WPD INNOVATION
Transforming the electricity network

Future Flex

NIA Major Project Progress Report

November 2019 – December 2021

WESTERN POWER DISTRIBUTION
Serving the Midlands, South West and Wales

Version Control

Issue	Date
D0.1	25/10/2021
D0.2	14/11/2021
D0.3	18/11/2021
D0.4	29/11/2021
V 1.0	02/05/2022

Publication Control

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Contents

1. Executive Summary

Future Flex was an NIA Project which started in November 2019 and ran through to October 2021. The principles were at the outset to look at matters relating to the consumer engagement, commercial and other factors that are part of residential flexibility. The consumer must be at the heart of the energy transition, and it is therefore essential that the industry understands fully what residential flexibility could look like and Future Flex sought to understand that.

It did this with a broad remit to gain consumer and market participant feedback first before undertaking any trial with the market, as well as exploring those factors including energy efficiency and the commercials that will be vital for consumer acceptance.

To do this, Future Flex Project was initially established on the unusual principal that rather than embarking on a specific innovation objective, it would commence with customer engagement workshops that hoped to identify a new perspective that was potentially being missed by those within the industry. By hosting and facilitating workshops that were attended by a broad range of stakeholders and customer groups, the first step would be to either identify new and more customer focussed challenges to address through innovation or even identify alternative approaches to conventional problems. To achieve this a third party was appointed to facilitate sessions that would tease out any suggestions that could then be assessed for viability before taking the successful proposals through the more conventional project planning processes.

The workshops successfully fulfilled their objective of producing a series of suggestions which reflected new insights to customers, their willingness to get involved and where they hoped to see improvement in the evolutions of smart grids.

The project team were able to identify 3 workstreams from the stakeholder suggestions that were then developed into full proposals and approved by the project governance board.

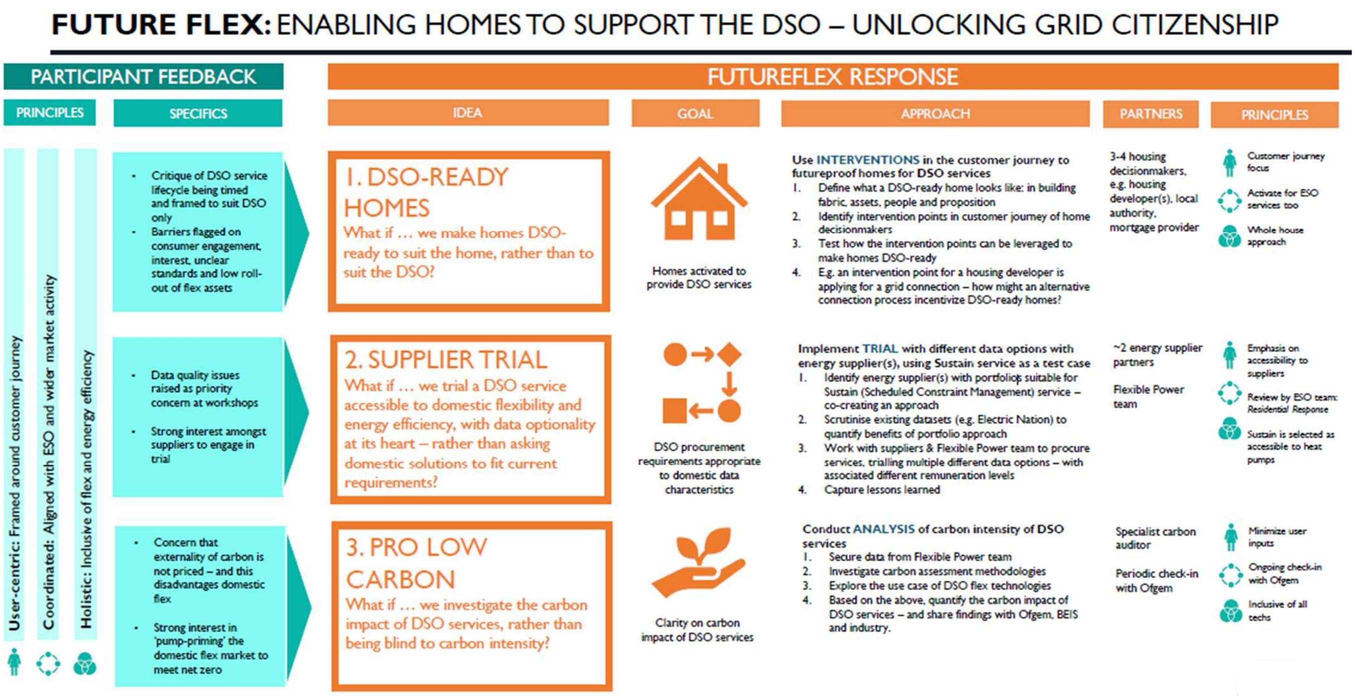


Figure 1-1: Future Flex on a page

This closedown report covers a summary of the 3 innovation workstreams including a summary and full breakdown of the customer benefits plus some suggested next steps are included in the relevant sections of the report. Each workstream is also supported by its own associated publications, which can also be found on the Future Flex part of the WPD's innovation website providing interested parties with a more detailed understanding of the innovation journey and comprehensive learning logs. (https://www.westernpower.co.uk/innovation/projects/future-flex)

2. Project Background

Future Flex was a participant-led trial of second-generation DSO services, deploying step-change innovations for procurement, testing a delivery which is suitable for domestic scale assets. Just as the Electricity System Operator (ESO) saved £200m by reframing frequency response in 2016, we sought multi-million savings and increased market liquidity through reframing DSO procurement. The project's innovation was twofold:

1. Reshaping DSO services themselves from a typically commercial focus, not asking domestic flex to reshape to fit DSO services: Ongoing innovation projects place the onus on domestic flex demonstrating capability to meet existing flex requirements, to fit a regime designed with larger and often more conventional generating assets in mind. We instead reframed DSO procurement itself, to ensure a genuinely level playing field.
2. Participant lead design, DSOs historically tended to propose changes, then consult stakeholders for review. Through the initial workshops we flipped this model on its head, with participants proposing changes, and the DSO reviewing suggestions for their potential viability. This was used to drive more bold solutions – albeit guided to be within the boundaries of what is feasible.

First generation DSO services are already being provided by large distribution-connected assets – as evidenced by Flexible Power, Piclo, Power Potential, and more. Western Power Distribution (WPD) alone procured 700 MW of flexibility since 2018 with volumes expected to increase as the service develops. Distribution System Operator (DSO) services are being standardised across DSOs under the *Open Networks* project and are becoming Business as Usual (BaU) across GB.

Whilst there are some smaller providers emerging, these services tend to be provided by relatively large (>200kW) assets, for instance batteries and generators. Flexibility providers to date have tended to be commercial actors for whom energy is core business (or a fundamental cost component of business), rather than individual householders. This includes aggregators who do not actually own the assets but manage them on behalf of their owners to provide a commercial return.

Second-generation DSO services will need to facilitate widespread participation from homes too. The market is fast developing new domestic flexibility solutions – spanning vehicle-to-grid (V2G), smart and hybrid heating, stationary batteries and more. The units of flexibility offered at domestic scale are individually small, often at the level of single kilowatts. This drives different requirements when participating in local flexibility markets. For DSOs to be a neutral market facilitator, they must ensure a level playing field for these new domestic solutions.

Facilitating domestic participation means developing the right services and products, in consultation with stakeholders that are attractive enough to encourage participation. This is not easy as services that have been developed to date are typically for much larger assets. Moreover National Grid Electricity System Operator's (ESO) *Residential Response* project, aimed to address some specific barriers to domestic flexibility providing Firm Frequency Response (FFR).

Issues include:

- Dynamic allocation of Demand Side Response (DSR) assets within domestic portfolios
- Bid windows to accommodate rapidly changing asset availability
- Automation in testing and delivery to accommodate very large numbers of assets
- Metering and baselining
- Commercial incentive design and risk allocation.
- Possible standardisation of requirements between DSO and other service

Potential for New Learning
Future Flex sought to explore opportunities in key learning areas for each phase. These were:

- Phase 1: Establishing what stakeholders want from second generation DSO services.
- Phase 2: How stakeholder requests can be implemented in practice – what specifically needs to change.
- Phase 3: Which step-change innovations work in practice, and which do not.

The innovations deployed were expected to apply across all licence areas: The project was inherently focused on procurement specifications and process, and hence is not DNO specific. We aspire that successful innovations will be rolled out to other license areas beyond WPD.

The project addressed the following objectives that were within WPD's Innovation Strategy (July 2018, Section 4.3):

- Ensuring that a network is technically and commercially developed to deliver the required flexibility to support current and future system needs.
- Enabling solutions that can be quickly transitioned to become business as usual.

2.1. Scale of Project

The project was a field based trial based around our current Constraint Management Zones (CMZ's).

2.2. Benefits to Customers

Facilitation of Domestic Flexibility services. Which should reduce costs of participation, increase liquidity in the market and ultimately reduce the cost of flexibility procurement.

If the problem is solved, in the long run we expect to see increased liquidity within DNO DSR markets and a corresponding reduction in pricing. The value of DNO DSR could reach up to £12.1m/year by the end of ED1 (£3.38m/year within WPD). This is based on the deferral of half the total EHV and 132kV reinforcement by three years. If increased liquidity drove a 10% saving in this value, the savings would be £340k/year across WPD or £1.21m/year across the UK. The 10% saving is deemed reasonable given National Grid ESO prior experience with frequency response.

3. Scope and Objectives

3.1. Scope

3.1.1. Participant engagement

a. This data-gathering phase was the bedrock of the whole project, using workshops to secure meaningful, deliberated participant input, with follow-on interviews, social media engagement and peer-review.
b. At the heart of this phase were two intensive workshops hosted by Everoze – with upfront explanation of key topics, and careful curation of agenda, invitee list and seating plan to ensure meaningful feedback.

Following the participant engagement, we had three areas of work to progress:

2A. DSO-ready homes
  a. This workstream was to identify and deploy interventions to futureproof homes for DSO services.
  b. The objective was to deliver a set of costed interventions to make DSO Ready Homes through adopting a customer-centric approach.

2B. Sustain-H Trial (with Aggregated Datasets)
  a. Develop different data options with energy suppliers and/or asset aggregators using the Open Networks existing definition of a 'Sustain' service as a test case.
  b. The objective was to demonstrate the provision of a demand reduction service, which is more accessible to domestic participation than existing BAU propositions with a reduced burden on data provision from the provider.

2C. Pro Low Carbon -Conduct analysis of carbon intensity of DSO services, with an emphasis on domestic flex.

3.1.2. Trial

The trial was a demonstration in the field focussed on our current CMZ's.

Table 3-1 Status of project objectives

Objective	Status
Explore the impact of flexibility services to feed into wider policy/regulatory setting.	✓
DSO- READY HOMES - Deliver a set of proven, costed interventions to make homes DSO-ready, through adopting a customer-centric approach.	✓
SUSTAIN-H To trial the provision of a DSO service suitable to domestic flex, which: Targets the impact of LCTs and gives options on data provision, rather than being prescriptive.	✓
PRO-LOW CARBON To explore and understand the carbon impact of procuring DSO services from local flexibility technologies.	✓

4. Success Criteria

The original project documentation articulated a number of success criteria that we aimed to achieve. These criteria are detailed below:

Table 4-1 Status of project success criteria

Success Criteria	Status
Two intensive workshops, adopting workshop best practice methodology	✓
Identify participant-led recommendations for domestic DSO services, segmented into new innovations and BaU tweaks, and clearly prioritised via impact/effort chart.	✓
Implementation of highest priority recommendations, via empirical trial, targeting at least two providers and 100 homes.	✓
Finalised designs following trial.	✓

A key measure of success though is the transition of innovative ideas into the business to benefit customers and as such, Future Flex can be regarded as a real success with the intent to transition the SUSTAIN-H product into business as usual.

5. Details of the Work Carried Out

The following section details the work that was carried out during this project across the four distinct workstreams as follows:

1) Initial FutureFlex workshop
2) DSO Ready Homes
3) Sustain-H
    a. Including Aggregated Datasets
4) Pro Low Carbon

Table 5-1 All Project activity is documented in the following outputs:

Phase	Public-facing documents describing journey and detail, available online here: https://www.westernpower.co.uk/projects/future-flex	Additional supporting material
1. Participant feedback	FutureFlex Workshop Primer FutureFlex Workshop Participant Feedback Ideas for Trial May 2020	
2A. DSO-Ready Homes	DSO-Ready Homes definitions DSO-Ready Homes: realizing the value of domestic energy efficiency in GB electricity distribution – July 2021 DSO-Ready Homes: Roundtable output – slides and discussion note	DSO-Ready Homes: Interventions document Report with detailed analysis of value of energy efficiency (the supporting paper to 'realising the value of domestic energy efficiency in GB electricity distribution).
2B. Sustain-H (including Aggregated Datasets)	Sustain-H Opportunity Sustain-H Design Guidance Value Calculator Sustain-H Product roadmap Aggregated Datasets Methodology Aggregated Datasets Third party datasets analysis Aggregated Datasets: Third party and Sustain-H datasets analysis	Detailed design report (May 2020). Gap Analysis paper (Document 1B), Aug 2021.
2C. Pro Low Carbon	Carbon Assessment Methodologies Carbon Impact of DSO flexibility services	Excel tool supporting carbon analysis

5.1. Workstream 1 Initial FutureFlex Participant Workshop

This data-gathering phase was the bedrock of the whole project, using workshops to secure meaningful, deliberated participant input, with follow-on semi-structured interviews, social media engagement and peer-review.

We engaged participants through three means:

Table 5-2: Participants Engagement Methods

METHOD	OBJECTIVE OF ENGAGEMENT
1. Workshops in Bristol and London	✓ Stimulate structured feedback from diverse group of industry experts – adopting co-creation approach

2. Interviews	✓ Secure ad-hoc feedback on workshop outputs, particularly from those unable to attend ✓ Probe deeper on specific topics
3. Webinar	✓ Disseminate workshop findings ✓ Invite informal feedback on ideas from the workshop

5.1.1. Workshops in Bristol and London

The purpose of the workshops was to stimulate feedback in structured form from diverse group of industry experts – adopting co-creation approach.

Workshop primer documents were prepared and shared with the participants in advance to give some context and allow the participants the opportunity to think through topics in advance. This was to enable the participants to come to the workshop prepared to hit the ground running. The primer pack presented some background and posed some interesting questions – rather than offering up any answers.

The participants at the workshops in Bristol and London were asked to think about two key questions that the FutureFlex project should focus on.

Q1. What are the **primary barriers** to **domestic flex** supporting the DSO?
Focussing on the relationship between DSO and supplier/aggregator intermediary (rather than between intermediary and consumer)

Q2. What **creative solutions** should we **trial** under FutureFlex?
Step-change innovations; not tweaks to business-as-usual BUT achievable to demonstrate within FutureFlex

Figure 5-1: Workshop Participants

Across the two workshops, which were supported by our existing Flexible Power team and Subject Matter Experts we hosted 43 organisations who provided feedback on the 2 key questions.
These organisations were:

Active Building Centre, Association for Decentralised Energy, Aurora Energy, Baringa, Bath & West Community Energy, BEIS, Bristol Energy, BSI, Centre for Sustainable Energy, Citizens Advice Bureau, ECA, Cornwall Insight, Ecotricity, EDF Energy, Egnida, Electron, Energy Systems Catapult, FootAntsey, FNC, Flexitricity, geo, Graham Oakes Consultancy, GreenFox, GridDuck, GridIMP, Groupe Atlantic, Kaluza, King's College London, Impex Energy, Larkfleet Group, Low Carbon Gordano, Moixa, OpenEnergi, Passiv UK, Piclo, Poset-renew, Regen, Rich Furniss, Sero, Social Energy, Solo Energy, Sustainability First, University of Exeter, University of Ulster.

5.1.2. The Interviews

The purpose of the interviews were to secure ad-hoc feedback on workshop outputs, particularly from those unable to attend and to probe deeper on specific topics raised.

These Semi-structured interviews were conducted throughout February 2020 – exploring some of the workshop findings.

5.1.3. The Webinar

The purpose of the webinar was to disseminate the workshop findings and to invite informal feedback on ideas from the workshop. The webinar was conducted in February 2020.

5.1.4. Overall Participant Feedback Summary

From the workshops we had 242 post-it notes on **primary barriers** to **domestic flex** written by participants**.** These were summarised by theme since some topics cut across the DSO services lifecycle.

Figure 5-2: Workshop Post-it Notes

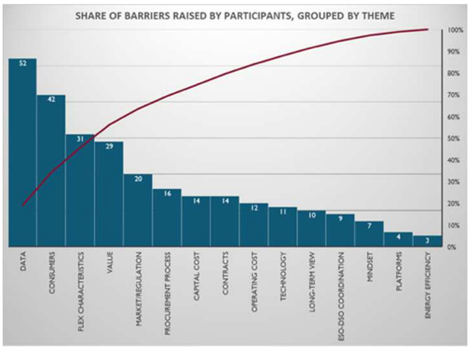


Figure 5-3: Share of Barriers Identified

The participant feedback on potential trials was documented as a long list of potential trial areas. The project team then used the following criteria to screen the longlist of project ideas to develop a shortlist.

Table 5-3: Trials Selection Criteria

Criteria
Cost: What will the trial(s) cost?
Impact: • How material are the barriers to be addressed? (According to participant feedback) • To what extent will the trial address key barriers? (As flagged by participant feedback)
Additionally: To what extent are the barriers being addressed elsewhere?
DSO fit: To what extent is it appropriate for a DSO to lead the trial(s)?

This shortlist, during a scoping meeting between FutureFlex team and Flexible Power team, was further refined. Based on this process we derived three key workstreams for FutureFlex:

1) DSO Ready Homes
2) Sustain-H with nested Aggregated Datasets workstream
3) Pro Low Carbon

The full report for this element of the project can be accessed here.

5.2. Workstream 2A DSO-Ready Homes: Making homes DSO-ready when it suits the homeowner

This workstream put the activities of home developers, occupiers, and owners centre stage by identifying events where these players are most open to making the changes required to become DSO-ready, even if DSO services are not currently required in the area.

DSOs have historically focused on rewarding large flexibility providers for constraint alleviation via DSO services; yet domestic LCTs have the potential to deliver network value too. Understanding the scale of domestic flexibility network value is the first step towards deciding whether it might be appropriate for the DSO to reward energy efficiency, and how this might be incentivised.

The approach we took to develop this workstream was broken into five stages as can be seen below;

1) Define the elements of a DSO-Ready Home
2) Identify the stakeholders who might influence each element of DSO-readiness
3) Scope out the intervention points for each stakeholder.
4) Test the DSO Intervention options
5) Examine the results

As part of the 1st stage, we defined what the elements of a DSO-Ready Home could be via project meetings and industry discussions. These pointed to the significance of energy efficiency, not just flexibility, in a home being ready to support the DSO. The report from this stage can be found here.

As part of the 2nd and 3rd stages we developed four example customer personas and identified the interventions they could take to make their homes more DSO-ready: this led to several shortlisted interventions, one of which was focused on energy efficiency.

The personas were reviewed to create a longlist of interventions. Where possible, the longlist was contributed to by individuals with lived experience like that of the persona, or otherwise very close contact with individuals with actual experience.

The approach was to think first about which organisations might influence the DSO-readiness. These are the organisations which influence each persona and may be potential partners for WPD in framing an intervention. It was decided to focus on organisations (e.g. local authorities) rather than individuals, as organisations have greater scalability – influencing multiple homes.

Each idea was briefly described in 2-3 sentences. They were categorised as being primarily pertaining to (a) Information, (b) Incentive, (c) Regulation or (d) Other. This categorisation was partly as a prompt to ensure that a diversity of ideas was developed. In addition, Everoze identified which of the five elements of DSO-readiness could be influenced by the intervention

We then defined a shortlist of interventions by adopting a fourfold set of criteria to distil the longlist to a shortlist. These criteria were:

Criteria(weighting)	Consideration
WPD unique impact (/9)	To what extent is WPD particularly well placed to intervene, relative to other actors?
Scalability (/3)	How many WPD homes might be affected if this works?
Trial feasibility (/3)	How feasible is a trial, including cost and timescales?
Vulnerable customers (/3):	To what extent does the intervention have potential to benefit vulnerable customers?
Impact (/3):	To what extent does the intervention deliver material impact?

Criterion 1 was given a greatest weighting to account for FutureFlex being a Network Innovation Allowance (NIA) project, for which the goal is ultimately to ensure value for money to DSO customers. As a result, it is considered important to focus on activities where DSOs have unique legitimacy and/or responsibility to intervene. Reflecting this importance, Criterion 1 was assigned a score out of 9, whereas other criteria were assigned scores out of 3.

Scores were proposed by one author, and then reviewed and refined by two subsequent authors. There was inherently some subjectivity to the scoring, not least because the interventions were only briefly outlined at this longlist stage. Nonetheless, the review process helped provide some robustness to the scoring.

The scoring results were then plotted on a two-by-two axis, with the most attractive ideas appearing in the top right-hand corner.

The next step was to turn the shortlist into of 2-3 trials by adopting a portfolio view in framing these interventions. This included:

- Intervention type. For instance, taking forward a portfolio that blends a mix of direct WPD intervention, regulatory change, and market partnership.
- Risk-weighting: Choose to pursue interventions with different risk/reward weightings. For instance, one high risk, high reward item (such as pursuit of regulatory change) together with one low risk, lower-impact item (such as provision of enhanced information).
- Blending interventions: It may be possible to combine multiple interventions into one trial. For instance, if pursuing regulatory change, it might be possible to combine multiple recommendations into one single White Paper, delivered through partnership with Association for Decentralised Energy (ADE) or similar.
- Customer diversity: Ensuring that a diverse range of customer interests are represented within the portfolio.

This shortlisting led to several interventions, one of which was focused on energy efficiency. We briefly consulted energy efficiency providers on this, and it was concluded that it was essential to better understand the value of energy efficiency to the DSO, before proceeding to any external trial.

Modelling Energy Efficiency

The transition to Net Zero offers a series of conflicting challenges, the need to decarbonise through the adoption of EV's and Heat Pumps for heating will increase demand but the adoption also requires investment in Energy Efficiency in order to a) ensure the customer experience is positive and b) ensure that subsequent increases in demand are minimised through thermal efficiency.

The next step we took was to implement a modelling phase to better understand the scale of energy efficiency (EE) and its potential network value. This was the first step towards deciding whether it might be appropriate for the DSO to reward energy efficiency, and if so how this might be incentivised.

The value of domestic energy efficiency to the DSO is driven by two elements:

1) How EE measures affect electricity consumption at peak times: Each EE measure, such as loft insulation, has its own unique impact on the pattern of electricity consumption. The impact will depend on both the type of home in which the measure is installed and how the occupier's behaviour changes in response.
2) How much this effect is worth: There is only benefit to the DSO if demand from the grid is reduced during constraint periods. This value differs between different areas of the network.

The project team developed a discounted cashflow model which calculates what level of funding WPD could offer to support EE uptake while receiving a return on investment. The model relies on several key inputs including government data on the effect of EE measures on energy consumption, half-hourly resolution domestic demand profiles, and WPD data on the value and demand reduction requirements of two CMZs. The objective was to calculate the per-home funding that would allow WPD to achieve a £0 NPV investment.

The model has therefore been developed to address each element:

- Firstly, the model calculates the impact of several EE measures on domestic demand. Analysis of public domain data describing the impact of EE measures has been combined with domestic demand profiles to understand how EE measures change the profile of domestic electricity consumption in a range of scenarios.
- Secondly, the model translates this into value to the DSO. Matching consumption profiles with Constraint Managed Zone (CMZ) availability periods and the value of constraint alleviation services determines the value to the DSO of the installation of EE measures.
- The value of EE to the DSO has been fed into a discounted cash flow model to calculate what level of funding the DSO could invest in any EE uptake, while still breaking even on their investment.

- Discounted cash flow modelling has been performed for numerous scenarios, to judge whether the DSO could receive a return on their investment. This approach takes account of the longevity of the constraint issue, and the costs of providing funding.

This modelling phase considered a wide range of variables to understand which factors are most material. Differences in home size, heating type, and the energy efficiency measures installed, the severity of the CMZ constraint and the duration of the requirement for constraint alleviation were all considered.

This modelling work required access to several data sources that contained detail on typical domestic demand profiles, the effect of EE measures on these profiles, and the nature and value of alleviating distribution network constraints. These are detailed in figure 5-13 below;

Dataset	Description	Relevant data fields
National Energy Efficiency Data Framework (NEED)	Matching of gas and electricity consumption data from energy suppliers to information on energy efficiency measures installed in homes (under Green Deal, ECO and Feed-in Tariff scheme). The 2020 dataset contains 23.8 million records.	Property information (including type, age, floor area, council tax band); EE measures installed (loft insulation, cavity and solid wall insulation, solar PV); Annual gas & electricity consumption.

Dataset	Description	Relevant data fields
WPD Diversified Demand profiles	DFES scenario profiles for generation and demand on WPD networks.	Seasonal, half-hourly profiles for multiple generation and demand profiles including domestic, heat pumps, electric vehicles and solar PV.
National Energy Efficiency Data Framework (NEED)	Matching of gas and electricity consumption data from energy suppliers to information on energy efficiency measures installed in homes (under Green Deal, ECO and Feed-in Tariff scheme). The 2020 dataset contains 23.8 million records.	Annual electricity usage for houses with non-gas heating representing the 25th, 50th and 75th percentiles.
4D Heat project data	An NIA innovation project aiming to identify whether flexible electric heating systems could help alleviate transmission network constraints brought about by high wind generation.	Storage heater demand profile

Dataset	Description	Relevant data fields
WPD CMZ service value	Value of constraint alleviation in each CMZ	Service value
WPD CMZ availability profile (Hereford – Ledbury Ring, Brimscombe)	Availability profiles for each CMZ (half hourly, monthly)	Availability (2021, WPD Best View)

Figure 5-4: DRH - Data Sources

Numerous scenarios were modelled to understand all the different factors that can affect the value of EE to WPD. To compare different scenarios, in each case the per-home payment from WPD that would result in a NPV of approximately £0 was calculated. A NPV £0 investment is one where the cost (including the cost of capital) is equal to the value of revenue resulting from the investment over its useful lifetime.

The outcomes of this modelling are presented in the 'Realising the value of domestic energy efficiency in GB electricity distribution'.

5.3. Workstream 2B Sustain-H, including nested Aggregated Datasets workstream:

5.3.1. Introduction

As mentioned previously, the transition to Net Zero offers a series of conflicting challenges, the need to decarbonise through the adoption of EV's and Heat Pumps for heating will increase demand but the adoption also requires investment in Energy Efficiency.

The Sustain-H Trial aim was to demonstrate the provision of a DSO service suitable to domestic flexibility, which was accessible to both flexibility and energy efficiency, whilst giving options on data provision rather than being prescriptive on requirements using the three principles of being agile, holistic, and user-centric:

5.3.2. Objectives & success criteria

The Sustain-H Trial workstream looked to achieve the following objectives which formed the backbone of the trial design and evaluation of options.

- Remove barriers to uptake for domestic flexibility providing DSO services
- Give participants the flexibility to provide different data options
- Transition the trial into business-as-usual procurement

The success of the Sustain-H Trial was reliant on its ability to demonstrate network benefit to the DSO whilst ensuring participant interests were maintained. To this extent, the trial aimed to:

- Quantify the network benefits
- Quantify the value of the service
- Document learnings from service procurement

5.3.3. Methodology

To design the live trial the project team incorporated feedback and recommendations from the WPD Flexible Power team and market intermediaries who were considering participating in the trial.

The project team therefore developed the Sustain-H service to be a scheduled demand reduction service procured from households with LCTs and energy efficiency solutions, aggregated as a portfolio.

- The service was for domestic households with high-impact demand technologies – EV chargers, heat pumps and battery storage.
- As a parallel task, the team explored the options for extending this service to other smart/flexible demand technologies and energy efficiency solutions for after the trial.
- Service was to be contracted through market intermediaries such as suppliers and technology providers (who have partnered with a supply license holding entity) who could aggregate domestic households as a portfolio.
- Delivery was to be assessed at an aggregate portfolio level.
- As an outcome of the trial, explore the options for extending this service to non-supply license holding entities

The project team designed the Sustain-H service around the following core agreed elements.

- The participants eligibility requirements
- Sustain-H was developed as a scheduled 'drop-to' service
- The Project team then developed a baseline approach that was derived from network models as follows

Further details regarding these elements can be found in the 'Sustain-H Opportunity' document on our website.

Once all the service design principles had been agreed and communicated to the potential FSP's, the next step for the project team was to develop a customer journey which would allow easy registration for participants. Again, the 'Sustain-H Opportunity' and 'Sustain-H Design Guidance' explain this process in detail. In summary, a set of 'Data Requirements' were developed as well as a validation process.

The FSPs were given three options for how they could provide meter data.

1. **Smart Meter Dataset**: - metered data from the household smart meters aggregated across all homes.
2. **Asset Meter Dataset**: - metered data from the asset-level meters aggregated across all homes.
3. **Hybrid Meter Dataset:** - a combination of smart meter data for some homes and asset meter data for other homes.

Table 5-4: Summary of data options for monthly aggregated meter data provision

	Smart Meter Dataset	Asset Meter Dataset	Hybrid Meter Dataset
Data source for assessment	Household smart meters	Asset-level meters	Mixture of household smart meters and asset-level meters
Data required for ongoing delivery assessment	A single dataset of half-hourly (HH) meter data aggregated across all homes.	A single dataset of meter data aggregated across all homes.	A single dataset of aggregated meter data from smart meters and asset-level meters from all homes.
Meter data resolution	Half-hourly metering	Data resolution will be based on metering capability. Anticipated to be higher-resolution than half hourly.	Half-hourly – although asset-level meters may have higher metering resolution, meter data provided by FSP will be limited by the resolution of the smart meters.
Data provision frequency	Monthly – as a single dataset for the full calendar month prior. FSPs provide data for the entire month, including weekends, days and times when the service is not procured.		
Data provision method	Data is provided as a single dataset for the whole portfolio – this will be as a single file per portfolio; file format discussed below. FSPs send the dataset via email to a dedicated WPD email address.		
Data format	A default data and file specification for the portfolio meter data is included in Appendix 3. Ideally, data provided by FSPs for their portfolio(s) will be in this default format. We are open to be flexible on data format for the monthly datasets where this default data specification is prohibitively onerous to FSPs. Data format options are outlined in Appendix 3 – we can discuss this further to agree on a mutually convenient data and file format (specific to each FSP) to use for the trial. Prior to this discussion, we ask FSPs to provide an example data export of a full month's dataset that outlines their standard data format. We require FSPs to maintain the agreed data format for the duration of the trial. If any changes to the agreed data format is required, we can review the request at that time.		

Table 5-5: Summary of data options for monthly aggregated meter data provision

Remuneration for the Sustain-H service was utilisation only as opposed to availability-based where Flexibility Providers were remunerated for the actual demand reduction achieved relative to the baseline demand. The contracted flexible capacity represented the demand reduction expected from the FSP for the domestic portfolio and this would be achieved when the FSP was able to reduce its portfolio demand to a level below the TD.

If the portfolio demand was not reduced to a level below the TD (i.e. there is under-delivery), the full demand reduction in line with the contracted flexible capacity has not been delivered. Under-delivery was reflected in the payment calculations. Tariffs for service payment were based on a pre-defined tariff set by WPD based on the current Flexible Power approach.

Delivery assessment: frequency

Delivery assessment was done on a day-by-day basis for all the contracted delivery days in each month.

Delivery assessment: approach

For each delivery day, service delivery was assessed on the highest HH metered demand over the contracted *Delivery Period* for that day. Therefore, if the portfolio demand exceeded the TD even for one HH settlement period during the 4-hour delivery period in that day and the portfolio demand was below the *Target Demand* for all other HH settlement periods during the delivery period, remuneration for that day was based on the single exceeding HH settlement period. This is illustrated in the example below:

- The TD for a hypothetical portfolio was 50 kW and the delivery period for this hypothetical case was assumed to be the evening period between 4-8pm.
- For 7 out of the 8 HH settlement periods the portfolio demand was below the TD .
- If 1 out of the 8 HH settlement periods the portfolio demand exceeds the TD at say 55kW, this highest HH-metered demand was used for assessment of service delivery.

This may appear to be harsh in the application of the rules, but it is linked to the risk associated with the type of constraint. In most cases the issue being managed is thermal and if the FSP is allowed to earn the majority of the value for reducing demand for the majority of the time then it vastly increases the potential risk to the network. By measuring performance against their poorest performance over the whole period it places the onus on them to only contract for a TD that they can confidently deliver and in turn providing improved confidence to WPD.

Delivery assessment: scoring

For each delivery day, the maximum HH metered demand over the delivery period for that day was used to calculate a non-dimensional payment score. This payment score captured the utilisation element of the service delivery.

- If the maximum portfolio demand was below the *Target Demand* for a particular delivery day, then the payment score for that day was set as 1.
- If the maximum portfolio demand was greater than the *Target Demand* (i.e., not fully meeting the delivery requirement) for a particular day, then the payment score for that day was set between 0-1.

The non-dimensional payment score calculated for each day in the month is averaged over the whole month (only for the delivery days) to calculate the payment score for the month. Payment score was calculated via a two-step process and was incorporated into the payment formula:

Step 1: <u>Calculate ratio of actual delivery against contracted delivery</u>.

The difference between the baseline demand for the portfolio and the maximum HH metered demand was calculated. The result represents the actual demand reduction achieved relative to the baseline profiles.

The ratio of this result and the contracted flexible volume was calculated. This value represents the ratio of actual demand reduction against the contracted demand reduction.

Step 2: <u>Translate the ratio to a non-dimensional payment score</u>.

Gradient scoring: A score between 0 and 1 was calculated based on the ratio of the actual demand reduction to the contracted flexible capacity. To do this, a scoring curve that matching the payment mechanism applied under Flexible Power was used. This was with a view to align with existing business-as-usual practices for the services already procured under Flexible Power and not introduce a new payment mechanism.

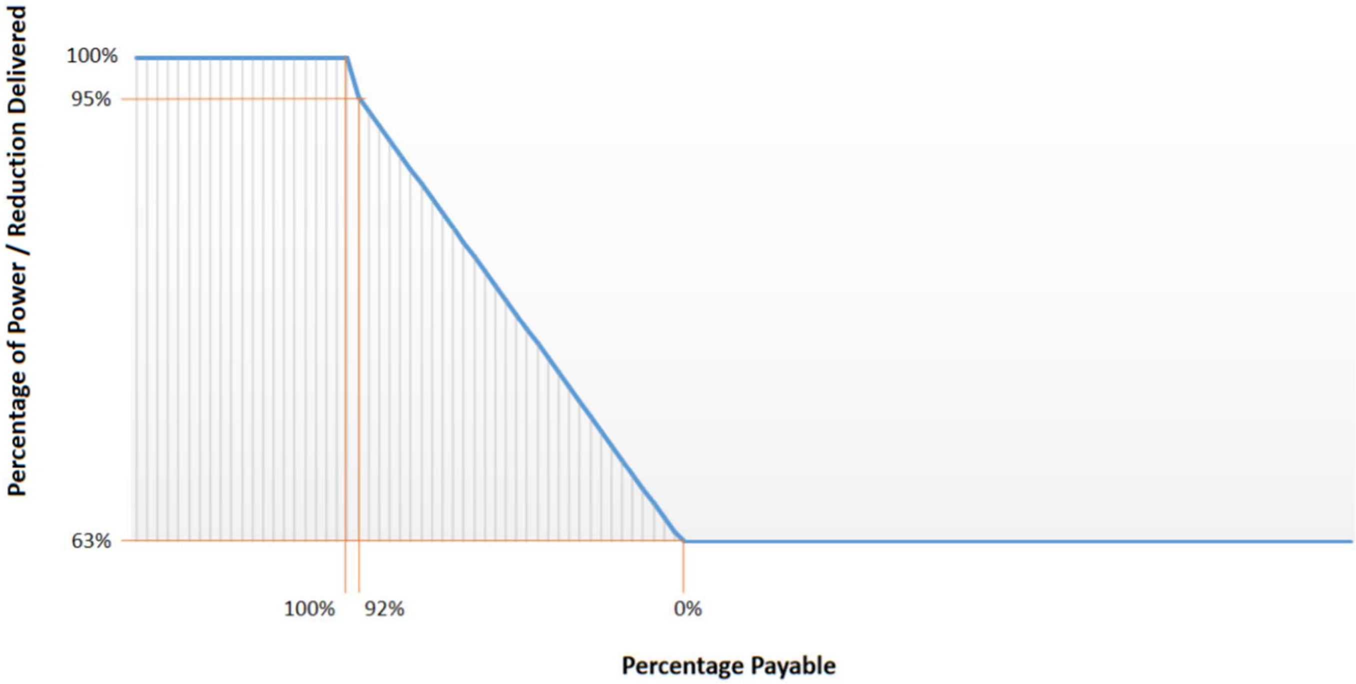


Figure 5-5: Payment % Curve

The formula to calculate the monthly payment to the Flexibility Provider was developed as shown below:

Monthly Payment = 'Tariff' × 'contracted flexible capacity' × 'monthly payment score' × 'de-rating factor'

The four variables included in the payment formula are as follows:

i) Tariff (GBP per kW per month): This is the pre-defined tariff for the Sustain-H service.
ii) Contracted flexible capacity: This is the contracted demand reduction and is the difference between the Baseline Demand and the TD for the portfolio.
iii) Payment score: This is the monthly averaged payment score calculated from the daily delivery assessments.
iv) De-rating factor: This reduces payments to reflect issues with data resolution, accuracy or completeness. The derating factor was neutralised and set at 1 for the Sustain-H trial.

Over-delivery

No payment for over-delivery by Flexibility Providers was offered as part of the remuneration mechanism. This was to avoid additional costs to WPD for such over-delivery where this may have minimal network benefit. The required flexibility volume would have been procured by WPD in advance (and therefore the cost already incurred) and so any over-delivery by a FSP is unlikely to help avoid these costs. This is also true of existing Flexible Power BaU services and furthers the alignment of Sustain-H with current principles.

All the performance and payment calculations were subsequently performed using the newly created "Performance Analyser Tool" specifically developed as a low cost, temporary manual system for the purposes of the trial. WPD ran this utility monthly by implementing the following tasks:

- Collection of all incoming performance data (demand) files by portfolio from all the participants.
- Filing all incoming performance data (demand) files by portfolio, month, season and potentially year in a permanent filing structure.
- Creation of standard Performance Analysis Utility input files for each FSP
- Clearing out any previous input files then copying the new input performance data set for the current analysis to the utility input folder.

- Clearing out any previous output files.   Ensuring that these were copied to the project permanent filing structure for permanent retention.
- Setting the required run control parameters on the '*Run Control Data'* input sheet in the Performance Analysis Tool Executable file.
- Setting the Portfolio details on the '*Portfolio Specific Data'* input sheet in the Performance Analysis Tool Executable file. This also allowed for adjusting of the main assessment parameters if the participants had requested to adjust these. This included items such as: Baseline power level, Target power level and which delivery periods were to be included that month.
- Running the Performance Analyser Tool.
- Inspecting the log file (if selected as written), Copying output files to the project permanent filing structure for permanent retention.

The '*Run Control Data'* Performance Analyser input sheet included the following block of main control flags and parameters.

Table 5-6: Run Control Data Parameters

Control Flags and Program Parameters	Value / Setting	Detail
Generate Accounts Payable Form:	**Yes**	
Omit Weekends:	**Yes**	If set to YES, Weekends are excluded from the performance analysis. Default setting is Yes.
Sustain-H Service Tariff GBP per kW:	**1.80**	Tariff in GBP per kW used in the payment calculation formula
Performance Assessment Method:	**Simple Drop-to Target**	The method used to assess the performance. The Simple "Drop to Target" option is the default as described in the project documentation, other options will be for Counterfactual assessment purposes and are not yet advised or implemented.
Payment Algorithm:	**Ratchet Reduction**	This defines how the payment drops off as a function of Performance Metric. Ratchet Reduction is the Default and is controlled by the parameters below defining the Grace Factor, the Drop percentage and whether to start the drop-off or not after the grace factor or from 1.
Payment Method:	**Pay Based on Mean Day**	Payment can be made for EACH day summing all day payments into a total for the window, or by finding the mean value for all days and using that. The latter results in a much lower overall payment and is the default setting
Payment Grace Factor:	**0.95**	This is the value (0 - 1) for the payment grace factor. Attainment above this value of the Performance Ratio gives maximum payment. The current default is a grace factor percentage of 95% corresponding to a value of 0.95. Participants are always paid in full for performance above the level of the Grace Factor.
Start Payment Drop after Grace Factor:	**Yes**	The drop in payment amount can begin immediately from 1 or can start immediately after the payment grace factor. The default is to start the drop-off after the Performance ratio falls below the grace factor.
Percentage Payment Drop per Percentage Performance Ratio Drop:	**3**	This figure defines the rate at which payment drops off as a function of the performance Ratio. Expressed as a percentage, it defines the drop in payment Score percentage per percentage drop in Performance Ratio. The default value is 3%
Direct Logging Output to Results File:	**Yes**	The User can choose whether to log the summary run results to the run log file. This is intended to track operationally significant job executions, testing, and conducting "what-if" analysis may not require logging to be conducted. It is left to the user to manage this, and the LOG file can currently be directly edited.
Create Accounts Payable PDF File for each Portfolio:	**Yes**	Directs the utility to create the accounts payable PDF file for each portfolio. Defaults to Yes.
Ask Before Overwriting Previous Output Files:	**No**	This control flag determines how the utility asks the user about overwriting existing output files. If set to "Yes" (Default) then the utility will ask about overwriting any previous output files in the working output directory. If "No", the utility will overwrite the files without first checking with the user.

Figure 5-6: Performance Analyser Utility User Guide

With all the preparations in place the project team launched the live trials in November 2020 which ran for 9 months until July 2021.

Dissemination and Transitioning to BaU Workshops

Following the conclusion of the live trials the project team digested the learnings and then delivered a dissemination Sustain-H workshop on the 1st of September 2021 sharing trial learnings and seeking participants feedback on the service. This was followed by several project team and WPD BaU team internal workshops which culminated in the compilation of a document “Product roadmap October 2021” which was the documented plan for commercial rollout and ongoing improvement of Sustain-H.

5.4. Aggregated Datasets:

The role of the Aggregated Datasets workstream was to quantify the impact of lower portfolio data quality for WPD’s DSO services. This was needed because domestic portfolios have different data characteristics to large commercial assets.

The methodology of the Aggregated Datasets workstream focused on data resolution, completeness, and accuracy. The methodology used is summarised in Figure 5-20 below: the approach was to independently analyse Resolution, Completeness and Accuracy Uncertainty Factors. These three uncertainty factors were then combined into a single ‘data quality factor’ for each technology type. This then informed any ‘data moderating factor’ that may be introduced in the longer-term for Sustain-H remuneration, after the service is established.

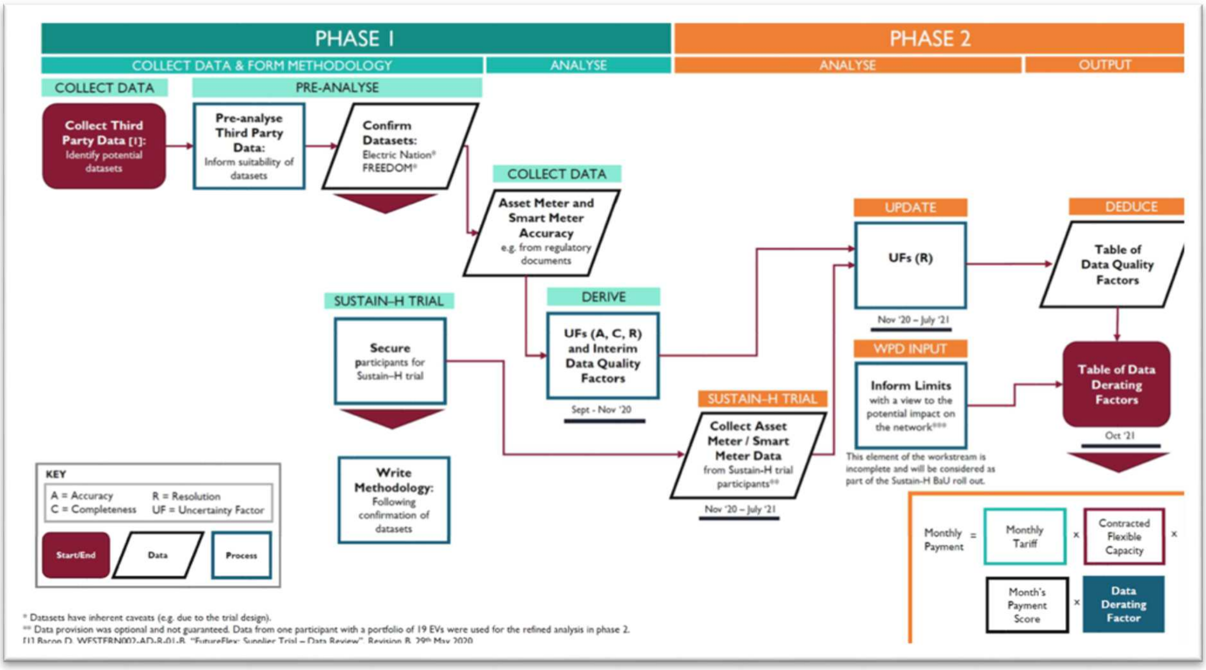


Figure 5-7: Aggregated Datasets Workstream Process

The Aggregated Datasets analysis was conducted in two phases. Phase 1 conducted analysis on third party datasets from two separate trials: ‘Electric Nation’ (electric vehicles) and ‘Freedom’ (heat pumps). Phase 2 refined the analysis using data from the Sustain-H service trial.

The findings from the analysis undertaken during this project were summarised in the report "Aggregated datasets – Third Party & Sustain-H Datasets Analysis" issued by the project team 1st November 2021. The findings are discussed in the Learnings and Outcomes section of this report.

5.5. Workstream 2C Pro Low Carbon: Promote lower carbon sources of flexibility.

This purpose of this trial was seeking to amend the design of DSO markets to actively reflect the negative externality of carbon and enable the net zero journey. With the objective of Pro Low Carbon being to explore and understand the carbon impact of procuring DSO services from local flexibility technologies.

Methodology

Assessing the carbon impact of DSO flexibility services required a specialised approach.

Measuring carbon impact is not the same task as measuring carbon emissions. Flexibility services interact with the electricity network and influence the makeup of grid generation.

The impact of this interaction needed to be measured, which is why measuring carbon emissions from just the flexibility asset was itself not sufficient. Understanding the impacts arising from both the flexibility technologies themselves and their interactions with the grid required a unique approach.

A positive example of this was previously demonstrated when National Grid balancing services were originally opened to wider participation through aggregators and there was a large influx of standby diesel generation seeking to participate in the new commercial opportunities including Short Term Operating Reserve (STOR). This was initially met with concerns regarding the carbon impact of what appeared to be relatively carbon intensive assets increasing their annual usage by up to 50 hours. However, for the majority of the time these assets fulfilled their primary 'stand by' purpose by remaining idle with the ability to activate in under 6 minutes. In doing so they were able to displace large coal, oil and gas power stations which were previously held as spinning reserve. This means they were consuming fuel just to remain warm and in a state of readiness, often without providing any meaningful contributions to the GB generation requirement. The net result of this in 2008 was equivalent to as much as 300 tons of CO_2 per MW per annum.

To understand the impact of procurement decisions we needed to be able to compare different technologies.

Our methodology enabled the impacts of different technology use cases to be viewed alongside each other. It measured impacts relative to a base case of not procuring the DSO service. This is known as a consequential approach.

The use of marginal carbon intensity data materially affects the results of this work.

A common alternative in carbon accounting is to use average grid carbon emissions. The carbon impact hierarchy for the different technology use cases assessed in this work is highly sensitive to the assumptions and data sources used, including the type of grid carbon intensity data selected.

Our methodology adopted a holistic approach to carbon assessment.

By calculating impacts from both operational and non-operational phases of a flexibility technology's life the full carbon impact of DSO service provision was captured. Carbon impact was defined as the sum of operational and non-operational impact, as depicted in Figure 5-21.

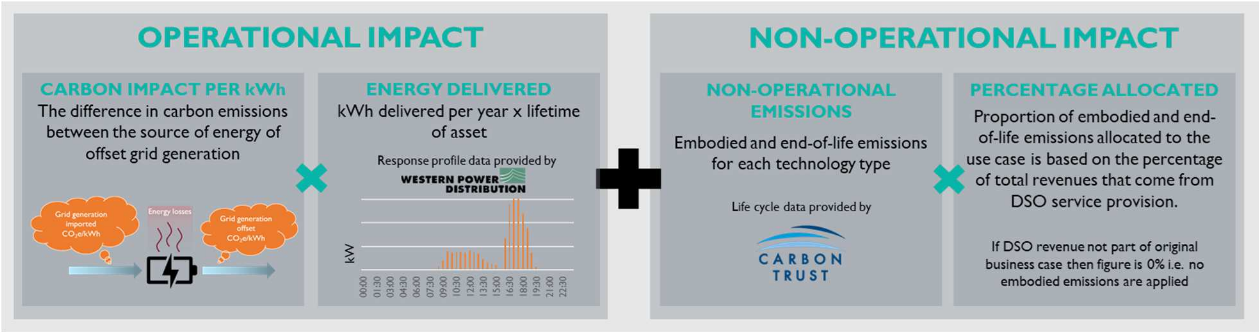


Figure 5-8: Pro Low Carbon's methodology for calculating carbon impact

Operational impact arising from the active provision of DSO services.

The operational impact of providing a DSO service is defined by the difference between (a) the carbon emissions incurred by the flexibility technology in providing the service and (b) carbon emissions of the generation that is offset. The operational carbon impact of providing a DSO service can be determined by calculating this difference for each technology use case:

ENERGY GENERATED OR IMPORTED				ENERGY OFFSET		
Energy in	x	Carbon intensity	–	Energy offset	x	Carbon intensity
kWh		gCO2e / kWh		kWh		gCO2e / kWh

This calculation is repeated for each half-hour period over a year. The sum of the result for each half hour gives the operational carbon impact for the year. Multiplying this number by the lifetime of the asset gives the operational impact of providing the DSO service over the full operational period.

Operational impacts were calculated as described in Figure 5-22. This calculation was built upon asset utilisation assumptions for DSO services, here representing the requirements of service delivery in one of WPD's Constraint Managed Zones.

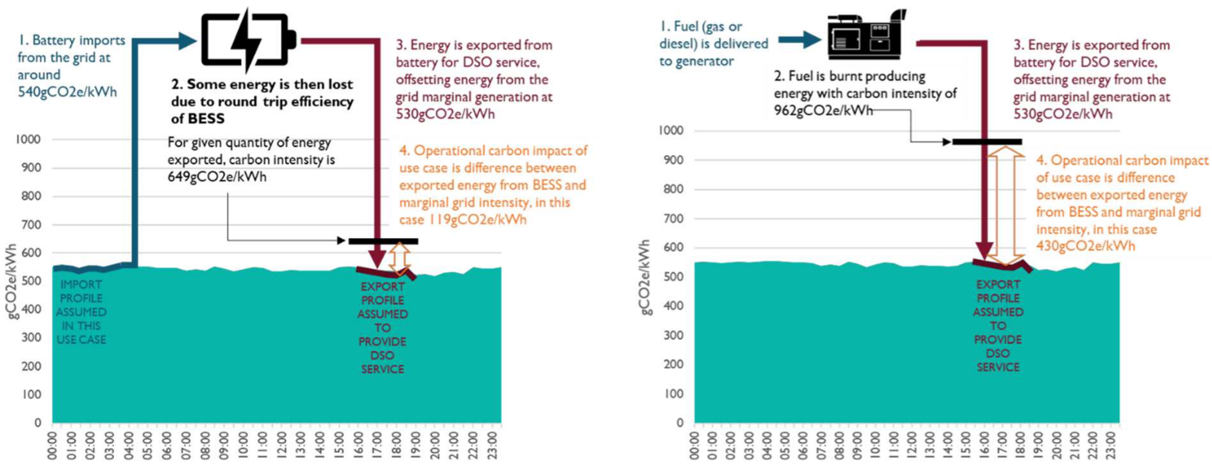


Figure 5-9: Calculating operational carbon impact for different flexibility technologies

Non-operational impacts made up of embodied and end-of-life emissions.

- The Carbon Trust provided data on non-operational emissions to this work, which was drawn from peer-reviewed life cycle assessments. The core methodological challenge was to establish the proportion of these emissions that should be assigned to the provision of DSO services.
- Only a proportion of non-operational emissions could be attributed to the carbon impact of DSO flexibility services because the technologies providing these services typically had multiple roles – including heating, mobility, and provision of ancillary services to National Grid ESO. The Pro Low Carbon methodology allocated a proportion of non-operational emissions equivalent to the contribution that DSO service revenues make to the asset investment case.

6. Performance Compared to Original Aims, Objectives and Success Criteria

Project outcome highlights:

- Sustain-H (including Aggregated Datasets): A successful trial has been run, engaging 7 participants rather than the 2 originally targeted. FutureFlex has developed a new DSO service which will proceed to be rolled into BaU, adopted by Flexible Power with support from the WPD Innovation. We have produced the Product Roadmap for this transition and three parties have already signalled their interest to participate in this commercial service.
- Pro Low Carbon: FutureFlex developed carbon quantification for DSO services which has been shared with and incorporated into the work of (a) BEIS and Ofgem's workstream on the carbon impact of flexibility, and (b) Energy System Catapult's Energy Digitalisation Taskforce. We took this approach because feedback from BEIS and Ofgem in late 2020 asked that Future Flex's outcomes should be considered at a whole system level rather than WPD directly incentivising lower carbon forms of flex – hence our workstream outcomes are reflected at a wider, whole system level.
- DSO-ready Homes: The project has not delivered the intended outcome of tested interventions on how to make homes DSO-ready, and amended its scope halfway through. Instead, we have created the enabling environment for tested interventions to take place. The reason for this was twofold:
- DSO-ready Homes: Insufficient data to develop a targeted scheme: We hit the barrier that the value of domestic energy efficiency to the DSO was not quantified, and so a business case and pilot could not be well framed. As a result, we focused on quantifying the business case, to address this problem.
- DSO-ready Homes: Industry feedback suggested that a partnership, cross-industry approach to be more appropriate: Domestic energy efficiency is a complex landscape, where value is stacked across multiple parties. It was not clear that the DSO should be conducting narrow DSO-led interventions by itself in this space – as such we amended the scope to develop a Roundtable (with Sustainability First) where a broad range of industry actors came together to form a consensus on what the DSO role should be. This was particularly timely in the run-up to ED2 business plan finalisation.
- DSO-ready Homes: rather than delivering proven interventions, we created the enabling environment in which those interventions can be delivered – and scoped out with industry how a 'beacon scheme' for energy efficiency might look. It is recommended that this is developed into a follow-on collaborative innovation project.

7. Required Modifications to the Planned Approach during the Course of the Project

The most substantial changes that embraced the commitment to and application of agile working were as follows:

Substantial scope of work and budget amendments following workshops: Industry participants did not just refine our thinking on running a trial, but also challenged us to raise our ambition and reach. In particular, they pointed out that a supplier trial was necessary but not sufficient for homes to support the DSO. In addition, it was needed to rethink the wider customer journey (including energy efficiency), and also to consider the carbon impact of domestic flex, with a view to pricing this in, to increase the value of providing DSO services. This industry feedback led to substantial scope and budget increases, as documented in detail in our 'Ideas for Trial' report. In response the workstreams of DSO-Ready Homes and Pro Low Carbon were added

DSO-ready Homes – transition away from developing proven interventions: We originally intended to develop a set of costed, proven interventions in this workstream. However, as we progressed, it became apparent that this was not achievable, and amended the scope accordingly. Instead, we have created the enabling environment for tested interventions to take place. The reason for this was twofold:

- Insufficient data to develop a targeted scheme: We hit the barrier that the value of domestic energy efficiency to the DSO was not quantified, and so a business case and pilot could not be well framed. As a result, we focused on quantifying the business case, to address this problem.
- Industry feedback suggesting that a partnership, cross-industry approach is more appropriate: Domestic energy efficiency is a complex landscape, where value is stacked across multiple parties. It was not clear that the DSO should be conducting narrow DSO-led interventions by itself in this space – as such we amended the scope to develop a Roundtable (with Sustainability First) where a broad range of industry actors came together to form a consensus on what the DSO role should be. This was particularly timely in the run-up to ED2 business plan finalisation.

Sustain-H budget increase: Our original budget assumed that we would have 2 participants in the Sustain-H trial. However, industry interest was much greater than expected. We ended up engaging 9 participants in detailed discussions in the trial, which ultimately led to 7 parties participating. This increase from 2 to 7 participants was incredibly valuable, because their allowed for a greater diversity of participants, coming from different backgrounds (big six, small suppliers, aggregators, community energy, EV innovators etc). Capitalising on this we were able to maximise learning by understanding the differing needs of different industry players. The decision was taken to proceed with all 7 participants and increase the budget to accommodate the additional work entailed.

Sustain-H – addition of Product Roadmap to aid BaU transition: The Sustain-H service gained good traction, and so we decided to transition it from innovation into BaU. This led to us adding an extra module to our project: development of a Product Roadmap, working in partnership with WPD's Flexible Power team.

Change Requests:

Change Request	Rationale
Pro Low Carbon De-scope	Following feedback from Ofgem we de-scoped some elements of the Pro Low Carbon work within the project. Notably we did not explore options to price carbon in DSO services, whom might pay, or trialling options. Instead, we focussed on understanding the carbon impact of the services procured and the provision of data to policy makers.
Amendments to Future Flex trial 1 following participant feedback in phase	We removed the £200k budget for system build; as this was no longer required to be trialled as it was possible to demonstrate a simpler Scheduled DSO service that honoured participant feedback. The £200k budget was reallocated to adopt a portfolio approach to trial development, to better capture the diversity of participant feedback on where the barriers to domestic flex lie. A large number of participant ideas were developed in workshops and subsequent interviews, and through criteria and consultation selected the strongest ideas.

COVID

Our project timing was fortunate in that we held our two industry workshops two months before the first COVID lockdown. However, we faced the challenge of scoping out the Sustain-H trial, and securing industry participation, all remotely. It also created personal challenges for some team members who had a disrupted work environment at home. We adapted by transitioning to virtual media, and by keeping to weekly calls to maintain momentum. In some instances, a virtual approach was potentially less efficient than face-to-face, but it did not materially affect our scope, and no budget amendments were required.

8. Project Costs

Final Costs are detailed below, the project has come in under budget and this is because of the following factors:

1. The impact of the pandemic and the reduction in contractor costs due to a lack of meetings face to face
2. More efficient use of internal staff

Table 8-1: Project Spend

Activity	Budget	Actual	Variance(£)	-Variance (%)
Project Management	£110,064	£68,485	-£41,579	-38%
Contractors	£632,249	£542,191	£-90,058	-14%
Total	£ 742,313	£610,676	-£131,637	-17%

9. Lessons Learnt for Future Projects

We have generated significant feedback over a range of topics. This has been analysed and is presented in the workshop report.

9.1. Workshop feedback

We generated significant feedback over a range of topics at the two industry workshops. This has been analysed and is presented in the workshop report, which is included in Appendix 1

9.2. DSO-Ready Homes

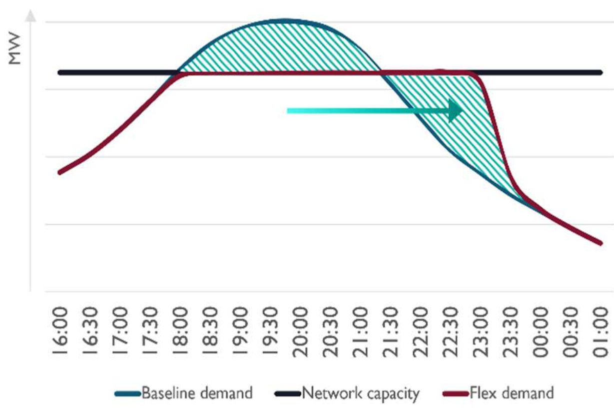
9.2.1. Findings from desktop work

Changes in domestic energy consumption can reduce the prevalence and severity of network constraints in two distinct yet complementary ways.

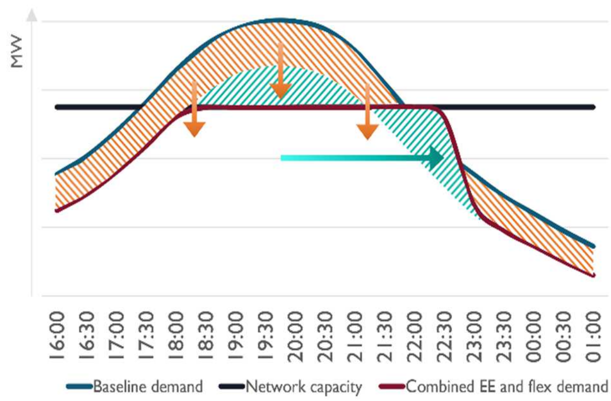
- **Flexibility** allows home energy usage to respond to appropriate signals, shifting energy consumption outside of peak times. Flexibility is ideal for ensuring that non-time-specific consumption does not unduly contribute to network constraints – for example, charging electric vehicles at times of ample network capacity.
- **Energy efficiency** delivers permanent changes to consumption patterns, reducing rather than shifting demand. Energy efficiency has the greatest network value when applied to consumption for which significant shifts in time are difficult, or where efficiency can act as an enabler for flexibility. An example is the growing demand for electrical heat in homes during winter evenings, which energy efficiency can permanently reduce and can also enable to be shifted, helping homes to act as thermal stores.
- Flexibility and energy efficiency are complementary, and their combined effect may be required where network constraints are most severe.

Energy efficiency for low-carbon constraint alleviation
Using flexibility to shift electricity consumption does not change how much energy is consumed and therefore does not have a significant, direct contribution to carbon savings. Future Flex project analysis shows that using domestic flexibility to manage distribution networks constraints results in between 7 and 109 grams of *additional* CO_2e per kWh, albeit this is below conventional flexibility technologies.

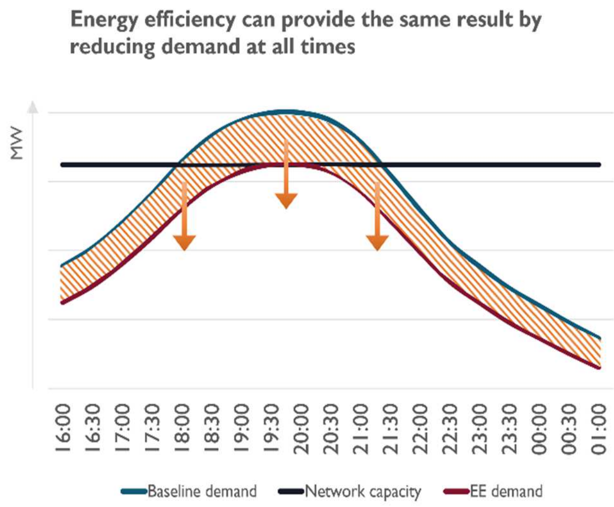
Flexibility protects against network constraints by shifting demand to off-peak times



For the most severe network constraints, the combined effect of both flexibility and energy efficiency may be needed



In contrast, energy efficiency can contribute to network management while simultaneously reducing electricity consumption. Therefore, prioritising energy savings from key sources of demand will help meet DSO requirements for network alleviation while also contributing to distribution system decarbonisation.



Energy efficiency has network value additional to the energy savings experienced by the consumer. To calculate the system value of energy efficiency, the Future Flex project used real-world empirical data from the National Energy Efficiency Data framework (NEED). Data showing the effect of household energy efficiency improvements on electricity consumption allowed the creation of efficiency-adjusted half-hourly domestic demand profiles. Mapping the adjusted profiles against WPD's known constraint alleviation costs provided an estimated energy efficiency system value for each profile.

The modelling was led by Everoze and checked by WPD, based on data from BEIS and Flexible Power[1].

Three key findings emerge from the analysis:

Key finding 1: energy efficiency could deliver an overall network value of up to £1,000 per home
The results of the modelling exercise show clear network benefits from energy efficiency improvements. However, the findings also reveal that the system value of energy efficiency is highly locational and varies widely depending on homes' energy usage profile and local network conditions.
The principal drivers of the scale of savings are the severity of local network constraints, the duration of the constraint, and the type of heating system installed in a home.

- Installation of energy efficiency measures in areas with **severe network constraints** realises approximately **seven times** more value than in areas with moderate constraints.
- Energy efficiency delivers **five times** more value in zones with **chronic network constraints** (5-year) than in regions with short-term (1-year) constraints.
- Among homes with electrified heating, the value of energy efficiency varies by **heating type**, with heat pumps or conventional electric heating delivering **three times** more value than storage heaters.

"In zones with severe and prolonged constraint issues, the installation or improvement of thermal insulation could have a network value of almost £1,000 over its lifetime."

Key finding 2: the size of home and type of energy efficiency measure are secondary factors

- Improving the energy efficiency of homes with higher underlying electricity consumption realises greater network value.
- The type of energy efficiency action also has an impact, with cavity wall insulation and solar PV having the most significant effect, based on the limited data available at present.
- However, these factors have a less significant influence than the severity of the network constraint, its longevity and the type of heating installed.

[1] A unified resource for the advertisement, procurement and operation of flexibility services across five UK DNOs: Western Power Distribution, SP Energy Networks, Scottish and Southern Electricity Networks, Northern Powergrid and Electricity North West.

"In very large houses, the network value of installing solar PV and improving thermal insulation could double to more than £2,000."

Key finding 3: homes with the greatest energy efficiency network value are uncommon but geographically clustered

- Currently, a minority of homes are located in areas with severe network constraints, but the prevalence of constraints is expected to increase.
- Network constraints are inherently local phenomena and can be addressed only from within a precisely defined area.
- Patterns also exist in the geographic distribution of heating types, according to local housing stock.

"The greatest potential exists in local areas with both severe, chronic network constraints and homes with heat pumps or conventional electrified heating."

Domestic energy efficiency should be a policy priority. Saving energy in the home offers a low-cost, low-carbon approach to mitigating network constraints that strongly aligns with broader policy and regulatory goals to meet net zero and protect vulnerable consumers. Given these advantages, we suggest that realising the distribution network value of energy efficiency should be an urgent priority for regulators, network operators, and other stakeholders in the GB electricity distribution system.

But at present, there are barriers to accessing this value. Future Flex has uncovered several key challenges to designing and implementing commercial and regulatory models that fully reflect the network value of domestic energy efficiency.

- **The existing funding landscape is complex:** There is a wide range of active schemes for domestic energy efficiency providing funding at a national, regional and local level. However, these schemes are difficult to navigate for the customer, are poorly integrated, and subject to frequent changes. They also fail to join up the efforts of the many motivated participants in the energy efficiency sector.
- **The benefits of energy efficiency are dispersed:** Energy efficiency benefits many different parties, presenting a challenge in how to draw diverse beneficiaries together into relationships that combine the value received by each and convert this into a single customer incentive.
- **Network services are designed around the DSO:** DSOs typically frame service procurement around their own technical requirements and timescales. This approach is suitable for dedicated flexibility assets but not for people's homes, where provision of DSO services is not a primary concern. DSO-centric processes contribute to the low consumer engagement in domestic flexibility reported by Future Flex workshop participants.
- **It is unclear how best to incentivise efficiency**: Future Flex has piloted a domestic incentive scheme that is agnostic to flexibility and energy efficiency in hundreds of homes. The findings of our 'Sustain-H' pilot and supporting work show that both operational payments and direct grant funding have their merits for energy efficiency, but there is no clear winner in all situations. Domestic energy efficiency solutions require a deep understanding of people and their homes, suggesting that a successful approach will be local and customer-focused, not centralised and technocratic.
- **The available data is insufficient:** To date, energy efficiency grant schemes have focused on collecting data to illustrate annual reductions in energy consumption. But to fully evaluate the system benefits of energy efficiency described here, high-resolution time-series data showing the impact of energy efficiency improvements over the course of the day is needed.

The first step towards realising the value of domestic energy efficiency in GB distribution networks is a series of large-scale trials to establish the evidence base for future commercial and regulatory arrangements. WPD is broadly supportive of the recommendation made by Sustainability First that DNOs should establish partnerships to deliver major 'beacon' energy efficiency schemes with a focus on vulnerable customers over the next five years. This is though a complex challenge given the current industry structure of Supplier Hub.

Going forward, it is essential that Ofgem provides clarity on the proposed funding route for trial schemes, whether through the Strategic Innovation Fund (SIF) proposed in the 2023-2028 electricity distribution price control (RIIO-ED2), or via some other mechanism. Well-designed trial schemes will provide the networks, industry, local authorities, energy suppliers, and customers the opportunity to develop and implement the necessary changes before network constraints become more acute, widespread, and costly.

To contribute to what we hope will become a major theme of network innovation, we have established five principles for successful energy efficiency trials in the distribution system:

1. Tailored by location

The network value of domestic energy efficiency is highly location-specific. Therefore, we must tailor trial schemes to the technical specifics of distribution network constraint issues, to local demographics, housing tenure and housing stock. This means that trials must draw on expertise held by local communities, local authorities, not-for-profits and businesses to achieve effective engagement.

2. Collaboration and coordination

Energy efficiency solutions cannot be isolated from the broader energy system. They have technical, market, regulatory, and social impacts involving many stakeholders from across society: value is shared between multiple actors. Successful trial schemes will therefore require DSOs to work collaboratively and take a whole-systems approach that builds on existing efforts, rather than starting anew. This includes integrating with existing energy efficiency activity supporting vulnerable customers.

3. Consumers at the centre, always

The energy system is egalitarian and exists for energy consumers. Future Flex engagement has shown the need for consumers to be at the centre of the energy system.

4. Commitment to experimentation, learning and innovation

Future Flex has examined the relative merits of various commercial arrangements and found no universally satisfactory model. Optimal approaches to realising the network value of domestic energy efficiency will be innovative and potentially novel. Therefore, trials should be open to the full range of commercial possibility, including, for example, the valuation of energy efficiency's social and strategic benefits. There is still some work to be done to fully realise the value of residential flexibility but as mentioned elsewhere in this report, DNOs do not currently have the remit to fully leverage the value due to the current market structure.

5. Data, data, data

There is a deficit of public-domain, high-resolution, real-world data on the effects of energy efficiency improvements on energy demand in homes[2]. To make better decisions, we need a stronger understanding of the relative merits of different solutions for energy efficiency and how they interact with other technologies and practices, such as flexibility. High-quality data gathering and dissemination should be a core aim of all trials.

9.2.2. Findings from industry roundtable

In this section, we summarise the findings from the DSO-Ready Homes industry roundtable convened by FutureFlex, attended by the following organisations:

Active Building Centre
Agility Eco
Association for Decentralised Energy
BEIS
Centre for Sustainable Energy
Citizens Advice
Climate Change Committee
Energy Savings Trust
Energy Systems Catapult
Energy UK
Everoze
Frontier Economics
Graham Oakes Ltd
Midlands Energy Hub
Regen
Scottish and Southern Electricity Networks
Smart Grid Consultancy
Greater South East Energy Hub
SP Energy Networks
SSE Energy Services
Sustainability First

[2] This finding is supported by the Final Report – Phase 2 of the Smart Meter Energy Data Public Interest Advisory Group.

EDF Energy	*National Energy Action*	*UK Power Networks*
Electricity North West	*Northern Power Grid*	*Welsh Government*
Energy for London	*Ofgem*	*West Yorkshire Combined Authority*
Energy Networks Association	*Ombudsman Services*	*Western Power Distribution*

9.2.2.1. In ED2, what gaps could DNO energy efficiency schemes or trials fill?

1) Improving understanding of the combined benefits of thermal insulation schemes for DNOs with a focus on:

- Consolidating the evidence and research that has already been carried out
- Exploring poorly understood sources of value
- Developing cost-benefit analyses (CBAs) to evaluate energy efficiency interventions

a. Considerable work has been undertaken exploring the benefits of energy efficiency (EE) for DNOs. Yet to date, there have been few efforts made to **i)** consolidate and reach agreement on the different sources of value and their scale, and **ii)** validate and evidence the results of small scale and desk-based studies. Proving the benefit at scale and across different network locations should be a priority.

b. EE comprises multiple different technologies with a wide range of use cases, conferring an equally wide range of potential benefits to the DNO, not all of which are well understood. We need to improve our understanding of the full range of benefits and their value to the network.

c. To be able to support large scale EE interventions, we need to be able to show how the cost-benefit stacks up for DNOs against alternatives (network investment, flexibility). As well as the costs (upfront capital, implementation etc.), any EE CBA tool should carefully consider all EE benefits (individual, societal, and enduring). The CBA should take account of uncertainty on both sides of the equation, considering the growth in electricity demand, the growth in flexibility and the option value that EE offers to the electricity system. The CBA tool developed by the ENA may offer a good starting point.

2) Coordinating and bringing together the diverse beneficiaries of EE

EE interventions offer co-benefits to many different parties. For instance, the network benefits to DNOs and the ESO, health benefits conferred on the health service, and money saved and home comfort improvements to the homeowner. However, from a pure network standpoint alone, EE investment is likely to be warranted at relatively few congested network locations. Elsewhere, investment can only be justified if the advantages for the network are combined with other benefits. With effective partnership and collaboration, DNOs will be well placed to help coordinate different beneficiaries, determining how their own funding contribution could best complement funding from others. To take on this role, DNOs will need policy and regulatory support.

3) Data gathering

There are significant gaps in our understanding of homes in each network area. Better data on home energy use is needed to understand where interventions should be focussed and in which homes. Any data gathering exercises should pay careful consideration to privacy concerns and data protection regulations and recognise the principles of the 'supplier hub' model.

4) Understanding other elements key to EE success, including:

- **The supply chain**
- **Consumer acceptance**

a. If DNOs are to initiate EE interventions at scale, they will need a good understanding of different actors and pathways to energy efficiency delivery, including knowledge of the supply chain and network of installers for EE technologies.

b. Domestic EE interventions cannot be delivered by DNOs without the approval and acceptance of the consumers who will be affected. DNOs will need to consider how best to integrate any plans they may have to offset network investment via energy efficiency schemes with the delivery of their vulnerability strategies. The needs of consumers should be prioritised to improve the acceptance of new measures.

9.2.2.2. What might the focus and outcomes of DNO involvement in energy efficiency schemes look like?

1) Ofgem require thorough justification of DNO involvement

Ofgem requires that the focus and outcomes of DNO involvement in EE schemes be thoroughly justified and firmly in line with the remit and licence duties of the DNO. There are many areas where EE can come under the remit of the DNO, including customer vulnerability, load management and as an alternative approach to network reinforcement. Ofgem encourages DNOs to explore the use of EE across such areas but will require firm justification in the ED2 business planning process, which is guided by achieving net-zero at the lowest cost to consumers. Investigation of the role of other parties and how efforts are shared is also encouraged.

2) DNO EE activity could be better coordinated, and look to upcoming UK government policy for strategic direction

DNOs need to be mindful of the risk of duplication of efforts on a topic where bespoke, local approaches are key. DNOs should be alert to this, ensuring coordination between schemes and being on the lookout for duplication where there are no clear consumer benefits. In the wake of the new Heat and Buildings Strategy, the ENA will be well positioned to bring DNOs together with key parties to support good coordination.

3) Information sharing

DNOs have a unique view across their networks, including on future development of electric heat and uptake of other low-carbon technologies. Analysis and communication of such information should be a focus of DNO involvement in EE schemes. This can have multiple benefits, from aiding (and persuading) consumers to make well-informed decisions on their home energy use, to helping local authorities in directing support toward areas and households which most need it and which have the greatest potential for positive network impact from EE. DNOs are trusted and could engage more actively in promoting the benefits of improved energy efficiency measures. To do this, they will need support and buy-in from others, especially from the energy suppliers that own the customer relationship.

4) Coordinated interventions across EE and flexibility

Consumer behaviour will change to meet net-zero targets. Smart meters, electrified heating, energy efficiency improvements, domestic flexibility technologies, and electric vehicles are all cornerstones of government strategy and will all require consumers to adapt. To ease this process, interventions need to be considered collectively and coordinated to bring minimum disruption and minimum cost to consumers.

9.2.2.3. How might schemes be funded?

1) Funding from existing pots can be used for small-scale projects

Careful consideration needs to be given to the exact nature of where funding for further trials is provided. Ofgem has stated before that DNO's could fund EE if a strong business case can be made for doing so but equally the current structure of the industry may prove a barrier to doing so. Moreover, there remain questions as to whether NIA funding is an appropriate source as its purpose if new low TRL projects or research, not the implementation of known and proven technology.

2) DNO thermal insulation projects as an offset to network reinforcement have yet to be funded as a business-as-usual approach

Modelling undertaken as part of several NIA projects suggests that thermal insulation of homes could be a cost-efficient alternative to network reinforcement at certain congested locations[3]. EE does not have a dedicated funding pot, but, subject to Ofgem's need for 'thorough justification', there are several approaches to funding for DNOs to explore.

3) DNOs are not the sole beneficiary of EE and do not need to be its sole source of funding

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[3] For reference, the NIA projects on energy efficiency presented at the workshop were: Project SAVE and Smart & Fair? (SSEN), Heat-up (SPEN), Firefly, CommuniHeat and Heat Street (UKPN).

DNO funding will only ever be part of the equation. Many other parties that benefit from the effects of EE interventions can also provide their share. The concept of 'revenue stacking' for flexibility technologies, where investment is only made viable through the combination of multiple different income streams, is well understood. The same idea should be applied to investment in EE. The major challenge then becomes how to develop collaboration between all beneficiaries to unlock collective funding, which benefits the individual household as well as delivering wider affordability and net-zero benefits.

4) Funding that is sourced from network charges can be regressive

All DNO-based funding is ultimately sourced from the charges that network users pay on their bills. This charging can be regressive. Equally, it is noted that EE should reduce the overall amount of network reinforcement necessary and its resultant costs. Fairness for the consumers should be a priority when considering funding mechanisms for EE schemes.

9.3. Sustain-H

9.3.1. Learnings pre-trial (2019-20)

- **There is high interest in DSO services in provision of domestic flex.** FutureFlex originally targeted inclusion of two participants for the operational trial but ended up with 7. However, a key challenge in securing signup was the low value of Sustain-H.
- **For domestic flex, there is a close relationship between network time-of-use (ToU) tariffs and DSO services.** As network charging rules are governed at national level, in this project we focused on amending DSO services which lie within a DNO's direct control. However, we believe that there are many benefits to a time-of-use approach baked into network charging arrangements which merit consideration – less administration, avoiding tricky baselining questions, avoiding asset qualification requirements. We strongly recommend that this is considered further, as in the mid to long term it is likely more sustainable and appropriate than a scheduled DSO service.
- **Domestic flex portfolios are dynamic**. Multiple parties have challenged whether confirmation of volumes and asset qualification was strictly necessary to be fixed upfront. Participants explained that they are onboarding and potentially churning customers on a continual basis and prefer to confirm portfolios as close to real time as possible.
- **It is still unclear who will lead the customer relationship for domestic flex:** There is an open question on who the market intermediaries are that WPD should be engaging with in domestic DSR, who own the customer relationship. Historically it has been assumed that these intermediaries are energy suppliers; i.e. organisations who hold a supply license. However, Elexon's code modification (P375) opens the door to asset-level metering. In addition, the Virtual Lead Party (VLP) route in the Balancing Mechanism is indicative of a growing route-to-market for independent aggregators. In terms of industry trends, we are witnessing a growth in tech aggregators, particularly in the EV and domestic battery space, who do not have a supply license. These tech aggregators may in theory be able to offer services to DSOs from domestic portfolios, without holding a supply license.
- **The current approach for treatment of battery storage in network planning (100% demand at all times of the day) is conservative** and beyond what a typical home battery system will be operating under even in extreme operating regimes. Notably, battery storage demand patterns would be heavily reliant on the use case – the profiles for a 24/7 FFR use case and a use case with surplus solar capture and export during evening peak periods would be considerably different
- **Baselining is an important aspect to clarify for participants.** All participants have a strong interest in baselining approaches, as this ultimately defines the revenue on offer. Multiple parties have requested greater understanding of the baselining methodology used by WPD (ultimately derived from the diversity profiles).
- **Industry views have been relatively diverse, reflecting a range of business models and approach.** For instance, whilst most parties value the Design Principle of Simplicity that we have proposed, a minority were comfortable with a more complex dynamic system. Similarly, views on the suitability of Sustain-H for battery technology are diverse: some parties say this is readily stackable with the current value stack; others are concerned about the high utilization implied, and the misalignment with EFA blocks. More generally, Sustain-H is particularly suited to energy suppliers, less so for aggregators. Stackability of Sustain-H with grid services is lower priority than accessing most revenue from the service.
- **There is also a diversity of views on the treatment of data.** We have received a diversity of comments from participants' legal teams regarding treatment of personal data. For instance, some parties suggested amendments

to the contract to reflect two-factor authentication, auto-delete of emails, and were concerned to clarify who was classified as data controller. Others did not have these requirements.

- **When opening a service to both licensed suppliers and asset aggregators, this introduces the risk of double counting homes.** The risk originates from market nascency, reflecting the fact that multiple organization types are seeking to own the customer relationship, and multiple models are being explored. Addressing the double counting issue is challenging given GDPR legislation.
- **The ENA standardised contract is a barrier.** The ENA's standardised Flex Services contract rolled out across DSOs is relatively long and cumbersome. Participants have found this time-consuming to review; this both delayed contract signature and required extra support to ensure that they continued with the trial. More generally, the contractual relationship between the intermediary (e.g., supplier) and homeowner with a suitable contract term and payment structure is challenging and are potentially not well aligned across DNOs or ESOs.
- **Confirming portfolios was a challenge for some participants:** One participant was not able to participate in the summer season because their customers weren't 'trial ready'. The participant had the customer portfolio, but the main bottleneck in getting them 'trial-ready' was delayed smart meter installations. Similarly, other participants tended to deliver smaller portfolios than originally planned due to customer onboarding issues, or due to only small numbers of customers having appropriate domestic flex equipment in their homes.

9.3.2. Participant feedback from trial

#	THEME	FEEDBACK
1.	**Value**	**Strong consensus** from participants that value is insufficient. Participants shared the following value benchmarks: • For DSR in general, min £50/home + value for intermediary: One participant said homes need min £50/year to be motivated in DSR; this is BEFORE adding in the intermediary's share. • For DSR in general, min £150/home including value for intermediary: Another participant suggested that £150/home is appropriate, including intermediary share. • For Sustain-H specifically, £10-15/kW/year: One participant suggested this was appropriate for a scheduled service. • For dynamic services, substantially higher: For a dynamic service, one participant said that their assets can earn £35-48/kW/year. Another said Sustain-H was 'almost two orders of magnitude lower' than what they earn from ESO services. On cost of participation, participants flagged: • General ongoing overhead • Upfront API setup costs of £3-4k (assuming service is digitalised) • Opex: for batteries, value must be sufficient to compensate for round-trip efficiency loss (~15%) and accelerated degradation. Current external market challenges (reflecting market immaturity): • Achieving material portfolio size: upfront costs are hard to shoulder when portfolio is small. Small portfolios also suffer larger performance penalties. • Supporting revenue stack: difficult to achieve threshold values for homes when not supported by wider revenue stack, which is currently immature for EV charge points and heat pumps in particular. Whilst participants clearly have an incentive to request higher payments, their comments are generally supported by Everoze's understanding of what assets can earn in flexibility markets, especially for batteries.
	Scheduled v dispatch	**Mixed views** on whether scheduled approach is appropriate: • EV charge points: Providers with EV charge points bias like simplicity, love the locationally homogeneous approach, and have low opportunity cost. • Batteries and heat pumps: Providers with batteries and heat pumps prefer more efficient dispatch-based approach. This is due to:

#	THEME	FEEDBACK
		o Losses: Round-trip efficiency losses (including from pre-heating homes) and accelerated degradation o More attractive alternatives: Batteries can access high value services such as ESO's frequency response products, so prefer low utilisation service which frees them up to maximise their wider value stack.
	Baseline	**Consensus** from WPD & participants that: • Baseline rationale needs greater probing for robustness. FSPs would find it straightforward to provide their own baselines. • Baseline needs to avoid gaming (selective pooling of homes, and inclusion of assets which are not used/functional)
2.	**Digitalization**	**Consensus** from WPD & participants that we need to automate processes, to achieve step-change reduction in cost of participation and administration. The current system is a manually intensive process – it is time consuming, with frequent user errors due to monotonous process, having to reset the tool if there were any issues and carry out the analysis again. Very easy to make a mistake – high probability of user error. Domestic flex potential (kW) is limited in scale – which means aggregating large numbers of households with current qualification processes seen as onerous.
3.	**Ongoing portfolio changes**	**Consensus** on desire for enabling closer to real-time portfolio updates. This is important given the speed with which homes change supplier or uptake new technologies.
	Breadth of eligible CMZs	**Consensus** on participants wanting this to be broader to achieve material portfolio size.
	Data requirements	**Mixed views** from tech aggregators and energy suppliers on metering and data requirements. Two participants (not holding supply license) prefer use of lat/long data to postcodes for validation. Mixed preferences on asset metering v smart metering.

- **The key question determining service viability remains VALUE (£).** The core challenge for a scheduled service is whether payments can ever be sufficiently high to mobilise significant participant engagement. Domestic market nascency, including on revenue stacking, exacerbates this challenge. Participants report that the value is insufficient to attract participation under a business-as-usual situation. The service tariff is low and does not allow homes to meet the ~£50 per home per year revenue reported as an absolute minimum. This should be considered in the context of the average DUoS bill for a customer of c.£100 per annum. Finding ways in which to stack payments from different actors in the supply chain may be the way forward.

9.3.3. Learnings post trial

These are summarised in the Product Roadmap – including the pathway to BaU transition. An overview is offered below figure. For further details on learnings, see Document 1B: BaU Recommendations. This gives line-by-line feedback on each of Sustain-H design feature, structured as a robust 35-page Gap Analysis in Appendix 3.

Sustain-H unlocks an entirely new asset class and customer type	The trial demonstrated that a simple scheduled service is effective at leveraging flexibility from homes. The service unlocks a new asset class for flexibility, one where demand change relies primarily on customer behaviour change rather than dispatchable control. A scheduled service is capable of attracting a wider pool of service providers and access an asset class that is currently unavailable to existing dispatch-driven services.
Service remuneration based on an average CMZ value is not sufficient	There is high locational variability in value of constraint management for WPD, with a few high-value zones and large number of medium to low-value zones. Participant feedback from the trial showed that remuneration based on the value of an average Constraint Managed Zone (CMZ) is insufficient. More focussed procurement can provide sharper price signals. Scale is equally important, as per-home home costs of provision are significantly reduced by aggregating a large number of homes into a single portfolio.
Digitalisation and automation is needed to reduce participation costs	Procurement, validation, data delivery, assessment and payment should be digitalised and automated to reduce manual intervention to a bare minimum. End-to-end digitalisation and automation is needed to remove admin-intensive processes and keep costs down to both WPD and the flexibility provider.
Flexibility to change portfolios frequently is needed to boost participation	Learnings from the trial showed that participating portfolios will need to be able to account for a certain level of 'churn' in suppliers' and aggregators' domestic customers. Dynamic portfolios need to be able to change portfolio make-up and volumes on a monthly basis to reduce participation risk.

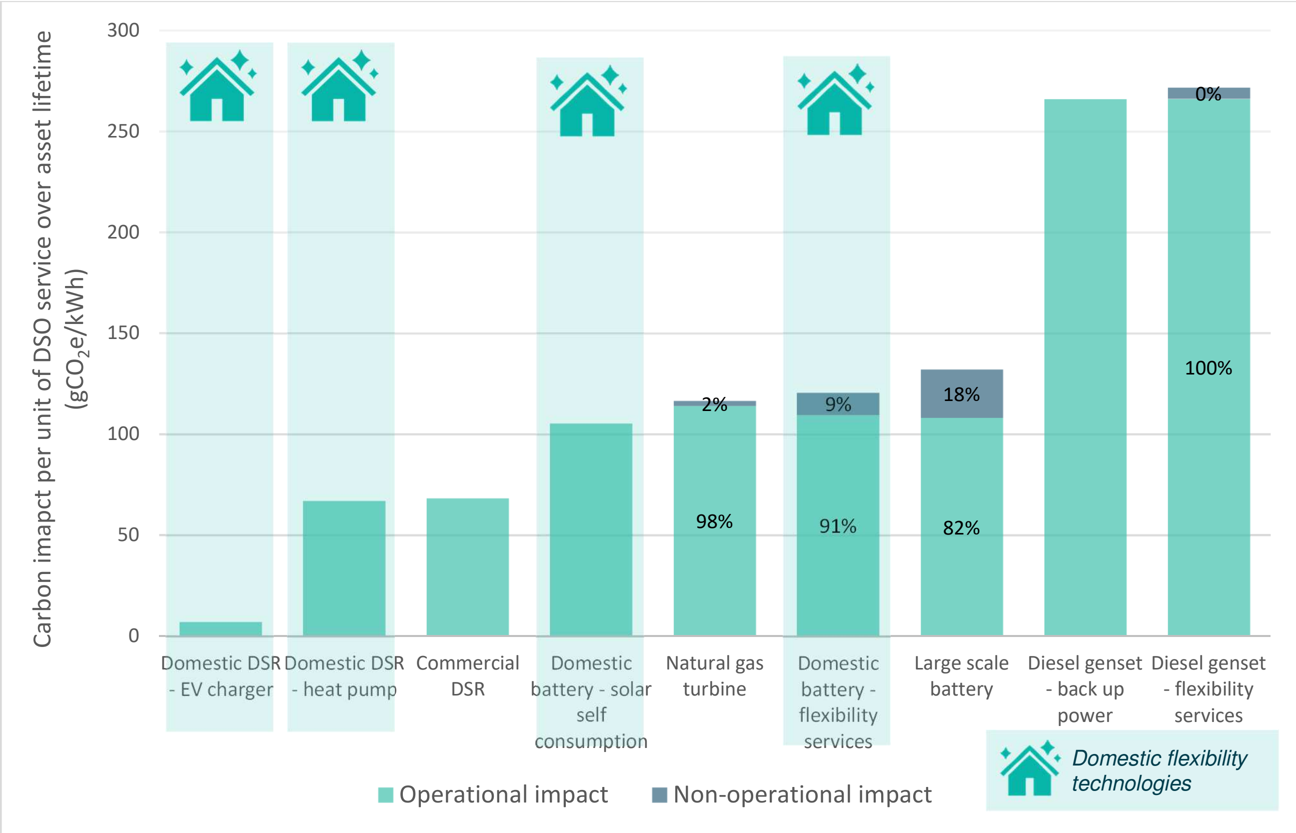
Figure 9-1: BaU transition Overview

9.4. Pro Low Carbon

Assessing the carbon impact of DSO flexibility services requires a specialised approach. Measuring carbon impact is not the same task as measuring carbon emissions. An understanding of total greenhouse gas emissions is useful when dealing with energy generation, but the role of flexibility services is not simply to supply electricity to the grid. Flexibility services interact with the electricity network and influence the makeup of grid generation. The impact of this interaction needs to be measured, which is why measuring carbon emissions from just the flexibility asset itself is not sufficient. Understanding the impacts arising from both the flexibility technologies themselves and their interactions with the grid requires a unique approach.

The use of marginal carbon intensity data materially affects the findings on the carbon impact of DSO service. A common alternative in carbon accounting is to use average grid carbon emissions. The carbon impact hierarchy for the different technology use cases assessed in this work is highly sensitive to the assumptions and data sources used, including the type of grid carbon intensity data selected.

The carbon impact of DSO services over asset lifetimes is summarises in the Figure below. The decision to procure a DSO service from any technology has an associated carbon impact and this impact varies with every technology and use case combination. The results show that this impact is between 7 and 272 grams of carbon dioxide equivalent per kWh of service provided, relative to a base case of not procuring the service. This study has not considered the carbon impact associated with alternative options to DSO services, such as investment in network infrastructure.



Operational emissions are the primary driver of carbon impact. The non-operational emissions allocated to the provision of DSO services are low, never exceeding one fifth of the total carbon impact. The low allocation of non-operational emissions directly reflects the low contribution of DSO services to an asset's total revenue stack.

Demand response (DSR) has the lowest impact of all technologies assessed at 7-68gCO2e/kWh. There are two primary reasons for this result:

- **Low or zero losses**: The losses associated with DSO service provision by DSR are low. Losses associated with DSR are also known as rebound losses, which describe the increase in total energy consumption that results from the demand response action.
- **Zero embodied emissions**: No embodied emissions are applied to DSR use cases because the assets either pre-exist or do not rely upon DSO services for their investment case.

Electric vehicle charge points are the leading low-carbon performer with an impact of just 7gCO_2e/kWh. This is because there are no rebound losses associated with shifting EV charging demand; the same quantity of energy is needed to charge the car regardless of the time of day that this consumption takes place. The carbon impact derives solely from the difference in the carbon intensity of marginal grid generation during the response period and the period to which demand is shifted.

Domestic flexibility solutions generally have a low carbon impact. Next in the hierarchy after EV chargepoints are heat pumps, then domestic batteries. The primary driver of the difference between these three technologies is the effect of losses. There are no rebound losses associated with EV chargepoints, whereas demand response provided by shifting heat pump use requires an increase in total energy consumption if the core function of the technology (heating the home) is to be maintained. Domestic batteries show the highest losses of the three because of the round-trip efficiency of battery storage technology.

Battery projects have a mid-level carbon impact of 105-132gCO_2e/kWh when using marginal grid carbon intensity data. At present there is minimal difference in the carbon intensity of the electricity imported and the grid generation that is offset. This means that the primary driver of operational emissions is the difference in the quantity of electricity imported and the quantity of electricity exported, as determined by the battery round trip efficiency.

Non-operational emissions on a per-MW basis are relatively high. This can be attributed to the energy intensive processes and raw materials required to produce battery cells. However, only a small proportion of the total non-operational emissions are allocated to the provision of DSO services. The order of results for total carbon impact is set by the different levels of allocated non-operational emissions within the different battery use cases.

Natural gas turbines have a mid-level carbon impact of 116gCO_2e/kWh, which is likely to increase over time. Operational emissions dominate the carbon impact of gas turbines because of their relatively high direct combustion emissions and the long lifetime of the technology. These operational stage carbon impacts are also likely to increase over time as the make-up of grid generation changes and the marginal grid carbon intensity falls.

Diesel generators have the highest carbon impact of all technologies, at 266-272gCO2e/kWh. The high emissions associated with burning diesel fuel mean that operational emissions dominate the carbon impact, as they do for natural gas turbines. This carbon impact is likely to increase in the future as the carbon intensity of marginal grid generation falls.

Assessing the carbon impact of flexibility services is challenging. This is due to the wide range of technologies providing DSO services, the variety of different use cases, challenges with the quality of available lifecycle assessment data, and the difficulty of appropriately allocating non-operational emissions. The assessment of the carbon impact of landfill gas presents particular difficulties.

At present, there are only minor impacts associated with the difference in timing of import and export from the electricity grid. The results suggest that optimising the timing of import to periods of low marginal carbon intensity currently has a limited positive benefit. This conclusion can be traced back to the low daily variation in marginal grid carbon intensity in the national level data set used in this study.
Changes in marginal grid carbon intensity will benefit flexible technologies and disadvantage thermal generators. The different time scales over which this change can be experienced affect flexible technologies and thermal generators differently:

- **An increase in intra-day volatility could allow demand response and battery storage technologies to optimise their actions to reduce carbon impact.** An increase in the daily volatility of grid marginal carbon intensity could be expected in the future. Including future projections of grid carbon intensity in this study would change the results by likely increasing the differential between the carbon intensity of the imported generation and that of the offset generation for DSR and battery storage. This work does not take account of the opportunity that these technologies have to optimise their behaviour to reduce carbon. An increase in the volatility of grid marginal carbon intensity would provide an opportunity for these technologies to optimise their behaviour to reduce carbon impact.
- **A fall in average annual gird marginal carbon intensity would disadvantage thermal generators.** The carbon impact of thermal generators would increase if the average grid marginal carbon intensity falls. This is because the carbon intensity of their source of energy (the combusted fuel) remains the same while the carbon intensity of the grid generation that they are offsetting reduces.

The conclusions of this work present novel findings with implications for the treatment of carbon in flexibility markets. There are several areas where the work of Pro Low Carbon could be developed and applied in the future:

- Develop the carbon assessment methodology to apply to all flexibility markets, including national services procured by National Grid ESO.
- Investigate how to use the methodology to report on carbon intensity in flexibility markets, providing radical transparency on carbon impact internally within WPD and externally to market participants.
- Explore how to measure and communicate real time signals that could help local flexibility market participants reduce their carbon impact.
- Monitor the historical and ongoing carbon impact of WPD Flexible Power services.
- Investigate what measures could be used to reduce the carbon impacts of flexibility service procurement.

Improving the Pro Low Carbon methodology could provide more accurate results and lead to a deeper understanding of the different factors that influence the carbon impact of DSO services. Potential areas for development include:

- Using local level grid carbon intensity data instead of national data.
- Modelling the impacts of assets adopting operational strategies that are optimised to reduce carbon, rather than solely to maximise financial returns.
- Developing the methodology to apply to an even wider range of technology types and use cases.

9.5. Ways of working in innovation projects

An agile approach to innovation delivers better results, more efficiently – and there is potential to update processes to better facilitate this. We submitted a number of variation requests along the way on this project, which proved crucial to the project's success. There were many uncertainties at the start of the project, and the changing environment meant that it became clear along the way that plans should change for us to deliver on our ultimate goal. In future, we recommend:

Availability of business-as-usual teams is crucial to success – product management best practice methods may be a solution: We were fortunate to have the time and input of the Flexible Power team, and always benefited from this – both in terms of delivering better outputs and reaching key decisions more swiftly. The project would have benefited from even greater input from WPD's business-as-usual teams, to ensure that project outputs were well aligned with WPD needs. This particularly applies to the DSO-Ready Homes and Pro Low Carbon workstreams. Again, product management best practice may provide ideas on how to better structure BaU input, in a more continuous manner (e.g. see books by Teresa Torres, *Continuous Discovery Habits;* and Gothelf and Seiden, *Sense & Respond*).

9.6. Knowledge and dissemination

Our approach to outreach has been to promote two-way conversations – not just *disseminating* what we're learning, but also *listening and adjusting* too. This has led us to generally favour participatory approaches which enable us to gather feedback and help align industry views – convening meaningful discussions.

A summary of our dissemination activity is provided below:

- Workshops:
  - 2 face-to-face industry workshops (Jan/Feb 2019)
  - Sustain-H participant workshop (Sept 2021)
- Ongoing LinkedIn posts
- LinkedIn blogs:
  - https://www.linkedin.com/pulse/two-things-weve-learned-from-pioneering-dso-service-homes-jones/
  - https://www.linkedin.com/pulse/realising-value-reducing-electricity-consumption-home-benjamin-lock/
  - https://www.linkedin.com/pulse/domestic-energy-efficiency-needs-brought-from-cold-benjamin-lock/
  - https://www.linkedin.com/pulse/demand-side-response-lowest-carbon-form-flexibility-benjamin-lock/
  - https://www.linkedin.com/pulse/our-top-five-learnings-from-pioneering-sustain-h-flex-nithin-rajavelu/
- Panel discussion on Sustain-H at Solar & Storage Live – involving WPD, Everoze and three Sustain-H participants (Dec 2020)
- Presentation at ESO Power Responsive webinar (Sept 2021)
- Sustain-H press release, leading to industry coverage: https://www.current-news.co.uk/news/wpd-launches-domestic-sustainability-pilot-sustain-h (Nov 2020)
- DSO-Ready Homes Industry roundtable (Sep 2021).

In addition, Pro Low Carbon and DSO-ready Homes have also involved bilateral and engagement with BEIS and Ofgem. This is because we discovered that our findings were whole system in nature, requiring policy/regulatory guidance and cross-system collaboration, rather than the DNO necessarily being the right party to lead on implementing interventions by itself. This BEIS/Ofgem discussion has substantially influenced our approach – whilst also providing a robust DNO evidence base to influence policy/regulatory thinking.

10. The Outcomes of the Project

The outcomes of the project will be discussed in the following section summarised by the distinct workstreams that formed the overall project.

Phase	Public-facing documents describing journey and detail, available online here:	Additional supporting material
4. Participant feedback	FutureFlex Workshop Primer FutureFlex Workshop Participant Feedback Ideas for Trial May 2020	
2A. DSO-Ready Homes	DSO-Ready Homes definitions DSO-Ready Homes: realizing the value of domestic energy efficiency in GB electricity distribution – July 2021 DSO-Ready Homes: Roundtable output – slides and discussion note	DSO-Ready Homes: Interventions document Report with detailed analysis of value of energy efficiency (the supporting paper to 'realising the value of domestic energy efficiency in GB electricity distribution).
2B. Sustain-H (including Aggregated Datasets)	Sustain-H Opportunity Sustain-H Design Guidance Value Calculator Sustain-H Product roadmap Aggregated Datasets Methodology Aggregated Datasets Third party datasets analysis Aggregated Datasets: Third party and Sustain-H datasets analysis	Detailed design report (May 2020). Gap Analysis paper (Document 1B), Aug 2021.
2C. Pro Low Carbon	Carbon Assessment Methodologies Carbon Impact of DSO flexibility services	Excel tool supporting carbon analysis

10.1. DSO Ready Home Outcomes

From the feedback and modelling work undertaken the following outcomes can be identified:

DSOs are well-placed to target intervention points because their interests are aligned with consumers.

- Unlike energy suppliers, they do not have the conflict of interest of a financial incentive to sell more energy. Unlike the ESO, they have direct contact with customers (e.g. vulnerable customer register, or during blackouts). Unlike BEIS and Ofgem, they are local actors, who understand best where domestic flexibility should be targeted.

The participant feedback is that at present DSO procurement timelines and processes are framed around DSO needs.

- For instance, services are advertised most heavily when needed by the DSO and are largely communicated in a technocratic fashion. Flex providers are targeted when they are based within a CMZ.

At the same time, consumer interest in domestic flexibility is generally low (albeit varying by segment).

- Workshop participants commented on the challenges of consumer activation, both in terms of awareness (14 comments) and trust (14 comments), with specific feedback citing the public's "lack of knowledge of problems and opportunities" and customers' "suspicion of big energy motives".

Workshop participants challenged DSOs to start with customers, rather than with DSOs.

- Specific quotes included: "mindset and consumer led business models", and "start at the consumer end – not the DNO end!" Workshop participants also critiqued the workshop approach of framing barriers according to the DSO services lifecycle, which was commented as not being truly user-led and indicative of implicit bias.

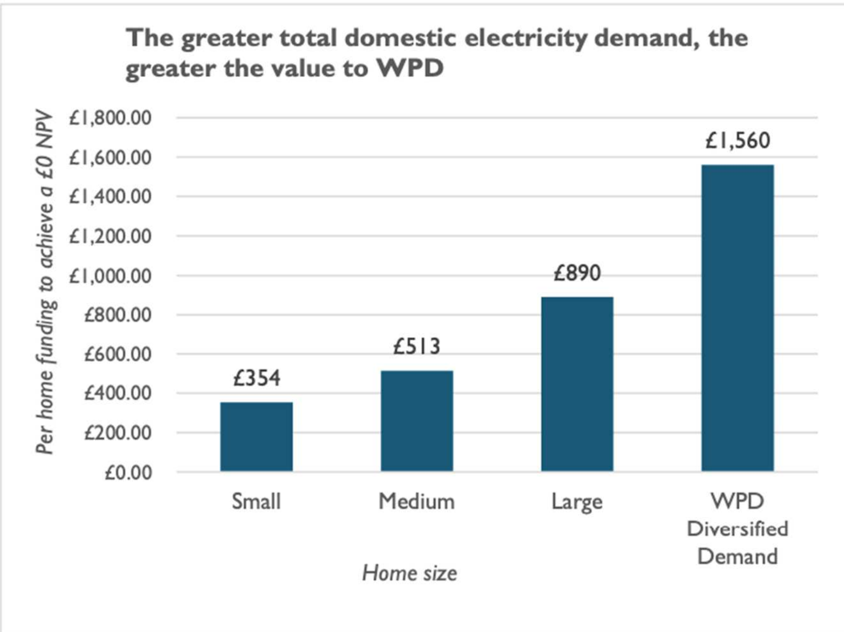
"Domestic flexibility should be bottom up. We need to rethink the concept for the long term"
– Workshop participant

Data limitations have proved challenging and may have reduced the accuracy of the results. In particular:

- Consumption data: better data is needed to understand how EE measures impact consumer behaviour and the timing of electricity demand from heating. No reliable readily available data source accurately describes this impact with the granularity required. Sourcing this data is important to estimate with greater accuracy the real- world value of EE to WPD.
- Constraint data: A better understanding of the value of constraint alleviation and the duration of constraints is needed.

Different sizes of home have different levels of annual electricity consumption, and those with the highest consumption have the most potential savings to make through EE.

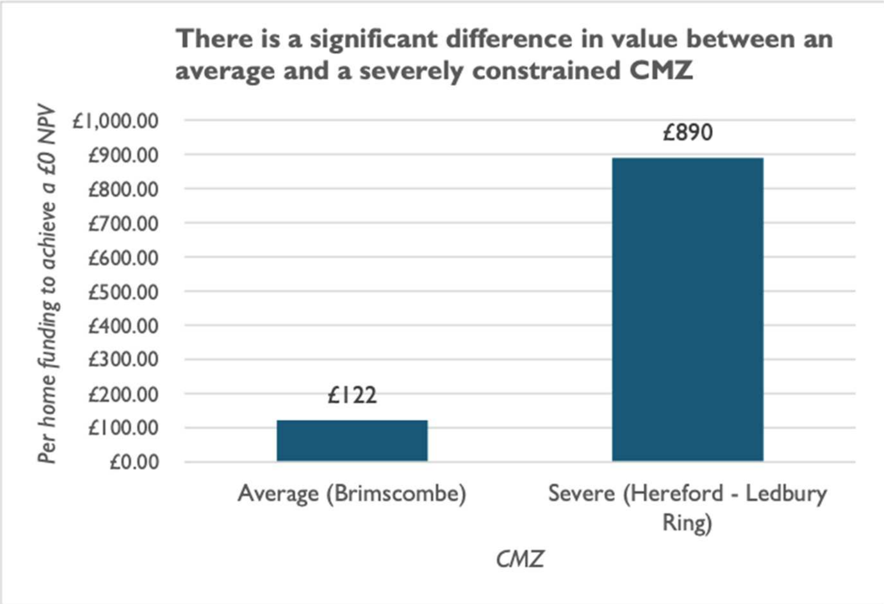
- Three sizes of home were modelled, alongside the unadjusted WPD Diversified Demand profile. EE measures in a large home bring around 2.5 times the value to WPD of a small home.



Modelling scenarios	
CMZ	Severe (Hereford - Ledbury Ring)
Home size	**Variable**
Heating	Heat pump
LI	Yes
CWI	Yes
Solar	No
Solar adjusted to 6.3%	N/A
Funding made	2021
Measure installed	2021
CMZ expires at end of	2025
Term	5 years

The CMZ in which the EE measure is installed is a key factor in the results.

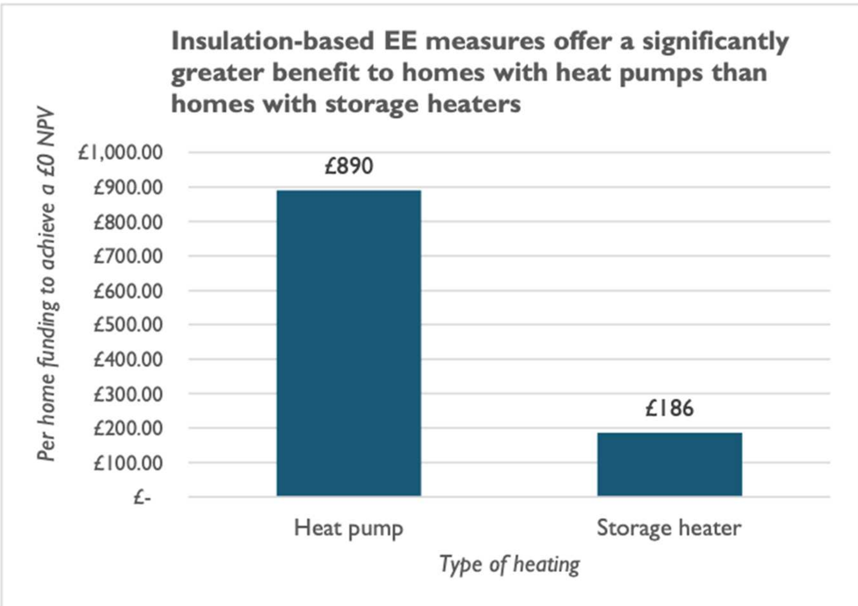
- A CMZ with a high value of constraint alleviation has been shown to offer as much as 7 times more value than an average CMZ. Below-average value CMZs may offer many times less value.



Modelling scenarios	
CMZ	**Variable**
Home size	Large
Heating	Heat pump
LI	Yes
CWI	Yes
Solar	No
Solar adjusted to 6.3%	N/A
Funding made	2021
Measure installed	2021
CMZ expires at end of	2025
Term	5 years

Storage heaters are less efficient than heat pumps, so in almost all scenarios will lead to higher total electricity consumption.

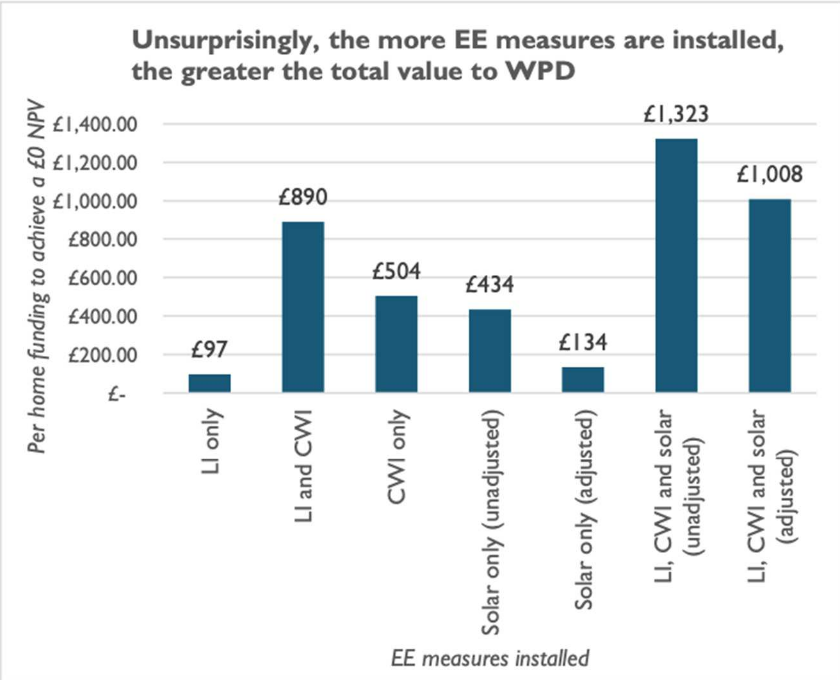
- This means that insulation could offer a greater benefit in terms of total energy savings to homes with storage heaters. However, because the demand from storage heaters is mostly overnight and not during network constraint periods, this saving in electricity demand is not of much value to WPD. The modelling suggests that installing insulation in homes with heat pumps is worth on average almost 5 times more than in homes with storage heaters.



Modelling scenarios	
CMZ	Severe (Hereford - Ledbury Ring)
Home size	Large
Heating	**Variable**
LI	Yes
CWI	Yes
Solar	No
Solar adjusted to 6.3%	N/A
Grant made	2021
Measure installed	2021
CMZ expires at end of	2025
Term	5 years

Of the measures considered, cavity wall insulation has been shown to have the highest value for a single measure.

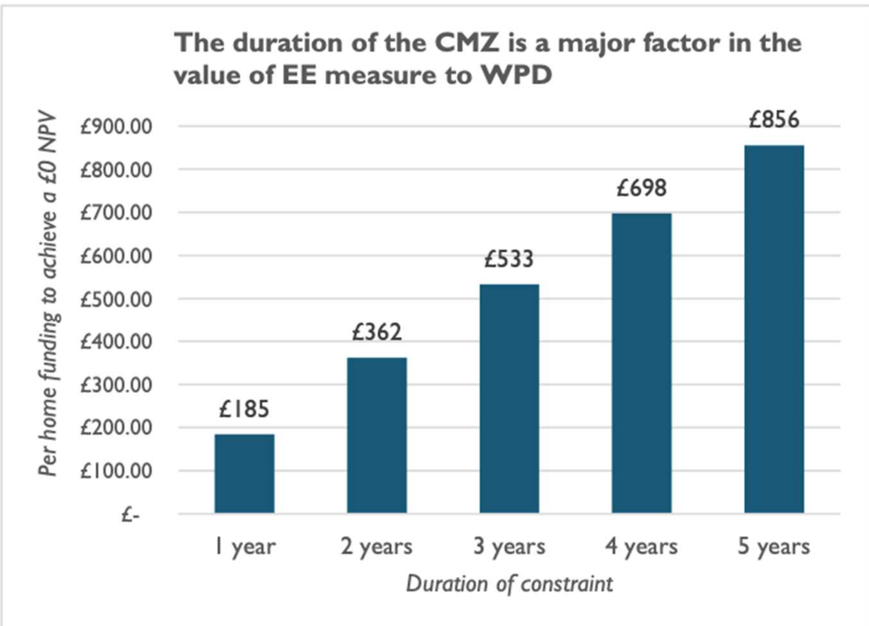
- A combination of both insulation measures and solar PV delivers the most value. The unadjusted solar PV impact is only slightly below that of cavity wall insulation, even though solar PV delivers a greater change in total electricity demand from the grid in most cases. The lower value to WPD arises from the fact that solar generates most of its energy in the middle of the day during summer, a time when the selected CMZs do not have any constraint issues



Modelling scenarios	
CMZ	Severe (Hereford - Ledbury Ring)
Home size	Large
Heating	Heat pump
LI	**Variable**
CWI	**Variable**
Solar	**Variable**
Solar adjusted to 6.3%	**Variable**
Grant made	2021
Measure installed	2021
CMZ expires at end of	2025
Term	5 years

The duration of the CMZ is a key factor in the results.

- The per-home funding WPD could provide increases almost linearly, meaning alleviation of a constraint issue that persists for 5-years would deliver slightly less than 5 times as much value as an issue that existed for a single year.

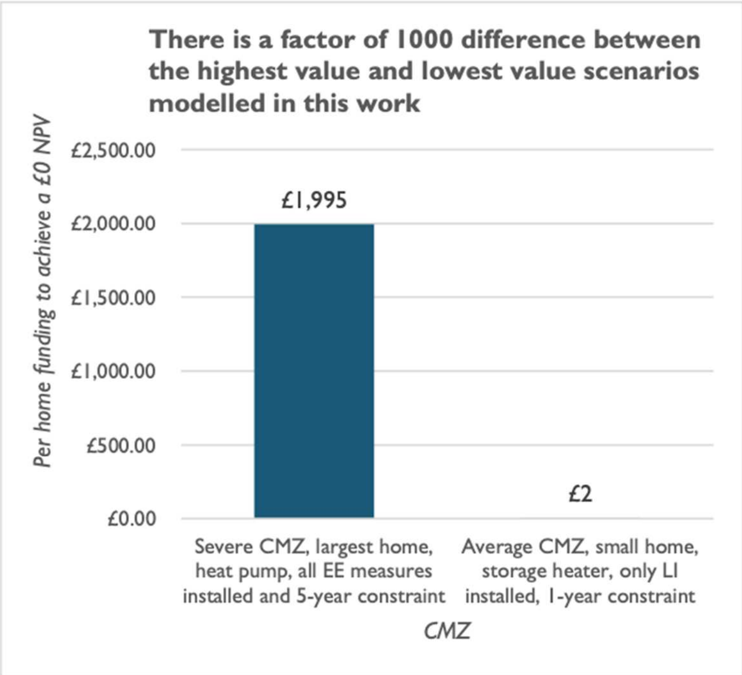


Modelling scenarios	
CMZ	Severe (Hereford - Ledbury Ring)
Home size	Large
Heating	Heat pump
LI	Yes
CWI	Yes
Solar	No
Solar adjusted to 6.3%	N/A
Grant made	2021
Measure installed	2021
CMZ expires at end of	2025
Term	**Variable**

Figure 10-1: Duration of CMZ

To illustrate the range in the value of EE installation in different types of home, two extreme scenarios were compared.

- A large home in a severe, long term CMZ with a heat pump that installs insulation measures and solar PV could deliver 1000 times more value than a small home in a short-term, average CMZ which uses storage heaters and installs only loft insulation.



Modelling scenarios		
	High value	Low value
CMZ	Severe (Hereford - Ledbury Ring)	Average (Brimscombe)
Home size	WPD. Div. Demand	Small
Heating	Heat pump	Storage heater
LI	Yes	Yes
CWI	Yes	No
Solar	Yes	No
Solar adjusted to 6.3%	No	N/A
Grant made	2021	2021
Measure installed	2021	2021
CMZ expires at end of	2025	2021
Term	5 year	1 year

Figure 10-2: Scenario value

- **The scale of value suggests that a business case for EE support could be built around a capex grant, but only for the highest value properties.**
  - For most households, monetary value that could be offered is unlikely to be sufficient to provide a meaningful contribution to the cost of installing EE measures. However, for a smaller number of high-demand households in severely constrained areas, a business case could possibly be built on the basis of capex grants.

10.2. Sustain – H Outcomes

The following recommendations are made for the commercial roll-out of the Sustain-H service:

- No derating factor for data resolution is used for initial BaU roll-out of the service.
- WPD considers introducing a derating factor in the future (based on the Data Quality Factor) to incentivize higher resolution meter data once sufficient liquidity for the Sustain-H service is established. As Sustain-H participation in the long term will likely be large scale domestic portfolios, and as impact of small portfolios of homes and assets on WPD's network is expected to be minimal, a simplified approach focusing on the impact of the larger portfolios (> 100 homes) is justified.
- WPD conducts further analysis to refine the Resolution UF analysis using high-resolution meter data across various technologies if new data becomes available in the future. This is needed to test the findings in this report, and to provide a robust evidence base for introducing any derating factors in the Sustain-H payment calculations in the future.
- WPD considers introducing an availability mechanism in the performance assessment and payment calculations in the medium to long term to incentivize higher completeness in the meter data submitted
- WPD be flexible with metering solutions used for Sustain-H and accept MID-compliant metering solutions. If WPD accepts the prescribed requirements for domestic flexibility as set out in PAS 1878, Everoze recommend WPD evaluates the Accuracy UF for these metering solutions and its overall impact on the Data Quality Factor.

Participants find current data requirements either unclear or unduly prescriptive.

- 18 comments/barriers were logged on Data by participants in the workshops; others flagged ‘High transaction costs’ and similar. This is elaborated further in Aggregated Datasets below.

Workshop participants – and particularly interviewees – emphasized the importance of DSO services being accessible to both flexibility and energy efficiency.

- Participants in the London workshop emphasised that DSO services should be ‘Holistic: accessible to both flex and energy efficiency’, a theme that was continued in subsequent interviews. For instance, a trade association talked of the need to view the retrofit market and DSR community together, asking ‘how can we achieve a joined-up view through a trial?’.

Participants were also eager to explore actual provision of DSO services from domestic flex through a trial.

- Multiple suppliers expressed interest in participating in a trial. There was openness to pursuing different commercial mechanisms within this. Most interestingly, one participant supported the WPD and SGC proposed service which allows for a “drop to a value” rather than a “drop by a value”, which is believed to be easier to achieve for DSR.

Discussion with the Flexible Power team flagged that the Sustain Service may be an appropriate vehicle to pursue the themes of (a) Data and (b) Holistic Flex + Efficiency further.

- Sustain has been historically referred to as Scheduled Constraint Management within Open Networks. It is a service whereby ‘the DSO procures, ahead of time, a pre-agreed change in input or output over a defined time period to prevent a network going beyond its firm capacity (thereby ensuring all load remains secure following the next fault).
- For example, a reduction in demand is procured over an evening peak period to mitigate risk of overload that might result should a fault occur on one of two in-feeds to a group.
- The service is considered appropriate because, with adjustments, as a scheduled service it is fulfillable by both domestic flexibility (where 4 workshop participants raised concerns about slow response times) and energy efficiency (which cannot be ‘dispatched’). Sustain is a hybrid of time-of-use tariffs and DSO services.

10.3. Aggregated Datasets

The role of the ‘Aggregated Datasets’ workstream was to quantify the impact of lower portfolio data quality for WPD’s DSO services. This will ultimately help to inform payment mechanisms for Sustain-H. The approach was to independently analyse resolution, completeness, and accuracy uncertainty factors, and then combine this into a single ‘data quality factor’ for each technology type. This then informs any ‘data derating factor’ that may be used for Sustain-H remuneration in the future. WPD is currently considering the plans and proposals for commercial roll-out of the Sustain-H service – specific recommendations for the Sustain-H service emerging from this analysis are included further below. Everoze has taken these recommendations into account in the Sustain-H Product Roadmap. Headline findings from the ‘Aggregated Datasets’ workstream are offered below.

- **Sourcing data from other DNOs can take many weeks**. Everoze have struggled to secure data from other DNOs on previous relevant innovation projects. As a long-term recommendation it would be helpful if this was readily available online, perhaps downloadable from the Smarter Networks Portal. That would save time for both ourselves and for other DNOs in fielding our requests. More generally, publicly available datasets for battery storage (and to a lesser extent heat pumps) are difficult to source. The current lack of suitable datasets which include domestic battery storage systems may impact the development of the Supplier Trial.
- **The limitations of available datasets pose a *substantial* challenge for reaching conclusions – emphasising the pressing need for WPD to gather more data in future**. Everoze’s analysis was materially affected by the limitations of the ‘Freedom’, ‘Electric Nation’ and ‘Sustain-H’ trial datasets. Most notably, key issues included the short duration of the datasets used, the ‘Electric Nation’ dataset not being a minutely dataset, and the lack of large portfolio datasets of minute granularity from the ‘Sustain-H’ trial. As such, Everoze strongly advocates seizing future opportunities to secure further domestic flexibility data, to build on these learnings and appropriately factor in the meter data uncertainties for Sustain-H remuneration in the long term.

- **Data resolution has the biggest impact on demand uncertainty, followed by Completeness, followed by Accuracy.** The standard deviation component of the Data Quality Factor is dominated by the 'resolution uncertainty factor' standard deviation (0.3), which is a magnitude of 10 greater than those calculated from the completeness analysis, and a magnitude of 100 greater than those calculated from the accuracy analysis. In short, lower resolution half-hourly data *substantially* reduces the confidence WPD can have in the ultimate peak demand compared to minutely resolution data. Meanwhile, completeness is of medium importance, and accuracy impacts are negligible.
- **Results vary significantly by dataset – hinting at a possible need for a technology-specific approach to analysing data resolution:** Consumption profiles vary dramatically between the 'Freedom' data (for heat pumps), and the 'Electric Nation' and 'Sustain-H' datasets (for electric vehicles); this applies both across the day and within individual half hour settlement periods. This has implications for the Resolution Uncertainty Factor (RUF), suggesting that it may be more appropriate to derive a separate resolution factor per technology. It is further possible that other assets (such as batteries) will show different behaviours again. At this stage, it is difficult to make firm conclusions on the technology-specific attributes when the data analysed are from trials with different interventions which have different impact on demand patterns. Moreover, as noted below in point 6, any technology-specific attributes may diminish for large portfolio sizes. In any case, more data are required to repeat the resolution analysis, should appropriate data become available, to draw firm conclusions on the technology-specific impact on data resolution.
- **For heat pumps at half-hourly resolution, the Data Quality Factor for a complete dataset was 1.43 for a 50% confidence level and 1.92 for a confidence level of 95%.** This means that we are 50% certain the peak demand recorded for a half-hourly metered heat pump portfolio is 1.43 times higher when assuming 1 minute resolution.
- **For electric vehicles at half-hourly resolution, the Data Quality Factor (DQF) for a complete dataset (using 'Electric Nation' data) was 1.18 for a confidence level of 50% and 1.53 for a confidence level of 95%.** This means we are 50% certain the peak demand recorded for a half-hourly metered electric vehicle is 1.18 times higher when assuming minutely resolution. For the 'Sustain-H' dataset, the DQF is 1.91 and 4.36 for the 50% and 95% confidence levels, respectively, which is significantly higher than the findings using the 'Electric Nation' dataset. The material difference in the findings using the two datasets is likely due to: (1) the constant power charging assumption made when processing the 'Electric Nation' data, (2) the flexibility provider's interventions in the 'Sustain-H' dataset where the EV chargers were responding to price signals on a minute-by-minute basis, and (3) low demand outside of 12am-7am in the Sustain-H dataset resulting in the peak-over-mean calculated to be statistically skewed due to the low half-hourly average demand during these periods.
- **Analysis to date suggests that portfolio size strongly impacts the half-hourly RUF, and consequently the DQF.** Everoze repeated the resolution analysis on reduced population samples for both the 'Electric Nation' and 'Freedom' datasets. Due to the small portfolio size, the 'Sustain-H' dataset was not included in this analysis. The smaller population datasets yielded larger RUFs. Interestingly, for a fixed portfolio size, the analysis yielded different results for the two datasets, which implies that technology type may also be a driver of variation in the DQF for small portfolio sizes. The impact of portfolio size and technology type on the calculated DQF (predominantly driven by the RUF), appears to diminish for large portfolios (> 100 assets). This convergence, or asymptotic behaviour, with increasingly large portfolios will have an impact in the design of the DQF/DDF where a simplified approach may be justified.
- **The linear impact of data incompleteness means that WPD can take a pragmatic approach.** In Everoze's analysis, demand uncertainty increased in a broadly linear fashion as the dataset became more incomplete. For instance, an 80% complete dataset led to a 125% increase in demand uncertainty when considering a 50% confidence level. As a result, there is potential for WPD to adopt a pragmatic approach here; for instance, for a 50% confidence level an 80% complete dataset might result in a multiplier of 1.25 within the DQF, with corresponding impact on payment. Everoze also investigated the impact portfolio size has on demand uncertainty for an 80% incomplete dataset, and found the impact is independent of portfolio size.
- **The following recommendations were identified for commercial roll-out of the 'Sustain-H' service:**

    - No derating factor for data resolution is used for initial BaU roll-out of the service.
    - WPD considers introducing a derating factor in the future (based on the DQF) to incentivize higher resolution meter data once sufficient liquidity for the Sustain-H service is established. As 'Sustain-H' participation in the long term will likely be large scale domestic portfolios, and as impact of small portfolios of homes and assets on WPD's network is expected to be minimal, a simplified approach focusing on the impact of the larger portfolios (> 100 homes) is justified.

- WPD conducts further analysis to refine the RUF analysis using high-resolution meter data across various technologies, if new data becomes available in the future. This is needed to test the findings in this report, and to provide a robust evidence base for introducing any derating factors in the 'Sustain-H' payment calculations in the future.
- WPD considers introducing an availability mechanism in the performance assessment and payment calculations in the medium to long term to incentivise higher completeness in the meter data submitted
- WPD be flexible with metering solutions used for 'Sustain-H' and accept MID-compliant metering solutions. If WPD accepts the prescribed requirements for domestic flexibility as set out in PAS 1878, we recommend WPD evaluates the Accuracy UF for these metering solutions and its overall impact on the DQF.

10.4. Pro Low Carbon Outcomes

During the workshops, the idea of developing low carbon incentives originated in the discussion of two barriers:

At present, DSO services do not price in the externality of carbon.

- There were 20 comments in the workshops which touched on the uncertainty, volume and, most importantly low value of DSO services. Participants commented that there were several externalities not currently priced – most notably carbon. For instance, one participant recommended that *"All externalities should be captured: carbon, air quality and more".*

There is no coordinated action in 'pump-priming' the domestic flex market for net zero.

- In the Bristol workshop, participants discussed the challenge of catalysing domestic flex to meet decarbonisation targets. They concluded that this requires market stimulation and termed this intervention 'pump-priming'.
- They observed that there is no actor in the energy sector providing this pump-priming, and suggested that, although this was not the sole responsibility of the DSO, that the DSO had a valuable contribution to make.
- They argued that it was a barrier to domestic flex roll-out that no actor was proactively taking a long-term view to stimulating market development. This led to wider commentary about the need for DSOs to take a more assertive position in their own decarbonisation.

During this workstream the following outcomes were identified:

DSO services have a carbon impact.

- The decision to procure a DSO service from any technology has an associated carbon impact and this impact varies with every technology and use case combination. The results show that this impact is between 7 and 272 grams of carbon dioxide equivalent per kWh of service provided, relative to a base case of not procuring the service. This study has not considered the carbon impact associated with alternative options to DSO services, such as investment in network infrastructure.

Operational emissions are the primary driver of carbon impact.

- The non-operational emissions allocated to the provision of DSO services are low, never exceeding one fifth of the total carbon impact. The low allocation of non- operational emissions directly reflects the low contribution of DSO services to an asset's total revenue stack.

Demand response (DSR) has the lowest impact of all technologies assessed at 7-68gCO2e/kWh.

- There are two primary reasons for this result:
  - **Low or zero losses**: The losses associated with DSO service provision by DSR are low. Losses associated with DSR are also known as rebound losses, which describe the increase in total energy consumption that results from the demand response action.
  - **Zero embodied emissions**: No embodied emissions are applied to DSR use cases because the assets either pre-exist or do not rely upon DSO services for their investment case.

- Electric vehicle charge points are the leading low-carbon performer with an impact of just 7gCO_{2e}/kWh. This is because there are no rebound losses associated with shifting EV charging demand; the same quantity of energy is needed to charge the car regardless of the time of day that this consumption takes place. The carbon impact derives solely from the difference in the carbon intensity of marginal grid generation during the response period and the period to which demand is shifted.

Domestic flexibility solutions generally have a low carbon impact. Next in the hierarchy after EV charge points are heat pumps, then domestic batteries.

- The primary driver of the difference between these three technologies is the effect of losses. There are no rebound losses associated with EV charge points, whereas demand response provided by shifting heat pump use requires an increase in total energy consumption if the core function of the technology (heating the home) is to be maintained. Domestic batteries show the highest losses of the three because of the round-trip efficiency of battery storage technology.

Battery projects have a mid-level carbon impact of 105-132gCO_{2e}/kWh when using marginal grid carbon intensity data.

- At present there is minimal difference in the carbon intensity of the electricity imported and the grid generation that is offset. This means that the primary driver of operational emissions is the difference in the quantity of electricity imported and the quantity of electricity exported, as determined by the battery round trip efficiency.
- Non-operational emissions on a per-MW basis are relatively high. This can be attributed to the energy intensive processes and raw materials required to produce battery cells. However, only a small proportion of the total non- operational emissions are allocated to the provision of DSO services. The order of results for total carbon impact is set by the different levels of allocated non-operational emissions within the different battery use cases.

Natural gas turbines have a mid-level carbon impact of 116gCO2e/kWh, which is likely to increase over time.

- Operational emissions dominate the carbon impact of gas turbines because of their relatively high direct combustion emissions and the long lifetime of the technology. These operational stage carbon impacts are also likely to increase over time as the make-up of grid generation changes and the marginal grid carbon intensity falls.

Diesel generators have the highest carbon impact of all technologies, at 266-272gCO2e/kWh.

- The high emissions associated with burning diesel fuel mean that operational emissions dominate the carbon impact, as they do for natural gas turbines. This carbon impact is likely to increase in the future as the carbon intensity of marginal grid generation falls.

Assessing the carbon impact of flexibility services is challenging.

- This is due to the wide range of technologies providing DSO services, the variety of different use cases, challenges with the quality of available lifecycle assessment data, and the difficulty of appropriately allocating non-operational emissions.

The assessment of the carbon impact of landfill gas presents difficulties.

- Because it makes use of the polluting waste product of a separate industry, landfill gas generation is generally regarded as having very low carbon emissions. However, this result can only be reached if the scope of the assessment is extremely wide, taking account of the effects that would arise if the gas were not captured for generation use. Calculating the impact associated with DSO service provision adds another complexity by heightening the importance of the base case that the results are being measured against.

At present, there are only minor impacts associated with the difference in timing of import and export from the electricity grid.

- The results suggest that optimising the timing of import to periods of low marginal carbon intensity currently has a limited positive benefit. This conclusion can be traced back to the low daily variation in marginal grid carbon intensity in the national level data set used in this study.

Changes in marginal grid carbon intensity will benefit flexible technologies and disadvantage thermal generators.

- The different time scales over which this change can be experienced affect flexible technologies and thermal generators differently:

An increase in intra-day volatility could allow demand response and battery storage technologies to optimise their actions to reduce carbon impact.

- An increase in the daily volatility of grid marginal carbon intensity could be expected in the future. Including future projections of grid carbon intensity in this study would change the results by likely increasing the differential between the carbon intensity of the imported generation and that of the offset generation for DSR and battery storage. This work does not take account of the opportunity that these technologies have to optimise their behaviour to reduce carbon. An increase in the volatility of grid marginal carbon intensity would provide an opportunity for these technologies to optimise their behaviour to reduce carbon impact.

A fall in average annual gird marginal carbon intensity would disadvantage thermal generators.

- The carbon impact of thermal generators would increase if the average grid marginal carbon intensity falls. This is because the carbon intensity of their source of energy (the combusted fuel) remains the same while the carbon intensity of the grid generation that they are offsetting reduces.

10.1.1 Conclusion

The conclusions of the Pro Low Carbon work present novel findings with implications for the treatment of carbon in flexibility markets. There are several areas where the work of Pro Low Carbon could be developed and applied in the future:

1. Develop the carbon assessment methodology to apply to all flexibility markets, including national services procured by National Grid ESO.
2. Investigate how to use the methodology to report on carbon intensity in flexibility markets, providing radical transparency on carbon impact internally within WPD and externally to market participants.
3. Explore how to measure and communicate real time signals that could help local flexibility market participants reduce their carbon impact.
4. Monitor the historical and ongoing carbon impact of WPD Flexible Power services.
5. Investigate what measures could be used to reduce the carbon impacts of flexibility service procurement.

Improving the Pro Low Carbon methodology could provide more accurate results and lead to a deeper understanding of the different factors that influence the carbon impact of DSO services. Potential areas for development include:

1. Using local level grid carbon intensity data instead of national data.
2. Modelling the impacts of assets adopting operational strategies that are optimised to reduce carbon, rather than solely to maximise financial returns.
3. Developing the methodology to apply to an even wider range of technology types and use cases.

The full report for this workstream can be accessed here https://www.westernpower.co.uk/downloads-view/206428

11. Data Access Details

Anonymised data will be available to share in accordance with WPD's data sharing policy
www.westernpower.co.uk/Innovation/Contact-us-and-more/Project-Data.aspx

12. Foreground IPR

No Background Intellectual Property was used for the project other than existing publicly available reports and information to set up the trial

No specific new IP was created as the service was created using very manual processes. The learning will of course create a design for the Sustain- H product which will inform the product roadmap for Flexible Power which is a solution used by the DNO’s and the costs of which are borne by the DNO’s.

13. Planned Implementation

The key elements of the project are broken down below in respect of our plans to implement into the business where there is a reason to do so:

13.1. Sustain H

It is intended that Sustain-H will be implemented into the business under our Flexible Power offering. The project has undertaken a recent product road mapping exercise to determine the optimal route to achieving such. The roadmap includes proposals to refine the product and changes to Flexible Power in order that it can be rolled out. It is intended that it will be available during Q2 2022. The Product Roadmap will be available on the Innovation Website for reference.

13.2. DSO Ready Homes

We have undertaken a workshop with interested stakeholders, including Ofgem, the NEA and other parties to explore how DSO Ready Homes could feature moving forward. However, actions are limited as WPD has no role in the rollout of energy efficiency measures under the current regime and price control.

13.3. Aggregated Datasets

The work undertaken produced a final report and this is available on the WPD website. WPD will be implementing any recommendations as appropriate.

13.4. Pro Low Carbon

The final report for this work is available on the Future Flex part of the innovation website, a number of the conclusions require policy changes or other changes outside of a DNO’s remit. However, it is incumbent on us when responding the industry change that the conclusions of this work are factored in when there is a customer benefit or network benefit. Moreover, it is also important that innovators are encouraged to look at these sorts of issue, for example developing methodologies and modelling profiles.

Glossary

Abbreviation	Term
BaU	Business as Usual
DSO	Distribution System Operator
DSO Ready Home	A home that is thermally efficient and has several Low Carbon Technologies that can then participate in services for flexibility.
DSR	Demand Side Response is all about creating flexibility on the demand side of the UK's energy market, so that the entire energy market is more resilient and more agile in times of real emergency.
EE	Energy Efficiency
ESO	Electricity System Operator
EV	Electric Vehicles
FFR	Firm Frequency Response is a service provided by energy users to National Grid, which uses approved assets to quickly reduce demand or increase generation to help balance the grid and avoid power outages.
Flexible Power	Flexible Power is a joint initiative from five UK Electricity Distribution Network Operators (DNOs); Western Power Distribution, Northern Powergrid, Scottish and Southern Electricity Networks, SP Energy Networks, and Electricity North West.
LCT	Low-Carbon Technology
NIA	Network Innovation Allowance
V2G	Vehicle-to-grid electricity put back into the grid from the electric vehicle
CMZ	Constraint Managed Zone is a geographic region served by an existing network where network requirements related to network security of supply are met using flexible services, such as Demand Side Response, Energy Storage and stand-by generation.
NPV	Net Present Value is the value of all future cash flows (positive and negative) over the entire life of an investment discounted to the present.

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