider how it can work with WPD to support vulnerable consumers through this transition, finding ways for them to participate in the decarbonisation of the energy system to benefit the community and achieve Net Zero equality. This will include investigating commercial models to establish which ones work best for consumers. The third and final project, led by Frontier Economics, will consider changes in electricity use during the Coronavirus pandemic and determine how likely these changes are to continue (e.g. the shift to home working), and whether this will have an impact on consumers in vulnerable situations. Each of these projects may prove invaluable to all Distribution Network Operators (DNO) in support of their business planning.

2.3 Aims and Scope

The overall aim of the research undertaken by Frazer-Nash Consultancy was to determine the feasibility of identifying vulnerable consumers through use of smart meter data, relating directly to one of the five main areas for improvement highlighted by Ofgem (2019) identified above (see Section 2.1). One of the workstreams of this research project aimed to establish the behavioural profiles of vulnerable consumers, especially in relation to their electricity usage. This was achieved through a review of extant literature and a series of

stakeholder workshops, undertaken by a dedicated team of behavioural psychologists at Frazer-Nash. This research complemented a separate, concurrent stream of work, which aimed to develop a model to identify patterns of energy usage for vulnerable consumers. The purpose of this report is to provide the detailed approach and findings of the former of these workstreams: the literature review and workshops.

2.4 Overview of Approach

Project researchers sought to consider the possible energy usage profiles of vulnerable consumers through a review of academic and grey literature, covering a broad spectrum of evidence relating to vulnerabilities along with research specific to the energy sector. A series of stakeholder workshops with WPD, and relevant charities and support organisations was conducted to gather opinion on definitions and manifestations of vulnerabilities relating to energy usage. In turn, a synthesised analysis of findings was carried out to support the identification of energy usage profiles, thereby providing the main implications of the work.

2.5 Caveats

Several potential caveats to the present research project should be borne in mind when reading this report. This project offered an opportunity to delve into territory where there existed a scarcity of prior research, representing an innovative application of smart energy data (i.e. to improve understanding of vulnerability). While a systematic approach was adopted when reviewing evidence, there inevitably existed an element of interpretation, and therefore the conclusions reached through this work must be considered as somewhat subjective, reflective of the researchers and stakeholders that took part. Nonetheless, it is suggested that the range of stakeholder input helped to ensure a representative view.

There are also conflicting definitions of vulnerability, with possible contributing factors ranging from natural disasters and broad market forces to individual circumstance. The definition favoured within this report is the one provided by Ofgem (see Section 3.3.1), which helped to guide the scope of the literature review. As this definition matures and as research advances, the scope of evidence included may need to be revised for the purposes of future work. The trainability of the model developed as part of the wider research project ensures an adaptive approach; one which can cater to new developments and understanding of vulnerability.

Finally, the nature of vulnerability itself creates difficulties in trying to identify distinct behavioural profiles. For example, factors associated with vulnerability can be static or transient; dimensional or categorical; simple or complex. Additionally, there exists multi-collinearity[1] across vulnerable and non-vulnerable groups, and between different vulnerabilities, creating considerable overlap in the resultant behavioural profiles. While it is reasonable to disentangle such profiles, it is suggested that groups can be first and foremost characterised in terms of their commonality rather than by their disparities. Profiles extracted from smart meter data, and the predictive model developed as part of this work, provide a partial and abstracted picture vulnerability, and therefore should be used in conjunction with other sources of information, not least given the limited availability and difficulties in accessing smart meter data.

Nevertheless, the research reported here provided a robust method of identifying behavioural profiles in support of a novel predictive model of vulnerability utilising smart meter data.

2.6 Structure of this Report

- Literature Review (Section 3)
- Stakeholder Workshops (Section 4)
- Synthesised Analysis (Section 5)
- General Conclusions (Section 6).

[1] Strong correlations between multiple relevant variables (factors), in this case relating to vulnerability.

3 Literature Review

3.1 Aims and Scope

The aim of the literature review was to establish existing research relating to vulnerability and energy usage. This was achieved by covering evidence relating to definitions of vulnerability, smart meter data, and the health-, financial- and geographical-related vulnerability factors (Whitty et al., 2019) affecting energy usage. While the wider purpose of the project exclusively implicated electricity usage, the literature search was not limited in this regard, with research on general household energy usage (including gas), along with more general vulnerability, also incorporated in the review. There exists a great deal of research interest in individual vulnerability, and, more recently, in smart meter data; however, this review did not aim to cover those fields in depth. Rather, as noted above, there is a distinct lack of evidence linking vulnerability research with smart meter data. The aim of the review was to bridge this gap. This review also supports a call for greater social science input within energy sector research, with an apparent lack of interdisciplinary studies that combine an understanding of occupant behaviour with smart meter data as part of a socio-psychological framework (Adams, Belafi, Horvath, Kocsis & Csoknyai, 2021).

3.2 Methodology

3.2.1 Search Strategy

Frazer-Nash researchers sought to find relevant academic and grey (e.g. government and organisational reports) literature relating to vulnerability and energy usage. The literature search was undertaken by three project researchers, who utilised Google and Google Scholar search engines to find relevant material. Keyword searches were undertaken (e.g. ‘vulnerability’, ‘energy’, ‘household’, ‘smart meter’) incorporating Boolean operators where appropriate (i.e. ‘AND’, ‘OR’). The search strategy was iterative to ensure sufficient coverage of the literature for the purposes of the present research. Project researchers then reviewed the material to identify and report upon key themes, which have been broadly organised in this section according to definitions (Section 3.3) and types of vulnerability (Section 3.4).

3.3 What is Vulnerability?

3.3.1 Ofgem Definition

Within the UK energy sector, the most frequently cited definition of vulnerability is the Ofgem definition, as reported in their 2013 and 2019 strategies (Ofgem, 2013; 2019). The 2013 definition determines a domestic consumer as vulnerable if ‘a consumer’s personal circumstances and characteristics combine with aspects of the market to create situations where he or she is:

- Significantly less able than a typical domestic consumer to protect or represent his or her interests; and/or
- Significantly more likely than a typical domestic consumer to suffer detriment or that detriment is likely to be more substantial.’ (see Figure 1 and Table 1).’

Figure 1. Ofgem Vulnerable Customer Definition

Ofgem's Consumer Vulnerability 2019 Strategy report (Ofgem, 2019) outlined the most recent definition of vulnerable consumers based on research within the energy sector. This definition further incorporates individual characteristics (e.g. age, disability, mental illness, cognitive ability), capacity, circumstance (e.g. living alone, low income, living in a rural area) or awareness (awareness of a disability) in combination with market factors (delivery of goods and services) associated with vulnerability (see Table 1).

Table 1. Ofgem Vulnerable Consumer Factors

Individual Factors	**Situation or Scenario**	**Market Factors**
Physical or Mental illness, cognitive impairment, literacy or numeracy difficulties, Speech Impairment, English as a second language, age, low confidence.	Consumers in some vulnerable situations may also be served less well by competitive markets because, for example: ▸ they may be more expensive to serve ▸ they have less market access ▸ they are a higher debt risk so greater risk to the company ▸ it is not cost-effective to meet their needs.	Lack of affordable phones, complex information on products or services, Customer services are not inclusive or accessible.
Living alone, no internet access, low income, unemployment, being a full-time carer, single parent, leaving care, relationship breakdown, bereavement.		
Living in: Rural areas, Off the gas grid, private rented accommodation, cold & energy inefficient home, meter type (pre-paid).		

Although the latest Ofgem definition of vulnerable consumers is comprehensive and touches on a wide variety of factors (market, situational and individual); the breadth of such a definition means that it can lack specificity and applicability. Such a broad conceptualisation requires further effort to determine the full range of factors affecting vulnerability. Wider vulnerability research and reporting within the energy sector, government and

academia includes a variety of factors pertaining to vulnerability further to those included in the Ofgem definition. In the sections that follow, we discuss the factors that contribute to vulnerability in more detail, including some of those alluded to in the Ofgem definition. We begin by outlining some of the difficulties encountered when attempting to apply models of vulnerability (Section 3.3.2). We then discuss factors associated with vulnerability and how they might relate (Section 3.4). The National Audit Office recommends regulators and government work more closely in identifying vulnerable consumers and vulnerability (Morse, 2019). The results of this investigation of vulnerability within the energy sector may prove useful for facilitating discussions between regulators and government.

3.3.2 Issues with Defining Vulnerability

3.3.2.1 Complex Vulnerability

An issue in conceptualising and researching vulnerability is the substantial degree of co-occurrence of risk factors. In statistical terms, there is significant correlation or collinearity across vulnerabilities that must be accounted for. There is also commonality across vulnerable and non-vulnerable groups. Moreover, there are complex relationships across vulnerabilities and risk factors that can create difficulties when analysing datasets.

The link between socioeconomic status and health, for instance, is well-documented (Marmot & Bell, 2012). For health-related conditions, one study reported that 68% of American adults with mental health conditions also had a diagnosis of at least one medical condition, while 29% with medical conditions also had at least one mental health diagnosis, leading the authors to suggest that comorbidity is the rule, rather than the exception (Goodell, Druss & Walker, 2011). In the same study, the authors highlight that many of the risk factors associated with mental and 'medical' conditions are the same (e.g. childhood adversity, stress, socioeconomic status), with health-related behaviours and outcomes (e.g. sedentary lifestyle, smoking, self-care, disability) having both a moderating[2] and mediating[3] effect. It is clear, therefore, that the relationship between risk factors, health-related behaviours, and mental and medical conditions is complex and multi-directional.

Complex vulnerabilities cannot be ignored or simply disaggregated, since co-occurrence may bring with it an increased burden for those individuals, over and above vulnerabilities that occur in apparent isolation. Research by Kavousian, Rajagopal and Fischer (2013) supported the notion that multi-collinearity across behavioural factors can be addressed using factor analysis to identify latent, underlying variables associated with vulnerability. For present purposes, vulnerability can be conceived of as a complex, multi-faceted construct with multiple possible risk factors, and modelled accordingly.

3.3.2.2 Categorical vs Dimensional Vulnerability

A complication when conceptualising and researching vulnerability is whether different types of vulnerability can be considered categorical, fitting into either 'vulnerable' or 'not vulnerable' groups; or dimensional, sitting on a spectrum, with no definitive point where 'vulnerability' starts or ends. This issue can be applied to different aspects of vulnerability, with a clear example of categorical versus dimensional vulnerability being conceptualisations of mental health.

When researching vulnerability with regard to mental health, there are various models viewing mental health as discrete, with people either having or not having a diagnosis of a mental health disorder; or continuous, whereby people fluctuate on a continuum. The medical/psychiatric model of mental health consists of diagnoses, meaning that one either has or does not have a mental health disorder. According to this model of mental health, vulnerability is categorical, determined by whether a person has a diagnosis or not. However, determining vulnerability is not this simple due to various caveats. For example, an important assumption to avoid would be assuming that a customer is vulnerable simply due to a diagnosis of a mental disorder (Money Advice Trust, 2017), when many customers with diagnoses of mental disorders have no energy-related

[2] A factor which *influences* the relationship between two other variables.
[3] A factor through which two other variables are *causally* related.

difficulties at all. The Mental Health Continuum Model views mental health as a continuum along which people fluctuate. Keyes' (2002) model consists of two spectrums: mental health (from low to high) and mental illness (from low to high) and a person will fluctuate on these spectrums. There is difficulty in determining vulnerability using a continuous model as it is unclear when a person is vulnerable, or where the threshold for vulnerability is. However, a continuous model approach provides an indication of the extent of vulnerability.

This complexity needs to be considered in view of other vulnerabilities, and not just mental health, as many types of vulnerability can be categorical or dimensional. For example, financial and health, amongst many other, can all be visualised categorically (either vulnerable or not vulnerable), or dimensionally (this person is on the threshold and may become vulnerable, or could move further from being vulnerable). Therefore, categorical vs dimensional vulnerability is a key consideration and should be taken into account when determining vulnerability.

3.3.2.3 Objective and Subjective Vulnerability

A further consideration in conceptualisations of vulnerability for model development is the divergence between objective and subjective perspectives. What some individuals may class as vulnerable circumstances, others may not. The use of objective factors of vulnerability is typical within smart meter research (e.g. Cayla, Allibe & Laurent, 2010). However, subjective perceptions of vulnerability cannot be overlooked. For example, in the context of financial and health-related vulnerability, *subjective* social status has been found to be a better predictor of health outcomes than *objective* socioeconomic status (Singh-Manoux, Marmot & Adler, 2005). Meanwhile, self-perceptions of energy affordability and thermal comfort have also been suggested as important metrics to consider (Pye & Dobbins, 2015). Thus, both idiographic (self-perceptions) and nomothetic (objective, general factors) approaches to vulnerability must be considered.

3.4 Types of Vulnerability

In this section, we describe some of the factors associated with vulnerability in more detail. These touch upon the individual, contextual and market forces incorporated within the Ofgem (2019) definition but are organised similarly to the Commission for Customers in Vulnerable Circumstances report (Whitty et al., 2019). The groupings of financial, health and capacity, and geographic and location, can be viewed as divergent but complementary to the Ofgem definition.

3.4.1 Financial

Perhaps owing to greater data availability, political pressures and societal interest, financial vulnerability is one of the more well-understood areas of study, and has received a great deal of research and policy attention (e.g. BEIS, 2021b; Pye & Dobbins, 2015).

3.4.1.1 Fuel Poverty

Fuel poverty is a concept central to financial energy vulnerability, which implicates three key metrics: income, energy efficiency (consumption) and price (Hinson & Bolton, 2021). Put simply, fuel poverty exists where a household has a low income in a home which cannot be kept warm at reasonable cost. A related concept, the *fuel poverty gap*, refers to the reduction in fuel costs needed for a household to not be in fuel poverty.

In practical terms, BEIS' (2021b) latest definition of fuel poverty (Low Income Low Energy Efficiency; LILEE) is a residual income (income after household costs, tax and National Insurance) below the poverty line (after accounting for required fuel costs), and accommodation with an energy efficiency rating below Band C (as defined by the Fuel Poverty Energy Efficiency Rating system). Required fuel costs are those needed to sustain a warm, well-lit home, with hot water and the running of appliances; a measure which is sensitive to who lives at the property. With the LILEE definition, approximately 13.4% of households in England were in fuel poverty in 2019 (BEIS, 2021c), while the average fuel poverty gap was £216. Previous definitions represented absolute or more simplistic means of determining fuel poverty (e.g. more than 10% income spent on energy, the Low Income High Cost definition), and would yield different figures.

While the most recent definition of fuel poverty represents a relatively mature approach, there are other financial indicators that need to be accounted for within a broader view of vulnerability. Definitions of fuel poverty may bias against otherwise vulnerable groups (Moore, 2012) or may simply detract attention from them. For example, single-parent families or those living with dependents may be more prone to financial vulnerability and may be more severely affected when fuel poverty strikes. Definitions of fuel poverty may not take account of the transient nature of household finances: the impact of short-term fuel poverty, for instance, is not known relative to longer-term financial vulnerability. Fuel poverty status may also be a relatively poor indicator of unhealthily cold homes, with underspend on fuel being a greater predictor (see Moore, 2012). Within the present context, there may be an opportunity to use historic smart meter data – which is attributable to heating – to help establish required heating costs and likely home temperatures, where electricity is the primary source of heating. Finally, although less applicable to the UK climate, fuel poverty doesn't account for energy requirements for cooling (e.g. air conditioning) to maintain a comfortable temperature, which may be important for the elderly or those with underlying health conditions.

At a more theoretical level, a potential problem with the fuel poverty approach is that it engenders a dichotomous view. In practice, there may be meaningful differences between households within the fuel poverty group; similarly, a household just above the fuel poverty line may nonetheless experience many of the hallmark difficulties of those in the fuel poverty group (e.g. Moore, 2012). Adopting a 'worst first' approach to tackling fuel poverty, which makes use of the fuel poverty gap, goes someway to addressing this issue. Such an approach may also be applicable when it comes to other types of vulnerability factors.

3.4.1.2 Financial and Complex Vulnerability

As with other areas of vulnerability, financial vulnerability is not a straightforward concept and frequently bears relation to other areas of vulnerability. There may be an increased burden for those with multiple financial vulnerabilities. For example, low-income households or individuals living in rented accommodation may not be able to make efficiency improvements to their home or appliances, thereby increasing required heating costs. One study conducted in the US found no significant correlation with household income and electricity consumption (Kavousian et al, 2013; cf. Cayla, Maizi & Marchand, 2011), perhaps indicating that lower income households do not benefit from the same energy efficiency savings as those with higher incomes.

Financial vulnerability may also implicate broader vulnerability factors. StepChange (cited in Whitty et al., 2019), who support those in financial debt, reported that 20% of their customers also have another vulnerability. Meanwhile, a report by the Vulnerability Registration Service (VRS, 2021) suggested that 77% of people who are unable to work, and 45% who are unemployed and looking for work, consider themselves to be vulnerable. Fuel poverty status has been found to predict lower subjective wellbeing (Churchill, Smyth & Farrell, 2020), while a limited ability to use heating when it is required may contribute to the prevalence and severity of health conditions (Public Health England & UCL Institute of Health Equity, 2014). Household financial vulnerability more generally has been associated with lower levels of education (Anderloni, Bacciocchi & Vandone, 2012), which in turn may impact upon access to information about suppliers and household energy savings.

In outlining the government's approach to tackling fuel poverty, the BEIS (2021b) report acknowledges the fact that certain fuel poor households may be more affected by living in a cold home than others. Age and long-term health conditions are both considered. However, while fuel poverty may be assessed with relative ease, there is much debate regarding how to determine those with health-related vulnerabilities who are particularly at risk, where those consumers do not otherwise self-identify or disclose such circumstances.

3.4.2 Health/capacity-related factors

3.4.2.1 Physical Health

Physical health factors can be a good indicator of vulnerability and are widely recognised as a factor in a majority of energy sector research reports. Vulnerability can be linked to physical health conditions caused or exacerbated by living in a cold home or physical difficulties with sight, hearing, or mobility (Money Advice Trust,

2017). Those with physical health problems that are exceptionally vulnerable are those who are electricity-dependent, relying on electrical Durable Medical Equipment (DME; Molinari, Chen, Krishna & Morris, 2017).

Previous studies have found that people using electricity-dependent DMEs such as oxygen conservers, ventilators, airway suction devices and dialysis machines, amongst others, are especially in danger during power outages (Greenwald, Rutherford, Green & Giglio, 2004), meaning that those with end stage renal disease, cardiovascular disease, and respiratory illnesses are exceptionally vulnerable (Lane et al., 2013). DME's enable people with significant medical needs to function well day-to-day (DeSalvo et al., 2014) when they have access to the energy needed to maintain usage of their DMEs; it is when they don't have access to electricity that they become extremely vulnerable. For example, during the 2003 New York City blackout, chronically ill patients who experienced respiratory device failure were responsible for 65 emergency department visits and 37 hospitalisations (Prezant et al., 2005, cited in DeSalvo et al., 2014). Whilst this is an extreme example of when physical health becomes a vulnerability factor, there are many other cases whereby a person can be considered vulnerable due to physical health factors when it comes to energy usage. This means that within the physical health category there is a spectrum of vulnerability ranging from low-level to high-level vulnerability, but that it might be useful to consider the category of exceptionally vulnerable consumers. Physical health is a more recognised vulnerability and often energy providers include various physical health conditions within PSR codes.

3.4.2.2 Mental Health

Mental health is a key aspect of vulnerability; however, several energy consumer research reports do not discuss mental health in depth. Mental health includes emotional, psychological and social wellbeing. It affects the way people think, feel and act. It can also determine their resilience to stress. Mental illness refers to health conditions involving changes in emotion, thinking or behaviour (American Psychiatric Association, 2021). Mental illness is not a distinctly different category to mental health, rather, there are various degrees of sickness and health, abnormal and normal behaviours (Scheid & Horwitz, 1999) and vulnerability can be determined through identifying abnormal behaviour patterns relating to a person's mental health, which may be applied to the context of the energy sector.

There are many different models of mental health and illness and one of the main distinguishing features of these theories is whether they explain mental health/illness as discrete or continuous (Mechanic, 1999). Commonly, mental 'health' is thought of as continuous, and it is thought that everyone lies on a continuum as demonstrated in the Mental Health Continuum model (Keyes, 2002). Mental 'illness' on the other hand is more often seen as discrete, and diagnosis of a mental disorder typically requires a set of symptoms for a minimum period.

The medical/psychiatry model of mental health views 'health' and 'illness' as opposite ends of a dichotomy, specifically people who are mentally 'ill' are placed into specific disorder categories according to a set of symptoms (Scheid & Horwitz, 1999). This means that one either has or does not have a mental disorder. This model stems from biomedical research into mental health, based on the idea that mental illnesses have biological, genetic, or neurological causes (Michels & Marzuk, 1993). The discrete model of mental health can be used to identify potentially vulnerable customers based on whether they have a diagnosis of a mental health disorder or analysing behaviour patterns consistent with symptoms of mental disorders. However, an important assumption to avoid would be assuming that a customer is vulnerable simply due to a diagnosis of a mental disorder (Money Advice Trust, 2017) when many customers with diagnoses of mental disorders do not have energy related difficulties.

Figures vary with regards to the prevalence of mental health conditions in the UK. Those identified by McManus, Meltzer, Brugha, Bebbington & Jenkins (2009) are provided below by way of example:

- Depression – 3% of the population each year
- Anxiety – 6% of the population (Anxiety combines with depression 8% of the population)
- Panic disorder – under 1%

- Obsessive Compulsive Disorder – around 1%
- Bipolar disorder – 2% of adults in their lifetime
- Schizophrenia – under 1% of adults in their lifetime.

The Mental Health Continuum Model views mental health as a continuum on which people fluctuate. Keyes (2002) operationalised mental health as a 'syndrome of symptoms of positive feelings and positive functioning in life' and described mental health as 'flourishing' and an absence of mental health as 'languishing'. This continuous model of mental health consists of two spectrums: mental health (from low to high) and mental illness (from low to high). A person can be considered 'flourishing' (complete mental health) if they have high mental health and low mental illness, 'languishing' (incomplete mental health) if they have low mental health and low mental illness, 'struggling' (incomplete mental illness) if they have high mental health and high mental illness and finally, 'floundering' (complete mental illness) if they have low mental health and high mental illness. A person will fluctuate on this depending on both internal factors (e.g. biological/psychological factors) and external factors (e.g. family bereavement).

Identifying vulnerability using the continuous model of mental health is particularly difficult, especially as people fluctuate on the spectrums on a day-to-day basis; however, this does not mean it is impossible to determine vulnerability from a mental health point of view. Certainly, the ease with which a categorical approach can be taken does not mean that it should be adopted within models of vulnerability. This report argues that vulnerability more generally should be viewed along a continuum where possible, recognising that categorisation may be necessary for operationalisation.

3.4.2.3 Mental Capacity

Mental capacity is often classified as a vulnerability and can have a great impact on a persons' life and behaviour, depending on the severity. Having mental capacity is being able to make and communicate one's own decisions (Mental Health Foundation, 2021). A person may have a mental capacity limitation if they are unable to: understand information needed to make a particular decision, remember/retain information long enough to make a particular decision, weigh up the information to make a particular decision or communicate that decision.

Legislation surrounding intervention exists where a decision-maker is considered to lack mental capacity, such as the Mental Capacity Act (2005). There can be cases when a person cannot be considered to have a mental capacity limitation, yet they appear unable to protect their best interests (O'Connor & Purves, 2009). On the other hand, there could be cases when a person may have a mental capacity limitation but may not be vulnerable in terms of the energy sector, or may have low-level vulnerability. This means that, as with other vulnerability factors, mental capacity can be considered as a spectrum along which individuals can vary.

3.4.2.4 Ability to understand energy advice or consumers who are 'hard to access'

Research and reports conducted in the energy sector to determine the uptake of government schemes have highlighted that those consumers who are 'hard to access' or have an inability to understand energy advice are particularly vulnerable (National Energy Action [NEA] & RS Consulting, 2012). This may include households where the person or people most engaged with energy are not comfortable using a computer (or may be digitally excluded), have difficulty with reading and writing, are hearing or visually impaired, or where English is not their first language. Physical and mental health conditions might also affect an individual's ability to engage with support schemes. Others may feel stigmatised or that support organisations would not understand their situation, for example, a household struggling with debt, addiction, or hoarding.

Consumers considered to be hard to reach and to be provided with support in the energy sector are domestic consumers rather than non-domestic. However, there are circumstances where domestic consumers take their energy through a non-domestic supply (e.g. a flat above a shop or pub, dual usage, or where the meter is in a third-party property) and who may, therefore, not have a formal legal relationship with the energy supplier.

3.4.2.5 Age

Energy consumer research reports often classify age as a vulnerability which is in line with government legislation around vulnerable energy consumers. Energy UK, who work with domestic energy suppliers to provide support to vulnerable consumers, define the following to be age-related vulnerability: a consumer is caring for an elderly person in the household; a consumer is of Pensionable Age or the age of any children living in the household is below 16 (Energy UK, 2016). The main concerns with age in the energy sector are around heating efficiency, chronic medical conditions, physical heath, mental health and, as aforementioned, being hard to access or having barriers to support. While older and younger age groups tend to have lower energy consumption (Kavousian et al., 2013), they may be at greater risk of consequences when energy disruption occurs, and so recognising and establishing support for these consumers is fundamental. Research also suggests that senior citizens are the demographic most likely to be beset by chronic diseases that consume more medical resources and experiencing one or more disabilities that can affect mobility and/or self-care, meaning that they are more likely to be vulnerable consumers. Furthermore, with the average life expectancy increasing, this suggests that the electricity-dependent population will grow steadily in the future, and faster in areas with large concentrations of elderly populations (Molinari et al., 2017). Therefore, further research into providing help to age-related vulnerability may need to be considered in light of the transition to Net Zero.

3.4.2.6 Health and Complex Vulnerability

For those with long-term health conditions or those in self-employed work (e.g. the gig economy), the impact of ill health may have far reaching financial implications. In turn, living in a cold home, as described above, may further exacerbate health conditions or prolong their impact. Additionally, it has been found that those with health and capacity related difficulties typically face additional financial burden that might create further vulnerability. For instance, those with physical health conditions have been found to have extra living costs (on average £583 a month more; Scope, 2019), while those with mental health conditions that reduce their ability to carry out daily activities (e.g. when choosing & paying for services, or when dealing with problems) incur additional average costs of £1100 a year (Citizens Advice, 2019). Once again, this highlights the complex and multi-dimensional nature of vulnerability for many energy consumers.

3.4.3 Geographic and Location

Geographic and location-based vulnerabilities arise where circumstances in the physical environment impact upon energy usage. Several of these factors are inherently linked to financial vulnerability.

Rurality, for example, may impact upon access to suppliers, digital services, well-insulated homes and employment opportunities (Whitty et al., 2019), in turn implicating financial vulnerability. Households in urban areas are the most likely to be in fuel poverty (13.8%); however, rural households have the highest fuel poverty gap (£585; BEIS, 2021c), indicating that fuel poverty reaches greater extremes in rural areas. The same report documents that those households living in rural areas tend to have less efficient homes and larger properties. They are also more likely to be off the gas grid, also implicating greater fuel poverty and a wider fuel poverty gap (£480 on average, compared to £162 for on gas grid households). Further, reductions in fuel poverty in the last 10 years seem to have benefitted on grid households to a greater extent than off grid households. Those paying for their electricity via pre-payment meter are also most likely to be in fuel poverty, despite having the lowest fuel costs.

Household tenure and occupancy also have a bearing on the likelihood of being in fuel poverty. For example, those caring for others in their household (e.g. children or an individual with a disability), may have the added financial burden of care coupled with a decrease in their capacity to pursue other employment. Households with several occupants with vulnerabilities may have similarly compounded vulnerabilities to contend with. Those in private rented accommodation or the social sector are more likely to be in fuel poverty. Meanwhile, single parents, couples aged over 60, young adults and children, and households with an ethnic minority occupant have higher incidence of fuel poverty (BEIS, 2021c).

Those living on flood plains and in other vulnerable locations are potentially at risk of sudden changes in their circumstances, which may impact upon their access to energy, as well as their health and finances. Further, such houses are more likely to be occupied by less affluent people (Morrow, 1999), for whom disaster may have a greater impact. Vulnerability also appears to be unevenly distributed across the UK, with 30% of those in Scotland reported to be vulnerable, compared to 44% in Greater London (VRS, 2021).

3.4.4 Conclusion: Approaches to Vulnerability

There are myriad potential factors that implicate household vulnerability, many of which are encompassed by the approaches to defining vulnerability adopted within the energy sector. These influences can be viewed through differing lenses (e.g. individual, circumstantial & market; financial, health & geographic factors), with each having their merit in aiding understanding of the breadth of factors. Regardless of conceptualisation, what emerges clearly is that many factors associated with vulnerability are highly inter-related, sharing complex relationships. Several government and sector reports highlighted the connection between consumer-related vulnerabilities; however, the nuanced nature of vulnerability is perhaps under acknowledged in the energy sector when it comes to health-related factors in particular. The extent of correlations between vulnerabilities is, for other factors (e.g. financial), relatively well-understood. Cause and effect are also often difficult to determine, especially given that relationships may be bidirectional. This complexity, combined with the transient nature of vulnerability, makes identifying and targeting groups in most need of support a challenge. Further, modelling of factors will, in most cases, provide only a probability that an individual is vulnerable: there exist exceptions to every rule. Additionally, a *threshold* approach to defining vulnerability, while a useful first step, may detract from the dimensional nature of many vulnerability factors. Identifying the *extent* to which an individual might be affected or considered vulnerable may provide the benefit of being able to support those most in need (‘worst first’). In sum, a complex model of vulnerability is needed, which considers the range of possible factors and relationships, the extent of vulnerability, and the confidence thereof.

4 Stakeholder Workshops

4.1 Aims and Scope

The main aim of the workshops was to capture stakeholder opinions regarding the possible energy usage profiles of vulnerable consumers. A series of workshops was carried out, first (Phase 1) with the operator (WPD), and subsequently (Phase 2) with a range of charities or support organisations that were involved in supporting vulnerable individuals. In addition to gathering stakeholder opinion, the WPD workshops also aimed to cover some of the main findings of the literature review and acted as a trial run for the approach for the Phase 2 workshops. The approach and findings of Phases 1 and 2 are reported below, in Sections 4.2 and 4.3, respectively.

4.2 Phase 1: WPD Workshops

4.2.1 Approach

To determine the content of the workshop, three researchers from Frazer-Nash initially extracted key findings and understandings from the literature review. Based on this, a workshop was held virtually via MS Teams by three project researchers (see Appendix A – Stakeholder Workshop Slides). During the first part of the workshop, the project aims were summarised and relevant definitions and findings from the literature review were presented to demonstrate the difficulty of defining vulnerability and its nuances. The latter part of the workshop involved two different activities in order to engage the attendees and gather their input in both defining vulnerability and identifying behavioural characteristics linked to these vulnerabilities. To round up the workshop, researchers described the next stages in the project and asked attendees if they knew of any charities or organisations that would be useful to run further workshops with. The full workshop was delivered over three 1.5-hour sessions in October 2021.

4.2.2 Analysis

Two project researchers conducted an analysis of the content of the amalgamated notes from across the three WPD workshop sessions. Key themes were extracted based on the exercises and discussion, which are described in this section.

4.2.2.1 Priority Services Register and Needs Codes

During the workshops with WPD, the Frazer-Nash research team were made aware of the needs codes[4] for consumers to register on the Priority Services Register (PSR). There are 27 needs codes in total, and they appear to be less health specific, citing medical equipment that may be used by vulnerable consumers and broader categories of vulnerability such as ‘chronic illness’, rather than specific illnesses. The needs codes do not cover fuel poverty due to the monetary responsibility not lying with DNOs such as WPD. Learning about the needs codes was useful, giving insight into vulnerabilities that are already identified and somewhat protected through the PSR. However, WPD itself recognises the limitations of the needs codes to cover how individuals self-identify on the PSR.

4.2.2.2 Health Factors of Vulnerability

Throughout discussions in the workshop, it was suggested that factors affecting how an individual interacts with the DNOs could determine vulnerability, rather than simply factors affecting behavioural profiles. WPD recognised the need for a review of vulnerability – specifically health related vulnerability, especially as understanding more about vulnerabilities can help DNOs adjust their approach to these consumers, particularly during energy outages.

[4] As used by suppliers and operators; those vulnerable groups deemed to be eligible for support.

4.2.2.3 Financial Factors of Vulnerability

Fuel poverty is not currently one of the 27 needs codes for the PSR as it is not relevant for DNOs; however, WPD expressed that the knowledge of whether a household is fuel poor would be useful in order to tailor approaches to help consumers. WPD also have 'social indicator mapping' which is useful to guide information around fuel poverty and which consumers may be susceptible. Financial factors of vulnerability are key to understand due to low carbon emission transitions being expensive, and this could lead to larger financial gaps and higher levels of vulnerability due to rising energy costs. When considering financial factors, contextual factors are closely linked; for example, changes in wholesale prices and varying governmental support affect financial factors. Furthermore, long-term, and short-term factors need to be considered regarding all types of vulnerability.

4.2.2.4 Location Factors of Vulnerability

WPDs 'social indicator mapping' provides rural area indicators of vulnerable consumers, and WPD place specific focus on power cut resilience of areas to determine vulnerable consumers due to location, response time and detrimental effects of power cuts. The 'worst served' consumers are those who experience power cuts between 12-40 times per year and are prioritised as more vulnerable. Rural living could increase the likelihood of vulnerability due to more inefficient and cold homes, and it was suggested that there appears to be a direct link between energy efficiency and a consumer's financial situation. A key factor brought up by WPD was the variation in regional support moving into Net Zero, with different councils having different Net Zero plans, meaning a consumer in one location may be more vulnerable than a similar consumer under a different council.

4.3 Phase 2: Charity and Support Organisation Workshops

4.3.1 Approach

The slides for the Phase 2 workshops were derived from those of the previous phase. In the interest of time, less detail was provided with regards to the outcome of the literature review. The workshops were delivered by two project researchers. A brief introduction to the project was provided, following which attendees were encouraged to take part in two of the same exercises as before (defining vulnerability and identifying behavioural characteristics). Additionally, an exercise geared towards understanding the nature of appliance usage, especially by vulnerable consumers, was included. Throughout, attendees were also encouraged to ask any questions they might have for the researchers. In total, four small-group workshops were conducted, each lasting 1.5 hours.

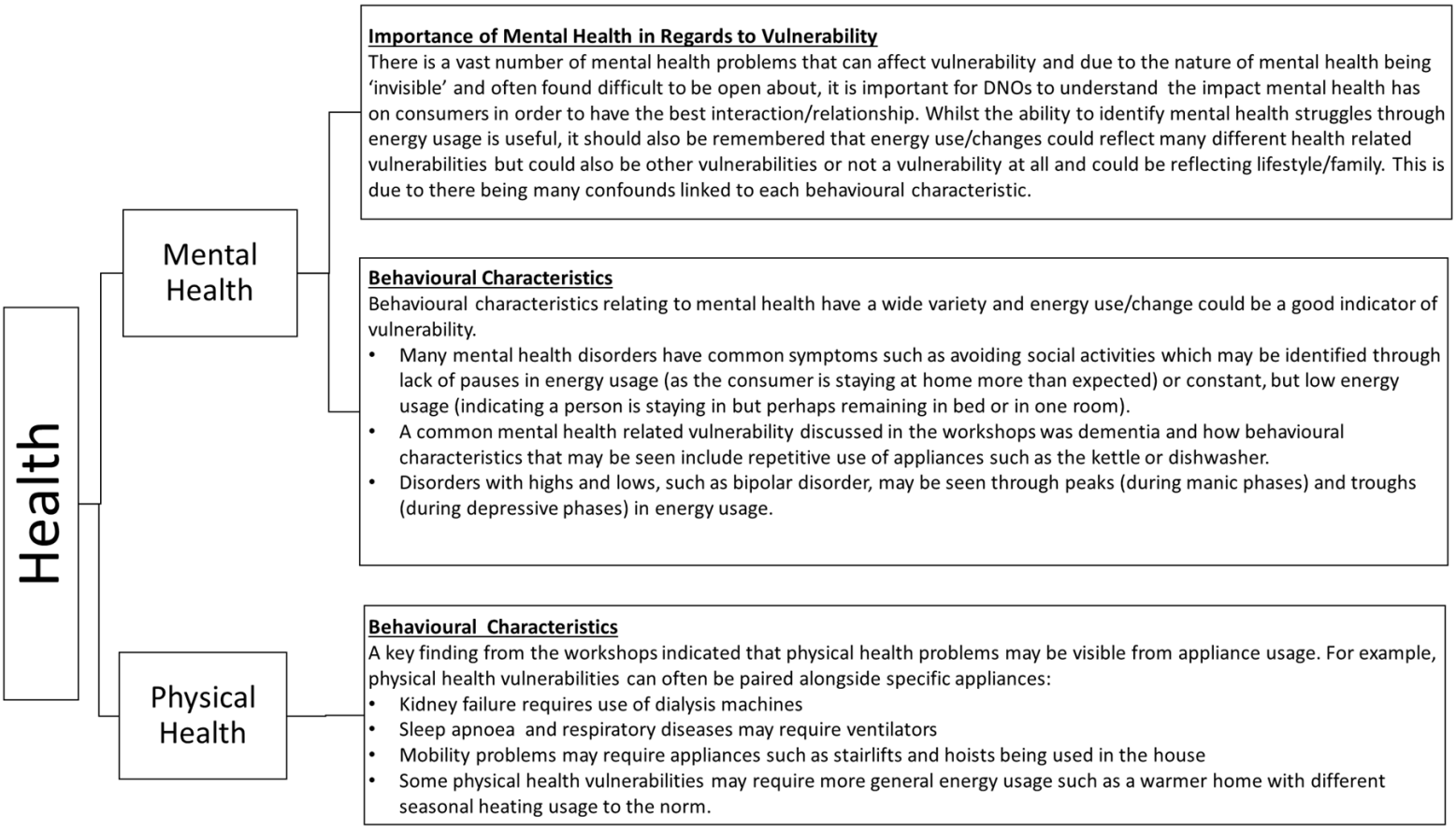
4.3.2 Recruitment of Charities and Support Organisations

Invitations to prospective attendees were sent via email (see Appendix B – Stakeholder Invitation Email) to those organisations which had been identified in Phase 1. To aid in recruitment for Phase 2, all attendees who took part in a workshop were entered into a draw for the opportunity to win a festive hamper. A name was pulled at random following completion of all of the workshops. Attendees were drawn from the following charities and support organisations.

- Money and Mental Health
- Centre for Sustainable Energy
- National Energy Action
- Age UK
- Citizens Advice
- Repowering.

4.3.3 Analysis

During the charity workshops, the definition of vulnerability was explored through breaking it down into three broad headings: health, location, and financial vulnerability. Health was further broken down into sub-headings of physical and mental health, recognising the importance of mental health as its own sub-category. Key features of health-related vulnerability that were expressed across workshops included disability, both mental and physical health, age, mobility, and capacity to communicate. Location-related vulnerability discussions identified factors such as rural living, occupancy and private tenancy as factors that may affect vulnerability. Finally, financial-related vulnerability features identified included: fuel poverty, change of circumstances (e.g., job), recipient of benefits and understanding of bills. The following diagrams describe key themes and findings from the charity workshops related to each category of vulnerability.



Financial

Patterns in Energy Usage Indicates Vulnerability

During the workshops, a recurring idea that could indicate financially vulnerable consumers was patterns in their energy usage:

- Short-Term Patterns:
  - At the beginning of the month energy usage may be similar to the expected.
  - As the month goes on, heading towards benefit pay-outs/pay day, financially vulnerable consumers may begin to self-ration by using less energy than would be expected, in order to make it to the next time they will receive money.
  - This pattern may repeat as the consumer receives money their energy usage becomes more fitting with the norm, then tailing off as the month goes on and bills begin to be paid.
- Unusual Patterns:
  - Financial vulnerability could be identified through unusual seasonal patterns, particularly in the winter, when energy bills are expected to be considerably higher due to hot water and heating needs. If a consumer is not using heating October through to February as often as expected for their EPC rated house or at all, this could indicate financial vulnerability.

Coping Strategies Indicates Vulnerability

Households struggling with financial vulnerability, including fuel poverty often display particular strategies in order to get by without essentials such as heating. Some examples of strategies include:

- Going to bed early to reduce energy usage in the evenings.
- Using the gas hob as a heating appliance.
- Not using lighting (perhaps candles instead) or only lighting one room at a time.
- Overuse of kettle instead of heating and many others.
- Prepayment metres and periods of no usage whilst the consumer tries to top up their credit.
- Repeated low value top-ups to prepayment meter and more frequent top-ups or top-ups that don't result in credit balance (due to meter debt).
- Top-ups made but lack of energy use.

Location

Housing Type As A Vulnerability Factor

Consumers may be more susceptible to vulnerability depending on their housing type:

- Flats tend to have higher efficiency due to residual heat from other flats.
- Newer buildings have far better efficiency than older buildings meaning heating the home is easier and cheaper depending on a consumers housing type.
- Inefficient and poorly insulated homes may be identified through higher usage of heating, perhaps on constant rather than timers.
- Private tenancy may also indicate higher risk for vulnerability due to inability to change meter/tariff or make energy improvements out of fear of losing tenancy.

Occupancy As A Vulnerability Factor

Over-occupancy and under-occupancy could both be a vulnerability and may be indicated through energy use:

- An over-occupied house is more likely to be fuel poor or perhaps may not be low income, but over-occupied, therefore fairly consistent patterns of energy usage.
- An under-occupied house may only have one person in a large house, struggling to pay to heat the house and therefore only using parts of the house.
- Age of the members of household and this may indicate vulnerability and could identified through energy usage:
  - Families with young children are more likely to have predictable patterns in cooker use (perhaps twice in the evening, once for children's meal and once for the adults meal).
  - Families are more likely to have set routines e.g. morning routines, evening routines, that they are unable to shift away from compared to an all adult household.

Rurality As A Vulnerability Factor

Living in a rural location could mean a consumer has a greater risk of becoming vulnerable. Rural living is becoming understood as more of an issue than previously thought, houses in these areas may be off-gas grid or off-electricity grid, have lower energy efficiency than new-builds in urban areas and have often outages such as power cuts. These reasons make a rural consumer more vulnerable due to the higher risk they have of being unable to afford their bills and having to wait longer for repair of supplies/boilers etc.

Whilst being able to identify vulnerability through energy usage is useful and important, there are confounds/caveats that need to be considered. Principally, many vulnerabilities could manifest in similar ways. For example, a consumer may be flagged as vulnerable (inefficient home) due to their high energy usage, however it may just be that they are a large family household with young children. Furthermore, a consumer may be flagged as vulnerable when this is not the case at all. For example, a sudden drop in energy usage could indicate financial vulnerability, or the consumer may simply have gone on holiday or to a second home.

As introduced in the literature review (see Section 3.4), it is important to recognise the relationship between type of vulnerability. Often factors that lead to vulnerability can impact upon each other meaning a consumer may spiral into vulnerability in multiple areas. Many mental health vulnerabilities can be closely linked to financial vulnerability. A consumer may be vulnerable due to loss of income and mental health problems, with each one affecting the other, and ambiguity as to which is the cause. The same goes for financial- and location-based vulnerability. An inefficient home is likely to have higher energy bills which could lead to financial vulnerability, yet a lower income could mean a consumer is unable to afford to move into a more efficient home. Figure 2 demonstrates the complex relationship between different vulnerabilities.

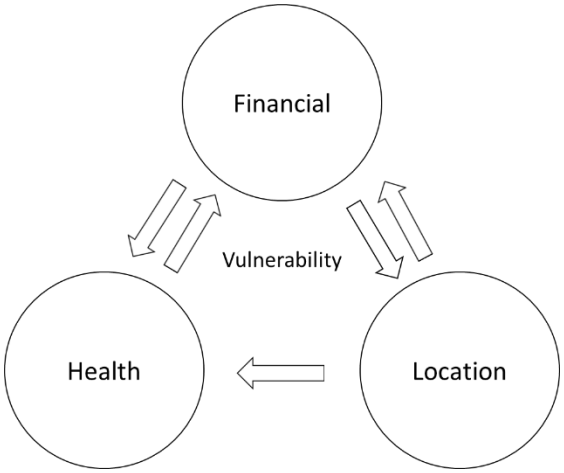


Figure 2. The complex relationships between factors relating to vulnerability in the energy sector.

4.4 Conclusions: Workshops

Several conclusions can be drawn following analysis of the workshops.

First, health- and- capacity-related factors may be less well understood by energy providers. It is important to bear in mind the differences between mental and physical health, notwithstanding their overlapping features and co-occurrence. This is especially important where those experiencing certain mental health difficulties may have difficulties engaging with their provider, and where mental and financial vulnerability factors may interact.

Second, vulnerability fluctuates over time, and it may be helpful to adopt a dimensional approach. This would allow suppliers and operators to better support individuals who have previously been vulnerable, or who don't quite meet the current threshold for support, but nevertheless require adjustments. Acknowledging the fluctuating nature of vulnerability would also engender an understanding of short- and- long-term vulnerabilities. Certain factors associated with vulnerability may be changeable to a greater (e.g. mental health) or lesser extent (e.g. location).

Third, while certain vulnerabilities may be detectable through energy usage, there are many potential confounds to consider. For example, energy usage changes may be reflective of health-related vulnerabilities but could equally reflect changes in lifestyle or household composition. Care needs to be taken to ensure a

balance of sensitivity and specificity can be reached to avoid falsely identifying or missing vulnerable consumers during development of a predictive model.

Finally, it was suggested that vulnerable consumers are ultimately very unlikely to go to operators, and possibly even their supplier, in times of need. Attendees were in favour of operators having better access to and use of smart meter data to support vulnerable consumers.

5 Synthesised Analysis

This section draws together the findings of the literature review and workshops, with the aim of identifying patterns of energy usage that are most likely to indicate vulnerability. Each research approach was complementary and overlapping: the workshops highlighted further nuances of vulnerability as touched upon in the literature review, while there were several factors that were identified both in the literature and in the focus groups (e.g. age was prominent in the literature and was also mentioned by participants as a factor of vulnerability). In addition, as a result of the combined analysis of the review and workshops, a consumer vulnerability questionnaire schedule was developed (see Appendix C – Householder Questionnaire) which can be used to gather further household data regarding energy usage and vulnerability.

In this section, the most and least detectable vulnerabilities are identified, before considering energy usage relating to the following:

- Overall energy usage patterns
- Appliance usage
- Trends and timing

5.1 Predicting Behaviour with Energy Usage

Energy usage and household behaviour do not share a one-to-one relationship, with energy usage being influenced by several other factors (e.g. energy efficiency). In one study, self-reported behavioural factors explained 4.2% of the variability in electricity energy consumption (Santin, Itard & Visscher, 2009, cited in Kavousian et al., 2013), while in another, 33% of usage was explained by household behaviour (Cayla, Allibe & Laurent, 2010). Such discrepancies may be in part due to varying definitions of behaviour and the range of behavioural factors considered in different studies. Several studies use self-report measures of behaviour, which may also act to distort relationships, such as due to social desirability bias or difficulties in recall. In any case, household behaviour seems to hold only part of the answer, with a degree of variance in energy usage explained by factors other than observed or self-reported household behaviour. This should be weighed up when considering the potential for smart meter data to be reflective of the behavioural profiles of vulnerabilities.

5.1.1 Behavioural Characteristics Most and Least Noticeable from Energy Usage

Table 2 below, provides an indicative list of vulnerable circumstances that were identified as being most and least noticeable, based on the findings of the literature review and workshops discussed in the previous sections.

Table 2. Vulnerabilities suggested to be most and least noticeable within energy usage

	Vulnerabilities identified from Needs Codes	**Vulnerabilities identified from Literature Review**
Behavioural Characteristics showing in energy usage	• Nebuliser and Sleep Apnoea monitor • Heart, lung & Ventilator • Dialysis, feeding pump & automated medication • Oxygen Concentrator • Stair lift, Hoist, Electric bed • MDE Electric Showering/ and bathing • Dementia(s) and cognitive development • Pensionable Age • Families with young children 5 or under • Temporary - Life changes	• Physical illness • Pensionable age • Living alone • No internet access • Low income • Unemployment • Full-time carer • Leaving care • Rural living • Off the gas grid • Energy inefficient home • Prepaid meter • Fuel poverty

	• Temporary - Post hospital recovery • Temporary - Young adult householder	• DME reliant
Difficult to identify from energy usage	• Restricted hand movement • Blind • Partially sighted • Physical impairment (except those associated with usage of particular appliances, e.g. electric wheelchair) • Developmental condition • Chronic/serious illness • Mental health • Developmental condition • Unable to communicate in English • Unable to answer door • Careline/telecare system • Medicine refrigeration • Poor sense of smell • Female presence preferred • Hearing impairment (inc Deaf) • Speech impairment • Water dependent	• Mental illness • Cognitive impairment • Mental capacity • Literacy/numeracy difficulties • Speech impairment • English as second language • Single parent • Relationship breakdown • Bereavement

5.1.2 Overall Energy Usage

The analysis of a household's overall energy usage over an extended period (e.g. quarterly) may be used to indicate vulnerable consumers. If a deviation from baseline is detected, where the normal energy usage for a household shifts, then this may be an indicator of vulnerability. Through discussions with charities the following situations could be indicative of vulnerability and be used to explain deviations in overall energy usage.

- A decreased or similar heating usage pattern during winter months (e.g. October – February) may flag that a household is in fuel poverty or on a low income and may need further support.
- If a household has a continually high heating usage this may indicate that the home is inefficient. Likewise, if heating bills are consistently high, this may also signify an inefficient home.

These deviation from baseline indicators may be particularly important to DNOs when they are assessed alongside the PSR registration data and EPC ratings. For example, if a household's overall usage deviates and the property has a low EPC rating, a DNO may be prompted to investigate or signpost the household to the PSR register.

5.1.3 Appliance Usage

At an individual level of analysis, smart meter data could be used to pick up on the use of certain appliances which may be an identifier of a more vulnerable household. For example, it was highlighted that those with physical health conditions may be reliant on the following types of appliances (see also DMUs, Section 3.4.2.1):

- Stair lifts
- Charging electric wheelchairs, electric mobility scooters
- Defibrillators or dialysis machines

Furthermore, appliance usage trends throughout the day may also be an indicator of type of households. Where vulnerable households may either have young children under five years of age or an elderly household. An example of an appliance usage pattern that could be an indicator of this would be:

- No TV usage or high TV usage during non-working hours
- High washing machine usage

However, the above usage may also indicate someone who is working from home or of a low-income household. Either way, findings suggest how appliance usage may indicate a requirement for investigation by a DNO or supplier.

Appliance identification from smart meter data may also be useful to identify a vulnerable consumer who may be in fuel poverty or at risk of fuel poverty. Specifically, recognising cookers or boilers may help to indicate fuel poverty. Researchers have found that a cooker type can be identified by using the BREDEM domestic energy model (BREDEM; BRE, 2012), which is a methodology for calculating the energy use and fuel requirements of households based on their characteristics. It is suitable for use in research work, such as stock modelling. There are several types of cookers that can be modelled in BREDEM. For example, if the household is fully electric it is assumed that a normal sized electric cooker is in use. Otherwise, it is assumed that a normal sized gas/electric cooker is in use. Therefore, where a gas connection is present (i.e. a gas meter is identified by the surveyor), but no gas space or water heating appliances are present, it is assumed that the gas connection is not in use. In these cases 100% of energy demand for cooking is assumed to be met by electricity. No gas standing charge will be applied in the final calculation of fuel cost. Where both gas and electricity are present in a household it is assumed that the proportion of gas and electrical energy demanded for cooking is split equally. Thus, using smart meter data may prove helpful in identifying fuel poverty through analysis of cooker usage.

In addition to cooker usage, the following appliances were suggested to be used by low-income households as a means to save on energy bills.

- Using a gas hob to heat the home
- Only heating one section of a household
- Turning lights off early, particularly in winter months
- Overuse of a kettle for hot water rather than using hot water from taps.

Further exploration of energy usage within focus groups highlighted that characteristics of the following appliances may also point towards households that are at risk of fuel poverty.

- Mains gas and electricity connections
- Primary space heating system type and fuels
- Boiler models
- Heat distribution systems
- Secondary heating system type and fuels
- Water heating system types and systems
- Hot water tank presence and levels of insulation

5.1.4 Trends and Timing of Energy Usage

Trends and timing of energy usage were highlighted as potential indicators in both the review and focus groups. For example, sudden deviation in baseline behaviours may be indicative of changes to personal circumstance that relate to vulnerability. Similarly, periods of low-or-no energy usage on pre-paid meters or repeated low-value top-ups may be a particular sign of vulnerability. The review also outlined behavioural habits related to mental health conditions such as insomnia (disrupted sleeping patterns), obsessive compulsive disorder (habitual energy usage) and eating disorders (e.g., nocturnal eating patterns), which may be identifiable from

time patterns in energy behaviour. In the focus groups, participants identified similar habits associated with age-related health conditions, such as dementia, where time patterns of behaviour may be identified. Although these results are convoluted due to the similarities in patterns of energy usage there is argument to suggest that vulnerability, be that age-related, physical or mental health, could be detectable through half hourly patterns of smart meter data. Particularly, when there are deviations in behaviour or consistent unusual patterns of usage (e.g. consistent nightly use of the cooker).

Trends were identified in focus groups, where it was outlined that trends in heating patterns may be indicative of those in fuel poverty or low-income households. For example, a vulnerable household's energy use may be consistent at the beginning of the month but may drop off before the end of the month prior to pay day/benefit pay outs to save money by self-rationing. Likewise, heating may still be used in such a way in winter months, or in extreme cases may be turned on sparingly, to save on heating. These trends (normal patterns and seasonal patterns) may become more identifiable as gas costs rise in the UK, and may prove to be useful identifiers of vulnerability for DNOs.

6 General Conclusions

This research has attempted to determine the behavioural profiles of consumers in vulnerable circumstances, and how differing vulnerabilities may manifest within energy usage. More broadly, it has responded to the Ofgem (2019) call for improved use of data to help consumers in vulnerable situations. A literature review and a series of workshops have indicated a number of potential consumer energy profiles, along with considerations for the adoption of energy usage data.

First, a fundamental conclusion that can be drawn from this research is that **the use of a probabilistic model is suitable for the present application**, specifically for modelling of smart meter data for the purposes of predicting vulnerability. An adaptive model is called for, one which takes into account the gamut of complex circumstances, and which 'learns' from present data to make incremental improvements in predictions. As more data regarding consumers becomes available, this ultimately may be fed into a more complex predictive model. This research project has provided the groundwork for the development of a preliminary predictive model of smart meter data, which may be built upon in future research projects.

Second, the nature of vulnerability is incredibly diverse. This report has generally adopted the overarching categories of financial, health and location factors (see Section 3.4); however, such classification does not capture the complex and nuanced relationships between factors for many consumers in vulnerable circumstances. **The impact of a given vulnerability will vary greatly between consumers, and will also fluctuate over time**, just as the behaviour of consumers more generally (both vulnerable and non-vulnerable) varies. Moreover, the noticeability within energy usage varies for each vulnerability: **certain vulnerabilities are more detectable than others**. It seems likely that some vulnerabilities will be virtually undetectable, whilst others will be more apparent. This research has tried to tease out those most detectable vulnerabilities.

Third, and relatedly, **smart meter data needs to be considered in conjunction with other available information** to build a composite picture of vulnerability. Since smart meter data is capable only of providing indicative estimates of vulnerabilities, wider sources of information should be taken into account. This might include the account history of the consumer, information about the residence and comparisons with other similar households. Such a triangulated approach would undoubtedly allow for more accurate predictions regarding the circumstances of consumers. **The relative confidence level of the predictive model should also be provided to support users in their decision making when reviewing cases**. This will help to combat over- or- under-reliance on the model, and support in the synthesis of several sources of information. It is hoped that adoption of the predictive model will enable better identification of vulnerable consumers and circumstances, and for more objective support decisions to be made.

Finally, while smart meter data represents one piece of the puzzle, this research has demonstrated the potential utility in employing such data to make predictions regarding consumer vulnerability. The findings of this research, when coupled with the success in the predictive modelling of synthetic data, suggest that **this approach would provide benefit for consumers, suppliers and network operators**. For those consumers for whom smart data is available, a strong case is therefore made for network operators to leverage such data, notwithstanding ethical and legal considerations. This would allow operators to better understand, support and anticipate consumer circumstances and their energy demands during the transition to NetZero.

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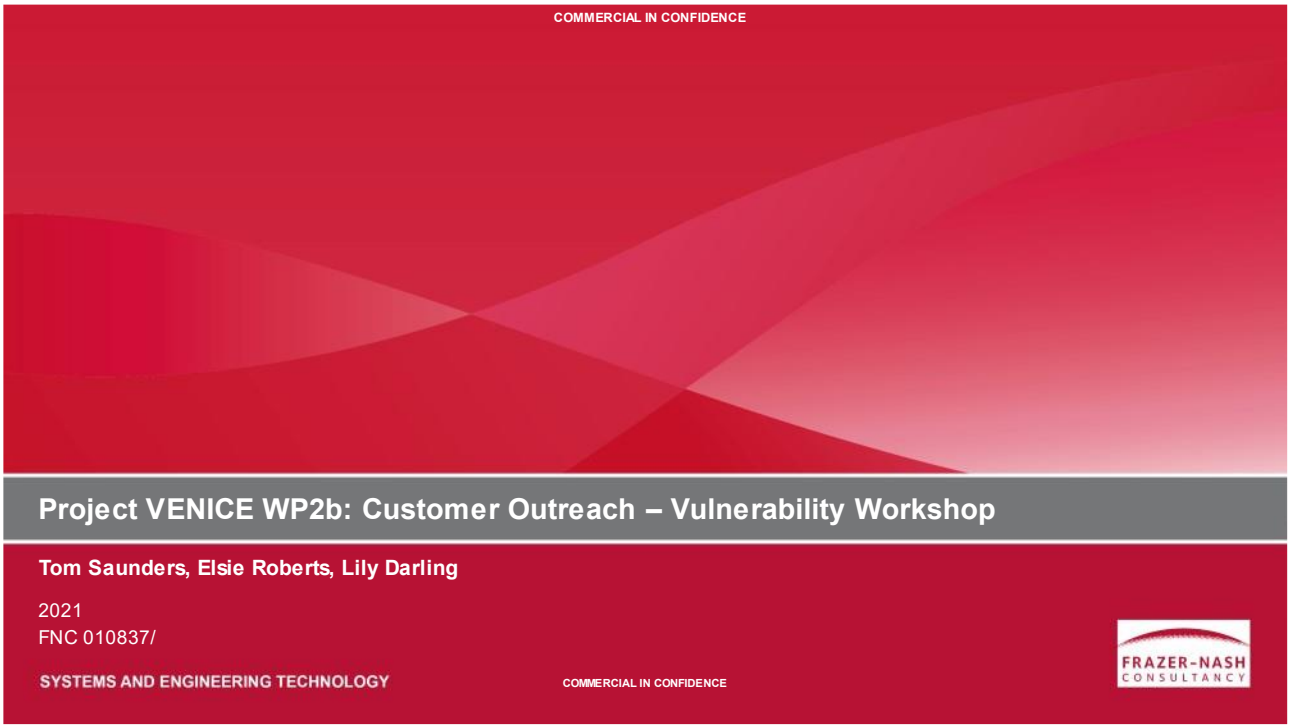
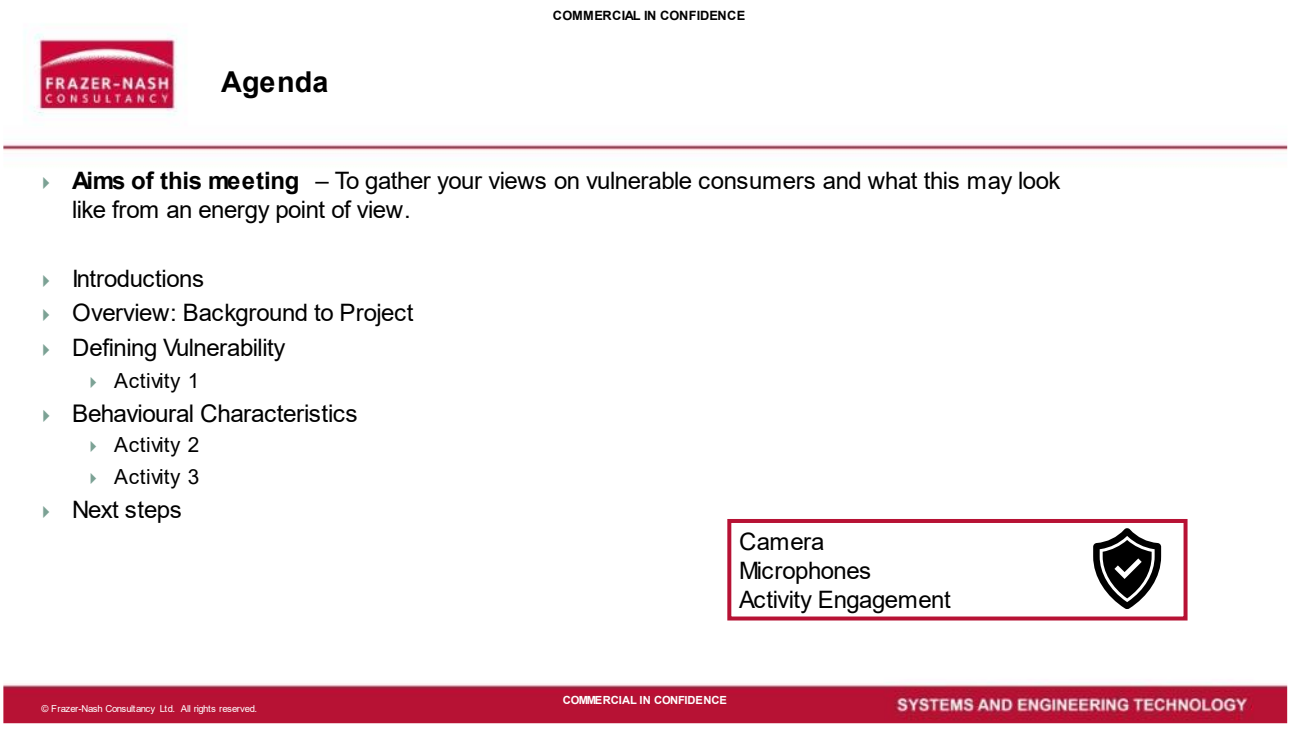
8 Appendices

8.1 Appendix A – Stakeholder Workshop Slides





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Agenda

- **Aims of this meeting** – To gather your views on vulnerable consumers and what this may look like from an energy point of view.

- Introductions
- Overview: Background to Project
- Defining Vulnerability
  - Activity 1
- Behavioural Characteristics
  - Activity 2
  - Activity 3
- Next steps

Camera
Microphones
Activity Engagement

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Context

Project Background

- Establish whether smart meter usage data can detect vulnerable consumers
- To train a pattern recognition machine learning model to recognise behavioural characteristics determined by behavioural profiles of people with a range of vulnerabilities built from literature review and community/charity outreach.
- If successful, the model will be deployed onto Western Power Distribution's (WPD) internal systems, to run as part of "Business As Usual"

Frazer-Nash Project background

WP2b aims:

Task 1: Determine Vulnerability Behavioural Characteristics

- **Aim: To determine what set of behavioural characteristics, in relation to electricity usage, a person might exhibit if they have a vulnerability.**

Task 2: Generate training data and develop model

- Utilize the identified behavioural characteristics to build pattern recognition models of vulnerability

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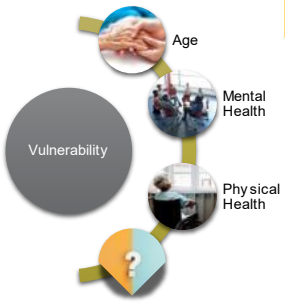
Activity 1: What is vulnerability?

Thinking about your experiences with vulnerable consumers, what do you consider vulnerability to include?



Health

Financial

Location

5

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Smart Meter Data – what we are aiming to achieve

What is smart meter data?

- A smart meter is an electronic device that records a consumer's household energy consumption.
- Smart meters communicate the information to the consumer for greater clarity of consumption behaviour, and electricity suppliers for system monitoring and customer billing.
- Data averaged over 30 min, from previous 13 months.

How we are using smart meter data:

- Data from the whole population not just vulnerable consumers.
- Behavioral characteristics shown in the smart meter data:
  - Timing of energy usage / Trends of energy usage
  - Appliance usage
  - Overall usage patterns.

Why we are using smart meter data:

- Provides high-fidelity household usage data.
- Wider aim to improve value from smart meter rollout.
- Document the utility of smart meter data for DNOs.

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Activity 2: Use of Appliances

Vulnerability	Appliance	How is it used? E.g. Plugged in?	When? How long? E.G time of day	Why is it used?
Sleep apnoea	CPAP device	Mains	At night, constant	Oxygen supply

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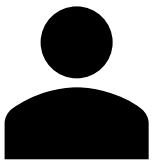
Example: Vulnerable Behavioural Characteristics Case Study



- **Name:** John Doe
- **Vulnerability:** Complex mental health (e.g. depression with eating disorder), low -income and rural location
- **Behaviours/Features of Mental Health**
  - Short sleep cycles = late/early (abnormal daily patterns)
  - Unusual eating patterns and increased/decreased appetite
  - Fatigue, leading to less physical movement and late starts
  - Helplessness and reduced mood
  - Lack of social support
- **Energy Profile**
  - Late/early appliance usage of fridge and/or cooker use due to sleep cycles and eating patterns.
  - Increase/decrease energy use at unusual times
  - Prepaid meter
  - Inefficient heated home (EPC E)
  - Lack of activity, low use of lights and showers etc.
  - Not registered on the PSR/not self -identified as vulnerable to their operator or supplier

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Activity 3: Vulnerable Energy Behavioural Characteristics

- Thinking about consumers from your engagement & experiences who may be defined as vulnerable, are you able to identify any particular **energy behaviour characteristics**?

Vulnerability	Energy Use/Changes	Similarities
E.g. Depression	There may be changes in appetite thus -> more/less use of cooking appliances used at different times OR increase/decrease energy use	Anxiety, OCD, eating disorders

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SYSTEMS AND ENGINEERING TECHNOLOGY

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Activity 3: Health Related Vulnerable Energy Behavioural Characteristics

Vulnerability	Energy Use/Changes	Similarities
E.g. Depression	There may be changes in appetite thus -> more/less use of cooking appliances used at different times OR increase/decrease energy use	Anxiety, OCD, eating disorders

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Activity 3: Financial Related Vulnerable Energy Behavioural Characteristics

Vulnerability	Energy Use/Changes	Similarities
Low Income	Having the heating turned off in the winter period (October -Feb)	Non-domestic supplied energy

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Activity 3: Location-Based Vulnerable Energy Behavioural Characteristics

Vulnerability	Energy Use/Changes	Similarities
Inefficient homes	Above normal energy use (expensive bills)	Large (family) household.

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Activity 3: Other Vulnerable Energy Behavioural Characteristics

Vulnerability	Energy Use/Changes	Similarities

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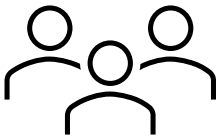
Activity 4: Vulnerable Behavioural Characteristics Case Study

- Who would your vulnerable consumers rely on?



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Any further thoughts….?

- Is there anything you feel we haven't covered?

- Any Questions?

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What happens next…

- We intend to run similar workshops with further charities to determine specific vulnerable consumers, their behavioural characteristics and energy requirements/use.

- Your responses will be used to help inform our smart meter data research to advance support to vulnerable energy consumers during the transition to net zero.

- **Do you know of any other charities that provide support to your vulnerable consumers who may be interested in participating?**

- **Would you like to be kept informed about this research?**

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Thank you for your participation

Contact Details:

Frazer-Nash Researchers:

Tom Saunders
Tel: +44 (0)3330 151 718
Email: t.saunders@fnc.co.uk

Zoe Hodgins
Tel: +44 (0)117 937 8470
Email: z.hodgins@fnc.co.uk

Volunteer Advocate: If you feel that this workshop has made you feel uncomfortable and you would like to talk to someone please contact the volunteer advocate:

Dr Heather Taylor
Tel: +44 (0) 117 945 8972
Email: h.taylor@fnc.co.uk

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8.2 Appendix B – Stakeholder Invitation Email

Dear [representative/team],

We are getting in touch to inform you about our current research project into vulnerability in the energy sector and would like to extend an invitation for you to play a key role in contributing to this research.

Background

The project is being conducted by Frazer-Nash Consultancy on behalf of Western Power Distribution (WPD). WPD have requested this research to determine how they can better support their more vulnerable consumers during the transition to Net-Zero*. This will be achieved by exploring how WPD could identify vulnerability requirements by taking into account consumer smart meter data, allowing them to be more proactive in offering support to vulnerable consumers that may or may not be registered on the Priority Service Register.

Therefore, this research aims to identify the behavioural characteristics and energy requirements of those more vulnerable consumers.

If you would like more information on this project, see this link: https://www.current-news.co.uk/news/wpd-targets-net-zero-equality-with-venice-project

Why are we contacting you?

Your organisation has been identified as playing a vital role in supporting energy consumers and individuals with vulnerabilities. We are keen to gather your experiences of supporting individuals with vulnerabilities to help identify their specific requirements and energy needs to inform this piece of research. This represents a key part of the overall research project.

What will I be asked to do?

Participation is entirely voluntary and would involve engaging in a 1-1.5 hour online (MS Teams) workshop led by the Frazer-Nash psychology team. The team will guide participants through a series of discussions and activities which will aim to capture experiences of supporting vulnerable consumers. Your input will support WPD's wider aim of predicting the needs of vulnerable consumers to help ensure critical energy requirements are maintained during the transition to net zero.

These workshops will be guided by the British Psychological Society's ethical principles. This means participation and engagement in the workshop is entirely voluntary, and your data will be stored anonymously. Workshops will not be recorded. Notes will be taken by researchers on key points raised during the workshop but no names or identifying information will be stored.

How can I take part?

Workshops will be held in November and December – please get in touch as soon as possible if you or any of your colleagues would be interested in taking part (feel free to share this email).

If you would like to take part in a workshop or enquire about the project please reply to this email (Lily Darling, at l.darling@fnc.co.uk) or contact the research lead, Tom Saunders, at t.saunders@fnc.co.uk, or project lead, Zoe Hodgins, at z.hodgins@fnc.co.uk.

Many thanks,

The Frazer-Nash Research team

*Net-Zero refers to the balance between the amount of greenhouse gas produced and the amount removed from the atmosphere. Reaching net zero occurs when the amount we add is no more than the amount taken away. Within the Energy sector this may mean changes to energy supplies to consumers.

8.3 Appendix C – Householder Questionnaire

1) Informed Consent

- [Organisation name], in partnership with Frazer-Nash Consultancy, are undertaking work on behalf of Western Power Distribution to understand the energy usage patterns of consumers.
- You are being contacted because you have previously engaged with [organisation name].
- We are seeking your input as part of this research to allow a more accurate picture of consumer electricity usage patterns and behaviour.
- The survey will take approximately 10-15 minutes.
- Your responses to the following questions will be held confidentially.

2) Demographics/Background

- Are you a homeowner/tenant?
    - Are you the main person responsible for the household?
    - If not, relationship to main person responsible?
- Are you on the Priority Services Register?
    - Which code(s)? (predefined list of codes)
    - Awareness of the Priority Services Register?
- Household composition
    - What is your age?
    - How many adults/children/elderly in household?
- Employment
    - Are you currently in full or part time employment?
        - How many hours per week are you in paid employment?
    - Do you currently work from home?
        - How many days per week do you currently work from home?
- Energy usage:
    - Would you say your energy usage is lower/the same as/higher than the average UK resident?
    - What electrical appliances/devices do you use:
        - Most (top 3)
        - Least (bottom 3)
- What factors have the most influence on your usage of energy? (E.g. seasons, energy prices, personal finances, health, other occupants – children, elderly).
    - What factors have the least influence?
- Is there anything you would consider unusual about your energy usage?

3) Health-related

- Do you/anyone in the household have a carer? (Whether a friend/family member or otherwise)
- Do you/anyone in the household consider yourself to be disabled and/or vulnerable?
    - If so, in what way are you disabled and/or vulnerable?
    - How does this impact upon your household's energy usage?
    - Do you rely on certain appliances for your health?
- Do you use any assistive/medical devices or appliances (such as a fridge for medicines, dialysis machine, breathing apparatus, mobility car/scooter, etc.)?
    - If so what appliances/devices do you use?
    - (For each appliance) How often do you use these appliances/devices (1 very infrequently-5 very frequently)?
    - (For each appliance) What times of day do you typically use these appliances/devices?
    - (For each appliance) Does your usage of these appliances/devices change over time?
    - Do you rely on these appliances/devices?
    - What would happen in the event of a power cut? (provide information on PSR if not previously aware).

4) Location-related

- Which local authority or area do you live in?
- Do you live in an urban or rural location?
- What is the main heating method in your home? (e.g. gas or oil central heating, electric radiators, night storage heaters)
    - Do you use any additional heaters? (e.g. oil heaters, multi-fuel stove)
    - Are you 'off gas grid'? (i.e. is oil your main source of fuel?)
- Do you know the current EPC energy efficiency rating of your home? (A-G)
- Do you struggle to heat your home?
    - If so, why? (e.g. financial/efficiency)
- Digital exclusion:
    - Do you have good mobile phone reception in your home?
    - Do you have internet access in your home?
    - Do you know what the net zero transition is?
        - Do you know how this might affect you? (signpost)
- How many power cuts have you had in the last 12 months?
    - How has this affected you?

5) Finance-related

- Do financial circumstances impact upon your energy usage?
    - If so, how?
- Do you receive any support from energy supplier/charities/support organisations?
    - If so, what kind of support do you receive?
- Are you in receipt of any benefits?
- Have personal finances affected your energy usage in the past 12 months?
- Do you believe that you are fuel poor? (brief definition)

6) Other

- Is there anything else that affects your energy usage which you feel hasn't been covered?
- Do you have a smart meter fitted?
    - Would you be willing to take part in confidential research?
    - If yes, your responses to this survey will be linked, confidentially, to your smart meter usage.

7) Debrief

- Thank you for your time.
- Confirm their data will be held confidentially for the duration of the project, after which it will be destroyed.
- Your responses will be analysed to allow Western Power Distribution to better understand and support the usage and needs of consumers.
- You may withdraw your data at any time during the project by contacting [organisation name & contact details]. Once the data have been analysed, this will form part of the overall reporting for the project, and it will then not be possible to identify individual data for the purposes of removal. (Confirm understanding/acceptance).
- Do you have any questions regarding the research?