CrowdFlex: Alpha

October 2022

D3.1 - Learnings for trial design

Strategic innovation Fund

ESO

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Contents

1 Objectives and approach

The objective of this literature review is to leverage learnings from prior domestic demand flexibility trials, experiments, and research work, focusing the scope of CrowdFlex and ensuring deliverability.

The methodology of the review was to create a list of known domestic flexibility trials, assess which have published results, and distil the key learnings from these projects with respect to trial design. Most trials reviewed are found on two lists[1] of BEIS funded domestic flexibility projects in the UK. Of the trials found, not all have fully published closedown reports, limiting the number of available trials for full review to 11 of 21. The projects review domestic flexibility using a range of technologies, including Electric Vehicles (EVs), heat (usually heat pumps with or without storage), storage batteries, solar PV, and white goods. The trials also test different incentive mechanisms for participation in domestic flexibility, as well as different flexibility pathways such as Time of Use (ToU) tariffs, smart charging, or manual response. Four of the trials reviewed involve thousands of participants; however, most count participants in the tens or hundreds (13 trials). This is detailed in Table 1 below.

Table 1: Reviewed projects. N/A in ESO/DSO column implies no ESO/DSO was a partner in project. N/A in final column implies no project closedown report on the trial available, so no full review possible.

Project Name	No. of participants	Main partners	DSO / ESO Partner	Final report date
Customer Led Network Revolution (CLNR)	ca. 13,000	NPG	DSO	2015
Low Carbon London (LCL)	16,300	UKPN	DSO	2015
Future Flex (Sustain-H)	310	WPD, Everoze	DSO	2022
Shift	>2,500	UKPN, Baringa	DSO	2021
Core4Grid	24	Everoze, Geo, UKPN	DSO	2019
Electric Nation	673	WPD, EA Technology, DriveElectric	DSO	2019
Domestic Scarcity Reserve Trial (DSRT)	105,320	Octopus Energy, NGESO	ESO	2022
Greater Manchester Smart Community Demonstration Project (GMSCD)	550	Greater Manchester Combined Authority (GMCA), NEDO, Electricity Northwest	DSO	2017
Flexibly-Responsive Energy Delivery (FRED)	250	Evergreen, Myenergi	N/A	2021
Consumers, Vehicles and Energy Integration Project (CVEI)	24	TRL, Baringa, Element Energy	N/A	2019
Home Response	65	UKPN, Moixa, Repowering London	DSO	2022
Demand response within community	N/A	Clean Energy Prospector	N/A	N/A
DSR for homes with air source heat pumps in Barnsley	N/A	Energise Barnsley, Centrica/BG, Northern Powergrid	DSO	N/A
Ubiquitous Storage Empowering Response (USER)	350	Levelise Ltd., Heatrae Sadia	N/A	N/A
OpenDSR	100	Carbon Co-op, Regen	N/A	N/A

[1] *BEIS Innovative Domestic Demand-Side Response Competition – Summary Project Details (Phase 1)*. BEIS, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/716273/BEIS_Innovative_Domestic_DSR_Competition_-_summary_project_details__1_.pdf.
BEIS Innovative Domestic Demand-Side Response Competition – Summary Projects Details (Phase 2). BEIS, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/783338/BEIS_innovative_domestic_demand-side_response-competition_phase_2.pdf.

Power of HOMEs	500	Votalis	N/A	N/A
Powerloop	135	Octopus, UKPN	DSO	N/A
Flatline	>46	Sero Energy, WPD	DSO	N/A
Flexible Energy Efficient Tanks	N/A	Mixergy	N/A	N/A
Whole House Energy Management for DSR (Powervault)	10	Octopus, Pixie Energy	N/A	N/A
Flexibility through communities	N/A	Energy Local CIC	N/A	N/A
Equinox	>1,000	NG Electricity Distribution, Octopus	DSO	N/A

2 Residential energy consumption

2.1 Baseline consumption and flexibility potential

The Household Electricity Survey (HES)[2] monitored a total of 250 owner-occupier households across England from 2010 to 2011, to identify the potential for energy efficiency savings and demand response. Slightly more recently, the Customer Led Network Revolution project (CLNR)[3]: confirmed that the patterns of consumption for monitored appliances tended broadly to match those from HES.

HES delineated between shiftable and non-shiftable demand and identified which might be best suited for demand response by including the annual energy consumed by the device (as a proxy for the flex value potential per device). HES recommended demand response prioritise cold appliances; however, more recent projects suggested hot appliances:

- CLNR identified laundry, washing dishes, and cooking as self-declared changes to demand responding to ToU Tariffs. Washing appliances were 12.3% of annual electricity demand (in houses where electricity was not the primary heating resource). However, the peak demand reduction observed in the ToU trial was described as “modest” (on average a drop of between 0.039 kW and 0.152 kW).
- This was supported by Low Carbon London (LCL)[4], which identified washing machines, dishwashers, and tumble dryers, as being the best technology for shifting demand from high rates onto low rates.

For shiftable baseline energy consumption, CrowdFlex should focus on hot appliances such as washing machines, dishwashers, and tumble dryers. However, CrowdFlex should also note the modest savings in demand that previous ToU tariff trials have found, and consider how this will impact the commercial viability of demand response from white goods; in particular compared to the flex response available per Low Carbon Technology (LCT) asset (see below).

2.2 Demand side drivers: grid impact of Low Carbon Technologies

The available literature agrees that the deployment of LCTs in the home – Electric Vehicles (EVs) and more so heat pumps, will have a transformational impact, significantly increasing the electricity demands in the home.

For heat pumps:

- Evidence from the HES survey (albeit on a small sample size) was that, on the coldest day in 2010, the 24 homes within the HES study that supplemented their gas or oil main heating system with electric heating used an average of 570 W for back-up heating during the peak hour, making up 84% of their electricity consumption at the time.
- CLNR found that the annual heat pump electricity consumption, averaged across all customers, was 82% of the average annual household consumption in the baseline monitoring group (i.e. Heat Pumps could nearly double the annual electricity demand of a typical house).
- With an outside temperature of -4ºC and a penetration level of 20% of household owning heat pumps, the peak daily load increased by 72% above baseline (LCL).

For EVs:

- Several sources identify that unmanaged EV charging demand can double peak demand per house (the after diversity maximum demand doubles (LCL[5])).

These sources show that the growth of unmanaged LCT will increase loads on the electricity system. Managed use of LCTs is required to avoid exacerbating evening peaks and reducing requirement for network upgrades.

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[2] *Household Electricity Survey*. Department of Energy & Climate Change, 2013, https://www.gov.uk/government/publications/household-electricity-survey--2.
[3] *Customer-Led Network Revolution Project Closedown Report*. Northern Powergrid, 2015, http://www.networkrevolution.co.uk/project-library/project-closedown-report-2/.
[4] *Opportunities for Smart Optimisation of New Heat and Transport Loads*. UK Power Networks, 2014, https://innovation.ukpowernetworks.co.uk/projects/low-carbon-london/.

[5] http://www.networkrevolution.co.uk/project-library/diversity-maximum-demand-admd-report/

The significant and adverse system impact of deployment of unmanaged LCTs in homes supports their consideration in the CrowdFlex project.

2.3 Supply side drivers: penetration of variable renewable resources

Challenges to the electricity system are also emerging on the supply side, with the deployment of Variable Renewable Energy Resources (VRES). Close to demand, photovoltaic panels can increase voltages on the Distribution Network making it challenging to manage these. On the transmission network, high VRES output is being managed by the ESO through constraint payments to (mainly) wind farm owners, constituting the largest grid management cost to ESO. Modifying demand on the appropriate side of a transmission network constraint could therefore generate significant revenues. Also, wholesale prices tend to be depressed during high VRES output, providing a source of savings to customers. Increased dispatch of variable renewable generation in combination with increased use of LCTs will require domestic assets to partake in flexibility services to allow for a transition to a low-carbon energy system.

One project which reviewed this supply side impact was LCL. It identified that 70% of high wind events[6] are below 3 hours in duration, while durations of between 3 and 20 hours occupy the next 20% of cases. This informed the design of the LCL Supply Following trials, most of which focused on shorter event durations, but did have one trial of 20 hours duration. LCL analysis showed that response to shorter duration events was greater than longer duration events, indicating that consumers make opportunistic use of low prices during the initial hours of an event. Note that the response to high prices was broadly identical across durations.

Responding to supply driven events could provide significant cost avoidance and revenue opportunities for customers, and should be explored in the CrowdFlex trial.

[6] *Residential Consumer Responsiveness to Time-Varying Pricing*. Imperial College London, 2014, https://innovation.ukpowernetworks.co.uk/wp-content/uploads/2019/05/LCL-Learning-Report-A3-Residential-consumer-responsiveness-to-time-varying-pricing.pdf.

3 Main objectives of prior projects

3.1 Stakeholders

The domestic flexibility projects reviewed often partnered with the DSOs or the ESO to complete the trial, but also to test specific system needs of the relevant partner. Of the 22 reviewed trials, 1 had a DSO as a partner, and only 1 identified the ESO as a main partner (Domestic Scarcity Reserve Trial[7], DSRT). Accordingly, the ESO/DSO services that these trials have reviewed as potential use cases for domestic flexibility have focussed on DSO services and their system needs. ESO system needs and services have generally been less reviewed, giving an opportunity for CrowdFlex to provide additionality with its Whole System approach.

Table 2: No. of system operator partners associated with reviewed projects

ESO / DSO partner	No.
DSO	12
ESO	1
N/A	9

3.2 Primary trial objectives

3.2.1 Flexible capacity (power and energy) of domestic assets

A main objective of all of the trials was to assess the capacity that domestic assets have to flex their power and energy demand, in order to understand the aggregate future impact that domestic flexibility can have on the power system. Generally, this was done by measuring a participant's ability to provide response in terms of power turn up/down (kW) or energy saved/used (kWh) against a baseline (defined below). This was completed over the service window of a DSR event, or continuously via ToU tariffs or smart charging, for example. Projects measured the effect of ToU tariffs on consumer's routine demand behaviour against those on a fixed tariff, the capacity of smart charging of EVs on consumers with or without ToU tariffs, and the flexibility of a range of consumers with different technologies in their homes. DSR events measured included both routine responses, for example smart charging based on signals from a ToU tariff as in the Consumer Vehicles and Energy Integration Project (CVEI)[8], or scheduled/dispatched events as in Sustain-H[9] trial or the DSRT.

All trials featured an element of peak-shifting as a main focus. With increasing penetration of unmanaged EVs and LCTs, the weekday evening peak will become a major problem for the electricity network. Shifting this peak throughout the night, and possibly to other days, is necessary to allow for a more efficient electricity system. If domestic customers participate in ToU tariffs linked to wholesale prices, electricity demand can pushed out of the evening peak. However, additional flexibility may also be required to meet other system needs.

Currently (2022) a price cap is protecting customers from exposure to all-time high wholesale power prices[10]. This means that ToU tariffs that track wholesale prices are likely to be ineffective, disincentivising flexibility. A key task for CrowdFlex will be to understand how ToU tariffs can be leveraged effectively in the current power market.

3.2.2 Baselining

To measure the response flexibility provides, whether capacity or energy provision, a baseline is required. Baselining involves creating a pre-flexibility demand forecast to be able to define how much flexibility was provided, either using historical customer data, control groups, or models of domestic demand. The trials adopted different approaches to baselining methodologies.

- The DSRT and the Flexibly-Responsive Energy Delivery trial (FRED)[11] used historical customer data during previous unmanaged periods to create baselines.

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[7] *Domestic Scarcity Reserve Trial Results*. Octopus Energy, 2022, https://octoenergy-production-media.s3.amazonaws.com/documents/OE-NGESO_Domestic_Scarcity_Reserve_Trial_Results_vSEND_v2.pdf.
[8] Skippon, Stephen, et al. Project Report: *Consumers, Vehicles and Energy Integration Project*. Transport Research Laboratory, 2019, https://www.trl.co.uk/publications/cvei---d8-1-final-project-summary-report.
[9] Rajavelu, Nithin. *Sustain-H Product Roadmap*. Everoze, 2021, https://www.nationalgrid.co.uk/downloads-view-reciteme/466258.
10 BEIS, Energy bills support factsheet, 2022, https://www.gov.uk/government/publications/energy-bills-support/energy-bills-support-factsheet-8-september-2022, Accessed Oct 2022.
[11] FRED Smart Charging Trial Findings. Evergreen Smart Power, 2021, https://cdn.evergreenenergy.co.uk/smart-power/fred-final-report-nov-21.pdf.

- CVEI used control groups to define their baseline by separating their consumers into three groups: 1) user managed charging, 2) supplier managed charging, and 3) control group (participants did not experience a managed charging scheme and were not incentivised to charge in any particular way.
- The Sustain-H trial used baselines pre-defined based on technology used for each contracting period and determined by the asset make-up and size of the participating portfolio. As such no ongoing baselining was required, although WPD periodically reviewed the baselines, derived from their distribution network models.

Overall, most trials did not have true control groups, choosing to use customer baselining as a control instead. However, this approach requires the use of historical data to create baselines, assuming customers will continue to behave in a similar way as they historically have done, irrespective of changing conditions such as weather or other events. Such baselining can be improved by accounting for such factors; however, this comes with a trade-off of statistical significance, as the number of events from which a baseline can be constructed decreases. A large-scale trial with both randomised control groups *and* historical customer baselining would allow CrowdFlex to inform confidence levels and capabilities for baselining domestic demand to energy suppliers, the ESO, and DSOs.

3.2.3 Meeting technical requirements of ESO/DSO services

A key objective of 4 of the trials was to establish the ability of domestic flexibility to participate in ESO/DSO services. The results of these trials are summarised in section 5.2. As demonstrated in Table 2, a significant portion of trials were partnered with DSOs, so their specific system needs were explored in these trials and usually considered the commercial framework of DSO flexibility services. This focused primarily on addressing constraint management of the high and low voltage (HV and LV respectively) networks, facilitating delayed network upgrades. Underlying this approach was the shifting of demand from peak times into the overnight period.

For trials that investigated meeting the technical requirements of ESO flexibility services, the approach was to trial whether domestic flexibility could be dispatched based on simulated flexibility events. The analysis conducted focused on assessing if response rates, ramp rates, and the length of delivery windows could be achieved. Those tested include NGESO Balancing Mechanism, Short Term Operating Reserve (STOR), and frequency response. The DSRT trialled domestic demand turn down that paved the way for the ESO's Demand Flexibility Service (DFS), rolled out for Winter 2022/23. A full list of the ESO/DSO services explored in trials can be found in

Table 3 below.

System operator	Flexibility Service	Trials that explored
ESO	Balancing Mechanism	Greater Manchester Smart Community Demonstration Project (GMSCD)
ESO	Reserve	Greater Manchester Smart Community Demonstration Project (GMSCD)
ESO	Frequency Response	FRED, Home Response
ESO	DFS	DSRT
DSO	Secure	Home Response
DSO	Sustain	FRED, Sustain-H, Home Response
DSO	Dynamic	FRED, Sustain-H, Home Response
DSO	Restore	FRED

Table 3: ESO/DSO services trialled and the respective trials that explored them.

4 Flex technologies included in trials

4.1 Summary of technologies trialled for flexibility

4.1.1 Electric vehicles

Of the projects that have published reports, EVs are the predominant technology being used to assess domestic flexibility. This is likely be due to the high capacity and potential for flexibility that EVs provide, as well as the early uptake of EVs compared to heat pumps in the UK. This early uptake allowed for easier trials as EV charging providers were frequently partners in smart-charging trials. Trials using EV charging providers as partners include Electric Nation[12], FRED, and CVEI. The only trial that specifically distinguished plug-in hybrid EVs from battery EVs (fully electric) is CVEI.

Table 4: Technology types in reviewed trials

Technology	No.
EV	10
Home battery	6
Heat	11
White goods	3
Open	3

4.1.2 Home batteries

Several trials included home batteries in the scope of technologies used for domestic flexibility. Generally, the use of home batteries has been less prevalent in trials, probably due to the lower penetration of home batteries in the UK due to high upfront costs. Home batteries are often seen in combination with solar PV, which makes the battery significantly more commercially viable. Trials that include batteries are the Core4Grid[13] project, the FRED trial, and Powervault[14]. Of these, only Powervault is assessing the impact that only home batteries can have on domestic flexibility, with the other trials including home batteries as part of the array LCTs included in the trial. We do not suggest including home batteries in the CrowdFlex trial, as home battery uptake will be significantly lower than EV uptake, and thus provide limited capacity for domestic flexibility.

4.1.3 Electric heating

As seen in Table 4, heat (usually heat pumps with or without storage) is prominent as a technology class in the reviewed projects. There are several ongoing projects that are expected to provide more insight into domestic flexibility and heat, including Ubiquitous Storage Empowering Response[15] (USER), Flexible Energy Efficient Tanks, Equinox[16], and Power of HOMEs[17]. Power of HOMES is a trial that is enabling UK participants to join a household domestic flexibility programme that already exists in France, allowing participants to connect their resistive electric heaters to a smart controller and automatically respond to DSR events. Home Response assessed the use case of hot water storage tanks and different flexibility services that could be provided, and has published results.

CrowdFlex is currently in the process of assessing the role heat should play in a large-scale consumer trial of domestic flexibility. This will consider the electric heat technologies of interest, the roll-out of electrified heat, and the innovative aspect of trialling the flexibility of domestic heat, drawing on the work covered by the heat trials identified in this literature review.

4.1.4 White goods

Few trials specifically recognise white goods as potential sources for flexibility, apart from CLNR and LCL. Connecting appliances to a smart controller is a main barrier for including white goods in domestic flexibility trials, even though they have significant capacity for flexibility. Further assessing how white goods can be included to provide large-scale flexibility would be a good insight for CrowdFlex.

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[12] *Summary of the Findings of the Electric Nation Smart Charging Trial*. Electric Nation, 2019, http://www.electricnation.org.uk/wp-content/uploads/2019/10/Electric-Nation-Powered-Up-Report-WEB.pdf.
[13] Jones, Felicity, et al. *Swarm Governance: Flying to a Future of Domestic Energy-as-a-Service*. Everoze, 2019, https://everoze.com/app/uploads/2019/06/Everoze-Partners-Swarm-Governance-Report-2019-06-13.pdf.
[14] *A Groundbreaking Smart Energy Trial with Powervault and AgileOctopus*. Octopus Energy, 2020, https://octopus.energy/blog/agile-powervault-trial/.
[15] "Unlocking the Smart Grid Potential of the UK's Domestic Hot Water Tanks." *Levelise*, 2018, https://www.levelise.com/news/user.
[16] "EQUINOX (Equitable Novel Flexibility Exchange)." *National Grid*, 2022, https://www.nationalgrid.co.uk/innovation/projects/equinox-equitable-novel-flexibility-exchange.
[17] "Power of HOMEs." *Powerofhomes*, 2022, https://www.powerofhomes.uk/.

4.1.5 Open technology

Some projects are technology blind, where the demand response is assessed from a holistic household perspective, allowing for reduced barriers to participation, but inherently giving less information on how exactly the flexibility was provided. Projects like this include the DSRT, and Flexibility through communities[18]. Sustain-H only requires participants to have any one of three different qualifying technologies (EVs, heat pumps, home batteries).

4.2 Customer communication

Trial participation also tested differing methods of communication and data collection. Trials that focused on manual engagement issued notifications via a prescheduled email. This includes the DSRT trial and Sustain-H which conducted demand turn-down events (issued up to 24hr in advance for DSRT). On data connection the Sustain-H trial only required participant meter data to be handed over monthly. The DSRT trial automatically collected participant half-hourly meter data. These trials did not enable participants to real-time monitor the financial benefit they were achieving by participating.

Meanwhile, automated trials involve higher volumes of data transfer for DSR events and benefits using apps / online communication hubs. As the participation in flexibility does not require participants to manually change their energy demand, it is seen as beneficial to allow participants to monitor how their energy use is being affected by the trial. The trials that used apps include CVEI, Shift[19], Electric Nation, GMSCD[20], and FRED. The Electric Nation trial specifically assessed the impact of introducing an app to manage smart charging. "Blind" smart charging, where participants were not able to monitor how their charging was managed, was transitioned to the next stage of the trial: introducing an app to allow different charging optimisations. Journey plans and charging priorities were input infrequently, and participant satisfaction did not change significantly. In contrast, the FRED trial found that participants requested more information during the trial, and therefore introduced an app that allowed participants to input charging plans, override smart charging, view historical data, and monitor financial benefits.

The key findings of introducing an app for a trial were that the level of information provided to participants matters, the app helps participants understand smart charging operations and benefits, and that trust in the reliability of the app must be earned through use. The trials show different levels of engagement with the apps, possibly due to different trial designs; however, it was clear that relying on the participant to input data such as state-of-charge, battery size, and charger power caused friction in the use of the apps.

CrowdFlex should take the learnings from these trials that clear communication of electricity consumption, especially when used for automated dispatchable flexibility is important to provide consumers with reassurance on how their demand is being used. The most successful interface to enable this is via an app. Apps should be easy to use and require minimal user participation to be functional, otherwise risk being neglected by less engaged consumers.

4.3 Half-hourly metering

Half-hourly metering was a requirement of all trials testing domestic flexibility and is thus a major blocker in scaling up domestic flexibility at a national level. The rollout of smart meters across the UK will allow for much greater capacity for domestic flexibility, as even the simplest manual dispatch trials (Sustain-H and DSRT) require half-hourly metering to participate. A higher resolution of metering is currently possible: the EV smart chargers used in the FRED trial can monitor grid frequency; however, participation in frequency response was not possible due to the inhibitive cost of high-resolution settlement.

[18] *Flexibility through Communities*. Energy Local, 2022, https://energylocal.org.uk/.

[19] Project Shift: Summary Report. UKPN, 2021, https://innovation.ukpowernetworks.co.uk/wp-content/uploads/2022/06/UKPN_Project-Shift_2021_Web-PDF-v2.pdf.

[20] *Greater Manchester Smart Community Demonstration, Executive Summary*. Greater Manchester Combined Authority, 2017, http://media.ontheplatform.org.uk/sites/default/files/GMCA%20NEDO%20Smart%20Communities%20Exec%20Report%20FINAL.pdf.

5 Services required by power sector stakeholders in prior trials

5.1 Peak-shifting

Regardless of whether specific ESO or DSO services were tested in the trial, one of the main aims of all trials was to assess the potential that domestic flexibility has to shift demand out of the evening peak. Reducing the evening peak has utility for both the ESO and DSO in terms of reducing the requirement to dispatch expensive and carbon intensive peaker plants or reinforce their networks. The method of shifting demand out of the evening peak differs between trials.

Manual scheduled turn down events allow for a lower barrier of entry - effectively only a smart meter is required to monitor the demand change over a baseline:

- Sustain-H trial allowed households with qualifying technology (1 of EV, heat pump, or battery) to participate in 4-hour turn-down events pre-scheduled 6 months in advance.
- DSRT allowed households to participate in turn-down events by being notified via email or app 24hr in advance. This supported the ESO when demand was high and renewable output was low. Only half-hourly metering was required to qualify.

Automated response was a more common method of utilising domestic flexibility to shift demand out of the evening peak. The technical requirement for this is higher, as not only half-hourly metering is required, but also some form of networked smart controller/charger.

- The Shift project allowed EV owners to participate in 3 different smart charging trials. All were automated and found that smart charging can be effective in moving demand out of the evening peak; however, smart charging in two sub-trials caused secondary peaks in demand. The concern raised is that this could exceed the baseline evening peak unless it is managed closely.
- Electric Nation trialled EV smart charging; however, this also created (what they described as) an avoidable secondary peak at a ToU tariff boundary.
- The GMSCD trial used networked heat pumps to test the capacity for heat pumps to provide pre-scheduled turn-down events. It found that heat-pumps can effectively reduce evening demand, yet the duration was generally limited to <60min intervals due to the drop in temperature of households. To increase the duration of response, the aggregator was able to split participants and create a two-hour response from two one-hour response groups, when usually the temperature drop would prevent this. At the one-hour mark, instability is seen when, for a short period of time, both groups are performing a demand reduction. The benefit is that longer-response times are possible using heat-pumps. However, the trade-off is that the power of the response is halved, with possible implications on revenue. Response times were less than 6 minutes in all cases.
- The FRED trial was EV owning participants mostly on ToU tariffs and therefore already outside the evening peak in the baseline. The smart charging trial was concerned with effectively managing charging beyond simple ToU signals. It tested how charging could better be spread throughout the whole night and avoid the already existing secondary peak. The initial peak was at around 00:30 at night, when a ToU tariff changed. Smart charging on top of the ToU tariff increased late evening charging on particularly windy evenings - the 01:00 peak was reduced, and much charging demand was shifted beyond 04:00.
- CVEI focussed on consumer preferences within different forms of EV smart charging. Smart charging was effective in moving demand out of the evening peak. User managed charging (ToU tariff with charging managed by user) predominantly shifted demand into the later evening. It was noted that user managed charging could lead to secondary peaks if many EVs start charging at the ToU boundary. Supplier managed charging (users specify state-of-charge requirements, supplier charges based on variable cost of electricity and passes benefit on to consumer) predominantly shifted demand into the early morning.

5.2 ESO and DSO needs and services

As seen in Table 2 in chapter 3, DSOs have been significantly more involved in domestic flexibility trials than the ESO in the UK. This means that specific DSO needs have been addressed more directly in the trials reviewed. However, peak-shifting is useful to both the ESO and DSOs.

5.2.1 DSO constraint management

DSO constraint management has been addressed directly as an aim by three of the reviewed trials:

- Sustain-H was led by Western Power Distribution (WPD) and trialled constraint management using domestic flexibility by pricing demand reduction per kW relative to a baseline (£1.8/kW in the trial). The service windows of the demand reduction are pre-scheduled six months in advance, such that the service reduces the requirement for dispatchable flexibility during peak times. Following the trial, the prices of the commercial product will depend on the value of constraint management in different zones. There will be a trade-off between focussing procurement in high-value zones, thus allowing for higher tariffs, with procurement over a wider area.
- The Shift trail used three sub-trials to provide DNO constraint management using EV smart charging. For all three approaches, smart charging was able to move demand outside the required windows.
  - ToU Distribution Use of System (DUoS) pricing,
  - Capacity-based DUoS pricing,
  - Flexibility procurement based on aggregator maximum allowed capacity.
- Electric Nation used portfolios of managed EV chargers and did not allow them to exceed certain capacity limits. This mimicked all chargers in a group being supplied by the same network. Charging management was only active when capacity limits were reached. The sub-group that did not distinguish between 7kW and 3.6kW chargers ended up managing 7kW chargers far more than 3.6kW, rather than sharing the capacity.

DSOs using domestic flexibility to reduce the need for network reinforcement during peak times conflicts with the need for high loads during periods of peak renewable generation. In a net-zero future, periods of high renewable generation will need to be met with high demands, requiring high loads on the electricity grid. Currently, DSO constraint management using domestic flexibility is focussing on demand led constraints. An opportunity for CrowdFlex is to see how it may be able to solve supply led constraints as well.

5.2.2 Other ESO and DSO services

Some trials tested the option of using domestic flexibility within the framework of existing DSO and ESO services. This was usually done by analysing trial data and assessing if the technical requirements of the service were met. Response times and the duration of service provision were important factors in this assessment.

Sustain-H directly informed the commercial rollout of a new WPD service of the same name. The Sustain-H commercial launch is planned in 2023 and will allow households without dispatch capable assets to participate in flexibility.

The GMSCD project was successful in demonstrating that heat pumps with automated control could produce response times and durations that are required for the following ESO/DSO services:

- Demand reduction and absorption for electricity aggregators, trading in the balancing mechanism,
- Demand reduction procured by DSOs for capacity management,
- Demand reduction for Short Term Operating Reserve,
- Demand reduction for wholesale trading,
- Demand shift for a retailer to reduce retailer imbalance.

The FRED EV smart charging trial assessed services by sending instructions that mimicked delivery instructions for each service. Balancing events were simulated and found “high suitability” as EV loads were able to turn-down in response to a 30-minute balancing mechanism simulation. The report does not comment on whether repeat Balancing Mechanism calls were trialled. DSO Sustain and Secure services with pre-agreed service windows were found to be “relatively suitable” via demand turn down in EV charging, as confirmed by Sustain-H. DSO Restore and Secure are fault response services and were found to not be suitable as it is difficult to guarantee delivery unless a large, localised portfolio is used. Frequency response, specifically Firm Frequency Response (FFR), was also tested and found to be technically possible, yet the data requirements for high frequency settlement are cost-prohibitive to incorporate in the low-cost high-volume asset class of EV chargers. It is also worth noting that FFR is currently being phased out by the ESO for a new suit of Response services that require faster response rates (1 second)[21]. FRED reported that while EV charging could potentially deliver Dynamic Containment in the required response time, "the data and connectivity requirements … are prohibitively expensive for incorporating in low-cost high-volume assets".

Home Response[22] assessed the business case for different ESO and DSO services that solar PV with home batteries and heating can provide. This included DSO Secure, Sustain and Dynamic services, and ESO Balancing Mechanism and Frequency services. The availability of a home battery[23] is not the same as an EV, yet the results can still be used to inform CrowdFlex. Simulations of delivery instructions were made, assessing different gate-closure times and service durations. As gate-closure and dispatch duration increased, the proportion of the total battery fleet capacity that can deliver the requested service decreases. The business cases do not necessarily reflect technical feasibility, as the report also recognises that frequency response in batteries is hindered by hardware readiness, as also found for EVs in the FRED trial. For heating, Home Response only regarded the Balancing Mechanism and a hypothetical demand turn-up service as technically feasible and stackable with ToU optimisation.

Table 5: Battery revenue stack of different services, Home Response.

Optimised Battery Revenue Stack	Average Revenue (£/kW/yr)
Battery & tariff arbitrage	99
UKPN Secure or Sustain	45
BM Offer (discharge)	9
BM Bid (charge)	6
Frequency Services	53

Despite the fact that multiple trials have demonstrated the technical capabilities for domestic flexibility to participate in ESO flexibility services, to date, no trials with published results have successfully provided flexibility services to the ESO. For domestic flexibility to become a business-as-usual resource of flexibility then it is essential to prove its ability to provide ESO services in a real-world scenario rather than through simulated trial signals. CrowdFlex should focus on this in a large-scale trial of domestic flexibility.

5.2.3 Stackability of services

The stackability of multiple ESO and DSO services allows a single asset (or portfolio) to benefit from several revenue streams from which it can optimise its economics. Naturally an asset can only perform one instruction at a time, however, over a longer period it may be able to optimise its participation in different services to maximise its revenue. ToU tariffs can encourage the stacking of routine services by allowing suppliers to introduce, for example, wholesale price or network capacity signals to acutely manage demand with benefits passed on to consumers. Such approaches should also focus on avoiding secondary peaks that ToU tariffs can create. Finally, domestic assets can provide dispatchable ESO and DSO services to provide further sources of revenue. Optimisation to create the perfect revenue stack is already done regularly for grid-scale batteries and the aggregation of I&C flexible assets. As such, it should also be technically possible for domestic portfolios, as drafted in the Home Response trial.

Where trials already had a significant portion of participants using ToU tariffs for automated EV charging, they were able to see how additional signals and incentives could provide further flexibility services in addition to peak shifting. This includes avoiding secondary peaks, providing ESO/DSO flexibility services, and other signals, such as carbon intensity. This is evident in the FRED trial, which investigated stacking various signals (including wholesale power price, carbon intensity, grid capacity, etc.) demonstrating it could provide better and smoothed out charging patterns than ToU tariffs alone. This can further be combined with dispatch signals to participate in ESO/DSO services that demand quick response rates. There is therefore a layered approach to domestic flexibility:

1. Moving demand away from peaks, e.g., using ToU tariffs,
2. Managing these ToU tariffs to avoid creating secondary peaks by either using dynamic tariffs, time-banding, or other grid signals like capacity,
3. Using flexible assets to participate in additional ESO or DSO services.

[21] *Dynamic Containment*. National Grid ESO, 2022, https://www.nationalgrideso.com/balancing-services/dynamic-containment#:~:text=Dynamic%20Containment%20(DC)%20is%20a,sudden%20demand%20or%20generation%20loss.
[22] *Home Response: Domestic Demand Side Response Insights Report*. Element Energy, 2022, https://www.london.gov.uk/sites/default/files/hr_-_insights_report_-_final.pdf.
[23] Home batteries are available at all times and are capable of export to the grid in addition to shifting its import times.

Sustain-H asserts that pre-scheduled flexibility does not compete with automated dispatch, as households that do not own dispatchable assets will not be participating in dispatch driven flexibility. This illustrates that while consumers responding manually can be incentivised to shift their energy consumption via ToU tariffs (and other incentives or information remedies), they cannot provide ESO/DSO services that require a dispatched response. For this, automation

is required. Furthermore, the simplicity of trials like Sustain-H and DSRT show that many households can participate in flexibility today via instructions that occur 24 hours or greater in advance, but also highlight that a lack of dispatchable LCTs will hinder many households in fully participating in the breadth of flexibility services, including dispatchable ESO/DSO services.

CrowdFlex should explore stacking in a large-scale trial following the three-step approach outlined above. To do this successfully, CrowdFlex must have visibility of the assets that are available in participants homes. Previous trials have shown that, while all households can provide flexibility based on day-ahead or greater notifications (Sustain-H, DSRT), automation is required to participate in dispatched ESO Services, such as the Balancing Mechanism. Currently, automation is strongly linked to LCTs, such as EVs and Heat Pumps rather than white goods. CrowdFlex will review the Energy Network Association's Open Networks Project[24], which sets out guidance on the stacking of both ESO and DSO services.

[24] Energy Networks Association, https://www.energynetworks.org/creating-tomorrows-networks/open-networks/, Accessed Oct 2022.

6 Information and incentives offered

6.1 Financial incentives

Financial incentives are used in all trials to engage customers with domestic flexibility. To maximise the engagement, financial benefits need to be large enough to engage consumers, easily visible and monitored by the customer. Financial incentives to join a trial were usually advertised as reducing energy bills. Other incentives included tablets to access the app (GMSCD) and the installation of the LCT or charger in the home. Visibility was achieved through apps in most trials.

Financial incentives included simple reductions on overall bills by participating in the trial services (GMSCD, Core4Grid Energy-as-a-Service). Shift and Electric Nation provided distribution network capacity-based ToU tariffs. The DSRT and Sustain-H provided utilisation payments to turn-down events. FRED passed financial benefits of smart charging during low wholesale prices on to participants, who were for the most part already on ToU tariffs. A potential opportunity for CrowdFlex is to assess the impact of different levels (prices) of financial incentives, to understand the price elasticity of demand. It is not possible to combine the data from several trials to calculate price elasticity of flexibility, as the trial designs and participants are not the same.

It is worth noting that different trials have differently engaged customers, and that financial incentives may have different levels of influence on engagement. The FRED trial had highly engaged participants and therefore reported that observations must be interpreted carefully. The CVEI trial purposefully recruited “mainstream” participants to specifically avoid this problem. When recruiting participants at a large scale for the CrowdFlex trial, the diversity of participants will naturally be higher. However, CrowdFlex should be aware of the different consumer segments participating in the trial to understand how the results could be extrapolated to a wider population.

6.2 Information needs

Engaging with customers does not only rely on using financial incentives. All incentives need to be communicated to customers in the most effective way to produce the highest potential for domestic flexibility. The status of a customer’s energy requirement and any corresponding DSR interventions that occur need to be understood by the consumer in order to provide confidence in the system.

The concept of domestic flexibility needs to be communicated properly to customers. The GMSCD project shows that satisfaction levels with installed heat pumps and domestic flexibility is correlated with an understanding of the system. Similarly, the FRED trial found that participants who had a good understanding of domestic flexibility were more positive toward it than participants who had a poor understanding. If domestic flexibility is to be scaled to a national level, the level of satisfaction and confidence in the system will affect how many customers will sign up to provide domestic flexibility.

Participants also wanted to know when DSR events had taken place, which is why they introduced an app in the FRED trial. To achieve better customer satisfaction and confidence, apps can be provided to monitor real-time and historical DSR intervention. Additionally, this allows customers to monitor their financial benefit of, for example, using a ToU tariff in real-time. The use of an app also allows customers to define their needs to enable alignment with domestic flexibility. Charging needs can be entered by requesting a state-of-charge and a time at which that must be reached. Alternatively, journey plans can be entered. In the Electric Nation trial, app users provided greater flexibility than non-app users. An override functionality is seen as important in many trials, including both heat and EVs, to give customers confidence in meeting their energy needs. This includes GMSCD, FRED, Shift, and Electric Nation. The CVEI report also concluded that participants desired an override feature which was not available during the trial.

Additionally, non-financial incentives can also be used to engage customers. The DSRT trial was also called the “Big Dirty Turn Down Trial” and advertised carbon savings by not using electricity during “dirty” periods of low renewable generation. Participating in one manual turn-down event earned on average £0.22, and repeated participation rates were high. During a trial that only lasted for eight events and gave relatively small earnings, it could be argued that the carbon-saving incentive was successful. If the trial continued for longer, the financial incentive would be larger and more influential.

For CrowdFlex and its wide-scale role out of domestic flexibility to be successful it must emphasise the continued importance of consumer engagement, education, and in the provision of domestic flexibility while rewarding consumers with a fair price that accurately reflects the service they are providing.

7 Residential DSR trial outcomes

7.1 Long-duration trials of enduring tariffs

Only a few of the trials conducted a longitudinal study of homeowner response to tariffs. For example, some test cells in the CLNR project (ca. 2012) put households on a static ToU tariff. This doubled the price of electricity during peak periods. The homes were equipped with an in-home display which provided a near real-time signal of their current electricity load through a traffic light system. Across over 600 participants, the reduction in the average peak demand over the peak period was measured at 8%. It should be noted that this test cell relied on white goods as the source of flexibility.

The trials undertaken by Octopus Energy as part of the CrowdFlex: NIA[25] study, tested the response of households to a dynamic ToU tariff (Agile) that was sustained over a period of at least six months. For non-EV and non-HP households, a 12% reduction in averaged peak demand was sustained over the 3-hour evening peak (-0.1kW per house). This increased to 23% when measured across EV-owning households (-0.2kW per house). Compared to CLNR, this higher response is encouraging, but it should be noted that the customers opted into a commercial offer (rather than a trial of limited duration) and so might be expected to be more motivated to save energy.

The Shift EV charging trial assessed response to distribution capacity based ToU tariffs. On average, peak EV demand at 8pm was reduced by 79%, compared to unmanaged EVs. Compared to a normal household evening peak including an unmanaged EV, the peak was reduced by 44%. The baseline used was the PC1 domestic demand profile, not using historic participant data. Customers chose to smart-charge 85% of the time.

7.2 Response from one-off events

Many projects were of limited duration and so explored the response to shorter-duration, or one-off calls for demand response. For example, LCL conducted a limited set of trials to move demand out of the peak evening period. They found wide variation in response, but typically a 5-10% reduction in peak demand (white goods) across the set of trials they conducted. They noted that the demand response of the most engaged 25% of customers was three times the average.

The CrowdFlex: NIA study also conducted one-off trials of household response. In both the “Big Turn-Up” and “Big Turn-Down” trials, customers were asked via a text message a day ahead of time, if they wished to opt-in to a two-hour wide demand response event. Big Turn-Up provided larger response (+5.8kW EV-owning and +1.5kW non-EV owning houses) compared to big turn down (-0.6kW EV-owning and -0.5kW non-EV owning houses). The trial also showed that when determining the combined response (ToU and big turn-down), great care a is needed to establish the correct baseline for EV owning houses. ToU would be expected to routinely move charging demand out of the evening peak, while the one-off experiments showed the capability to make larger, though significantly less frequent, adjustments to demand.

The DSRT involved eight manual turn-down events over the course of two months. Average turn-down per household was 0.51kWh, with participants on static and dynamic ToU tariffs outperforming those on fixed tariffs (0.79kWh and 0.46kWh respectively). Though the trial was not designed to assess price impact on response, the average cost per turn-down was £227/MWh. On average, participants received a payment of £0.22 per event, when the incentive was a credit of the value of electricity consumed. A B group of the trial was offered an alternative incentive, equivalent to a payment per kWh of turn down. This group achieved an average payment of £0.30 per event and showed greater participation and depth of response. Based on result extrapolation, Octopus estimates up to 1.9GW of demand reduction during the evening peak GB wide today, growing to a potential of 7.8GW by 2030.

The GMSCD project involved automatic turn-down of heat pumps at pre-scheduled response windows during the morning and evening peaks. The success rate of demand response was limited by the duration of the call. 92% of 60-minute events were successful, compared to only 52% of 90-minute events. The report suggests 60-minute turn-down events to be the most suitable for heat pumps. The maximum demand turn-down measured was 375kW, which equals 0.68kW per household (550 participating); however, only 28% of settlement periods achieved the minimum target of 200kW turn-down (144 of 513 settlement periods, 200kW equates to 0.36kW/household).

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[25] *CrowdFlex – Phase 1 Report*. National Grid ESO, 2021, https://www.nationalgrideso.com/document/230236/download.

CrowdFlex has an opportunity to continue to investigate how enduring tariffs and one-off events affect demand response, testing across a wider range of technologies and a higher number of participants. There is a valuable opportunity to test how these different types of demand response can interact with each other.

7.3 Deep-dive on response achieved

7.3.1 Seasonal variation of response

CLNR, CrowdFlex, and Low Carbon London examined demand response across the year and evaluated seasonal variation as well as the capability to generate a response on the day and time of the system peak (evening, winter).

The CLNR project showed that the reduction in consumption during the peak period was consistent throughout the year; however, it did not reduce demand on the day of greatest system peak demand. From this, they conclude that network risk is reduced, but is not eliminated and additional interventions would be required to encourage response at these times (they suggest Critical Peak Pricing as an alternative).

The CrowdFlex: NIA study showed that customer response to dynamic ToU tariff was much lower in winter, indicating less capability or willingness to shift demand out of the evening peak in wintertime.

Low Carbon London found that the average customer response to high prices at peak times was greater in winter compared to summer. This may be explained by the customer baseline demand (and therefore, their demand response capability) increasing during the winter months. The finding is in line with the CLNR study, as LCL reports the average response across the season, and not on a peak day.

To be a successful large-scale trial of domestic flexibility, CrowdFlex will need to run over the course of a year to test how domestic flexibility is affected by seasonality. This is particularly important during system stress events, where the capacity of domestic flexibility might be limited.

7.3.2 Duration of response

All bar one of the trials explored response to short duration events (2-4 hours), reflecting the width of the evening peak demand period they wished to avoid. Only the LCL project attempted to measure longer response durations, as they were evaluating Variable Renewable Energy Source induced events on the power system (where a 20-hour long increase in demand could support 90% of high wind events). LCL found that, for requested turndowns from 3-hour to 12-hour duration, the response to high price events was the same. For low price events, shorter durations had a higher response.

There is opportunity for CrowdFlex to trial different durations of response. This is particularly interesting regarding response to wind events, that have a wide range of length. The GMSCD trial staggered the response of HPs to allow for longer response periods. This could be tested at a larger scale and including a wider range of technologies in CrowdFlex.

7.3.3 Secondary (new) peaks in demand

One unintentional consequence of demand response is shifting load downstream and concentrating it, so when the aggregated load appears, it can generate a secondary peak, which could become a new system peak.

Low Carbon London did find secondary demand peaks in industrial and commercial (I&C) loads to be much more prevalent (compared to residential) given that I&C demand would be displaced rather than avoided. LCL did find that the most engaged consumers (25%) responded to low-price events by increasing demand up to a level beyond their pre-trial peak. UKPN suggest a managed approach to demand response would be required, i.e., dynamic (network) capacity-based pricing allows for peak smoothing rather than secondary peaks.

The Shift trial evaluated EV smart charging to avoid DSO network constraints:

- In one sub-trial, which was fully automated, ToU distribution tariffs were not exposed to customers. The secondary peak became as large as the pre-trial evening peak.
- Another sub-trial (EV.Energy) involved automated smart charging based on an aggregator whose portfolio capacity was contracted not to exceed limits within a service window (18:00-21:00). Secondary peaks in demand formed after the service window, and these new peaks were higher than the baseline evening peak.

The GMSCD project showed that, when heat pumps are switched back on after longer DR calls, particularly when group splitting is used to double the length of the DR event, the aggregated demand is higher than before. This is because, after a DR event, most of the heat pumps will switch on simultaneously to respond to the drop in internal temperature.

CrowdFlex should note that previous trials have created secondary peaks that match or even exceed original evening peaks. This should be avoided as reducing peak demand is one of the main outcomes of using domestic flexibility. The generation of secondary peaks will depend on the technology and design of the flexibility response call, and therefore will have different solutions.

7.3.4 Persistence (response following repeated calls)

There was very limited information on the persistence of the response - i.e., that the response to one-off events is consistent even if they occur over consecutive days. Some Low Carbon London test cells evaluated the response to peak avoidance for up to 3 consecutive days. No significant trends were identified between event persistence (number of consecutive days) and either peak reduction or mean demand reduction. However, they note that they did not test at or near system peak days, and that this could have an adverse impact on the level of response.

By trialling for at least a year, CrowdFlex can test the persistence of response across different seasons, technologies, and stress events. This will provide comprehensive data that will allow greater confidence in the use of domestic flexibility.

7.3.5 Asymmetry of response

Low Carbon London and CrowdFlex: NIA examined the difference in incentivising turning up and turning down demand. LCL found that there was a much greater (turn up) response to low price events compared to high price events, even though the asymmetry in the price incentives was in the opposite direction; consumption during high price periods was penalised by £0.55/kWh relative to the mid-price, while shifting consumption to low price periods was rewarded (compared to mid-price) by only £0.08/kWh.

CrowdFlex: NIA found a similar result, in that the Big Turn-Up response was greater than the Big Turn-Down.

However, both of these may be expected, given the diversified average load in houses (ca. 1-2kW) is much closer to zero (hence, limited turn-down envelope) and it is much further away from the peak load a house can sustain.

CrowdFlex should consider the different response homes provide depending on turn-up or turn-down. The price-incentives for the directions of response should reflect this.

7.3.6 Price elasticity

Few trials examined customer price elasticity. Low Carbon London did find a very large spread in the level of response measured, despite all households being given the same price incentive.

The Sustain-H project did not test different price levels, however the commercial rollout of the product will include three prices depending on the value of flexibility within the constraint management zone the homes are in. This suggests that homes will be price sensitive to provide flexibility, as higher prices are offered where the requirement for flexibility is greater. The three price tiers are: high value £8/kW, medium value £2.50/kW, and low value £1/kW. Data on the rollout of the Sustain-H product will inform how these price levels impact the amount of flexibility provided.

Knowledge on the price elasticity of demand response would be very valuable for the ESO and DSOs to efficiently provide services at best value to customers. As no trials have assessed price elasticity, there is an opportunity for CrowdFlex to collect this data. This might prove to be a very difficult implement in a large trial with many test cells, as the complexity will dramatically increase. Additionally, it would also be valuable to use data collected from the CrowdFlex trial to assess how different consumer segments (levels of engagement) respond to price elasticity.

7.3.7 Speed of response and ramping rates

The speed of response is important to determine suitability for providing certain services. Also, stakeholders are concerned that the sending of control signal to dispatch demand can erode the natural diversity of demand and introduce sudden changes in demand that may also be challenging to manage.

GMSCD measured turn down response from heat pumps (in aggregate, providing STOR response). They found the average time for demand reduction across the portfolio (from nominal output to minimum) was 2.3 minutes, with the slowest response time being 6 minutes.

The FRED trial showed that EV chargers can respond quickly enough to provide Frequency Response services. However, they found the technology required for high frequency metering is cost prohibitive to install in current smart chargers.

While ESO and DSO stakeholders have expressed concern about avoiding sudden changes in demand (which could be difficult to manage), no projects reported on the intentional modulation of demand response assets to provide a required ramp rate. However, in theory it should be possible to add artificial noise to the dispatch signal, or intentionally ramp the instruction to assets to provide the required response rate in the CrowdFlex trial.

7.3.8 Automation

Earlier trials explored demand response from a range of household assets and were primarily not automated. LCL compared manual and automated responses and concluded that automation was critical to achieving high levels of response. More recent projects focussed on EV charging, and those that included a degree of automation included Shift, Electric Nation, Core4Grid, GMSCD, FRED, CVEI, Home Response.

CrowdFlex should assess the impact of manual and automated response. These differences can be measured by assessing the impact the different response types can have on the same response instruction. However cumulative response should also be assessed, by, for example, combining enduring tariffs with one-off manual responses.

8 Work Package 3 recommendations

8.1 Technology

- The adverse system impact that increased deployment of unmanaged LCTs will have, such as exacerbating evening peaks, supports exploring managing their use in the CrowdFlex project. **LCTs should be considered within the scope of CrowdFlex.**

- **Grid responsive electric heating** will have an important impact on the electricity system. Crowdflex should consider the scope of other trials to determine the additionality of including this technology in the trial stage.

- **CrowdFlex should consider how white goods can provide domestic flexibility**. Hot appliances such as washing machines, dishwashers and tumble dryers should be the focus.

- CrowdFlex should note the **modest demand savings and associated commercial viability that white goods provide**, especially compared to LCTs.

- **Home batteries should not be included in the CrowdFlex trial**, as uptake is significantly lower than other LCTs, especially EVs, and will provide less total capacity for domestic flexibility.

8.2 Trial design

- **CrowdFlex needs to include both randomised control groups *and* historical customer baselining** to inform confidence levels and capabilities for baseline domestic demand and flexible response to dispatch instructions/incentives.

- Many previous trials have not been able to provide ESO services in real-world scenarios, only through simulated trials. **CrowdFlex, should provide real-world ESO (and DSO) services** where possible to prove the commercial viability of domestic flexibility, and at scale.

- **Automation of technology (primarily LCTs) will be critical for CrowdFlex** to dispatch some ESO services and will be an essential component of the trial.

- **Manual responses should also be considered** as they have been shown to generate significant responses in previous trial events. Test cells should examine the relative efficacy of manual versus automated.

8.3 Commercial

- ToU tariffs are effective mechanisms to encourage an enduring response from domestic customers. Their benefits include, shifting demand from peak times and reducing total energy costs by accessing cheaper wholesale prices. **ToU tariffs will form a vital part of a CrowdFlex trial.**

- **CrowdFlex should explore stacking in a large-scale trial** following the three-step approach:

  1. Moving demand away from peaks, e.g., using ToU tariffs,

  2. Managing these ToU tariffs to avoid creating secondary peaks by either using dynamic tariffs, time-banding, or other grid signals (e.g. capacity),

  3. Using flexible assets to participate in additional ESO or DSO services.

- Little is currently understood around the price elasticity associated with domestic flexibility. **CrowdFlex should seek to produce greater understanding of price elasticity.**

- This literature review was completed in October 2022, as the Energy Price Guarantee was introduced to support consumers during unprecedentedly high wholesale prices. A **key task for CrowdFlex will be to understand how ToU tariffs can be leveraged effectively** in the current power market.

8.4 Incentives and communication

- **Consumer attitudes and non-financial incentives** can have as large an impact as financial incentives, on the level of participation and response. Signposting to customers that participation would reduce their carbon impact has proved a particularly effective. CrowdFlex should target appropriate consumer groups and develop and test non-financial incentives alongside financial ones.

- **Consumer engagement, education, as well as fair and transparent pricing is essential** for a successful wide-scale rollout of domestic flexibility in CrowdFlex.

- For automated dispatchable flexibility, it is important to provide consumers with **reassurance on how their energy is being used**.

- **CrowdFlex should consider apps to clearly communicate** electricity consumption and other information and incentives to consumers.

8.5 Technical performance of demand response assets

- **CrowdFlex should test the response to enduring incentives (such as TouT) as well as one-off events**. The cumulative impact of these should also be evaluated.

- **There is an asymmetry in customer response** to high and low-price incentives. This should be reflected in the incentives provided.

- **Trials should extend over at least one year** to gather information on the seasonality of response.

- The **response on the peak day** (more generally, during system stress events) should be measured.

- The **persistence of response** (repeated calls over a limited number of days) should be tested.

- The trial should test the **duration of response from ca. 3 hours up to 12 hours**. Response after the event should also be measured to identify if secondary peaks occur.

- The trial should **evaluate the introduction of noise, or staged dispatch of assets** to ensure response does not exceed a specified ramp rate.

- The trial will need test cells with automated dispatch. Separately, some **test cells should evaluate the efficacy of manual versus automated dispatch**.

- The trial design should where possible reflect the **need to avoid generating secondary peaks**.