CrowdFlex: Alpha

November 2022

D2.1 – Plan for priority consumer segments and questions to trial

Strategic Innovation Fund

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ESO

Contents

Terminology

Term/Acronym	Definition
Aggregator	Third party intermediaries specialising in coordinating or aggregating demand response from individual consumers to better meet industry parties' technical requirements for specific routes to market. Aggregators send signals to their consumers to modify their demand as a response to the System Operator requirements and/or market price signal.
Balancing mechanism	The Balancing Mechanism (BM) is used to balance supply and demand in each half-hour trading period of every day. The BM is used to either increase or decrease generation (or consumption).
BaU	Business as Usual
CNZ	Centre for Net Zero
CPO	Charge Point Operator: A charge point operator installs and maintains charge stations so drivers can charge their electric vehicles. CPOs can either own and operate a set of charge stations, or simply operate them for third parties.
Demand Side Response (DSR)	Modifying generation and/or consumption patterns in reaction to an external signal such as a change in price, to provide a service within the energy system.
DRS (ambiguation)	Domestic Reserve Scarcity
Economy 7 tariff	With an Economy 7 tariff your electricity will be charged at two rates - a day rate and a night rate. You pay a cheaper rate for electricity for seven hours at night (off-peak) and a higher one in the day. This means the meter will show two different numbers; one set of numbers for your 'normal' or daytime electricity use, and another for your 'low' or cheaper night time use. This can also sometimes appear as Rate 1 and 2, or R1 and R2.
Electricity curtailment	Deliberate reduction in output below what could have been produced to balance energy supply and demand or due to transmission constraints.
ESA	Energy Smart Appliances: communications-enabled device able to respond automatically to price and/or other signals by modulating or shifting its electricity consumption.
ESO	Electricity System Operator: the Electricity System Operator (ESO) performs several important functions; from second-by-second balancing of electricity supply and demand, to developing markets and advising on network investments.
EV	Electric vehicle
Flexibility	Change in feed-in or withdrawal in response to an external signal (price signal or activation) with the aim of providing a service in the power system.
Flexibility capital	Term that accounts for factors that affect the provision of flexibility, from affluence to geolocation to technological and social means.
(G-M-k)W	(Giga-Mega-Kilo)Watts: unit of power
(G-M-k)Wh	(Giga-Mega-Kilo)Watts-hour: unit of energy
HP	Heat pump: ASHP refers to Air Source Heat Pumps, GSHP refers to Ground Source Heat Pumps
IMD	Index of Multiple Deprivation: widely-used datasets within the UK to classify the relative deprivation (essentially a measure of poverty) of small areas. Multiple components of deprivation are weighted with different strengths and compiled into a single score of deprivation.

IO	Intelligent Octopus: Octopus Energy beta smart tariff just for EV drivers that gives access to 6 hours of cheap electricity every night between 11:30pm and 5:30am and automates EV charging
IoT	Internet of Things: the term IoT encompasses everything connected to the internet, but it is increasingly being used to define objects that "talk" to each other.
LCT(s)	Low Carbon Technologies: innovative technical solutions that are characterised by a low emission intensity, compared to state-of-the-art alternatives. In a way, they can be seen as best-in-class technologies with a focus on environmental impact.
LIV	Low Income and Vulnerable (customers)
Octopus Agile	Octopus Energy smart tariff that works by tracking daily wholesale energy prices and providing the next day's pricing sometime after 4pm the day before. The pricing can change every 30 minutes.
Octopus Go	Octopus Energy smart tariff with cheap 12p / kWh rate for four hours every night (between 00.30 and 4.30am) designed primarily for EV owners.
Smart thermostat	A smart thermostat is a Wi-Fi enabled device that automatically adjusts heating and cooling temperature settings in your home for optimal performance.
Smart/unmanaged charging	Smart charging allows the charging operator (be it an individual with a charger at their home or a business owner with multiple charging stations) to manage how much energy to give to any plugged-in EV. The amount used can vary depending on how many people are using electricity at that time, putting less pressure on the grid. Unmanaged charging on the contrary refers to charging sessions which overlook these considerations and charge the EV as soon as it is plugged in.
SoC	State of Charge: level of charge of an electric battery relative to its capacity. The units of SoC are percentage points (0% = empty; 100% = full).
Solar PV	Solar photovoltaics
ToUT	Time of Use Tariff: Time of use tariffs use different prices to encourage consumers to use electricity at times when more is available cheaply.
V2X	Vehicle-to-X technologies allow an electric vehicle to export the energy within its battery for another use, for example to a home (V2H) or to the electricity grid (V2G).

1 Introduction

This report summarises the research findings from a Literature Review and Segmentation Analysis to inform the basis of the consumer-facing aspects of the CrowdFlex trial, ensuring that it is well-evidenced and based on relevant knowledge of the key customer segments and their user journeys.

With the energy system continuing to decarbonise, the need for more flexibility within the system is becoming more apparent. Traditionally, flexibility has been provided by increasing generation output rather than by reducing demand, and due to system parameters, domestic level participation has been limited to date. However, low carbon technologies such as electric vehicles and heat pumps are becoming increasingly common within households and, with their inherent flexibility, are capable of providing grid services. Domestic level flexibility will not only provide the Energy System Operator (ESO) with much needed dispatchable capacity but will also enable end consumers to participate in the decarbonisation journey and give them the ability to reduce their energy costs and carbon emissions.

In broad terms, and in the interests of this Literature Review and Segmentation Analysis, what is considered as consumer-facing is based upon an understanding of domestic customers (i.e., residential customers) within the energy system, and experience of how they respond to incentives that change their energy consumption behaviour. Response to incentives is a well-established field of scientific research; however, its application to consumers in energy markets is relatively underdeveloped compared to other sectors of the economy.

This Literature Review and Segmentation Analysis complements other CrowdFlex work streams to deverlop a well-evidenced trial of flexibility in the energy market at scale. The Literature Review baselined the current state of the literature in relation to consumer incentives in the energy sector, and in doing so:

- Provides a current state of the understanding of consumer preferences and reaction to incentives within the energy market, across a variety of consumer market segments;
- Complements the work of Task 2.2 (Identify priority consumer segments) in identifying key consumer segments considered in the existing literature and their responses to incentives;
- Provides an initial direction for Task 2.3 (Develop trial delivery approach for consumer aspects) of potential approaches to use in the trial, or key areas in the trial to investigate, to fill a knowledge gap.

The Segmentation Analysis built upon the findings of the Literature Review to identify priority consumer segments based upon data from real world customers, aligning the approach across two datasets that would be used in a CrowdFlex trial. This commenced with the dataset of Ohme EV customers being used to identify a consumer segmentation approach, which recommended an approach that uses a variety of attributes to split customers into four segments. This approach was then generalised to Octopus Energy datasets, which required us to align on a common data model and broaden out the approach to non-EV customers. Finally, we make recommendations on segments that would be most beneficial to analyse during CrowdFlex, based on the learnings from the Literature Review and the Segmentation analysis. This report provides an overview of the analysis undertaken, the methodology used and the recommendations.

2 Methodology

2.1 Literature Review

The methodology of this deliverable was a two-phased review of literature into consumer attributes and how they impact the amount of flexibility that can be delivered, and a consumer perspective on the preferred types of incentive structures and reward mechanisms for flexibility. The work package scope specifically identified several key areas of general interest that were considered useful for developing the trial design. The Literature Review parameters (Table 2-1) were confirmed by the Project Sponsor. It was reaffirmed that, where feasible, a representative range of consumers should be incorporated within the literature review.

Table 2-1: Literature Review Parameters

Consumer attributes and amount of flexibility delivered	Consumer perspectives on preferred types of incentive structures
• Types of low carbon technologies owned, and how they are used at the moment. Potential for them to change usage in the future, and the conditions under which they would consider changing their behaviour. • Level of automation vs non-automation/manual in consumer's expected response to flexibility, across different technology types. • Consumer attitudes towards flexibility: frequency, type of event (turn up vs turn down) and engagement motivation reasons.	• Time-of-Use (ToU) tariffs and non-ToU tariff incentives. • Carrot vs stick incentives.

In choosing the literature to be reviewed, a structured search was utilised of academic papers, government reports, and publicly-accessible research. Internal research documents of Centre for Net Zero, Ohme Technologies, and Octopus Energy for which access was possible and summary results have been presented publicly were also utilised.

Within each of the Literature Review Parameters set out above, a series of search terms were brainstormed and identified. As the searches were undertaken, these search terms were refined to narrow the results further. The search terms used are identified in Table 2-2.

Table 2-2: Identified search terms

Area of interest	Search terms used
Consumer attributes and amount of flexibility delivered	Electric Vehicle, Flexibility, Heat Pump, Trial, Energy equality, Flexibility Capital, Consumer preferences, Equality, Green Technology, Gender, United Kingdom, ToUT, Automation, Solar Panels, Battery, Domestic energy use, Urban vs rural, Affluence
Consumer perspectives on preferred types of incentive structures	Electric Vehicles, Heat Pump, Solar Panels, Battery, Affluence, Incentive, Tariff, Benefit, Trial, Consumer preferences, Automation, Green Technology

The terms were searched in several different search engines to identify suitable academic, government, and industry sources to be the subject of this analysis. These are listed below. Whilst no time period was set for papers, papers published within the last 5 years were generally considered to be of greater relevance. The search engines used are listed below:

- Google Scholar and ScienceDirect for access to academic papers and research;
- Searches on Gov.uk websites for access to government reports, including those of BEIS and UKRI;
- Google, where applicable narrowing search results to specific websites.

In addition to this, members of the consortium were also identified and invited to recommend specific papers and interesting research to be considered for this literature review.

From this process, a list of research papers and articles were identified. As part of this process, duplicate studies were identified and removed. The executive summaries of these papers were reviewed to ensure that the researchers had a degree of confidence that the context of the research would be of relevance to CrowdFlex.

Finally, when reading the papers, the method of ‘snowballing’ was applied, where interesting references were identified and reviewed for their relevance. In considering these references of references, the same terminology and restrictions on the age of the research were applied.

In the process of reviewing this literature, the authors attempted to construct an overall narrative of the current literature. Being mindful of the requirement to assist Deliverable 2.2 in defining key research questions to be considered by trial design. This was primarily achieved through clustering the research into discrete topic areas, which are presented in this paper.

2.2 Segmentation Analysis

2.2.1 Segmentation analysis on Ohme customers

In CrowdFlex: Discovery, Ohme developed a segmentation model across their EV cohort. This segmentation methodology took tens of engineered features about customer charging sessions and applied a k-nearest neighbours algorithm - a clustering technique - to reduce the dimensionality of this dataset to k=4 dimensions.

Once this clustering has been applied, each individual cluster could be manually inspected and interpreted to see the dimensions that explain the structure of the higher-dimensional data best. The two dimensions identified were summarised as “Value” in the Flexibility Market, and “Potential” for customers to participate in events (which correlates strongly with likelihood of participation, and thus engagement).

In each cluster, we can analyse the distribution of attributes that forms this cluster, which enables us to develop proxy rules that would classify future customers into one of these 4 segments.

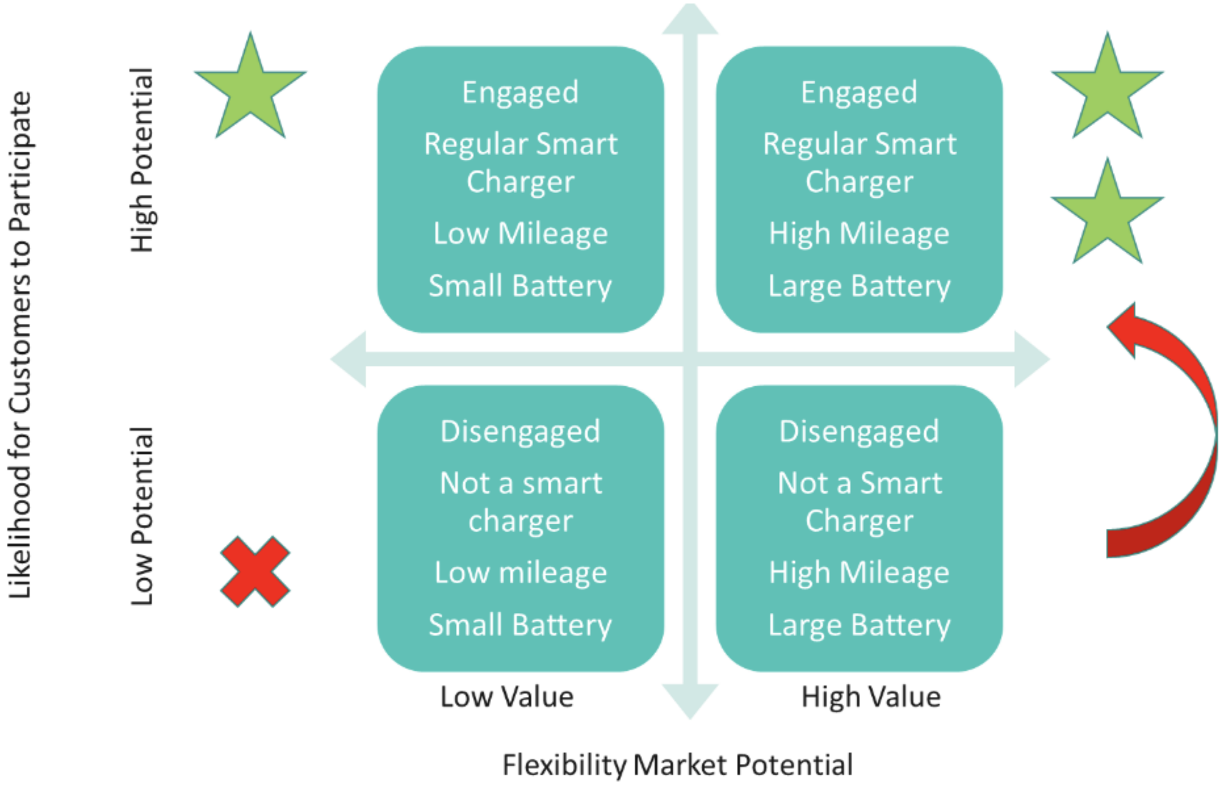

Figure 2-1: The initial segmentation model proposed a simple 2x2 matrix for segmenting customers across two dimensions: likelihood for customers to participate vs Flexibility Market Potential

2.2.2 Revising the analysis to align approaches across EV datasets between Ohme and Octopus Energy

To rerun the Ohme analysis across EV customers at Octopus, the data model needs to be aligned to run across attributes within both datasets. The following features that could be calculated for EV customers across both datasets include:

- Average kWh used per charging session, as well as charging session durations and idling times.
- The battery capacity (size) of the vehicle, in kWh.
- The maximum charging rate (kW) of the session, and proportion of the time they charged at the maximum rate.
- The proportion of time / energy from charging sessions split into the following 4 categories:
  - Overnight (00:00 - 06:00),
  - Morning (06:00 - 12:00),
  - Afternoon (12:00 - 18:00),
  - Evening (18:00 - 00:00).
- Number of weekly charging sessions (and proportion of which occurred in peak vs off-peak).
- Tariff type.

A full list of all 29 attributes is included in Appendix B.

However, it was harder to commonly measure attributes such as engagement in a consistent way. Ohme uses a charging app, from which statistics can be calculated to measure engagement, whereas Octopus uses a separate app for all customers, which includes a specific charging tab for Intelligent Octopus customers only. Customers on an Octopus EV tariff such as Go or Go faster can still use the general Octopus app, but do not have access to the Intelligent Octopus charging tab.

2.2.3 Generalising the analysis to the wider OE customer base

The data attributes in the previous section are mostly specific to EV customers, since attributes like plug in/out consistency, charging or idling duration and battery capacities only apply to customers with an EV. However, there are methodologies to simplify and generalise across the wider OE customer base to use a broadly consistent methodology.

First, we aligned terminology on time windows:

- Overnight - 00:00 - 06:00
- Morning - 06:00 - 12:00
- Afternoon - 12:00 - 18:00
- Evening - 18:00 - 00:00

Then, for each customer day over a period of Autumn 2022 for a random subsample of Octopus Energy customers, we calculated during each of these time windows:

- The 95th percentile of kWh usage
- The sum total kWh usage

This analysis focused on one season to avoid seasonal factors, which would be an important consideration when assessing a customer's flexibility provision during the trial (and one that the baselining methodology could accommodate providing it considers a reasonable amount of past history).

To get a single classification for each customer, we needed to aggregate over customer days which was done by looking at:

- The average of the 95th percentile of kWh usage - a proxy for "value".
  - If the 95th percentile is higher, it means the potentially shifted load is higher in that time window.

- The standard deviation of the sum total kWh usage - a proxy for “ability to shift”.
  - If the standard deviation (or variance) is higher, it means that in that time window customers have typically more variable demand, so may be able to load shift out of this time if properly incentivised to do so.

A customer was categorised as “high value” if their average 95th percentile kWh usage in a single half hour was greater than 1kWh, and a customer was categorised as “high potential” if they were above the median standard deviation. Their “value label” and “potential label” were joined together to get the distribution amongst customers shown in Figure 4-3.

The segmentation analysis was performed over a sample of 150,000 customers using data from Autumn 2022. In this sample we included data from customers who had filled out previous Octopus surveys which captured what low carbon technologies they owned. This sample was supplemented with randomly chosen but representative customers from the remaining OE smart meter customer base. Due to the nature of the methodology, it would have been harder to generalise this to non-smart meter customers, so this was excluded. For all customers in the sample, we added information about their currently active tariff.

While the methodology could be improved during CrowdFlex, this shows the potential to align methodologies across both the Ohme and Octopus customer base and get broadly consistent results. This specific segmentation could be a dimension for analysis in the trials in addition to other key dimensions of interest. In the Discussion section, we will discuss ways to extend this segmentation analysis during CrowdFlex, and make key recommendations for the trials design and modelling Work Packages.

3 Key findings from the Literature Review

3.1 The need for flexibility in the domestic sector

The electricity system in the UK has seen significant changes to provide greener and more affordable electricity. In the last 25 years, the grid has had an increase in renewable generation. Renewable firm capacity has increased from 2 GW in 1996 (3% share) to almost 50 GW at the end of 2021 (47% share).[1] Despite positive figures reporting 39.6% renewable generation in the UK in 2021, the UK still required record electricity imports to support its own generation: 24.6 TWh or 7.4% of the total electricity supplied. The hot weather registered in winter 2021 increased electricity demand but also lowered wind generation 3.5% points compared to that in 2020, generating the need for imports from Europe.[2] The numbers evidence the necessity for demand and supply to be flexible. This concept is known as demand side response (DSR).[3] More broadly, Ofgem defines flexibility as follows: “modifying generation and/or consumption patterns in reaction to an external signal such as a change in price, to provide a service within the energy system”.[4]

As more intermittent renewable generation comes into the system the electricity grid needs to become more responsive to possible changes in both demand and supply to avoid, to the extent possible, electricity curtailment from renewable sources.[5,6] This ensures we can maximise the benefits of renewables, which produce the cheapest electricity, and reduce carbon emissions by displacing gas and coal generation.[7]

Additional electrification of heat and transport make DSR a solution to a problem that has changed over time, and now more innovative solutions are needed. DSR is a “static tool”, which was conceived to move demand to periods where supply is higher or, on occasion, increase demand to avoid the need to curtail supply. However, peaks of demand and generation have evolved dramatically in the last few years. Changes in consumption patterns (e.g., increased electrification and home working) and more intermittent generation have modified the way demand behaves, creating a much more complicated scenario if we only provide flexibility through supply-side assets such as peak load power plants or by curtailing generation.[8]

Indeed, one of the Future Energy Scenarios from National Grid forecasts that 15TWh of electricity (roughly 5% of current annual demand) will be curtailed by 2030.[9] Additionally, the Climate Change Committee forecasts that electricity demand will nearly double by 2050 due to electrification of heat, transport and hydrogen generation.[10] Traditionally, generation has been controlled to “match” demand, but with increasing renewable penetration and increasing electricity demand, smarter and more sensible ways need to be considered to avoid electricity curtailment. ‘Intelligent Demand’ involves embedding the concept of domestic demand flexibility into the energy market, that is, moving demand to periods when there is plenty of cheap, renewable electricity generation.[11] Assets like electric vehicles (EVs), heat pumps (HPs) and potentially other home appliances will need to adjust their demand profiles to provide more flexibility from the demand side.

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[1] “UK Energy in Brief 2022”, GOV.UK. https://www.gov.uk/government/statistics/uk-energy-in-brief-2022, (accessed Aug. 31, 2022)

[2] “Digest of UK Energy Statistics Annual data for UK, 2021”, GOV.UK. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1094629/DUKES_2022.pdf (accessed Aug. 31, 2022)

[3] “Moving from ‘Demand Side Response’ to Intelligent Demand’”. Octopus Energy. https://octopus.energy/blog/intelligent-demand/ (accessed Sep. 1, 2022)

[4] “Ofgem position paper on Distribution System Operation: our approach and regulatory priorities”, Ofgem. https://www.ofgem.gov.uk/publications/ofgem-position-paper-distribution-system-operation-our-approach-and-regulatory-priorities (accessed Aug. 31, 2022)

[5] L. V. Villamor, V. Avagyan, and H. Chalmers, ‘Opportunities for reducing curtailment of wind energy in the future electricity systems: Insights from modelling analysis of Great Britain’, Energy, vol. 195, p. 116777, Mar. 2020, doi: 10.1016/j.energy.2019.116777.

[6] A. Fragaki, T. Markvart, and G. Laskos, ‘All UK electricity supplied by wind and photovoltaics – The 30–30 rule’, Energy, vol. 169, pp. 228–237, Feb. 2019, doi: 10.1016/j.energy.2018.11.151.

[7] F. Teng, M. Aunedi, and G. Strbac, ‘Benefits of flexibility from smart electrified transportation and heating in the future UK electricity system’, Applied Energy, vol. 167, pp. 420–431, Apr. 2016, doi: 10.1016/j.apenergy.2015.10.028.

[8] “Moving from ‘Demand Side Response’ to Intelligent Demand’”. Octopus Energy. https://octopus.energy/blog/intelligent-demand/ (accessed Sep. 1, 2022)

[9] “Future Energy Scenarios 2022 Report”. National Grid ESO. https://www.nationalgrideso.com/document/263951/download (accessed Sep. 1, 2022)

[10] “Net Zero. The UK’s Contribution to Stopping Global Warming” Climate Change Committee. https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf (accessed Sep. 1, 2022)

[11] “Moving from ‘Demand Side Response’ to Intelligent Demand’”. Octopus Energy. https://octopus.energy/blog/intelligent-demand/ (accessed Sep. 1, 2022)

By harnessing flexibility in all parts of the power system, both generation and demand, the UK can more cost-effectively transform its energy system towards a cleaner one dominated by renewable sources. In fact, the introduction of flexibility to fully utilise renewable generation could potentially save as much as £17-40 billion cumulative to 2050 compared to a business as usual (BaU) scenario, where flexibility is not considered.[12]

3.2 Potential of flexibility in residential households

The current socio-economic situation, with rising gas prices and a political ambition to push for a decarbonised energy system, is accelerating the need to unlock demand-side flexibility. Different methods for influencing patterns of electricity consumption have been employed for several decades - e.g., the introduction of the UK Economy 7 tariff in 1987.[13,14,15]

It has been shown that these methods can be helpful at shifting some demand to fixed times, but it no longer suits the constantly changing demands of a future energy system, depending on household characteristics. When looking at the best options to unlock system flexibility from the demand side, for example using new technologies such as smart appliances (e.g., thermostats, charge points, and other Internet-of-Things enabled devices), we must consider consumer needs and ensure everyone can benefit from this system. CrowdFlex seeks to investigate novel services that can exploit domestic flexibility using existing technologies, remove regulation barriers and understand how to best incentivise and reward domestic assets that provide this flexibility.[16]

Domestic electricity consumption represented almost one third of the total electricity demand in the UK in 2021.[17] With increased penetration of electric vehicles and electric home heating, such as heat pumps, electricity demand is expected to increase, potentially adding more stress on the grid in terms of peak demand and unpredictability (if not controlled smartly).[18] Residential DSR and intelligent demand shifting will be essential for the future of Britain's electricity system, with previous studies showing a potential reduction of 23% of demand during the evening peak for EV-owning customers participating in demand-side flexibility schemes.[19]

In principle, the amount of demand response that can theoretically be provided depends on the size of the load available and how long this can be influenced, and therefore depends on the controllable household assets.[20] As well as the Low Carbon Technologies (LCTs) - such as electric vehicles (EVs), heat pumps (HPs) and Solar PV - that a household has, there are other factors to consider that affect the amount of flexibility provision:

- LCTs, such as EVs, HPs or solar PV micro generation, are likely to be concentrated geographically around more affluent areas.[21] Therefore, how can people who don't own these LCTs provide flexibility?

[12] "An analysis of electricity system flexibility for Great Britain", GOV.UK. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/568982/An_analysis_of_electricity_flexibility_for_Great_Britain.pdf (accessed Aug. 31, 2022)

[13] J. Crawley, C. Johnson, P. Calver, and M. Fell, 'Demand response beyond the numbers: A critical reappraisal of flexibility in two United Kingdom field trials', Energy Research & Social Science, vol. 75, p. 102032, May 2021, doi: 10.1016/j.erss.2021.102032.

[14] The Electricity Council, "Electricity Supply in the UK: A chronology". Fourth edition, London, UK, 1987

[15] W. L. Kidd, 'Development, design and use of ripple control', Proceedings of the Institution of Electrical Engineers, vol. 122, no. 10R, pp. 993–1008, Oct. 1975, doi: 10.1049/piee.1975.0260.

[16] "CrowdFlex Discovery Phase". National Grid ESO. https://www.nationalgrideso.com/future-energy/virtual-energy-system/crowdflex (accessed Aug. 31, 2022)

[17] "Digest of UK Energy Statistics Annual data for UK, 2021", GOV.UK. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1094629/DUKES_2022.pdf (accessed Aug. 31, 2022)

[18] J. Torriti, 'Household electricity demand, the intrinsic flexibility index and UK wholesale electricity market prices', Environ Econ Policy Stud, vol. 24, no. 1, pp. 7–27, Jan. 2022, doi: 10.1007/s10018-020-00296-1. Note: in the UK, residential consumption is responsible of 60% of the peak demand.

[19] "CrowdFlex - Phase 1 Report". National Grid ESO. https://www.nationalgrideso.com/document/230236/download (accessed Aug. 31, 2022)

[20] J. Crawley, C. Johnson, P. Calver, and M. Fell, 'Demand response beyond the numbers: A critical reappraisal of flexibility in two United Kingdom field trials', Energy Research & Social Science, vol. 75, p. 102032, May 2021, doi: 10.1016/j.erss.2021.102032.

[21] E. McKenna, I. Richardson, and M. Thomson, 'Smart meter data: Balancing consumer privacy concerns with legitimate applications', Energy Policy, vol. 41, pp. 807–814, Feb. 2012, doi: 10.1016/j.enpol.2011.11.049.

How will the grid manage the local constraints in the distribution network due to this load concentration? How can we incentivise other customers without access to these LCTs to also provide flexibility?[22]

- The level of flexibility will depend on consumer attributes as well as the technologies they own. Household routine and their ability and willingness to effectively participate in a response event will have an effect on the technically possible provision of flexibility. A wide variety of socio-economic factors including social practices, working patterns, household composition and occupation, culture, religion and/ or wealth have an impact on how much flexibility households can provide.
- Although implicit in the above, it is important to emphasise the range of temporal factors that affect flexibility provision: time of day, day of the week and month of the year (season). For example, customers with solar panels may be more flexible in the summer, as they are able to store more energy during the day and import at different times according to signals. Conversely, in the winter, customers might have strict times when they would like to heat their homes and therefore will be more inflexible.[23,24,25]

The above mentioned factors have been investigated in different trials and studies over the past decades. In the Appendix, a review of the literature regarding field trials deployed in the UK will be presented. Usually, these trials focus on the impacts of different DSR design choices, such as the introduction of time of use tariffs (ToUs), smart charging or vehicle-to-X charging with EVs, and smart heating with HPs. Highly technical trials whose ambition is to assess economic incentives and explore technical feasibility to provide flexibility often put less emphasis on social dynamics and domestic practices across households.[26] These socio-economic factors and their importance in flexibility provision will also be outlined and described in the following sections.

3.3 Low carbon technologies and automation

The goal of the CrowdFlex project is to advance our understanding of domestic demand as an emerging source of flexibility which will further benefit both the energy system and electricity consumers. In this context, CrowdFlex NIA, revealed that ToU tariffs can reduce peak electricity demand between 15-17%, maintaining that reduction over 6 months in the 25,000 households studied. Moreover, EV consumers have a greater potential to flex their demand, reducing their peak demand consumption by 23%.[27]

In addition to this work, Octopus Energy, Scottish Power Energy Networks and National Grid ESO investigated the response of households to one-off signals during 8 different turn-down events and 6 turn-up events in the Domestic Reserve Scarcity Trials, also known as the Big Dirty Turn Down and the Windy Day Fund respectively. These trials, which involved more than 105,000 customers, the largest number of customers involved in a single event to date, found that as much as 1.9 GW of domestic flexibility are readily available in the UK. EV owners with an automated response to the event were the customers who could provide the highest levels of flexibility.[28,29,30]

This is largely consistent with supporting literature that argues that direct load control (switching appliances off and on, or turning heating/cooling up/down) and indirect methods (use of price or other signals to motivate the

[22] É. Mata, J. Ottosson, and J. Nilsson, 'A review of flexibility of residential electricity demand as climate solution in four EU countries', Environ. Res. Lett., vol. 15, no. 7, p. 073001, Jul. 2020, doi: 10.1088/1748-9326/ab7950.

[23] P. Fitzpatrick, F. D'Ettorre, M. De Rosa, M. Yadack, U. Eicker, and D. P. Finn, 'Influence of electricity prices on energy flexibility of integrated hybrid heat pump and thermal storage systems in a residential building', Energy and Buildings, vol. 223, p. 110142, Sep. 2020, doi: 10.1016/j.enbuild.2020.110142.

[24] P. K. Wesseh and B. Lin, 'A time-of-use pricing model of the electricity market considering system flexibility', Energy Reports, vol. 8, pp. 1457–1470, Nov. 2022, doi: 10.1016/j.egyr.2021.12.027.

[25] I. Koncar and I. S. Bayram, 'A Probabilistic Methodology to Quantify the Impacts of Cold Weather on Electric Vehicle Demand: A Case Study in the U.K.', IEEE Access, vol. 9, pp. 88205–88216, 2021, doi: 10.1109/ACCESS.2021.3090534.

[26] S. Bell, E. Judson, H. Bulkeley, G. Powells, K. A. Capova, and D. Lynch, 'Sociality and electricity in the United Kingdom: The influence of household dynamics on everyday consumption', Energy Research & Social Science, vol. 9, pp. 98–106, Sep. 2015, doi: 10.1016/j.erss.2015.08.027.

[27] "CrowdFlex - Phase 1 Report". National Grid ESO. https://www.nationalgrideso.com/document/230236/download (accessed Aug. 31, 2022)

[28] "The Big Dirty Reveal", Octopus Energy. https://octopus.energy/blog/the-big-dirty-reveal/ (accessed Sep. 1, 2022)

[29] "Octopus-National Grid ESO Domestic Scarcity Reserve Trial Results", Octopus Energy. https://octoenergy-production-media.s3.amazonaws.com/documents/OE-NGESO_Domestic_Scarcity_Reserve_Trial_Results_vSEND_v2.pdf (accessed Sep. 1, 2022)

[30] "Powering up: Scottish customers use energy to help the grid AND cut bills in UK-first trial", Octopus Energy. https://octopus.energy/press/powering-up-scottish-customers-use-energy-to-help-the-grid-and-cut-bills-in-uk-first-trial/ (accessed Sep. 1, 2022)

adjustment of electricity consumption) which use automation technologies result in larger responses compared to events where manual responses to signals are needed.[31,32,33,34]

Adding to the existing literature, Centre for Net Zero (CNZ) is currently conducting a complementary analysis about characteristics that have influenced the flexibility provided during the aforementioned Domestic Reserve Scarcity (DRS) trial. Although this work is yet to be published, internal conversations with the CNZ team about preliminary results have confirmed the main insights noted in the paragraphs above:[35]

- Consumers who own an EV provide the most flexibility during night-time events. Despite only accounting for 15% of the customer base, they provide 50% of the total electricity reduction during overnight events.
- The average demand reduction of EV owning households is much higher than non-EV owning households overnight. It is likely that this occurs as EVs are likely to be plugged in overnight but not during the day as incentivised by their tariff.
- Non-EV owning households make the highest median reduction during grid peak, similar to EV-owning households at that time. Given appropriate incentives to opt-in, there may be significant potential for demand shifting from households who do not own EVs or other LCTs.
- Low demand consumers were less successful at reducing their demand compared to their target.
- The median demand reduction of EV owners on the Intelligent Octopus tariff was twice as high as EV owners on Octopus Go (Figure 3-1) suggesting that managed or automated can increase turn down capacity.
- Within the non-EV customers, a higher proportion of customers on a dynamic ToUT (Octopus Agile) were successful at reducing their demand sufficiently compared to those on standard tariffs (Figure 3-2).

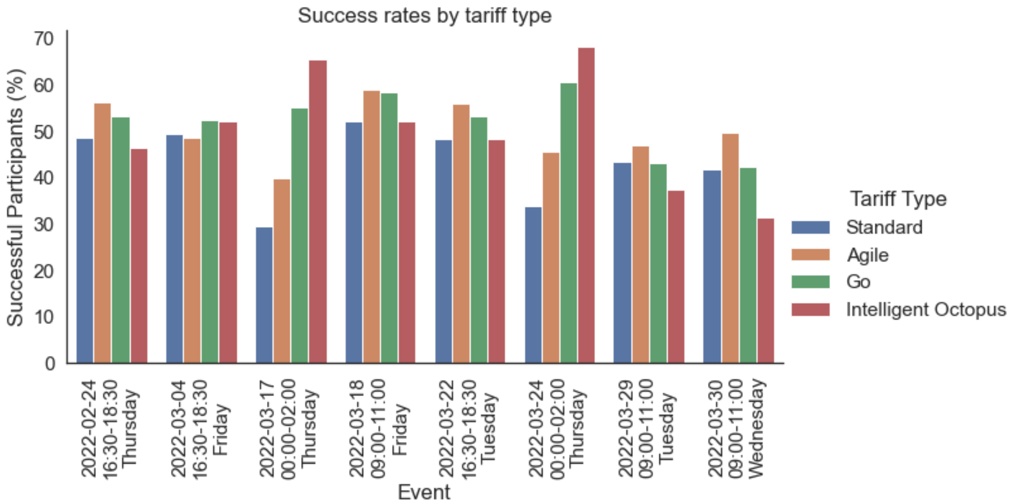

Figure 3-1: Median demand reduction of all participants by event window and tariff type. Demand reduction is relative to predicted demand ("four-week average").

[31] A. N. M. M. Haque, M. Nijhuis, G. Ye, P. H. Nguyen, F. W. Bliek, and J. G. Slootweg, 'Integrating Direct and Indirect Load Control for Congestion Management in LV Networks', IEEE Transactions on Smart Grid, vol. 10, no. 1, pp. 741–751, Jan. 2019, doi: 10.1109/TSG.2017.2751743.

[32] "Demand Side Response in the Domestic Sector - A Literature review of Major Trials", Frontier Economics and sustainability First. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/48552/5756-demand-side-response-in-the-domestic-sector-a-lit.pdf (accessed Sep. 1, 2022)

[33] "Customer Acceptance, Retention, and Response to Time-Based Rates from the Consumer Behavior Studies", U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/12/f34/CBS_Final_Program_Impact_Report_Draft_20161101_0.pdf (accessed Sep. 1, 2022)

[34] J. Stromback, C. Dromacque and M. H. Yassin. "The potential of smart meter enabled programs to increase energy and systems efficiency: a mass pilot comparison Short name: Empower Demand." Vaasa ETT (2011). Online: https://www.cse.org.uk/pdf/vaasa_ett_2011_potential_of_smart%20meter_enabled_programs_etc.pdf

[35] "Domestic Reserve Scarcity Trial. Final Report" National Grid ESO. [Unpublished report]. Centre for Net Zero, Octopus Energy and National Grid ESO. 2022

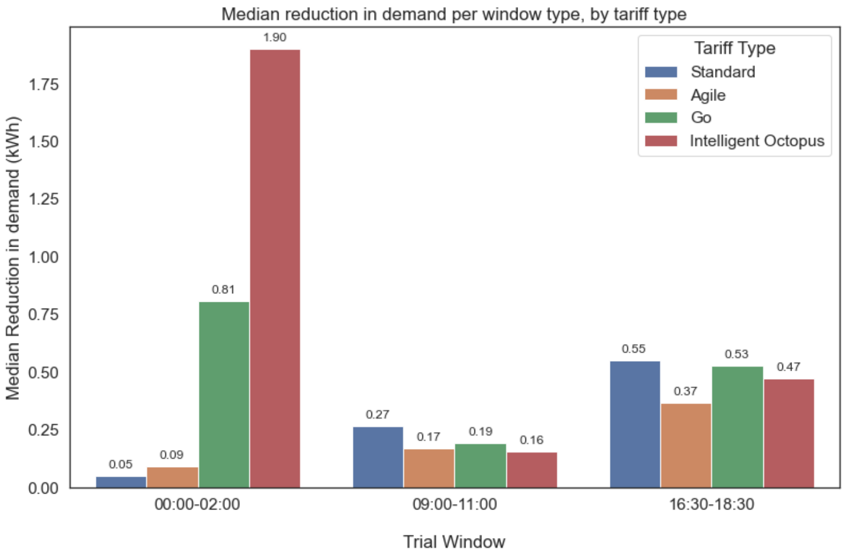

Figure 3-2: Shows the proportion of successful participants by tariff type. Success is defined relative to the predicted demand ("four-week average"). Preliminary results provided internally by the CNZ team.[36]

Previous studies have been undertaken to understand and demonstrate how EV smart charging can not only reduce the costs to the end consumers but also provide a level of flexibility to the market. Studies such as Project Shift[37] demonstrated that, by introducing mechanisms to incentivise flexibility, EV aggregators were able to show the difference between "unmanaged charging" and "smart charging" in three different market structures and provide a load reduction service during peak times.

Early use of home EV charging was predominately "unmanaged", whereby as soon as a user plugged in their car, it proceeded to charge the vehicle until the required state of charge (SoC) was achieved. In practicality this meant most users were plugging in when they got home during peak hours, which in turn increased the overall peak demand.

As shown in the CrowdFlex NIA project,[38] users typically plugin for 11 – 12 hours and only actively charge for 3.5 – 4 hours, meaning demand can easily be shifted to times that are cheaper for the users and better for the system. Other studies such as Project Shift[2] showed that, on average, EVs are only actively charging 19% of the time they are connected. Smart charging enables drivers, charge point operators (CPO's), and energy suppliers to take advantage of this to schedule charging at times that are cheaper and less carbon intensive. This capability in recent years was achieved via timers in chargers and cars to match on and off-peak energy tariffs.

CrowdFlex aims to add-to and scale up the previous attempts to provide domestic flexibility. Nonetheless, given the variety of technologies and trials employed, there is a large range of outcomes across different geographies within the UK. In Appendix A, we present some findings from some of the most impactful and relevant domestic demand response or flexibility trials all over the country. This summary is far from exhaustive, with some brief comments on qualitative aspects of the trials, but helps to understand the wide variety of solutions that have been proposed over the last decade and the effects - whether positive or negative - that different load controls and indirect methods have shown.

3.4 Socio-economic consumer attributes

In order for customers to be willing and able to adapt and provide flexibility, we must consider the effect of their household routines on their energy consumption.[39] In fact, a study held in the UK concluded that the

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[36] "Domestic Reserve Scarcity Trial. Final Report" National Grid ESO. [Unpublished report]. Centre for Net Zero, Octopus Energy and National Grid ESO. 2022

[37] Project Shift; https://innovation.ukpowernetworks.co.uk/wp-content/uploads/2022/06/UKPN_Project-Shift_2022_Web-PDF-v2.pdf

[38] CrowdFlex NIA; https://smarter.energynetworks.org/projects/nia2_ngeso001/

[39] K. Gram-Hanssen, 'Retrofitting owner-occupied housing: remember the people', Building Research & Information, vol. 42, no. 4, pp. 393–397, Jul. 2014, doi: 10.1080/09613218.2014.911572.

variation of electricity consumption can largely be attributed to occupant behaviours, accounting for more than 37% of the total energy consumption variation.[40]

As mentioned above, being flexible refers to the ability to shift the energy use in time (that is, to other times of day) or in space (e.g., to respond to different regional network constraints). As originally proposed by Powells and Bulkely, the ability to be flexible can be conceived as a form of capital.[41] Powells and Fell define flexibility capital as: “the capacity to responsively change patterns of interaction with a system to support the operation of that system”. Many degrees of diversity across and within different societies have been identified as determinants of flexibility capital, making it unevenly distributed. In their work, Powells and Fell suggest that the flexibility capital also presents some impacts via other major “dimensions of difference”, such as age, gender, levels of digital inclusion, and, what they consider to be the clearest interaction, affluence.

This interaction is subtle - it does not solely imply that the more affluent benefit from while others do not. On the contrary, some being able to provide energy services paves the way to the provision of service quality costs for those who in principle do not have that ability.[42,43] The authors argue that, ultimately, this can be framed as a justice issue and highlight some known examples where certain segments of the population are unable to shift demand to equal extents. Some examples in the literature delve into the impact of ToU tariffs in consumer bills on different socio-demographic groups.[44,45,46,47] CrowdFlex should note and consider the system cost benefit from a proportion of the total possible market of domestic households and quantify the cost savings for those who do not actively engage in flexibility, not just those who do.

Analysis being undertaken by the Centre for Net Zero on the Domestic Reserve Scarcity (DRS) trial has also indicated how much some consumer characteristics affect the amount of flexibility that households can provide:[48] Initial findings indicate that consumers in rural areas are more likely to succeed in the trial and provide more flexibility than consumers in urban areas. Whilst there is no direct evidence in the literature, there are two possible hypotheses for this. First, rural consumers may have higher energy consumption, and are therefore more likely to provide more flexibility. Second, rural consumer habits let them provide more flexibility due to their household behaviours.

This work also identified that consumers in less deprived areas have higher levels of opt-in to flexibility events. Twenty five percent of households that participated in the DSR trail are within postcodes with very low deprivation levels, compared to 10% from postcodes with high deprivation levels, as indicated by the Indices of Multiple Deprivation. Additionally, the median demand reduction was highest from households in the least deprived areas and the lowest from households in the most deprived areas.

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[40] Z. M. Gill, M. J. Tierney, I. M. Pegg, and N. Allan, ‘Low-energy dwellings: the contribution of behaviours to actual performance’, *Building Research & Information*, vol. 38, no. 5, pp. 491–508, Oct. 2010, doi: 10.1080/09613218.2010.505371

[41] D. G. Powells and H. Bulkeley, ‘Flexibility as Socio-Technical Capital (Briefing Note no. 10)’, DEI Briefing Note Series Durham University Energy Institute, Durham (2013)

[42] K. Vringer, ‘Analysis of the energy requirement for household consumption’, Sep. 22, 2005. https://dspace.library.uu.nl/handle/1874/7420 (accessed Sep. 02, 2022).

[43] G. Powells and M. J. Fell, ‘Flexibility capital and flexibility justice in smart energy systems’, Energy Research & Social Science, vol. 54, pp. 56–59, Aug. 2019, doi: 10.1016/j.erss.2019.03.015.

[44] “Distributional Impacts of Time of Use Tariffs”. Ofgem. https://www.ofgem.gov.uk/publications/distributional-impacts-time-use-tariffs (accessed Sep. 1, 2022)

[45] Hledik, Ryan, et al. "The value of TOU tariffs in Great Britain: Insights for decision-makers." Citiz. Advice Final Rep 1 (2017): 1-63.

[46] L. Nicholls and Y. Strengers, ‘Peak demand and the “family peak” period in Australia: Understanding practice (in)flexibility in households with children’, Energy Research & Social Science, vol. 9, pp. 116–124, Sep. 2015, doi: 10.1016/j.erss.2015.08.018.

[47] T. Yunusov, M. J. Lorincz, and J. Torriti, ‘Role of household activities in peak electricity demand and distributional effects of Time-of-Use tariffs’, presented at the British Institute of Energy Economics 2018, Oxford, UK, 2018. Accessed: Sep. 02, 2022. [Online]. Available: https://centaur.reading.ac.uk/79505/

[48] “Domestic Reserve Scarcity Trial. Final Report” National Grid ESO. [Unpublished report]. Centre for Net Zero, Octopus Energy and National Grid ESO. 2022

Socio-economic factors that have been covered in the existing literature in direct relation to the amount of energy consumption in households and are not strictly related to affluence are:

- Household size[49,50,51]
- Life-stage[52,53,54,55]
- Gender[56,57,58,59]
- Occupation[60,61]

3.4.1 Low income and vulnerable customers

Previous studies have already focused on the importance of the inclusion of low income and vulnerable (LIV) customers. CrowdFlex should prioritise a human-centred and innovative approach to deliver smart services and facilitate the provision of flexibility for LIV customers, not just the affluent who already own LCTs that can inherently provide this flexibility. In the context of this project, it is important to identify potential barriers that could prevent many customers from accessing and purchasing smart products that could potentially provide flexibility and provide incentives for these consumers to participate in the electricity market.

Relevant literature suggests that fairness will not just emerge as a result of the market operations to provide flexibility, but deliberate action and dedicated attention to this matter has to be given by policy makers and regulators to deliver smart energy offers which don't leave anyone behind and protect customers, particularly LIV customers.[62] Further studies point out that projects which have included LIV customers usually don't follow common standards to onboard these customers, but rather had multiple approaches, not based on previous experience. Additionally, obstacles for these customers to adopt smart technologies or provide different services have not been explicitly investigated, which won't provide any light on how to overcome these barriers in the future energy system.[63]

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[49]K. Gram-Hanssen, C. Kofod, and K. N. Petersen, 'Different Everyday Lives: Different Patterns of Electricity Use" Proceedings of the 2004. American Council for an Energy Efficient Economy, 2014..

[50] M. Hayn, A. Zander, W. Fichtner, S. Nickel, and V. Bertsch, 'The impact of electricity tariffs on residential demand side flexibility: results of bottom-up load profile modeling', Energy Syst, vol. 9, no. 3, pp. 759–792, Aug. 2018, doi: 10.1007/s12667-018-0278-8.

[51] M. Hayn, V. Bertsch, and W. Fichtner, 'Electricity load profiles in Europe: The importance of household segmentation', Energy Research & Social Science, vol. 3, pp. 30–45, Sep. 2014, doi: 10.1016/j.erss.2014.07.002.

[52] Y. G. Yohanis, J. D. Mondol, A. Wright, and B. Norton, 'Real-life energy use in the UK: How occupancy and dwelling characteristics affect domestic electricity use', Energy and Buildings, vol. 40, no. 6, pp. 1053–1059, Jan. 2008, doi: 10.1016/j.enbuild.2007.09.001.

[53] R. Hitchings and R. Day, 'How Older People Relate to the Private Winter Warmth Practices of Their Peers and Why We Should Be Interested', Environ Plan A, vol. 43, no. 10, pp. 2452–2467, Oct. 2011, doi: 10.1068/a44107.

[54] S. Sareen, 'Digitalisation and social inclusion in multi-scalar smart energy transitions', Energy Research & Social Science, vol. 81, p. 102251, Nov. 2021, doi: 10.1016/j.erss.2021.102251.

[55] I. F. Fjellså, M. Ryghaug, and T. M. Skjølsvold, 'Flexibility poverty: "locked-in" flexibility practices and electricity use among students', Energy Sources, Part B: Economics, Planning, and Policy, vol. 16, no. 11–12, pp. 1076–1093, Dec. 2021, doi: 10.1080/15567249.2021.1937403.

[56] L. Tjørring, C. L. Jensen, L. G. Hansen, and L. M. Andersen, 'Increasing the flexibility of electricity consumption in private households: Does gender matter?', Energy Policy, vol. 118, pp. 9–18, Jul. 2018, doi: 10.1016/j.enpol.2018.03.006.

[57] Torriti J, Hanna R, Anderson B, Yeboah G, Druckman A. "Peak residential electricity demand and social practices: Deriving flexibility and greenhouse gas intensities from time use and locational data". Indoor and Built Environment. 2015;24(7):891-912. doi:10.1177/1420326X15600776

[58] C. Johnson, 'Is demand side response a woman's work? Domestic labour and electricity shifting in low income homes in the United Kingdom', Energy Research & Social Science, vol. 68, p. 101558, Oct. 2020, doi: 10.1016/j.erss.2020.101558.

[59] P. Grünewald and M. Diakonova, 'Societal differences, activities, and performance: Examining the role of gender in electricity demand in the United Kingdom', Energy Research & Social Science, vol. 69, p. 101719, Nov. 2020, doi: 10.1016/j.erss.2020.101719.

[60] J. Palm, M. Eidenskog, and R. Luthander, 'Sufficiency, change, and flexibility: Critically examining the energy consumption profiles of solar PV prosumers in Sweden', Energy Research & Social Science, vol. 39, pp. 12–18, May 2018, doi: 10.1016/j.erss.2017.10.006.

[61] D. Ribó-Pérez, M. Heleno, and C. Álvarez-Bel, 'The flexibility gap: Socioeconomic and geographical factors driving residential flexibility', Energy Policy, vol. 153, p. 112282, Jun. 2021, doi: 10.1016/j.enpol.2021.112282.

[62] "Smart and Fair? Exploring social justice in the future energy system. Phase 1", Centre for Sustainable Energy. https://www.cse.org.uk/downloads/reports-and-publications/policy/energy-justice/smart-and-fair-phase-1-report-september-2020.pdf (accessed Sep. 30, 2022)

[63] "How can innovation deliver a smart energy system that works for low income and vulnerable consumers? Project InvoLVe", BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/994845/project-involve-smart-energy-system-low-income-vulnerable-consumers.pdf (accessed Sep. 30, 2022)

4 Key findings from the Segmentation analysis

4.1 Segmentation analysis in the literature

Maximising the possible flexibility benefits from domestic Energy Smart Appliances (ESA's) will require consumer understanding of the benefits of domestic flexibility services, agreement to allow flexibility service providers to access and use their data, and for EV drivers in particular, a change in behaviour to ensure their vehicles are plugged in, and capable of providing flexibility should the service provider require access.

As recognised in Clear and In Control[64], energy consumers' views on data sharing and smart devices, engagement from energy consumers will be vital in the transition to a low carbon and high-tech market. Indeed, with consumers without smart meters being less likely to trust their supplier and more likely to think that smart meters collect intrusive information, there is a recognised need to improve consumer understanding. This is an important consideration for the trial design, as c. 50% of UK households are still to have a smart meter installed[65].

Trust is also higher in some demographic groups than others with younger people being more likely to trust their supplier with their smart meter data. It was also found that people from lower socio-economic groups were less likely to be aware of choices around data. This is an important consideration for the Beta trial as, if we are to optimise the potential for domestic flexibility, we will need to engage with all consumer demographics, young and old, tech-savvy and vulnerable, and ensure that everyone has the opportunity to benefit from this emerging market.

Smartening up - How to improve people's confidence in smart home technology[66] also highlights the need to ensure that different approaches are used to engage consumers. For 11% of people, their biggest barrier was not knowing "whether these offers were right for them" or "finding the offers difficult to understand", with consumers who are digitally excluded being less able to access or understand deals and services that require an app or an internet connection, an important consideration as the Beta trial is designed.

Innovation in the tariff market discussion paper[67] reviews how the development of smart-enabled ToU pricing and bundled offers are developing in the UK market, with consumers finding the most appropriate tariff or bundle for their particular behaviour and circumstances a daunting task.

As the Beta trial is designed, the focus must therefore be on making the consumer experience "clear, accessible and smooth", recognising different motivations, understanding behaviours, and ensuring consumer trust is enhanced with the development of the domestic flexibility services being offered.

Project FRED[68], also clearly states that "devices cannot be used without consent and so consumer buy-in and support is critical to the success of any of these flexibility services" with a recognition that "propositions shaped around customers participating in DSR are yet to be seen outside of trial contexts, but they will more than likely include a financial incentive for offering flexibility". The design of incentives and rewards will be a key aspect in developing the Beta trial.

4.2 The purpose of the segmentation analysis

There are many attributes that affect a household's flexibility provision: both the magnitude of the potential flexibility that can be shifted, as well as their ability to shift during a certain time.

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[64] "Clear and in control: Energy consumers' views on data sharing and smart devices", Citizens Advice England. https://www.citizensadvice.org.uk/about-us/our-work/policy/policy-research-topics/energy-policy-research-and-consultation-responses/energy-policy-research/clear-and-in-control/ (accessed Oct. 21, 2022)

[65] "Smart Meter Statistics in Great Britain: Quarterly Report to end December 2021" GOV.UK. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1059591/Q4_2021_Smart_Meters_Statistics_Report.pdf (accessed Oct. 21, 2022)

[66] "Powering up or facing resistance? How people understand the benefits of smart appliances", Citizens Advice England. https://www.citizensadvice.org.uk/Global/CitizensAdvice/Energy/Energy%20Consultation%20responses/Citizens%20Advice%20-%20Powering%20up%20or%20facing%20resistance%20-%20latest.pdf (accessed Oct. 21, 2022)

[67] "Innovation in the tariff market discussion paper", Citizens Advice England. https://www.citizensadvice.org.uk/Global/CitizensAdvice/Energy/Innovation%20in%20the%20tariff%20market%20discussion%20paper%20(1)%20(1).pdf (accessed Oct. 21, 2022)

[68] "Project FRED", Evergreen Energy. https://cdn.evergreenenergy.co.uk/smart-power/fred-final-report-nov-21.pdf (accessed Oct. 21, 2022)

Segmentation is a way of analysing key metrics, such as trial opt-in rate or flexibility response (turn down, or turn up, in kWh) for a given flexibility event *filtering out on different attributes of interest*.

For a given trial event run over all customers we can split out the results over a given segment (e.g., location) and see how the results vary across this segment. Amongst trials run over a specific cohort, such as EV customers only, segmentation enables us to further split this cohort into “groups of interest”.

It is important to note the distinction between a “segment” and “an attribute that varies for each trial event”. CrowdFlex will run multiple large-scale trials, varying attributes between sessions including (but not limited to) the flexibility window length and start time, turn up vs turn down, consumer messaging and others. For each trial event, we will run it (where applicable) over all customer segments, but the results can be analysed segment-by-segment.

If we see a significant difference in a metric for a given segment, then that attribute is an important factor to include in the modelling that predicts the amount of flexibility provision a household will provide.

There are many different ways to segment a population. The methodology for the approach taken for this Work Package is outlined in Section 2. In this section we highlight the key findings and make recommendations in subsequent sections which can be fed into WP7 (trial design).

4.3 Recommended customer segments to trial

Splitting customers and potential customers into groups is a method that has been utilised by the business world for many years. Segmenting customers into groups enables businesses and studies to get insights into the drivers of certain patterns, enabling businesses to improve targeting of prospective customers, on boarding of new customers, and more effective management of existing customers. Previous studies whose primary focus was on EVs have utilised segmentation to understand how EV customers can be grouped into similar cohorts, what drives their charging behaviours and which customers can provide the potential for grid flexibility.

Project Sciurus[69] segmented participating customers into several archetypes, to analyse and gain insight into the features or value propositions that will appeal to different groupings. The customer archetypes were created by an earlier study by Cenex, which consisted of developing 34 customer archetypes. Each archetype had a profile that included the following variables: age range, employment status, income bracket, parking pattern, location, V2G availability, primary motivation, battery size and type of vehicle. In total, twenty-two key data points were used in the assessment of each archetype. Once survey responses were analysed, responses were matched to charge point data and compared. The results showed that some differences between archetypes can be found, such as mean availability.

Like other studies, plugin frequency was a crucial factor in the level of flexibility a participant can provide. However, as this study utilised V2G chargers, the annual mileage did not play as a significant factor when compared to smart charging (unidirectional) studies. For instance, the retired professional archetype had a high availability and low mileage, which in the V2G use case translates into a high flexibility potential; however, this is unlikely to be true for unidirectional charging (smart charging) as mileage impacts the frequency a driver plugs their vehicle in.

CrowdFlex:Discovery[70]-like Project Sciurus utilised segmentation. However, rather than access consumer data via surveys, it utilised charge point, energy tariff and vehicle data to segment customers into 4 clusters. This segmentation split participants into 4 mutually exclusive groups:

- Low value & low potential,
- Low value & high potential,
- High value & low potential, and
- High value & high potential.

Attributes that contributed to the segmentation included battery size, annual mileage, engagement level, and whether they utilised smart charging functionality. Utilising data from drivers input into a smart charging app and analysing their charging behaviour enabled the study to obtain a large dataset, improving the confidence

[69] “Project Sciurus Trial Insights: Findings from 300 Domestic V2G Units in 2020”, Cenex. https://dl.airtable.com/.attachments/76f2c9c3f517ed40036ae910b233d114/3adb8f80/Sciurus-Trial-Insights.pdf (accessed Oct. 21, 2022)
[70] “CrowdFlex Discovery” Energy Networks Association. https://smarter.energynetworks.org/projects/10027180/ (accessed Oct. 21, 2022)

of the results, and demonstrating that the level of flexibility available per group can be determined without requiring additional inputs from the end consumer. Although this method was effective it should be noted that, without gathering demographic and economic data from participants, it may not identify other attributes that may lead to increased levels of flexibility provision.

Consumer Structure in the Emerging Market for Electric Vehicles recognised several interesting segments; "Keen Greens" and "Early Innovators", who are consumers adopting EV's at scale but driven by very different motivations requiring different approaches to unlock their flexibility potential. This is clearly relevant for the Beta trial design as, in order to unlock the full potential, different approaches for different customer behaviours will be required. However, the segmentation approach utilised in the research, based upon customers attitudes, is not practicable for day-to-day use.

An earlier study; Who will adopt electric vehicles? A segmentation approach of UK consumers[71] also recognised 8 distinct EV segments, based upon variables such as identity, anxiety, and symbolic motivations rather than traditional demographic profiling. Traditional, socio-economic/demographic characteristics proved to be insufficient in separating the identified segments, with the analysis stressing the importance of less tangible issues such as attitudes concerning EV performance, personal image and enthusiasm for technology, attributes that are difficult to recognise in day-to-day customer interactions. Again, whilst interesting, and highlighting the importance of attitudes and motivations towards EV's and new technology, the segmentation approach had limited practical applications in real life.

A more recent study; I did my bit![72] The impact of electric vehicle adoption on compensatory beliefs and norms in Norway, recognised that that consumers who have performed a difficult pro-environmental action, such as buying a BEV or a PHEV, hold compensatory beliefs that can justify not doing other things for the environment, an important consideration when designing incentives to encourage EV drivers to participate in 'Flex' initiatives, but again has limited practical appeal.

Whilst many of these studies recognise different customer archetypes within the emerging EV market, it is clear that none published to date are practical or relevant for the proposed flexibility trials. It is therefore proposed that the trial continues to build upon the initial segmentation detailed within CrowdFlex:Discovery, identifying EV drivers that have the possibility to deliver flexibility potential, whilst also recognising the need to tailor the approach towards differing driver motivations and behaviours.

4.4 Results of the segmentation analysis

4.4.1 Ohme Customers

Using the segmentation methodology in Section 2, Figure 4-1 outlines the proportion of customers in each category that Ohme customers belong to. The dataset includes 12 months of charge sessions and app usage and related data from a set of 17,000 GB customers. By using the last 12 months of data, seasonal trends are averaged out to establish overarching yearly profiles baselines. Charging behaviour varies between seasons and initial analysis was part of the CrowdFlex Discovery Phase and can be further detailed by segment.

Given the nature of Ohme's smart charging platform in the current initial shift of the EV and EV-charging industry from early adoption to early majority, the dataset is skewed towards tech-savvy, highly engaged users that were probably part of the niche and early adopter EV market stages – in this analysis, customers are flagged early adopters if the first charge occurred before 2022.

The Highly Engaged segment is characterised by long charge session durations and high idle times, which in theory can increase the potential to flex demand for longer and diverse opportunity windows and satisfy the customer's battery requirements. Moreover, the customers in this cluster seem to be highly engaged with EV-specific tariffs such as Octopus Go, Intelligent Octopus, Octopus Agile, EDF Go Electric, OVO Drive Anytime and obviously recognise the financial and carbon savings when coupling these products to a smart charger – almost all of their charge sessions were on smart tariffs, they charge largely off-peak and consistently set "price caps" (price cap is a feature in the Ohme app to prevent the charger from importing power above a set limit – widely popular when Octopus Agile was cheaper in 2020 and early 2021). In addition, they display an

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[71] "Who will adopt electric vehicles? A segmentation approach of UK consumers", European Council for an Energy Efficent Economy. https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2011/4-transport-and-mobility-how-to-deliver-energy-efficiency160/who-will-adopt-electric-vehicles-a-segmentation-approach-of-uk-consumers/ (accessed Oct. 21, 2022)

[72] A. Nayum and J. Thøgersen, 'I did my bit! The impact of electric vehicle adoption on compensatory beliefs and norms in Norway', Energy Research & Social Science, vol. 89, p. 102541, Jul. 2022, doi: 10.1016/j.erss.2022.102541.

above average time of plug-in/out consistency suggesting that it's probable that their main car is an EV. It is hypothesised that this cohort will likely engage positively with flexibility opportunities as they are keen on saving money and not afraid to try new mechanisms given their experience with non-standard tariffs. It will be important and interesting to test their availability and reliability during demand turn up events, especially for those customers in key renewable constraint areas such as Scotland and North of England.

The other two bigger and, to an extent, similar clusters are the High Value, Low Engagement and Medium Value, Low Engagement. The shared behaviours in these clusters might represent the initial cohorts of early majority customers because of the less optimised and less "engaged" performance. The preference for "dumber" tariffs such as standard variable or fixed rate, more frequent peak-charging, low price cap activation rates, low plug-in/out consistencies and shorter (some intraday) charge sessions hint to a possible low understanding or knowledge of the EV-specific tariffs market and hands-off approach to EV charging. These clusters could include people owning an EV as a secondary car and/or people with flexible routines (work from home, vulnerable customers). The intrinsic value differentiator between these clusters is the size of the car battery, as it is directly proportional to the amount of energy that can be turned up or down within a charge session occurring in a flex event. The High Value cluster includes large sized batteries (>75 kWh) and the Medium Value includes medium sized batteries (20-75 kWh). The hands-off approach to EV charging and tariff optimisation mean that, during the trials, the customers will have to be approached in different ways to understand which strategies are more effective to increase engagement with the flexibility opportunities world. This could unlock a share of these clusters to be a reliable source of flexibility and understand what could work with the wider and larger markets in the coming years.

The smallest cluster represents the smaller share of customers owning a Plug-in Hybrid EV (PHEV). These customers have a very distinctive charging behaviour; they plug-in frequently to consistently top up their battery but still have a low weekly energy consumption compared to the other clusters and they tend to max charge the most (max charge is a feature selectable in the app to allow the customer to use the charger at full power on demand, overriding the smart charging schedules). The inherent value of these customers is little given the small size of the battery, even though they plug-in very frequently during the week, a desirable behaviour for reliable EV flexibility. Nevertheless, they could still provide some source of flexibility. For these customers, PHEVs might be a steppingstone to full BEV ownership, and it will be important to incentivise the same plug-in behaviour even if charging is not required. Engagement with smart EV-specific tariffs is average, as smart and dumb tariff usage is pretty even – therefore, "smart" and "dumb" customers within this cluster will have to be engaged separately with different messaging to test availability and reliability.

The segmentation highlights the potential to move the second largest segment - medium value, low engagement - as well as the third largest segment - high value, low engagement - to be more engaged in flexibility provision.

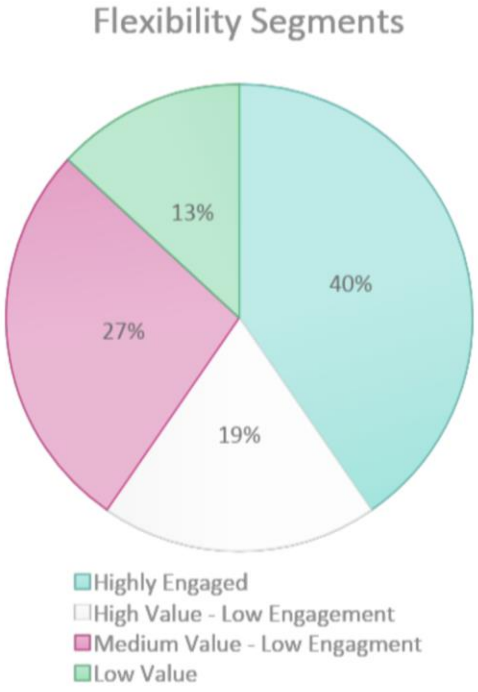

Figure 4-1: The outcome of the segmentation analysis based on the revised and aligned segmentation analysis over Ohme EV customers

High Value / Low Engagement – 19%	Highly Engaged – 40%
Highest weekly consumption	Longest charge session duration
Lowest plug-in consistency	Highest 'idle' time – therefore highest flex potential
Lowest early adopters	Highest evening and night plug-in, (after 6pm)
Low 'price cap' activation	Very consistent plug out behaviour
High 'dumb tariff' – Fixed price / SVT	Lowest 'Max Charge' – highest flex potential
High Index of peak charging – between 4pm and 10pm	Highest 'early adopters' < 2021
Highest mix of 'expensive car'	Highest 'price cap' activation
	Highest API integration – State of Charge accuracy
	High smart tariff selection
	High degree of 'off-peak' charging

Low Value Currently – 13%	Medium Value / Low Engagement – 27%
Small Battery - PHEV	Best Car Efficiency
Lowest weekly consumption	Highest active charging during session
Highest # of weekly sessions	Highest morning 'plug – in'
Highest mix of afternoon sessions	Most random 'plug – out' consistency
Very consistent charge, i.e. they top up when battery empty	Lowest 'early adopters'
Lowest API integration	Lowest 'price cap' activation
Highest Max Charge	Low API integration
	Lowest smart tariff adoption
	Highest peak charging
	Highest share of LIV customers

Figure 4-2:: The distribution of characteristics in each segment, across Ohme EV customers

In Ohme's analysis, the following additional dimensions were noted that would be beneficial to look at when seeking to apply this approach to a more general dataset such as those of Octopus Energy, including:

- Total household consumption and smart vs dumb meters (which Octopus collects for all customers, Ohme can collect total household consumption for a subset of customers, but difficulty with smart vs dumb).
- Other Energy Smart Appliance ownership (which Octopus collects for a sample of its customers through a survey, and could be collected using surveys at the start of CrowdFlex) namely:
  - Electric heating - storage heaters and heat pumps.
  - Solar PV / Battery.
  - Other "Smart Home Management systems" including smart thermostats.
- Demographic data to identify Low Income Vulnerable households and more affluent homes (which Octopus collects for all customers).

4.4.2 Octopus Customers

In extending the analysis to a sample of randomly selected Octopus customers, we found the following distribution of characteristics:

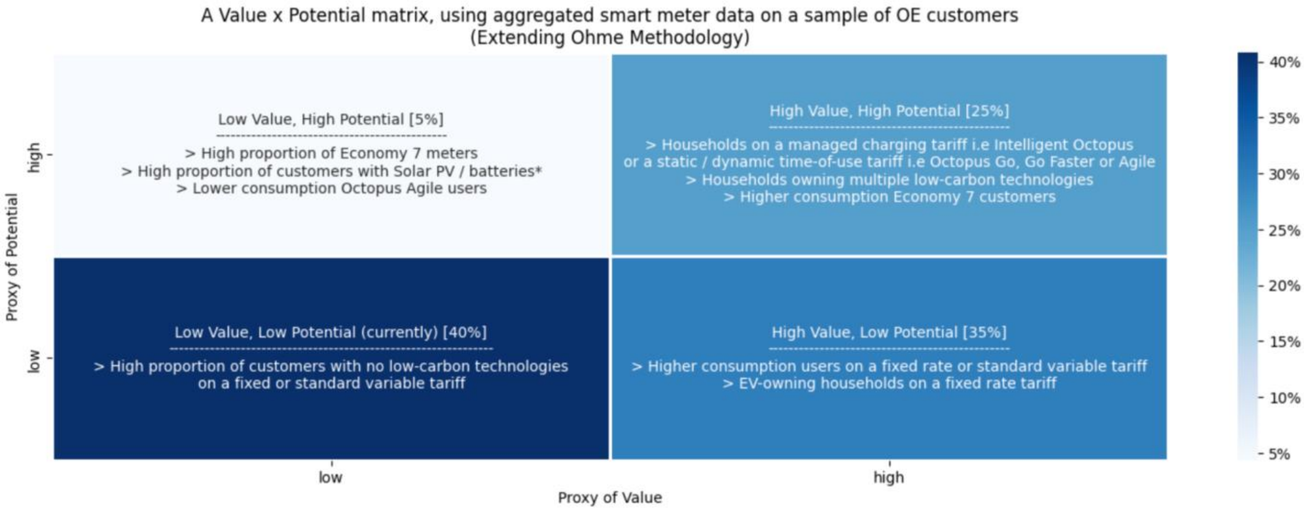

Figure 4-3: One way of extending the Ohme 2x2 segmentation matrix to all trial participants, which shows the percentage in each segment, and the defining characteristics of the different customer segments

The most prominent segment is Low Value, Low Potential (currently). Most of the customer base have no LCTs, and are typically on a fixed or standard variable tariff. Despite having lower peak loads, since these customers represent the largest segment, CrowdFlex trials that encourage them to shift to the Low Value, High Potential category would be beneficial in aggregate.

Customers in this category already are lower consumption Octopus Agile users, which shift their demand well outside of evening peak times, as well as a higher proportion of customers with Economy 7 meters, where demand is also incentivised to shift to the overnight window. We also find that customers with some low carbon technologies, such as Solar PV and batteries, already do a good job of smoothing out their peak consumption, so typically have low values of peak load but have high potential.

The customers that are of High Value, Low Potential are households with typically quite high consumption values that are on a fixed or standard variable rate tariff (which make up the majority of this segment), as well as any EV owning customers on a fixed rate tariff (a much smaller, but still important, proportion). In both cases, there is not much incentive to shift demand around and profiles are less variable.

Customers occupying the upper right quadrant include customers on time-of-use or managed EV tariffs, customers with multiple low carbon technologies (which include electric heating and hot water), and higher consumption economy 7 customers. In this category, we also find customers without EVs that have the most variable electricity profiles.

It is also worth noting that when following this methodology that:

- Households that own electric radiators / electric hot water can be placed in any of the four categories, there aren't any particular strong peaks on this technology ownership attribute alone, likely due to size of homes, number of radiators, etc., being a more apt predictor of the segmentation above.
- Heat pump owning households can be placed in any of the four categories, but typically a high potential one since these households are quite flexible with their consumption. Being placed into high value vs low value depends on the number of other electrical appliances they have in their home.
- Households off the gas grid, or that do not use much gas, are likely to be higher value for CrowdFlex, since using gas to heat hot water, cook and do space heating means their electricity consumption profiles are less peaked compared to households that rely more on electricity consumption.

The methodology is imperfect, which is worthwhile noting when considering the results. In particular, we consider that the method could be improved by:

- Devising better metrics of engagement other than tariff information alone:
  - The initial segmentation analysis undertaken by Ohme categorised engagement with the Ohme cohort as the behaviour associated with using all features of the Ohme app. But such metrics need to be consistent across datasets. This would enable more accurate categorisation into each of the

segments, and give a better proxy for "flexibility potential" or "readiness to engage in a trial". Thinking of ways to measure engagement in a consistent, scalable way will be crucial for CrowdFlex, and the discussion of potential metrics is deferred until future sections of the report.

- Using other demographic or property data:
  - Information such as property size (e.g., floor area) and other joined demographic data, such as using (elements of) the Index of Multiple Deprivation methodology, would be interesting dimensions to cluster and segment on, and see how these factors are distributed in each of the four quadrants. They may also warrant separate segmentation.
  - Information on low carbon technology ownership, or the Energy Smart Appliances (ESAs) that households own would be a useful addition to the property data for segmentation.
  - More granular information such as the number of, and/or capacity of, radiators and hot water would enable a more accurate clustering, but is a datapoint we are unlikely to have for all CrowdFlex trial participants. The disaggregation of capacities of specific devices is extremely difficult from 30-minute smart meter data alone. Sub half-hourly data may improve the disaggregation potential.
- Running the analysis over different seasons:
  - Extending the analysis to longer timeframes in a principled way would require additional thought and computational resource, due to the scale of the data, and was excluded due to time constraints. However, understanding how the variability and peak of customers changes seasonally will be crucial for CrowdFlex, and their segmentation may change seasonally throughout the trial.

In particular, we believe establishing sensible metrics of engagement and an agreed definition for Low Income Vulnerable households will better help us categorise, segment and cluster customers. For each of these, there are several tractable approaches, which we outline in the Discussion section.

5 Recommended improvements for trial modelling

Whilst the results of the analysis undertaken give us confidence in recommending hypotheses to test and segments to analyse, our experience with the analysis has led us to make specific recommendations to consider as part of the modelling work package (Work Package 8), that should similarly be considered in the trial design in Work Package 7.

5.1 Improving our modelling of key dimensions

The segmentation analysis enabled us to broadly align methodologies amongst EV customers, and generalise to non-EV Octopus customers, but highlighted two key areas that require more detailed definitions. In this section we propose potential ways to measure these key dimensions which will form part of our recommendations for the Trials Design Work Package.

5.1.1 Engagement

Ohme customers use the Ohme app, from which a variety of metrics can be used to determine "engagement". These include how often the app is used, what tariff set up they have in the app and how often they are changed. Some Octopus customers use the Octopus app, from which similar metrics can be derived. There are many ways to determine the "engagement" of a customer from these apps, but not all customers on CrowdFlex will use the app, or use it regularly. Therefore, a simple feature could be defined as "Has the {Ohme, Octopus} app, and uses it at least X times per month" to define engaged vs non-engaged customers.

For customers without the app, there are other ways to measure engagement for the opted-in trial participants at the start of CrowdFlex, including:

- Prior to having a smart meter, how many times were manual reads given to their electricity supplier?
- How many previous Octopus trials have they participated in?
- Asking in a start-of-trial survey how energy engaged the household would say they are (potentially using multiple questions to determine this).

Note that if we pursue an "opt-in" approach to trials, then customers will be self-selecting and potentially skew towards more engaged households. It should also be noted that the three approaches above have drawbacks in the sense that there would be missing data for some CrowdFlex trial participants. For example, customers may not fill in the start-of-trial survey.

Another, more promising CrowdFlex specific way of measuring engagement would be to create statistics of the previous number of events they have opted in to. The main drawback of this is that customer's engagement levels would not stabilise until after the first couple of events, but the main advantage is that it gives us a way to easily compare trial participants amongst each other (if they opt in more than the average CrowdFlex participant, or less).

5.1.2 Low Income Vulnerable Households

To look specifically at the response and opt-in rate of customers in CrowdFlex that are categorised as Low Income Vulnerable, a consistent definition should be used. There are many potential ways to define this based on datasets that exist to suppliers, including:

- Does the household qualify for the Warm Homes Discount?
- Does the Index of Multiple Deprivation (IMD) value of the LSOA / LAD that the household is located in fall into the bottom tertile, or quintile, of all IMD values?

Other methods include looking inversely at affluence, which would also have to be defined by proxy (for example, based on house size, or other household characteristics).

5.2 Additional segmentation dimensions

The "classification score" methodology that places a customer in one quadrant of a 2x2 matrix gives a useful metric to track over the course of each trial event, enabling us to see whether customers move into higher potential categories with repeated participation in the trials. But this classification score reflects a model of many underlying attributes about a household, some of which are beneficial to analyse separately.

From CrowdFlex:NIA, and other trials Octopus Energy has run, including Big Dirty Turn Down and Windy Day Fund, the aspects worth analysing specifically for each trial are the response rate and participation rate across the following segments:

- Location (e.g., Rural vs Urban, and Grid Supply Point region).
- Tariff Type (Fixed, Standard Variable, Time-of-Use tariffs, managed charging tariffs etc).
- Degree of automation, e.g., managed vs unmanaged response.
    - Note that all Ohme customers could respond to signals via automation, as could some non-Ohme Intelligent Octopus customers, but other trial participants would participate through manual schedule.
- Low carbon technology / Energy Smart Appliance ownership.

6 Recommended hypotheses to trial and segments to analyse

The Segmentation Analysis and Literature Review has identified several hypotheses that should be considered for testing as part of the trial design in Work Package 7 and to be considered as part of the work on Deliverable 2.2. These hypotheses are based on the conclusions or "next steps" of previous trials, as well as helping to fill the gap in the literature on key aspects of flexibility. These hypotheses are summarised in Table 6-1.

When considering the testing of these hypotheses, and their further refinement during Work Package 7 and as part of a Beta trial, several key elements need to be considered as elements to vary by event for each of the CrowdFlex trials:

- Incentive
  - Previous studies have shown that customers are willing to engage in flexibility in return for a reward, but the precise value of that reward is yet to be fully determined, and (according to the literature review) is likely to depend on multiple factors, including the time of day and season. The literature states that customers should be rewarded fairly for their participation. Customers may respond more to carbon signals than price signals alone, so there are some variations of incentive that should be trialled in CrowdFlex:
    - £0/kWh - no incentive or carbon only incentive is shown.
    - £unit-rate/kWh, £1/kWh, £2/kWh, … (or pricing via some other methodology consistent with the market they are participating in, or other similar markets).
- Messaging and Communications
  - The literature suggests messaging and communications is crucial for striking the right tone for LIV households specifically. A more detailed treatment of this is given in D2.2.
  - To ensure sustained engagement in trials, there is the potential to vary messaging and communications strategies to understand which combination of messaging maximises participation rates.
  - Customer communications should be simple and jargon free. This includes the messaging of the incentive above. Previous trials have included a "cliff" target percentage, only after which you are rewarded for your flexibility. Others have included "tiered" approaches to the incentive. While targets could still be provided for the customer, it is recommended that the messaging is as simple as possible for each event.
- Flexibility Window length and start time
  - Previous trials have focused on fixed window lengths, and have varied the start time in some instances (though typically focusing around the evening peak). As domestic flexibility becomes more mature, it will be important to understand flexibility provision at different times of the day, and for different durations. CrowdFlex can add to the literature by varying the window length and start time of flexibility events, across multiple seasons and years. This will be crucial in determining how much flexibility can be provided in different conditions.
- Flexibility type (turn up or turn down)
  - Previous trials have looked at both turn up and turn down. CrowdFlex:NIA was the first demonstration of potential in this, and subsequent studies by Octopus Energy looked at sustained turn-down and turn-up events. Varying this over an even longer period (across seasons) will broaden our understanding of domestic flexibility.

It is assumed that the baseline methodology may be iterated and improved slightly over the course of the trial, but it will be consistent for each event. Where possible, we should use the baselining methodology from other markets, but a more detailed treatment of this will be deferred to Work Package 8.

Based upon the analysis in this report on flexibility potential and flexibility value, several segments are worth analysing in detail. These are summarised in Table 6-2, and as such form our recommendation of segments to consider as part of the trial.

In this deliverable, we show one methodological extension of the segmentation work to broaden it to energy supplier datasets. While this component should be tracked in CrowdFlex, we consider that several attributes are worth analysing in isolation as part of the trial design, due to their importance in flexibility potential. These are important for the trial design in Work Package 7 insofar as additional surveys pre-trial may need to be sent out to collect additional information regarding these components. However, these attributes are not going to be varied as specific subgroups for each trial (in general, with the exception of some automated-only trials) but rather dimensions over which the response to each trial (flexibility provision, opt-in rates, etc.) will be analysed over.

These additional attributes for specific segmentation are:

- Tariff Type;
- Low carbon technology ownership, e.g. EVs and other Energy Smart Appliances (ESAs);
- Overall Household Consumption;
- Location, specifically urban and rural households and Grid Supply Point (GSP) region;
- Degree of automation;
- Household composition (including occupation, age, gender, life stage);
- Low Income / Vulnerable Households.

Much of this can be easily obtained from existing datasets, but some cannot. The recommended data source for each component is outlined in Table 6-2.

We would therefore recommend that Work Package 7 consider a pre-trial survey. This would be particularly important in ascertaining low carbon technology ownership (including electric heating and hot water, Solar PV, Battery, electric vehicles, and heat pumps), household composition, and general energy engagement and awareness. We do not think that the completion of this survey is a prerequisite for participation in the trial, since the literature shows this would likely lead to high levels of attrition. However, we can analyse the results of the subgroup of customers that did fill out the survey, and encourage more to fill out the survey at various points during the trial if needed.

Additionally, engaging with customers early through small-scale focus groups may be helpful to understand, pre-trial, how customers expect to engage in domestic flexibility, and provide some early learnings for CrowdFlex to iterate on.

It is also recommended that engagement (e.g., calculating percentage participation in previous flexibility events) be monitored consistently throughout the trial, as it will be a crucial attribute for understanding the flexibility provision in subsequent events. Monitoring this throughout CrowdFlex can also mean additional targeted emails can be sent to those that are less engaged, or surveys / focus groups could be undertaken to understand reasons why people don’t want to engage in domestic flexibility, and how the service can be improved.

Table 6-1: Recommended hypotheses to test, and attributes to vary or randomise per event. The specific details will be refined in Work Package 7.

Recommended hypothesis to test	Attribute	Potential options	Whether to randomise or vary	Notes relevant for trial design (WP7)
Flexibility response and opt-in rate differs when customers receive financial incentives. The flexibility response is larger if a greater financial incentive is given. Differences in response and opt-in rates, in turn, differ by customer group.	Incentive	Unit rate of payment-per-kWh offered: £0/kWh (customer shown no incentive or carbon based incentive), £1/kWh, £2/kWh, £3/kWh, …	Vary (by event) Could potentially randomise, but harder	Pricing would have to be fair amongst customers, and randomisation would be hard. One way to randomise would be a strategy where customers are randomly selected on one event to be offered “twice the normal rate” (or equivalent) and everyone gets randomly opted into this at least once, for example.
Framing flexibility in engaging ways and pro-social communication strategies increases customer response and opt-in rates.	Messaging and Comms	Messaging e.g emphasising financial incentive vs carbon savings? (Includes any other aspects including loss vs gain framing and gamification)	Randomise	There are many different types of messaging that can be trialled here, to be refined in WP7. Messaging should be simple in all cases and give a clear customer benefit for participation.
Customer response, and how response changes over the flexibility window, is different depending on the length of the flexibility window (likely diminishing returns over longer windows).	Flexibility Window Length	Length of window (e.g 1 hour, 2 hour, 3 hour)	Vary (by event)	The combination of flexibility window length, flexibility window start time and flexibility type should be taken together. A good mix of events should be run overall.
Response rate varies depending on the time of day.	Flexibility Window Start Time	Overnight, Morning, Afternoon, Evening	Vary (by event)	
Customers respond differently (on average) to turn-down events compared to turn-up events Different types of customers respond differently to turn-down vs turn-up.	Flexibility type	Turn down vs turn up	Vary (by event)	
Customers respond differently to “event-based” response services when compared to “ongoing” routine services.	Flexibility service	Response services and routine services (outlined in more detail in Appendix C)	Vary (by event) for response services	Note that for the intraday automation events, only EV owning customers. Specific consideration would be required for the joint running of routine and response services concurrently for a given household.
Frequency of events (gaps between events) affects opt-in rates. This relationship is non-linear.	Event frequency	Consecutive days, twice in a week on non-consecutive days, once a week, once a fortnight, …	Vary (by event) is easiest Randomisation harder but potentially useful	

Table 6-2: Recommended segments to use as analysis dimensions for each trial event, including the extended Ohme methodology as well as several key segments in isolation, raised as relevant during the literature review.

Segment	Data source	Suggested methodology or metric
Flexibility "Value"	Derived	Extend Ohme methodology to full supplier cohort, using techniques described in this deliverable
Flexibility "Potential"	Derived	Extend Ohme methodology to full supplier cohort, using techniques described in this deliverable
Engagement	Derived	[Preferred] Percentage of previous trial events opted-in to (relative to others on the trial) OR Simple definition based on X times using an app per month, if they have an app
Location	Supplier, joined to open datasets	Take the latitude/longitude position of each household (or postcode of the household) and join to: Grid Supply Point - GSP - Region Urban vs Rural, based on UK Government Rural Urban Classification of the LSOA / LAD
Degree of automation	Supplier + Ohme	Either {managed, manual} response, derived from whether or not they are an Ohme customer, or on a specific supplier tariff partaking in the automated events
Tariff Type	Supplier	Either {Standard (Fixed or Standard Variable Rate), Static Time of Use (Economy 7, Octopus Go, …), Dynamic Time of Use (Octopus Agile)
Low Income / Vulnerable Household	Supplier	Potential approaches include: Eligibility for the Warm Homes Discount [Preferred] Use the Index of Multiple Deprivation of the LSOA or LAD of the household, and check if it is in the bottom tertile or quintile of all IMD values. IMD values are released at a GB level.
Household composition (including occupation, age, gender, life stage)	Pretrial survey	Collect information on number of occupants and standardise composition types, using methodology similar to the Census
Low carbon technology ownership	Pretrial survey	Collect information on {Electric Vehicle, Heat Pump, Electric Heating, Electric Hot Water, Solar PV, Battery} and related characteristics. If missingness, assume unknown.

Appendices

Appendix A: Literature review of flexibility trials in the UK

Study+Date	Region	Sample size - Selection	Length of trial	Load	Automation	Effects on demand (if not specified reduction)	Comments
Big Dirty Turn Down (2022)	UK wide	105,320 - OE customers opt in	1 month	Anything	No	12.3 MW turn down per event on average. Total turn down of 197 MWh	The programme proved the ability of customers to respond to real grid signals day-ahead and reduce demand, supporting the grid during low de-rated margins, which typically occur when system demand is high and renewables output is low.
Windy Day Fund (2022)	Scotland, select postcodes only	2,500 OE customers, opt-in	6 weeks	Anything	No	Shifting 20MWh out of peak times, “turning up” in other windows outside of the peak	This programme was more localised to a specific area, but encouraged customers to respond to local grid signals to turn up to align with high expected wind generation, shifting their usage outside of traditional grid peaks.
SHIFT (2022)	Dumfries and Galloway (Scotland)	2,500 - OE customers opt in	6 weeks	Anything	No	1.68MW increase on average per demand event	Trial consisted in increasing demand in periods when generation is high
Project LEO (ongoing)	Oxfordshire (Britain)	Varies within trial	-	HPs, EVs, solar PV panels	Yes	-	Several projects are still ongoing. No definite results yet
Flexibility Beta Zappi (ongoing)	UK wide	Recruiting - zappi customers opt in	-	EVs	Yes	-	Smart charging for existing zappi customers to be trialled after recruitment
LEM (2020)	Cornwall (Britain)	100 households - Opt in	3 years	Batteries, solar panels	Yes	310 MWh in total	Batteries powered by solar panels aggregated to act as a domestic Virtual power plant

Sciurus (2021)	UK wide	325 households - Ovo customers opt in	3 years	EVs	Yes	750 MWh in total	Customers provided vehicle to grid services through kaluza's platform
Powerloop (ongoing)	UK wide	135 - OE Powerloop customers	1 year	EVs	Yes	-	Commercialisation of V2G through ancillary services participation
V2Street (2020)	North West (Britain)	-	2 years	EVs	Yes	-	Feasibility study of V2G on public charging networks with a local authority and a charge point provider. No report found
CLNR project (2013)	Northeast, Yorkshire and northern Lincolnshire (50%), rest UK wide	9000 - British Gas customers mostly, some recruited for additional analysis	2 years	EVs, solar panels, batteries, heat pumps, other appliances (ToUTs)	Yes (only some)	Varies with each technology introduced. Not specific values are given for each customers	The trial aimed to assess the effectiveness of different kinds of demand side intervention in encouraging those taking part to change the pattern of their electricity usage. It was found that only domestic charging of EVs could have a major impact on the network,
Low Carbon London (2014)	London (Britain)	16,000 across all trials	5 years	EVs, HPs, other appliances (ToUTs)	No	Not given	13 flexibility events which evidenced the impacts of EV and HP adoption
Electric Nation (Smart charging) (2019)	Britain and Wales	673 - Western Power Distribution customers	18 months	EVs	Yes	60%* (Given as shifting load to night periods)	EV tariffs (offered by an energy supplier) coupled with flexible smart charging has the ability to provide the lowest-cost solution for customers whilst ensuring a high level of customer satisfaction
Electric Nation (V2G) (ongoing)	Britain and Wales	100 - Western Power Distribution customers	1 year	EVs	Yes	-	Study the real-world effects of V2G charging and look to provide a smart solution to provide management
Smart Community Demonstration Project in Greater	Manchester (Britain)	433 - approached by the Arms-length management	2 years	HPs	Yes	50-320 kW	Pilot within the social housing sector across Greater Manchester to trial the implementation and use of Air

Manchester (2017)		organisation in Greater Manchester					Source Heat Pumps (ASHPs) at scale, testing the effectiveness of Demand Response in the social housing sector. The results were even higher than anticipated (200 kW of turndown) in some events
Energywise (2018)	London (Britain)	538 households - energy risk households in Tower Hamlets who opted in	4.5 years	Anything (ToUTs)	No	86 GWh (annual) 27 MW (peak)	Two trials to explore how residential customers who may be struggling with fuel bills can better manage their household energy usage
Core4Grid (2021)	East England (Britain)	24 households - UK Power Networks customers	2 years	Solar panels, EVs, batteries	Yes	£84-850 savings per household per annum (no reduction given in terms of energy or capacity)	Energy savings through Hybrid Home platform which minimises energy consumption through smart operations of solar PV, battery, EV charging and HP usage
FRED (2021)	UK wide	250 customers - zappi and eddi customers	2 years	EVs	Yes	Savings of £110 per annum per customer on average (no reduction given in terms of energy or capacity)	Real-world potential of Virtual Power Plant platforms to orchestrate domestic vehicle charging
USER (ongoing)	UK wide	350 households - opt in	5 years	Hot water tanks	Yes	-	Artificial Intelligence (AI) to optimise a virtual community of 350 homes across the country to transform traditional hot water cylinders into grid-interactive water heaters that are context aware

ESO

OpenDSR (ongoing)	Great Manchester (Britain)	100 households (60 carbon Co-op members, 40 social housing) - opt in	-	EVs, solar panels, water tanks	Yes	-	Test and demonstrate the potential for multiple household energy loads to be controlled remotely to reduce demand at particular times
Home Response (2021)	London (Britain)	160 households	2 years	Hot water tanks, solar PV, batteries	Yes	Varies with type of load controlled	

Appendix B: Ohme Segmentation Variables

A full list of segmentation variables for customers with an EV can be found below. This shows the 29 characteristics that were used to reduce onto 4 key dimensions. The values have been Red, Amber, Green (RAG)-statused to show low, medium and high proportions in each cohort, respectively.

Categories
Energy Consumption
Consumption behaviours over time
Primary motivators for changing behaviours
Access to technologies, including automation
Tariff information
Sub Clusters

	Values			
Row labels	Very Engaged	Large Less Eng	Medium Less Eng	Small
Average of Average kWh per Session				
Average of Average Weekly Consumption kWh				
Average of Average Car Efficiency Wh/km				
Average of Small Batteries				
Average of Medium Batteries				
Average of Large Batteries				
Average of Home Charging				
Average of Average Session Duration hours				
Average of Average Active Charging during Session %				
Average of Average Idle during Session %				
Average of Weekly Sessions				
Average of Night Plug-in %				
Average of Morning Plug-in %				
Average of Afternoon Plug-in %				
Average of Evening Plug-in %				
Average of Plug-in Consistency (1 very cons, -1 random)				
Average of Plug-out Consistency (1 very cons, -1 random)				
Average of Session duration Consistency (1 very cons, -1 random)				
Average of kWh consumed per session Consistency (1 very cons, -1 random)				
Average of Max Charge Sessions %				
Average of Early Adopters %				
Average of Inactive Users %				
Average of Session Price Cap Activation %				
Average of Average Weekly Offline Messages				
Average of Battery SoC provided cars				
Average of Session Smart Tariff selection %				
Average of Session Dumb Tariff selection %				
Average of Session Peak Charging % (charging between 16 and 22)				
Average of Session Off-peak Charging %				

Appendix C: Potential trial services and customer propositions

From conversations with National Grid ESO, and as a result of the other Work Packages, five types of flexibility service have been identified as potential trial services for CrowdFlex. In Table C-1 below, we outline the high level customer proposition for each of the trials, based on how the service is run and what the core customer message would need to be.

Table C-1: A table outline the types of service in scope for CrowdFlex, whether or not they are automated, the timescale for customers and the core proposition for customers to engage in the service.

Type of Service [Response, Routine]	Automated (Yes/No)	Timescale	Consumer Proposition
[Response] Provision of Reserve & entry of domestic assets into the Balancing Mechanism	Yes	Intraday	Allow **control of EV / ESA** for **x hours** and **receive £y availability payment** and **reduce CO2 footprint**
[Response] Introducing diversity in domestic appliance to Load Managed Areas switching	Yes	Intraday	Allow **control of EV / ESA** for **x hours** and **receive £y availability payment**
[Response] Provide demand turn up/down on either side of constraint	Yes + Manual	DA notification for x hours	**Increase / Reduce consumption during notified time period vs target (baseline)** and **receive £y / MWh utilisation payment** and **reduce CO2 footprint**
[Response] Evolution to the Demand Flexibility Service	Yes + Manual	DA notification for x hours	**Reduce consumption during notified time period vs target (baseline)** and **receive £y/MWh utilisation payment**
[Routine, daily] Reducing peak demand on both the HV & LV networks	Yes + Manual	Seasonal contract	**Consumption 'cap' at peak periods** to receive **£y availability payment**. Peak hours premium ppu for excess over daily 'cap'