EQUINOX

Learning from trialling novel commercial methods

Project deliverable 4

August 2024

1. Executive summary

Equitable Novel Flexibility Exchange (EQUINOX) is exploring the potential role that domestic heat pump demand response flexibility can play in electricity network planning and management by Distribution Network Operators (DNOs) like National Grid. EQUINOX is testing novel commercial arrangements at scale across three winter trials which incentivise domestic heat pump owners to shift their heating from peak hours, while ensuring fair and safe participation for all participants, including those with potential vulnerabilities.

This report focuses on findings from trial two, which was held in winter 2023/24 with over 1,000 participating households, each with a heat pump installed. EQUINOX hitting its overall recruitment target with a trial to spare reflects strong customer interest in engaging with the transition to low carbon heating. Participants were offered financial incentives to turn down their heating for two-hour EQUINOX events during weekdays between 4-8pm. Events tested participants' willingness and capability to provide demand response across a range of commercial arrangements, notice periods, event timings, and heat pump control methods. Participants were rewarded financially for their performance in demand response events as part of a wider 'trial incentives' package that averaged at £43 per participant over the winter.

Trial two uncovered key findings on domestic heat pump flexibility. These findings deepen our understanding of how customers will accept and respond to requests for flexibility from their heating and how much networks may be able to rely on that flexibility to manage constraints in a net zero future. These findings include:

1. **Heat pump behavioural change provides meaningful demand shifting out of the evening peak period for individual customers.** Participants provided statistically significant demand response, totalling 6.5 MWh across 36 two-hour events. An average of 47% of participants opted in to and turned down in each event. Opted in participants provided an average measurable demand response of 0.6 kW (1.2 kWh) per two-hour event, which represented a 48% reduction in their home's peak load.
2. **Heat pump flexibility can help to resolve distribution network Constraint Managed Zones (CMZs) when combined with other assets.** Scaling up the average trial two demand response per heat pump across several scenarios for the Hayle-Camborne CMZ indicates that heat pumps are well-placed to meet a proportion of the CMZ's base weekday flexibility need. Heat pumps could reach 20% of the CMZ's projected peak demand in 2028, demonstrating the need for additional assets for shorter periods to meet the remaining peak demand. This analysis highlights that heat pumps are a valuable option for advanced dispatch to form a reliable peak reduction solution.
3. **Minimal impact on thermal comfort was reported by EQUINOX participants**. Even when surveyed after the coldest events (< 3°C), 85% of participants reported either no change or a slight change in comfort. Additionally, amongst participants reporting feeling any discomfort during events, 91% reported experiencing just mild discomfort. These results indicate heat pump flexibility can be delivered without households experiencing significant discomfort.
4. **External temperature was one of the strongest drivers of demand response**. The average participant offered 0.07 kW more demand response during an event for every 1°C drop in external temperature below 6.1°C (the trial average). Meanwhile, the opt in rate – taken as a metric of ongoing willingness to participate – was only 10% higher for the warmest events (>7°C) than for the coldest events (<3°C). These results strongly suggest greater

demand response per heat pump household can be procured when the weather is coldest, despite slightly fewer households opting in.

5. **A key driver of demand response was whether a participant's electricity tariff was already incentivising them to shift load out of the evening peak.** Participants on tariffs offering different unit rates during the day were already contributing to peak load reduction and had limited additional demand response to offer through concurrent EQUINOX events. These results highlight that explicit flexibility like that in EQUINOX trial two and implicit flexibility such as time of use tariffs both have a role to play de-loading the distribution network during peak hours.
6. **Heat pump flexibility is open to all households, including those with potential vulnerabilities.** Customers with potential vulnerabilities were not found to differ significantly from other customers in either their demand response volume or in their event participation rates.
7. **Automated control over the heat pump is not necessary for the delivery of flexibility.** Participants with manual and remote (app) controlled heat pumps provided demand response at a statistically equal rate and magnitude. This shows the potential for manual shifting to help alongside automation. Whilst our aggregator-controlled cohort also appeared to offer demand response during events, the sample size was too small to obtain statistically significant results.
8. **Participants provided the same demand response at the same opt in rates for two-hour events across different commercial arrangements, event notice periods, and event times during the evening peak.** There was a statistically insignificant variation in outcomes whether participants were paid higher or lower £/kWh rates for the demand response that they provided in each event. This was also the case if participants were notified a day ahead of, the morning of, or two hours prior to the event; and if they were asked to participate in events held between 4-6pm, 5-7pm, or 6-8pm. This demonstrates that heat pump households can be adaptable in providing event-based flexibility.

The third and final EQUINOX trial in the winter of 2024/25 will continue to innovate and advance the conversation on domestic low carbon heating flexibility. A key feature will be exploring the potential for heat pumps to provide base peak-load reduction flexibility through a pre-scheduled, longer-term flexibility commercial arrangement in alignment with findings highlighting the baseload flexibility potential for heat pumps. Additionally, trial three aims to implement stacking between EQUINOX and another flexibility offering, trial longer events, and test customer acceptance of events held during the morning peak.

Trial three will also build on work completed alongside trial two to create an Equitable Participation Framework (EPF). The EPF identified factors that could increase the likelihood a participant will be in a vulnerable situation with regards to home heating, which could compound and impact their ability to unlock benefits from participating in flexibility. We expect to refine our data measurement and analysis for these participants.

We also expect to continue to explore ways to capture as broad a sample of customers as possible. We are planning to onboard a second DNO, SP Energy Networks, for trial three. This will open up participation from customers in additional license areas.

Overall, we are extremely encouraged by the results and findings from trial two and believe it has offered unique insights into how much networks can rely on customer demand response through domestic heat pump flexibility. We are looking forward to the upcoming winter 2024/25 trial.

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2. Purpose and guide

2.1. Purpose

The purpose of this report is to share learnings from trialling novel commercial methods in trial two of the Equitable Novel Flexibility Exchange (EQUINOX) project. It is also intended to provide an overview of the customer experience during trials, the simulated network impact, and the commercial terms for Distribution Network Operators (DNOs), energy suppliers, and customers.

2.2. Guide to this document

- **Section 3** introduces the EQUINOX project, trial two, and project partners.
- **Section 4** provides a summary of the trial two design, including commercial arrangements and high-level analysis methodology.
- **Section 5** sets out trial two's recruitment approach and resulting participant demographics.
- **Section 6** outlines the demand response results of trial two.
- **Section 7** outlines key participant experiences, focusing on survey responses, interviews and focus groups.
- **Section 8** summarises the network impact of scaling up EQUINOX demand response in Hayle-Camborne CMZ.
- **Section 9** outlines next steps for further research in trial three.

3. Context

3.1. Introduction to EQUINOX

EQUINOX is a Network Innovation Competition (NIC) project, funded by the Office of Gas and Electricity Markets (Ofgem). It is developing, trialling, and implementing commercial arrangements at scale that can maximise participation of domestic heat pumps in DNO flexibility while meeting the needs of all customers, including those with vulnerabilities.

Heat pumps are a key technology for the UK to decarbonise its domestic heating enroute to net zero. The UK government has targeted 600,000 heat pump installations per year by 2028. An impact of the heat pump rollout is a significant increase in electrical load. Since domestic heating and hot water needs typically overlap with existing morning and evening peaks in electrical demand, electric heating is forecast to considerably increase demand at peak times. Managing heat pump operation via flexibility services could alleviate these peak load impacts. A better understanding of heat pump flexibility from the EQUINOX trials could enable domestic heat pump households to become a key asset type which flexibility service providers can reliably call upon to fulfil network flexibility contracts. This could enable DNOs to defer network reinforcement, ultimately benefiting all end consumers in the form of reduced energy bills.

EQUINOX is testing multiple novel commercial arrangements across three winter trials. Trial one ran from December 2022 to April 2023. With nearly 400 households ('participants'), it served as a proof of concept for commercial-scale UK demand flexibility from residential heating. Trial two, which is the focus of this report, ran from November 2023 to March 2024. It increased EQUINOX's scale to over 1,000 participants and iterated on trial one's commercial arrangements to test new ones more closely resembling existing commercial flexibility procurement arrangements with availability and utilisation payments. A third EQUINOX trial will run in 2024/25, building on trial two learnings and testing additional elements that will further inform what is possible for business as usual (BaU). The overall EQUINOX project timeline is shown in Figure 1.

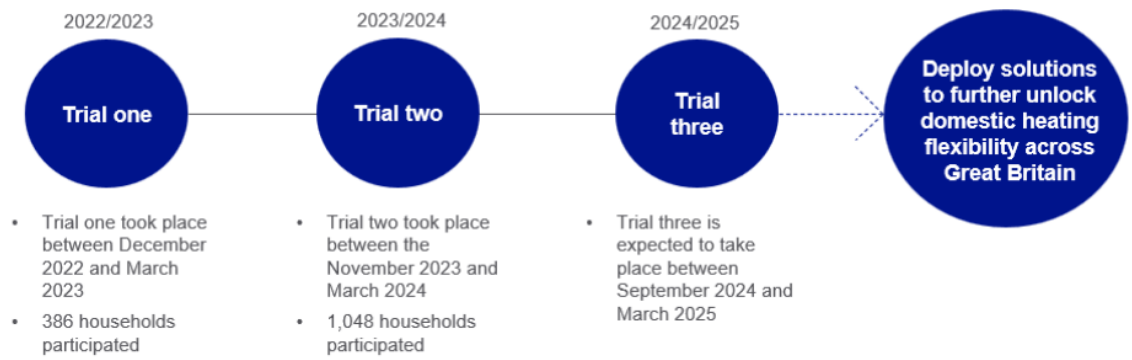

Figure 1. EQUINOX project timeline

3.2. Introduction to project partners and collaborators

EQUINOX is led by National Grid, along with multiple project partners and collaborators, as detailed in Table 1.

Table 1. List of EQUINOX partners and collaborators

Name	Project function	Role
National Grid (Electricity Distribution)	DNO	Project lead. Responsible for running the technical integration, trial design, and project management and knowledge workstreams.
Guidehouse	Consultancy	Partner. Responsible for supporting the commercial arrangement design and customer engagement workstreams. Supporting on trial design, data analysis, project management, and knowledge dissemination.
Octopus Energy	Energy supplier	Partners. Responsible for planning and delivering EQUINOX trials with participants from their customer base. Supporting on all project workstreams as commercial flexibility service providers and customer experts.
Sero	Energy supplier[1]	
ScottishPower	Energy supplier	
Passiv UK	Smart technology company	Partner. Responsible for simulating the flexibility impacts for different intervention strategies and household archetypes.
West Midlands Combined Authority	Local government	Partner. Responsible for coordinating a social housing heat pump installation programme which can contribute customers to trials two and three. Also advising on equitable participation.
Welsh Government	Government	Partner. Responsible for running a social housing heat pump installation programme which can contribute customers to trial three.
National Energy Action	Charity	Collaborator. Responsible for running participant focus groups to understand trial perceptions. NEA will ensure that the needs of customers with vulnerabilities are accounted for in the trial design.
SP Energy Networks	DNO	Partner. A DNO brought on board to ensure that the design is interoperable for all DNOs. SPEN's license areas will join trial three.
National Grid (Electricity System Operator)	ESO	Collaborator. Responsible for sharing learnings between EQUINOX and other ESO flexibility programmes, notably the Demand Flexibility Service and Crowdflex project.

[1] Sero is not an energy supplier but is assuming the role for the purpose of this trial.

4. Trial two design

4.1. Introduction to trial two

EQUINOX trial two built on trial one with significant innovations. Trial one demonstrated that heat pump demand turndown can be measurably achieved in a two-hour event window during the evening peak period without unduly affecting customer comfort and with a high-level of customer satisfaction. Trial two was designed to explore more deeply which factors impact the magnitude and consistency of the demand response provided by heat pumps during the evening peak. It also aimed to examine commercial arrangements more closely representing BaU DNO flexibility procurement.

During trial two, participants were asked to turn their heat pump down for specified two-hour events ("events"). These events occurred between the hours of 4-8pm on 'event days' held up to three days per week, excluding weekends. There were 36 events in total between 3rd November 2023 and 13th March 2024.[2] Each participant experienced a maximum of 19 events across the trial period, during which their household electricity consumption was observed. Each participant's own historical electrical consumption data was used as a personalised baseline for each event. Participant consumption during an event was compared against this baseline to calculate their reduction in electricity demand ("demand response"). Across all commercial arrangements, participants received a utilisation payment per kWh of reduction in demand they achieved in each event.

To be eligible for the trial, customers needed to:

- Have an electricity smart meter operating in smart mode.
- Be customers of an EQUINOX partner supplier (Octopus Energy, ScottishPower, or Sero).
- Have a ground source or air source heat pump installed and operating in their home.
- Not be participating in any other demand flexibility services running during winter 2023/24.
- Be located within National Grid's Distribution Network license areas.

These eligibility requirements were intentionally broad, ensuring that a wide range of customer experiences and flexibility performances could be captured in trial two. Participants were financially incentivised to fill out a series of long and short surveys across the winter. Some participants were invited to participate in additional qualitative research such as focus groups and interviews. Research participation payments were additional to performance-linked utilisation and availability payments from the events themselves.

[2] Note that events were also held on five consecutive evenings between Monday 18th – Friday 22nd March 2024. These events formed an additional mini trial to assess how participants responded to being called for five days in a row. These events will be analysed in a separate report.

4.2. Trial two factors of interest

Trial two aimed to better understand the amount of aggregated flexibility that can be procured from domestic heat pumps. Where trial one showed that demand response could be measurably achieved, trial two assessed the drivers of that demand response. The magnitude and consistency of participants' demand response was therefore evaluated across various factors of interest to identify which had statistically significant impacts. These factors included payment premise, heat pump control type, event notice period, external temperature, event timing, and participants' electricity tariff type. The above factors were tested across three commercial arrangements: M1, M2, and M3. These are summarised in Table 2 below.

Table 2. Trial two commercial arrangements

Commercial arrangement	M1	M2	M3
Payment structure	High utilisation payment (per kWh).	Low utilisation payment (per kWh).	Availability payment + medium utilisation payment (per kWh).
Control type	Manual and remote customer control.	Manual and remote customer control.	Aggregator controlled.
Notice period	Day ahead, morning ahead, two hours ahead.	Day ahead, morning ahead, two hours ahead.	Day ahead, morning ahead, no notice.
Payment amounts	• Day ahead: £0.80/kWh. • Morning ahead: £1.60/kWh. • Two hours ahead: £2.40/kWh.	• Day ahead: £0.40/kWh. • Morning ahead: £0.80/kWh. • Two hours ahead: £1.20/kWh.	• Day ahead: £0.50/kWh. • Morning ahead: £1.00/kWh. • No notice: £1.50/kWh. • Availability payment: £8 upfront per participant.
Eligible supplier tariffs	Any tariff.	Any tariff.	All M3 participants were on a tariff of interest.
Participation approach	Participants opted into events.	Participants opted into events.	Participants opted out of events.
Event duration	Two hours.	Two hours.	Two hours.
Event timing	Between 4-8 pm any weekday.	Between 4-8 pm any weekday.	Between 4-8 pm any weekday.
Event frequency	Zero to three events per week.	Zero to three events per week.	Zero to three events per week.
Supplier notice	Informed by National Grid on Wednesday of the following week's events.	Informed by National Grid on Wednesday of the following week's events.	Informed by National Grid on Wednesday of the following week's events.

Each participant was assigned to one arrangement. As Table 2 shows, some of the above factors of interest, like payment structure and heat pump control type, varied in specific ways between M1, M2, and M3. Other factors like temperature and event timing were explored across all three arrangements. Each factor of interest is described in more detail below, including why they were explored.

Payment structure

Trial two aimed to examine commercial arrangements more closely representing BaU DNO flexibility procurement. Where trial one linked customer performance incentives to length of participation in an event, trial two instead used customer performance incentives linked to their utilisation and availability as an asset. These payment structures are commonly used across DSO and ESO flexibility services.

It is not well understood how participant heat pump demand response is impacted by differing price signals for occasional (non-daily) flexibility needs. Trial two events were therefore designed to represent aspects of National Grid's Secure and Dynamic flexibility products, which procure flexibility on a non-regular basis to resolve network constraints for a few hours (see Table 3). Payment amounts were set according to the range of commercial values typically associated with Secure and Dynamic procurement, noting these can vary significantly based on location and actual needs. Rewarding participants' demand response in line with existing commercial flexibility prices is an important step in demonstrating the BaU viability of heat pump flexibility, albeit by proxy as BaU commercial relationships between suppliers and customers are at each supplier's discretion.

Table 3. National Grid flexibility products

Flexibility product	Network constraint	Customer notice period	Duration
Secure	Peak load management.	Week ahead, real time, within day.	30 mins to several hours, over a single day.
Dynamic	Unscheduled maintenance.	Week ahead, real time, within day.	30 mins to several hours, over a single day.
Sustain	Constraint management service.	Advanced pre-agreed schedule.	Four hours, for several weeks Monday to Friday.

The Sustain flexibility product was initially considered as well, but ultimately was not used to inform trial two payments as it did not align with trial two event design. Sustain is an advance scheduled longer-term National Grid flexibility product that procures demand response daily between 4pm-8pm, Monday to Friday, for multiple weeks in a row. Testing this form of long-term behavioural change in home heating was not within the scope of trial two, though is an ambition for trial three as discussed in Section 9.

As shown in Figure 2, utilisation prices in National Grid's Secure and Dynamic services range from £0.01/kWh to £9.17/kWh, with additional availability prices ranging from £0/kWh to £1.25/kWh.[3] As higher prices are available in limited locations, it was decided to focus payment amounts around average prices. All trial two participants were offered a utilisation payment rate linked to their measured kWh demand response during an event. These payments were varied per event according to the notice period afforded to participants, further reflecting existing commercial structures (see event notice period section below for more details).

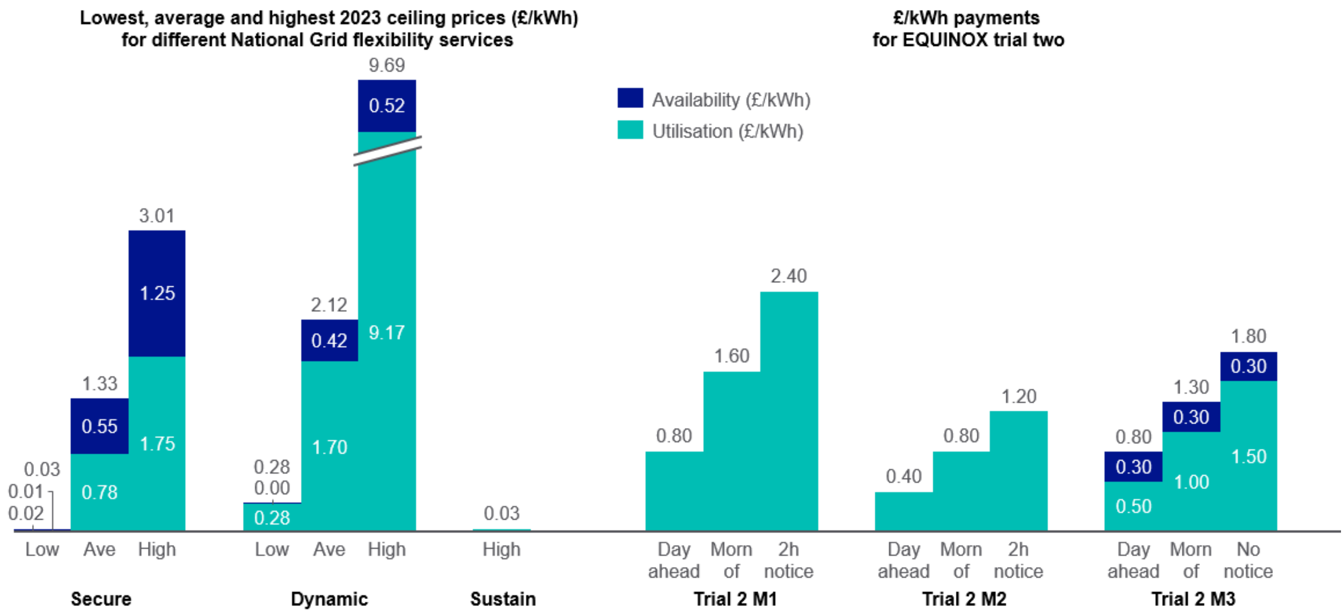

Figure 2. Comparison of the 2023 ceiling prices for National Grid's Secure, Dynamic, and Sustain flexibility products with trial two payments from suppliers to participants.

To examine the hypothesis that participants may have different participation rates at different incentive rates, commercial arrangements M1 and M2 were configured identically, varying only in the £/kWh utilisation rate offered to participants for each event (denoted as high and low, respectively, in Table 2). In contrast, commercial arrangement M3 was designed with both availability and utilisation payments, incentivising customers to allow their supplier to control their heat pumps in events and automatically dispatch demand response. The final agreed payment amounts are shown in relation to National Grid's flexibility product prices in Figure 2.
In recognition of the value of customer participation in EQUINOX, overall customer incentives were made up of participation rewards in addition to event performance payments; this included an adjustment payment made to participants in M2 to normalise their overall payment with that of M1 participants. Customer motivations for participating in EQUINOX trial two were determined to not be primarily financial,[4] which is a limitation on this study of consumer price sensitivity in demand response events.

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[3] Note that availability prices are commercially quoted in £/kW but have been converted to £/kWh for ease of comparison.
[4] See the Trial 2 Customer Report for more details

Heat pump control type

Heat pumps and other low carbon technologies (LCTs) like domestic battery storage are being increasingly designed with smart automation capabilities. A recent government consultation on implementing a smart and secure electricity system proposed equipment standards for enabling automated control of LCTs.[5] There is therefore an assumption that future flexibility services will be driven by automation. Most trial two participants did not have smart heat pumps as this capability is still nascent, though a minority did. We therefore explored how the amount and reliability of heat pump flexibility varied between different types of control. We trialled three heat pump control approaches during events:

- Manual customer control: participants turned down their thermostat manually in their home.
- Remote customer control via phone app: participants turned down their thermostat via an app.
- Aggregator control: participant thermostats were turned down remotely by their supplier (or aggregator).

Event notice period

A key element of the commercial arrangement design was to test different notice periods for contacting customers in advance of an event. We aligned utilisation incentive rates the magnitude of the notice period as flexibility service payments are often more lucrative when called upon at shorter notice. The notice periods trialled broadly align with different DNO flexibility services and enabled testing of the impact of varying notice periods on participant engagement and demand response magnitude. The notice periods were:

- Day ahead, with around 24 hours of notice ahead of events.
- Morning of, with around eight hours of notice ahead of events.
- Two hours ahead, with around two hours of notice ahead of events.
- No notice, with participants not informed of an upcoming event.

No notice events were called for aggregator control participants when customer control participants received two hours' notice. These participants were told that this was a possibility in their terms and conditions and explicitly gave their consent to being automated in this way.

External temperature

Heat pumps have a lower coefficient of performance in colder weather and have to act against a greater temperature gradient to warm spaces to the desired set point. These elements combine such that heat pumps use more energy on colder days. Conversely, households may be less inclined to opt into an event on a colder day, out of concern that their homes may become too cold. We therefore held events across a spread of temperatures throughout the winter to see how these two factors interacted, and how demand response and external temperature were related. We scheduled event days to cover the widest possible spread of temperatures, based on the forecast for the week ahead. Forecasts were checked regularly to identify cold periods and we had the ability to schedule contingency events if needed. Nevertheless, the relatively mild winter limited the number of cold days (<3°C) that events could be held on.

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[5] UK Government, 2024; Delivering a smart and secure electricity system: implementation

Event timing

If DNOs request flexibility from suppliers for the full four-hour period, suppliers may need to spread heat pump flexibility across two-hour windows to achieve the requested flexibility. We therefore investigated whether the exact timing of events impacts the demand response achieved by participants. All events were held during the evening peak, but cycled between 4-6pm, 5-7pm, and 6-8pm to test how flexibility procurement from heat pumps varies across DNOs' overall evening peak demand period. This built on trial one, which only held events from 5-7pm. For more information on how events were scheduled, please see Appendix A: Event scheduling and operations

Electricity tariff

A significant proportion of households engaging in trial two had pre-existing financial incentives to engage in flexibility via supplier Time of Use (ToU) tariffs. ToU tariffs have more than one electricity unit rate (£/kWh) in each 24-hour period, incentivising households to use electricity when rates are cheaper. Doing so can offer these customers significant financial savings on energy bills. ToU tariffs have recently been more targeted towards customers with LCTs. They are available from an increasing number of retail energy suppliers and are expected to remain a feature of the domestic energy landscape.

Where a household is already incentivised by their tariff to shift consumption outside of peak demand hours (4-7pm), it is not known if there is significant additional flexibility that can be unlocked by offering a second flexibility incentive in the form of EQUINOX event incentives. For trial two, participating households were characterised into one of two tariff groups – those with and without a 'tariff of interest':

- Tariff of interest: Those offering different unit rates during the day, particularly disincentivising electricity consumption across the evening demand peak. This included Cosy Octopus (a tariff aimed at customers with Heat Pumps), Octopus Flux (a tariff aimed at customers with solar generation and home batteries) and Agile (a unique tariff mirroring the wholesale electricity market that can have up to 48 different unit rates per day (one per settlement period)).
- All other tariffs: This includes standard tariffs that do not have more than one unit rate per day, and ToU tariffs that incentivise electricity consumption overnight but do not have varying unit rates during the day. This means they do not specifically disincentivise electricity consumption across the evening demand peak. Such tariffs are typically aimed at customers who charge electric vehicles (EVs) at home.

Beyond the factors listed above, we also explored the impact of the following variables on heat pump demand response magnitude and consistency.

- House energy performance certificate (EPC) rating: used as an industry standard metric for household energy efficiency, and therefore as a proxy for thermal efficiency of a home.
- Self-reported fuel poverty indicator: This was used as a metric to observe whether demand flexibility was being accessed equitably in trial two.

4.3. Randomised control trial approach

Trial two was implemented as a crossover Randomised Controlled Trial (RCT), wherein participants are randomly assigned to two groups (referred to as 'group A' and 'group B') each consisting of around half of the total participant pool. Although the participant's group does not change during the trial, each group switches between being the control or the treatment group depending on the event day. In this way, each event has around half of trial participants in the treatment group and half in the control group.

This programme design is known to produce an unbiased estimate of programme impacts. Because participants are randomly assigned into a treatment group or a control group, they are expected to be equivalent in every way except programme treatment. In this case, programme treatment is the receipt of notifications of trial two demand response events. As such, any differences between the treatment group and the control group observed in the trial period are assumed to be the result of the events. Although the crossover RCT approach introduces a risk of behavioural 'spillover', where having previously been in the treatment group causes ongoing changes during periods where that participant is then in the control group, it was felt to be the most appropriate approach for maximising the number of active participants in trial two.

Difference in Difference (DiD) demand response approach
Following industry best practice for evaluating RCT programmes, suppliers leveraged a DiD approach for calculating demand response. DiD approaches provide an unbiased estimate of programme demand response when energy consumption from the entire treatment group is compared to the entire control group for each event. This is known as the intent-to-treat (ITT) effect. Equation 1 below provides the DiD specification used for EQUINOX Trial two to calculate an unbiased estimate of demand response for each event. Equation 2 details the calculation of uncertainty (standard error).

Equation 1: DiD demand response calculation[6]

$$Demand\ response = \left[mean\left(observed\ demand_{treatment,\ event}\right) - mean\left(observed\ demand_{control,\ event}\right)\right] - \left[mean\left(observed\ demand_{treatment,\ non-event}\right) - mean\left(observed\ demand_{control,\ non-event}\right)\right]$$

Equation 2: DiD standard error calculation[7]

$$Demand\ response\ standard\ error = \sqrt{\frac{Variance\left(observed\ demand_{treatment,\ event}\right)}{Customer\ count_{treatment,event}} + \frac{Variance\left(observed\ demand_{control,\ event}\right)}{Customer\ count_{control,event}} + \frac{Variance\left(observed\ demand_{treatment,\ non-event}\right)}{Customer\ count_{treatment,non-event}} + \frac{Variance\left(observed\ demand_{control,\ non-event}\right)}{Customer\ count_{control,non-event}}}$$

Treatment group participants in M1 and M2 were deemed to have delivered demand response for an event if they both opted in when informed of the event and reduced their energy consumption during the event as per Equation 1. This was similar for treatment group participants in M3, except they had to not opt out when informed of the event, rather than opting in. Given these opt-in requirements for analysing the treatment group, the treatment effect on the treated (TOT) can be calculated from the demand response value estimated using Equation 1 by scaling that value by the opt in rate, as defined in Equation 3.

[6] Observed Demand = household consumption in kWh; Treatment = group of customers called to participate during an event; Control = group of customers not called to participate; Event = time frame during which consumption was averaged across the treatment or control group of customers on event days; Non-event = time frame during which consumption was averaged across the treatment or control group of customers on non-event days.
[7] Variance = statistical measure quantifying estimate uncertainty; Customer count = number of customers called during event.

Equation 3: Opt-in rate calculation

$$Opt\ in\ rate = \frac{Number\ of\ participants\ opted\ in\ and\ showing\ energy\ reductions\ during\ the\ event_{treatment,event}}{Number\ of\ participants\ called\ to\ participate_{treatment,event}}$$

Customer Settlement

For customer settlement purposes, a personalised, historical baseline ('baseline') approach was implemented. The baseline approach assists in closing the gap between the best-in-class accuracy that the crossover RCT approach can provide in determining the magnitude and statistical significance of any demand response provided during EQUINOX events, and the individualised approach that is needed to calculate the demand response performance of individual customers so that they can be promptly paid their performance incentive.

In accordance with wider industry practice, the p376 methodology, without in-day adjustment, was chosen for generating baselines. This method uses the last 10 non-event weekdays to generate an average consumption value per settlement period, resulting in a half-hourly baseline demand profile for an event day. A participant's demand response is calculated by deducting their observed electricity consumption from their baseline consumption. Demand response achieved during an EQUINOX event is multiplied by their utilisation payment rate for that event to determine the performance incentive owed to that participant.

4.4. Event process

We used the following approach to schedule and manage trial two events.

- Before the trial:
  i. **Scheduled events:** A weekly event schedule was finalised before trial two began. This minimised administrative burden for suppliers as it meant the suppliers knew for each event which group of participants (A or B) would be the treatment group, what the notice period would be, and what time the event would start. During the trial, specific weekdays were chosen for the following week's scheduled events based on the weather forecast. This maximised the opportunity to hold events across a range of temperatures. See Section 10.1 for more detail on the event scheduling approach.
- For each event:
  ii. **Informed treatment group of events:** Before each event, suppliers reached out to that event's treatment group participants to inform them of an upcoming event. Suppliers sent these communications in line with that event's notice period. M1 and M2 participants were asked to turn down their heating during the event. M3 participants were told their heating would be automatically turned off during the event.
  iii. **Collected opt ins and opt outs:** M1 and M2 participants were asked in the event invitations to opt into the event. M3 participants were asked to opt out of the event, so that their supplier knew not to automate their heating on that occasion. This explicit opt in/out approach helped suppliers to better understand which participants were eligible for post-event payment in step vi.
  iv. **Held event:** The suppliers received a dispatch signal from National Grid via the Flexible Power platform. This informed them of the event start. Please see below for more information on the Flexible Power

process. Each supplier had someone on hand to respond to any queries or concerns from participants during the event.

v. **Sent post-event survey:** All treatment group participants, including those who had not opted in (M1/M2) or opted out (M3), received a short survey via email immediately after the event. As detailed further in Section 4.5, this gathered information on participants' immediate experience of the event.

vi. **Settled utilisation payments with participants:** Suppliers used the approach detailed in Section 4.3. Randomised control trial approach under 'Participant Settlement' to pay participants who had opted in and provided measurable demand response. Payments aligned with the relevant £/kWh rate afforded by their assigned commercial arrangement and that event's notice period.

4.5. Overview of participant feedback approach

During EQUINOX trial two, customer research was carried out to understand:

- Why participants signed up and were motivated to participate.
- What the demographics of participants were and how that compared to the UK population.
- How satisfied participants were with the trial design and experience.
- How EQUINOX events altered participant behaviour and if they impacted thermal comfort.
- What the barriers and benefits were of participating.
- Whether or not participants with potential vulnerabilities were equally able to take part in events and benefit from participating.
- How participant experiences were shaped by the factors described in 4.2. Trial two factors of interest, and whether views and preferences complemented or deviated from the demand response evaluation.

This research was carried out through quantitative and qualitative methods. This included surveys, interviews, and focus groups. The qualitative research included a specific focus on engaging potentially vulnerable customers to understand any specific challenges to participating. Customer research was gathered from:

- Online survey sent at the start of trial two ('start of trial survey') to understand motivations to participate, experience with trial sign up, and information about home heating set-up and participant demographics.
- Online survey sent after the first 9 events to understand trial experience thus far and obtain early feedback on trial design to determine if any changes needed to be made for the duration of trial two.
- Online survey sent during the last week of the trial ('end of trial survey') to understand satisfaction with trial design, views on technology automation and stacking, and the impact of trial on customer comfort.
- Short online survey sent to treatment group participants immediately following all 36 EQUINOX events ('post-event survey') to gather information on whether customers participated, whether customers were adjusting anything besides their heat pump, and if they experienced change in comfort. It also allowed customers to provide information in a free text to ensure suppliers could respond to any concerns.
- 8 focus groups with 37 customers, including 4 focus groups with customers with potential vulnerabilities, to enable more context and personal narratives to be captured around motivations for taking part in EQUINOX, home heating practices and comfort, heat pump learnings, and trial design.
- 13 individual customer interviews to capture qualitative learnings of the same nature as the focus groups.

The results and insights gathered need to be interpreted with the understanding that the responses are from a self-selecting sample of households who took part in the trial. Their experiences cannot be interpreted as representative of all households but are thought to be representative of existing heat pump homes. Important insights can be drawn, particularly for consideration in future iterations of low carbon heating demand side flexibility offerings.

Insights gathered through this research were utilised to monitor customer experience throughout the trial and will be used to inform EQUINOX trial three.

5. Trial two participants

5.1 Recruitment approach

Customer recruitment for trial two focused on the eligibility requirements noted above. Each supplier led customer recruitment activities for their customer base and oversaw trial delivery for their own participants.

Suppliers followed common approaches to recruitment, though each had suitable freedom to engage with their own customer base as they felt was appropriate. Recruitment activities occurred for one month and were completed before the trial period began on 1st November 2023. An overall recruitment target of 600 participants was set, aiming to approximately double the number of participants in trial one. Suppliers were very successful in recruiting participants from their customer bases, with the overall pool of recruited customers exceeding 1,000 (1,048). This considerably surpassed the target and met a key project goal.

Customer sign-up journey
Suppliers predominantly conducted customer outreach via emails which included messaging about EQUINOX project aims, a description of what would be requested of customers participating in trial two, and potential financial benefits of taking part. Of note, participation in trial two was framed as an opportunity to take part in an innovation project furthering collective understanding of how low carbon heating could be utilised flexibly for network benefits. As part of the recruitment process, customers completed a sign-up survey and agreed to the terms and conditions of the trial.

The customer sign-up survey was consistent across suppliers and was designed to collect information about the customer's household make-up, house properties, and heating system. This data was used to conduct the analysis described in Section 4.3 and to examine whether the customer demographics represented in trial two were representative of the general UK population. This comparison was particularly important as residential heat pumps are still in an early phase of general adoption in the UK and it is unclear whether some EQUINOX results may be less applicable in future when heat pumps are a mass market technology with a wider user base.

The trial terms and conditions set out the supplier's expectations of their customers participating in the trial and what customers could expect from their supplier while participating in the trial. This included how financial incentives would be paid to customers and a fair use policy to provide recourse if a participant was thought to be gaming the utilisation payment settlement method. It was stressed that participants were under no obligation to participate in events, they would not be penalised for under-participation in events, and that they could exit the trial at any time by contacting their supplier with such a request. Data collection, processing, use, and sharing were covered in the terms and conditions, with consent to these data uses forming part of the agreement.

5.2 Participant details

Motivations for participation

Participants were highly motivated by environmental concerns. This was consistent across several metrics in the surveys, focus groups, and interviews:

- When asked about how important environmental and financial reasons where in participants deciding to participate in the trial, 75% of participants indicated that environmental reasons were either very or extremely important to their decision to participate, compared to 46% for financial reasons (see Figure 3).
- This was consistent with focus group and interview responses who also noted environmental reasons as the driving factor, also citing financial benefits and/or an interest in contributing to research and innovation.
- 97% of trial two participants indicated being somewhat or very worried about the impact on climate change, compared to 76% of the UK average[8].
- 64% of participants used the now closed Renewable Heat Incentive (RHI) to help purchase their heat pump, demonstrating that the participant pool was skewed towards particularly early heat pump adopters.

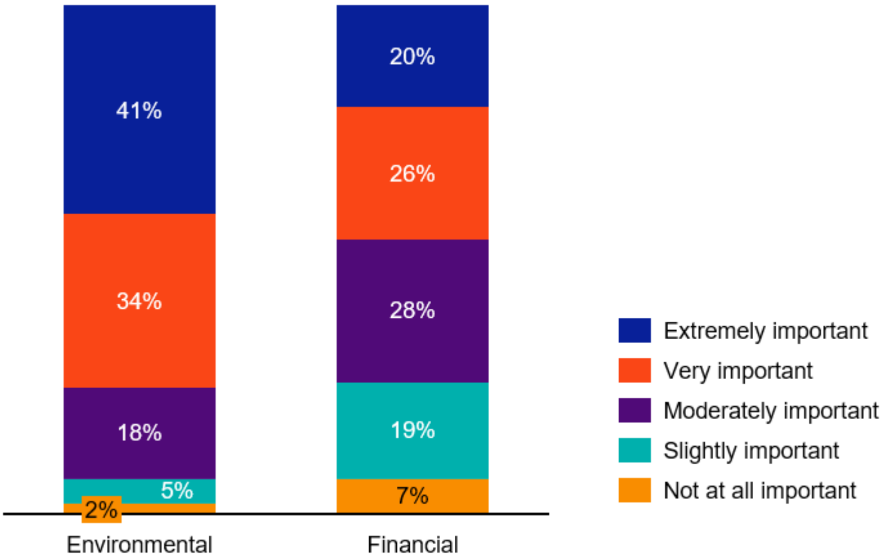

Figure 3. Trial two participant responses to the question 'how important were environmental / financial reasons in influencing your decision to participate in the trial, if at all?' (n = 732)

Representation

While there is still room for greater representation of different subsets of the population, trial two made progress in recruiting a more diverse customer base. We cannot currently quantify the impact that this variation from the UK demographic has on our trial results, but will continue to assess this in the projects next trial as we aim to increase representation of rented properties. Increasing representation from non-homeowners including those who privately rent and socially rent was a key priority area. As demonstrated in Figure 4, most trial two participants still own their

[8] Office for National Statistics, Census 2021

home, but there was an approximately 8% increase in participants who reside in social housing, compared to trial one. However, this is still below the UK average of 17%.[9] This could be because homeowners have more control over altering the fabric of their home, making heat pump installations more viable for them. Thus far there has also been slower uptake for landlords in installing heat pumps[10]. Therefore, it is somewhat expected to see high home ownership in this trial as compared to the UK average.

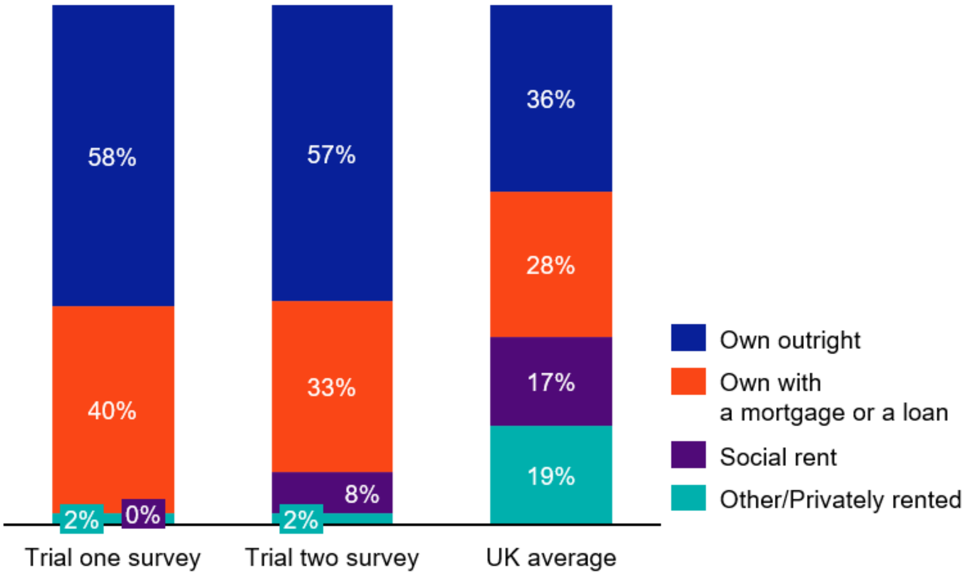

Figure 4. EQUINOX participants relationship to their property, compared to the UK average

As it relates to participants' ability to pay their energy bills (see Figure 5), in trial two there was greater alignment to the UK average,[11] however, there were still fewer participants who were often unable or rarely able to afford to pay their energy bill. The variation between trial one and trial two could be attributed to the fact that during trial one participants were experiencing the evolving energy crisis, and the cost-of-living crisis which may have put added strain on participants ability to pay their energy bills.

[9] Office for National Statistics, Census 2021
[10] UK Collaborative for Housing Evidence, Heat Pumps and Domestic Heat Decarbonisation in the UK, 2023
[11] Office for National Statistics, Census 2021

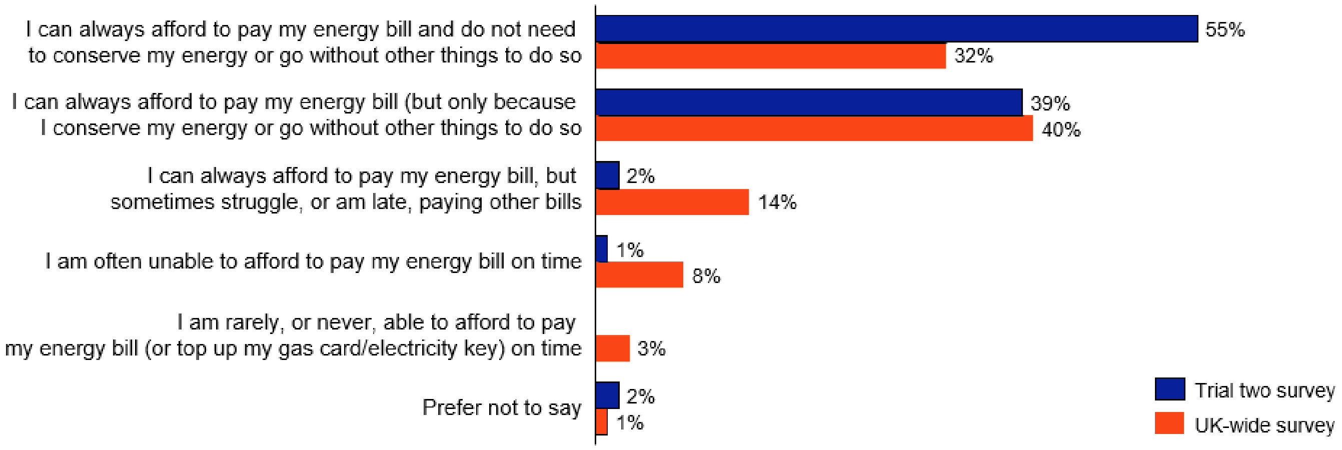

Figure 5. Trial two participants' ability to pay energy bills compared to the UK average.

Lastly, as demonstrated in Figure 6, most households in the EQUINOX trial had total household income between £40,000 and £75,000, which is not representative of the UK average.[12] However, there was again greater variation in household income in trial two than compared to trial one.

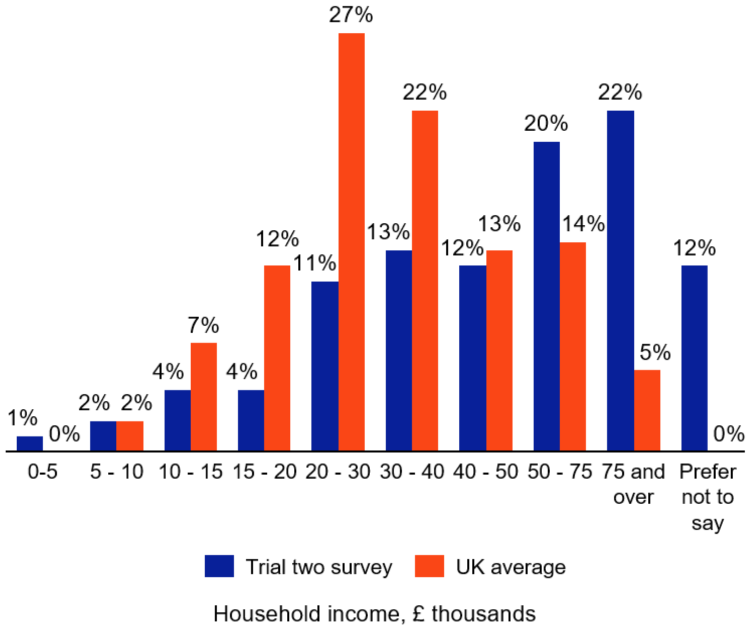

Figure 6. Trial two participants' household income compared to the UK average.

[12] Office for National Statistics, Census 2021

6. Demand response results

Demand response results contains the following sub-sections:

- Overall findings: outlines key trial two results, including the influence of tariff type on demand response.
- Event factors: outlines findings on the relationships between demand response and opt in rates, and event-specific parameters like event day temperature, notice period, and time of event.
- Participant factors: outlines the same findings as the previous section for participant-specific factors like commercial arrangement, heat pump control type, and EPC rating.
- Aggregator-control: outlines the experience of aggregator-controlled participants, who were analysed separately due to their small sample size limiting direct comparison with other groups.

All results were obtained using the baselining and DiD methodologies outlined in Section 4.3.

6.1. Overall findings

Trial two produced statistically significant evidence that participants provided demand response during EQUINOX events, confirming that heat pump behavioural change can result in measurable demand shifting. On average, participants who opted into events provided 0.6 kW of demand response over each two-hour event, representing a 48% reduction in consumption. Scaling up this average figure across all participants and all events, 6.5 MWh of total demand response was achieved during trial two. The average demand response value per opted in participant, however, was caveated by a relatively wide 90% confidence interval of 0.14 kW, demonstrating the inherent variability of demand response provided by different participants on different days. Scaling up, the aggregated 6.5 MWh figure therefore sits within the bounds of 4.9-7.9 MWh.

An average of 48% of called participants[13] opted in across all 36 events. This opt in rate was derived through the DiD approach, highlighted in Section 4.3, as the proportion of called participants that achieved a measurable reduction in their household electrical load relative to the representative control group. The demand response provided during EQUINOX events is visualised in Figure 7 below. The graph shows the half-hourly demand profile of participants who opted into events, averaged across all event days,[14] and the average non-event day baseline demand profile[15] of those same opted in participants. It also shows the average half hourly demand profile of the control group and the control group's baseline demand profile.

[13] Called participants: treatment group participants asked on an event day to provide demand response.
[14] Opted in participants: treatment group participants who opted into an event when called and provided demand response during an event.
[15] The forecasted demand profile based on historic electrical load during the previous 10 non-event days.

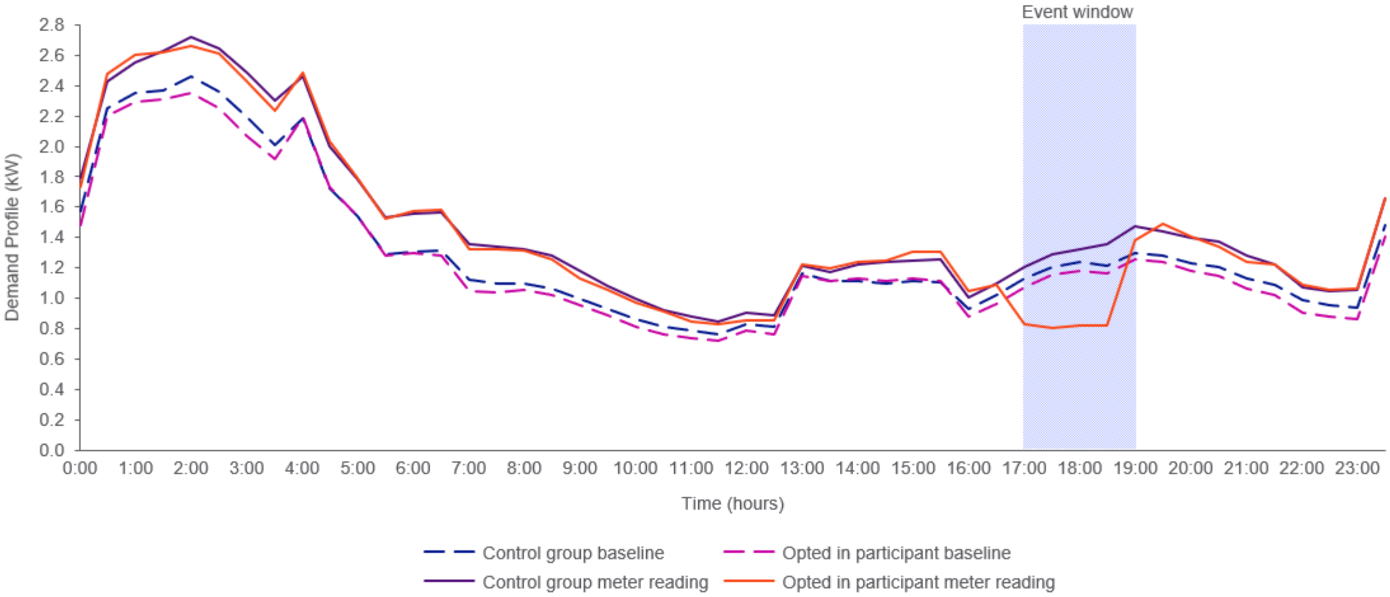

Figure 7. Average demand profile of EQUINOX participants, for events starting 5pm only[16]

Actual demand profiles for the control group and opted in participants are very well matched throughout the day, except for the event period from 5-7pm. This provides visual confirmation that the RCT groups are well matched to one another. The baselines of both groups are well matched, but are noticeably offset from the actual consumption, under-predicting consumption to various degrees across the day. This under-prediction is attributed to weather factors; the p376 baseline method is susceptible to under-prediction when an event day is meaningfully colder than the average temperature of the baseline days. Conversely, it is susceptible to over-prediction when an event day is meaningfully warmer than the average temperature of baseline days. Weather conditions across trial two were relatively mild and the coldest days were specifically targeted for EQUINOX events, which may have produced this average effect of under-predicting consumption.

Nevertheless, the overlaid profiles highlight a clear average reduction in consumption during an event by the opted in participants. This average demand response is achieved without increased demand before the reduction window due to abnormal pre-heating, or afterwards due to snapback,[17] though note these effects may be noticeable for individual events or participants.

The figure also shows peaks in consumption between 1-4pm and 11pm-7am. This is because these demand profiles take the average of all participants, regardless of which tariff they are on. The 1-4pm peak is likely due to participants

[16] Figure 7's demand profile only includes events held between 5pm-7pm. This extends to Figure 8 and Figure 9 below. This is to better visualise the peak reduction trial participants made relative to their own non-event baselines and the control group. This focus on 5-7pm, however, does not distort the results. Event time did not have a statistically significant impact on demand response provided by EQUINOX participants, as is further explained in 6.2. Event factors. Very similar profiles were recorded for events held at 4-6pm and 6-8pm.
[17] Snapback: a rapid increase in electricity consumption immediately after a flexibility event ends.

on tariffs of interest moving their consumption out of peak hours. The overnight peak is likely due to participants with EVs taking advantage of tariffs with lower overnight rates to charge their EVs. Below, we explore the role that participant tariff type played in determining how much demand response participants provided after opting into events.

Tariff type

Trial two findings suggest there could be a relationship between demand response and tariff type, but there was no statistically significant result observed. Figure 8 compares the average opt in rate and event demand response per opted in participant on a tariff of interest with those on all other tariffs.[18] Whilst the opt in rates for both groups are almost equal, participants on a tariff of interest provided lower average demand response (0.25 kW) than those without (0.49 kW). However, this relationship is statistically insignificant at the 90% confidence interval level.[19]

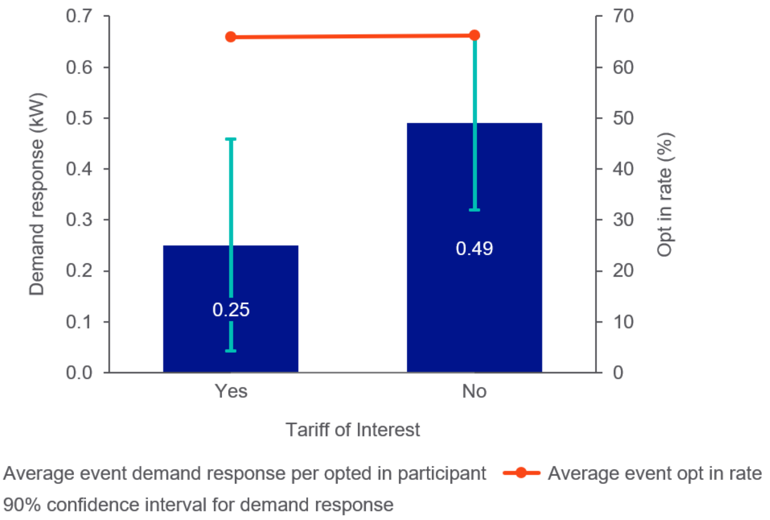

Figure 8. Average demand response per opted in participant and participant opt in rate by tariff type

Nevertheless, the difference between the two groups is striking. The likeliest explanation is that participants on tariffs of interest were already shifting their peak demand away from the evening peak hours targeted by EQUINOX in response to the price signal built into their tariff. As they were already peak load shifting, these participants would have more limited additional flexibility to offer through EQUINOX events, as they are already providing benefits to their DNO.

[18] As explained in Section 4.3, EQUINOX project has defined tariff of interest as a ToU tariff with multiple £/kWh unit rates between 8am-11pm. Tariffs not included under this definition were any tariffs with a single £/kWh unit rate during the daytime, or with one daytime unit rate but a different overnight pricing rate.

[19] Note the demand response values for tariff type are calculated via the same method as above. However, the opt in rates used here were determined using a baseline calculation of whether each individual participant had provided demand response in a given event. This approach produced a slightly higher opt in rate than the approach used for the overall figure above, causing demand response values to skew downwards.

This hypothesis is bolstered by a comparison of Figure 9 and Figure 10 below. They show the same demand profiles as Figure 7 but separately for participants on tariffs of interest and on all other tariffs, respectively. There are three key distinctions between the two sets of demand profiles. Firstly, tariff of interest participants had noticeable demand peaks during off-peak periods between 4am-7am and 1pm-4pm across all four demand profiles. Participants on other tariffs did not.

Secondly, the baselines for tariff of interest participants already indicated that consumption would remain low during the event window. The actual meter readings of these opted in participants closely followed the baseline. In contrast, the baselines and control group for participants on all other tariffs expected consumption to spike during the event window. The actual meter readings of these opted in participants showed a clear dip in demand during the event. These two findings strongly suggest that participants on tariffs of interest were already load shifting from the hours targeted by EQUINOX events, that they were already providing broader benefits to DNOs, and therefore that they had limited additional flexibility to offer through EQUINOX events. Participants on all other tariffs, meanwhile, had a greater ability to provide flexibility through EQUINOX events.

Finally, Figure 10 shows a clear overnight spike representing customers on ToU tariffs which incentivise the overnight charging of EVs. The tariff of interest profiles in Figure 9 however, do not show any such overnight peak as these types of tariffs were not included as part of their remit.

Of additional interest to DNOs, both figures show the metered demand profile of opted in participants varying little from the baseline before and after the event window, particularly Figure 10. This highlights a clear peak reduction, and the theoretical ability for suppliers to provide a longer flexibility offering for the DNO by staggering heat pumps. This will provide DNOs with confidence that procuring heat pump flexibility for a certain time-period will not result in coordinated increased consumption in another time-period, thus creating a new peak.

To summarise, these demand profiles suggest that in BaU, flexibility through events-based procurement can achieve greater measured demand response when targeting customers that are not already shifting their demand out of the target time due to a tariff-based price signal. Additionally, multiple unit rate ToU tariffs provide an alternative demand response solution to displace household electricity demand from peak hours.

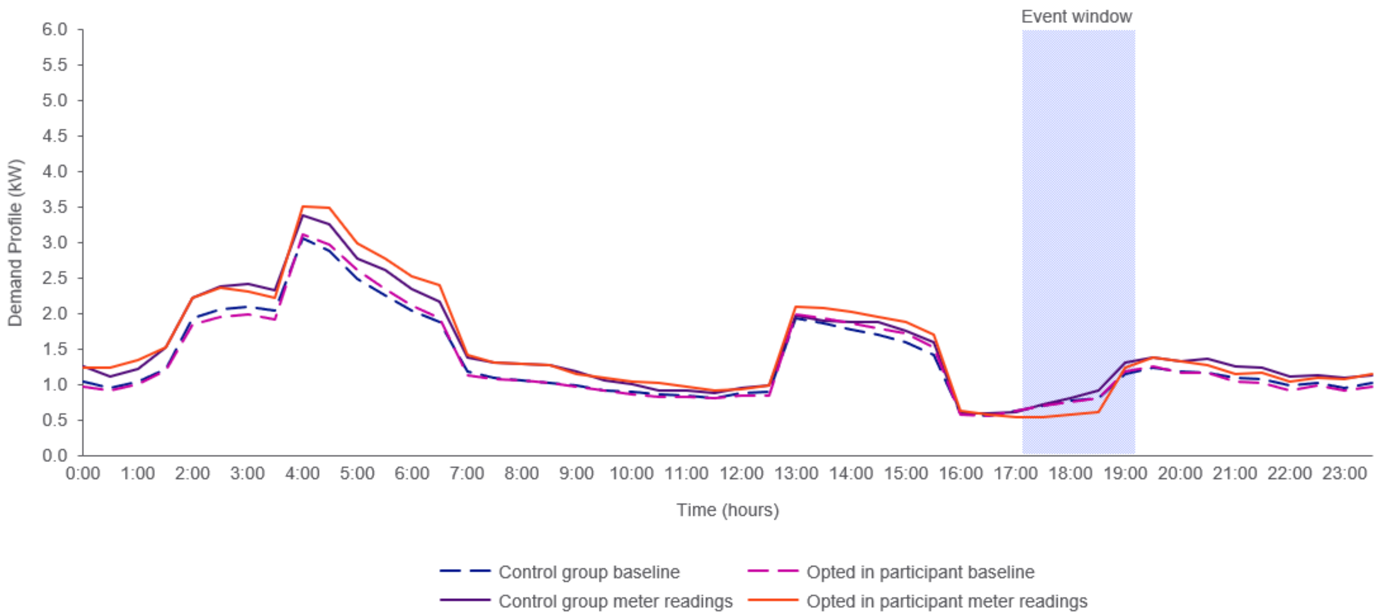

Figure 9. Average demand profiles of participants on a tariff of interest (opted in treatment group participants relative to control group, for events 5pm-7pm only).

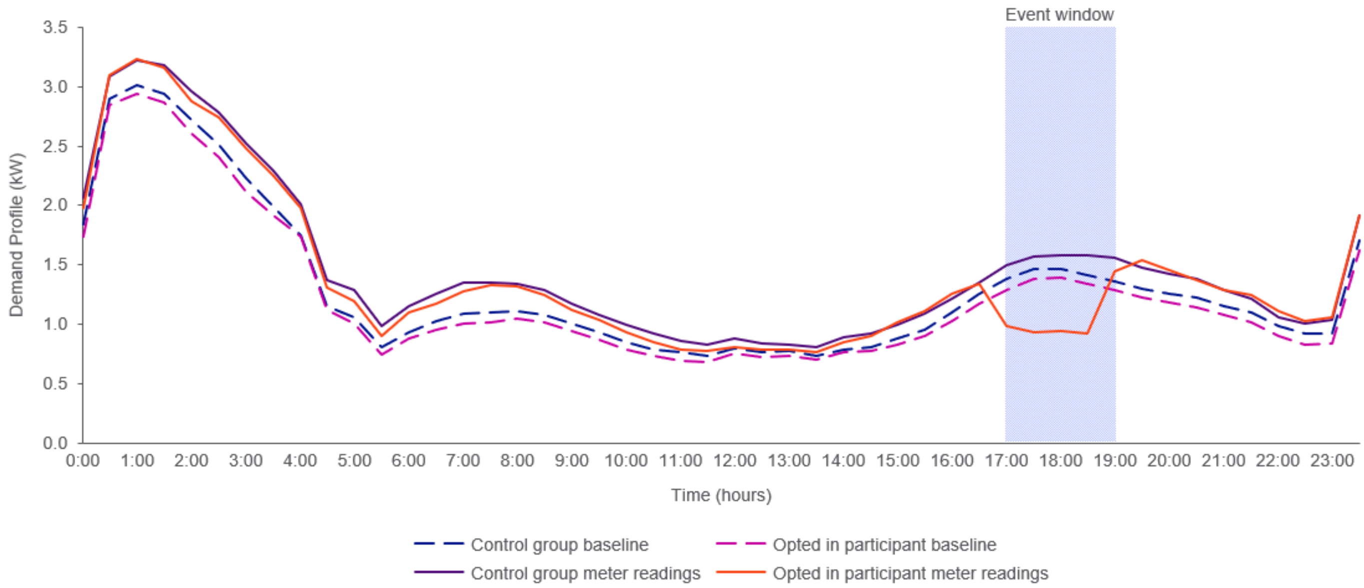

Figure 10. Average demand profiles of participants on all other tariffs (opted in treatment group participants relative to control group, for events 5pm-7pm only).

6.2. Event factors

This section explores demand response and opt in rate for the event-specific factors temperature, notice period, and event timing. Note the demand response values in this section were calculated using the DiD approach and DiD opt in rates. The DiD analysis produced slightly lower event opt in rates than the baselining analysis, so these demand response values skew downwards slightly from those calculated using the baseline opt in rates (when controlling for participant factors, including Section 6.1 and Figure 8).[20]

External temperature

A statistically significant correlation between temperature and demand response was observed. Figure 11 shows the average event opt in rate and demand response provided by opted in participants for events grouped by three external temperature ranges: <3°C (cold), 3-7°C (mild), and >7°C (warm). Figure 11 shows that opted in participants provided an average of 1.1 kW of demand response during cold events, which is a statistically significant 175% increase on the 0.4 kW provided during warm events. This can be explained by heat pumps having higher demand when the weather is colder, meaning they can provide greater demand response when they are turned down. The temperature impact on opt in rate was less significant, although 10% fewer participants did opt in during the coldest events (42%) compared to the warmest (52%), showing some impact of temperature on participants' willingness to engage with events.

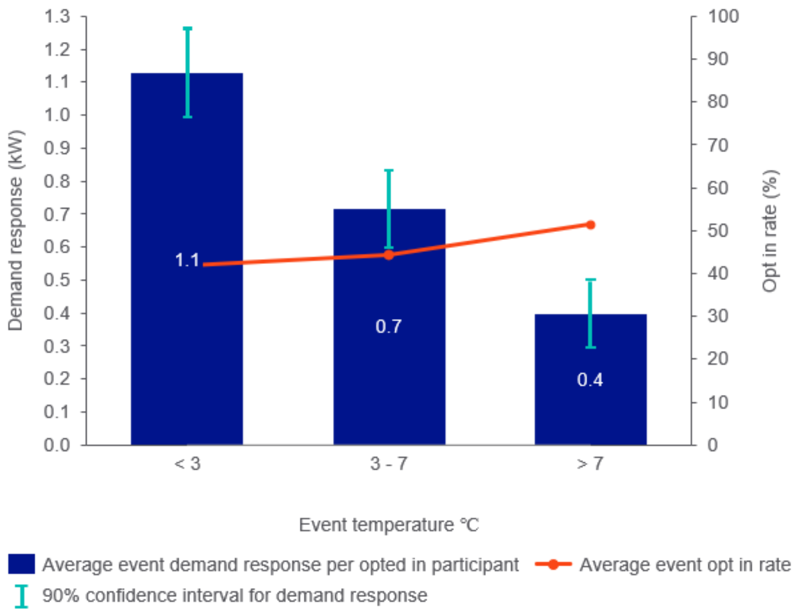

Figure 11. Average participant demand response and participant opt in rate by event day temperature.

[20] Some customers were determined to have achieved demand response in some events by the baselining analysis but not by the DiD analysis. A condition of opt in is providing measurable demand response, and since this was measured in different ways across the two methods, differing opt in rates were recorded.

The trend line in Figure 12 illustrates this relationship even more clearly. It shows that the average participant would be expected to offer 0.07 kW more demand response for each 1°C drop in temperature from the 6.1C trial average. This relationship was obtained by running an exploratory regression on the unbiased turndown estimate calculated through DiD. The graph covers the range of temperatures experienced by trial two participants. Using this regression beyond that range comes with more uncertainty and risk.

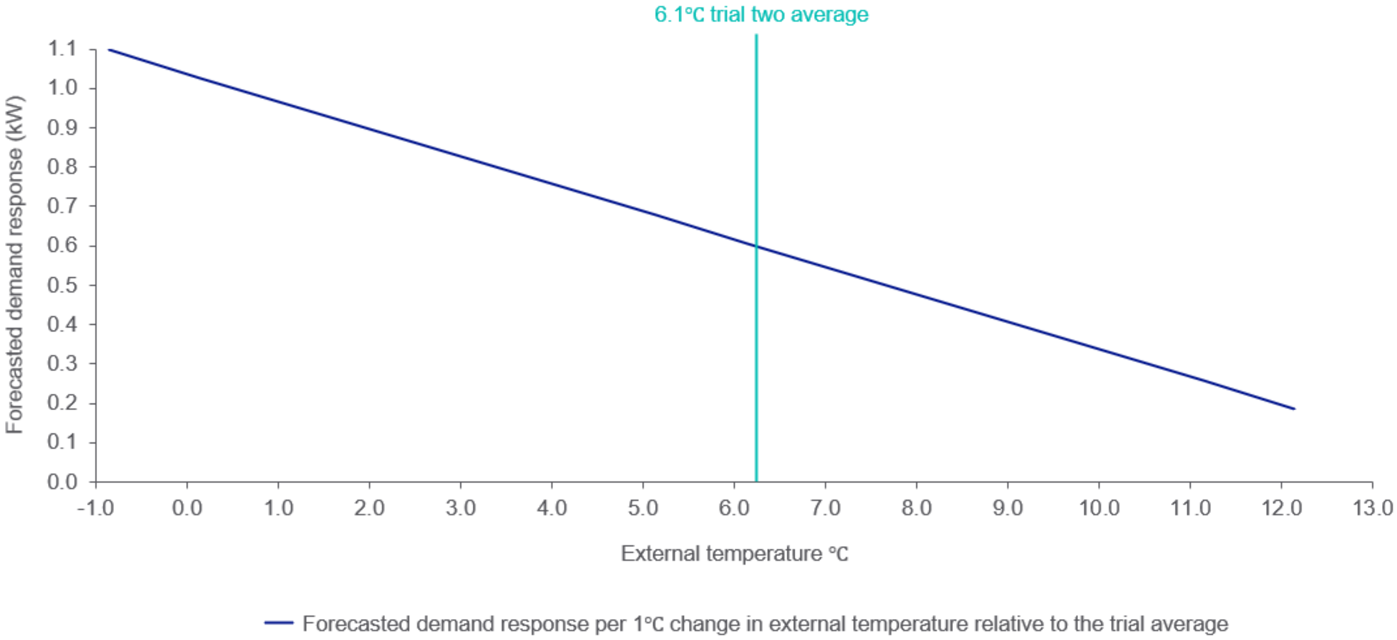

Figure 12. Average forecasted demand response per opted in participant, per 1℃ change in external temperature relative to the trial average

These results suggest that fewer households need to be utilised by suppliers on colder days to provide sufficient heat pump demand response to meet the targets set by the contracting DNO. This holds even when accounting for the lower opt in rate.

Event notice period

We did not observe a statistically significant relationship between notice period and demand response magnitude or opt in rate. Figure 13 shows that participants provided higher average demand response of 0.69 kW when given two hours' notice, relative to 0.57 kW and 0.56 kW for day ahead and morning of, respectively. Nevertheless, this variation is not significant as evidenced by the overlapping confidence intervals. There was also a negligible difference in opt in rate across notice periods. This suggests this factor did not impact the magnitude of demand response participants provided when opting into EQUINOX events, or their decision to opt into events.

These results align with the participant survey data on notice period preferences summarised in Figure 14. Day ahead was modally reported as the preferred notice period (38%). However, another 25% selected morning of and 29% indicated no preference. Most participants (62%) did not believe that notice period affected their ability to participate. While the two hours ahead notice period was least preferred (7%), and 173 respondents felt that two hours was too short, Figure 13 shows this did not translate to reduced demand response or opt in rates compared to other notice periods.

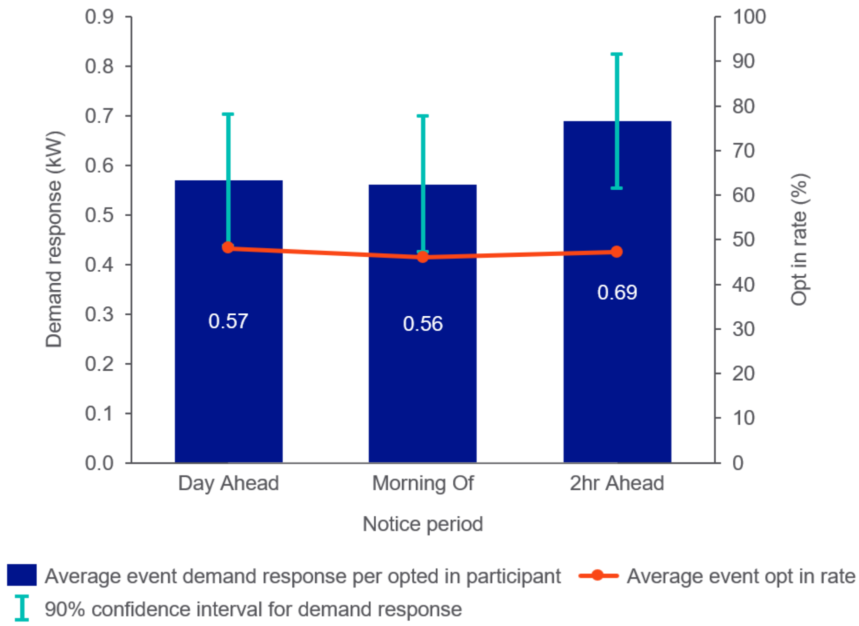

Figure 13. Average demand response per opted in participant and participant opt in rate by notice period.

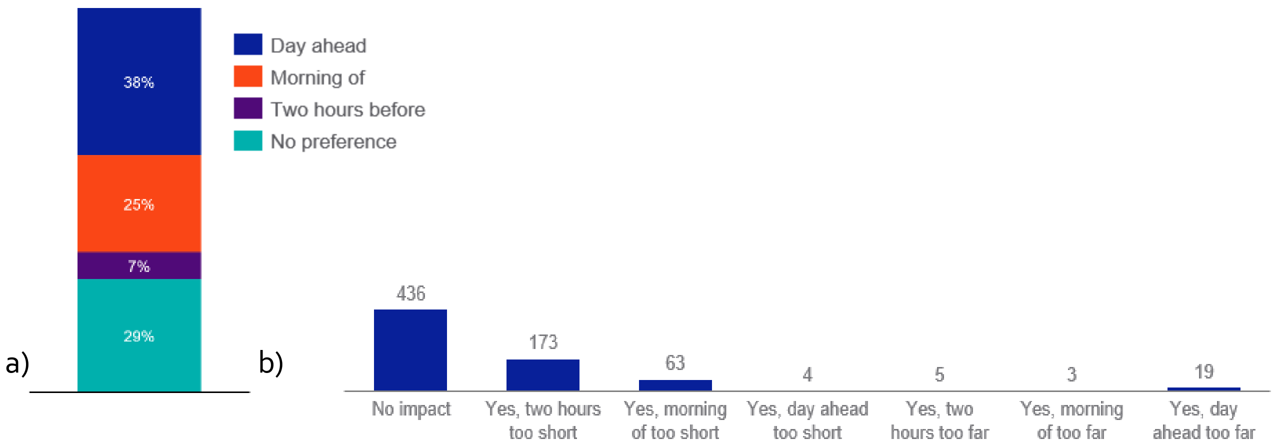

Figure 14. Participant survey responses to the questions a) 'what was your preferred notice period?' (n = 636) and b) 'did the different notice periods impact your ability to participate in EQUINOX events?' (n = 703[21]).

For BaU, these findings imply flexibility service providers could expect a similar level of demand response regardless of whether notifications are sent day ahead, morning of, or two hours ahead of an event. While the results are

[21] Participants could select multiple options.

indicative that day ahead is slightly preferable from a customer satisfaction perspective, the results suggest providers can achieve the same response even with much shorter notice. This may sometimes be needed to respond to closer to real time network requests.

Event timing

There were no statistically significant differences in demand response magnitude or opt in rate between different event timings. As captured in Figure 15, the average event opt in rate and demand response per customer were almost the same across all three timings tested in trial two. This suggests suppliers should not expect a variation in amount of demand response from heat pump households if procuring at any given time between 4pm to 8pm.

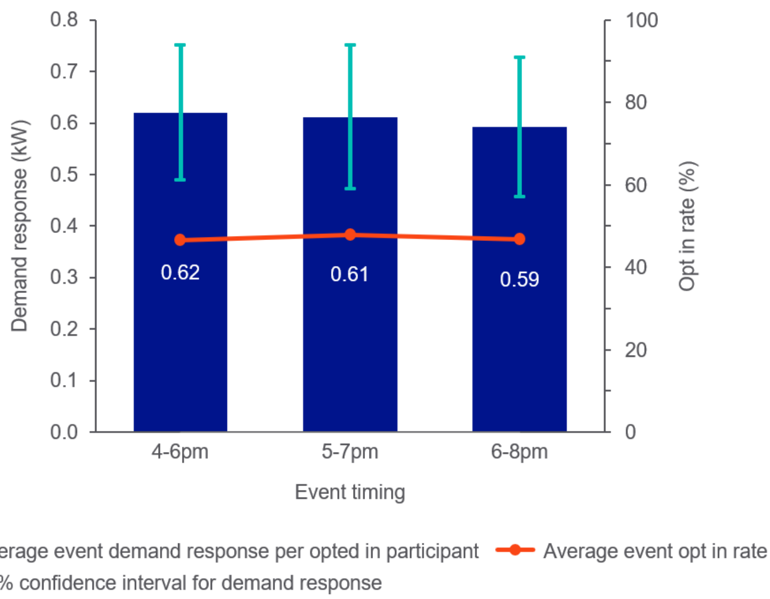

Figure 15. Average demand response per opted in participant and participant opt in rate by event time.

6.3. Participant factors

This section explores demand response and opt in rates for factors that varied between participants: commercial arrangements, heat pump control type, and EPC rating. Note the demand response values in this section are calculated via the same method as those in Section 6.2. Event factors. In brief, the DiD demand response figures for average demand response of the treatment group were scaled using opt in rates to provide an accurate kW demand response result from participants opting into events. Unlike Section 6.2. Event factors, the opt in rates used for this section were determined using a baseline calculation of whether each individual participant had provided demand response in a given event. This approach produced a slightly higher opt in rate than the approach used in Section 6.2. Event factors., causing demand response values to skew downwards from those in Section 6.2. Event factors. The results in Section should accordingly be compared amongst themselves, not directly with those in Section 6.2. Event factors.

Commercial arrangements

A key goal for trial two was to examine any price sensitivity of participant response to events between commercial arrangements. Arrangements M1 and M2 incentivised participants to provide demand response using £/kWh utilisation payments set to the average range of current BaU market rates for NGED's 2023 Secure and Dynamic flexibility products.[22] There was not a statistically significant difference in demand response provided by participants on these two commercial arrangements.[23] Figure 16 shows participants on M1 (lower utilisation rate)[24] provided statistically the same demand response as participants on M2. Figure 16 also shows opt in rates were around 66% for both M1 and M2. This suggests that participants' willingness to opt into EQUINOX events was not sensitive to the variation between M1 and M2 payment amounts. These important findings suggest that evening peak demand response can be successfully procured from domestic heat pump households with payment incentives corresponding to National Grid's current flexibility products. A caveat of these results is that customers participating in EQUINOX trial two were strongly motivated by non-financial factors (including environmental factors) and it is not clear how these motivations will persist outside of a trial environment.

[22] National Grid's 2023 ceiling prices for Secure ranged from: £0.01-£1.75/kWh utilisation payment, averaging £0.78/kWh. For Dynamic, the prices ranged from: £0.28-£9.17/kWh utilisation payment, averaging £1.70/kWh.

[23] Note that our M3 automated control participant group was too small and uniform to directly compare with the two customer control types analysed here. For more information on these customers, please see Section 6.4.

24 Participants on M1 were paid between £0.80/kWh to £2.40/kWh per event; M2 participants were paid between £0.40/kWh to £1.20/kWh per event; M3 participants were paid £8 up front, and then £0.50/kWh to £1.50/kWh per event.

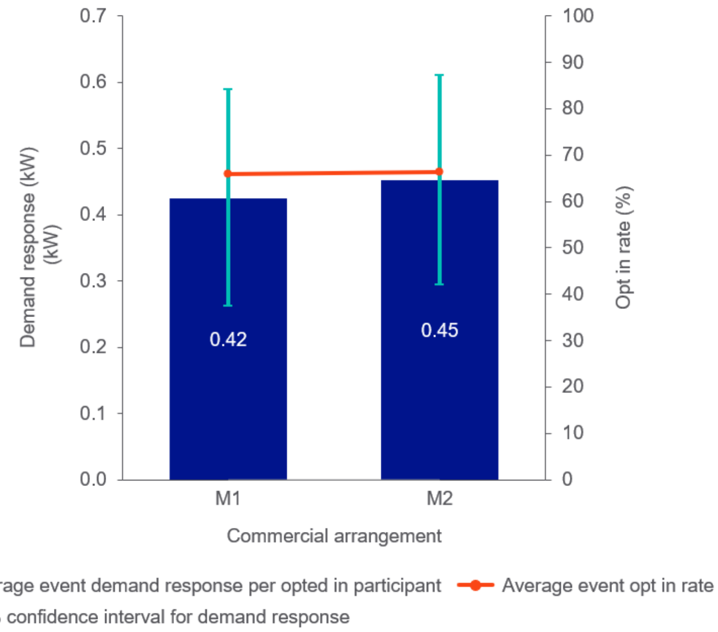

Figure 16. Average opted in participant demand response and participant opt in rate by commercial arrangement

Control type

Participants provided the same average turndown and opted into events at similar rates regardless of whether they controlled their thermostats fully manually or through an app, as shown in Figure 17. These findings suggest that the added requirement to be at home to action an EQUINOX event did not impact the magnitude or frequency of demand response provided by manual control participants.

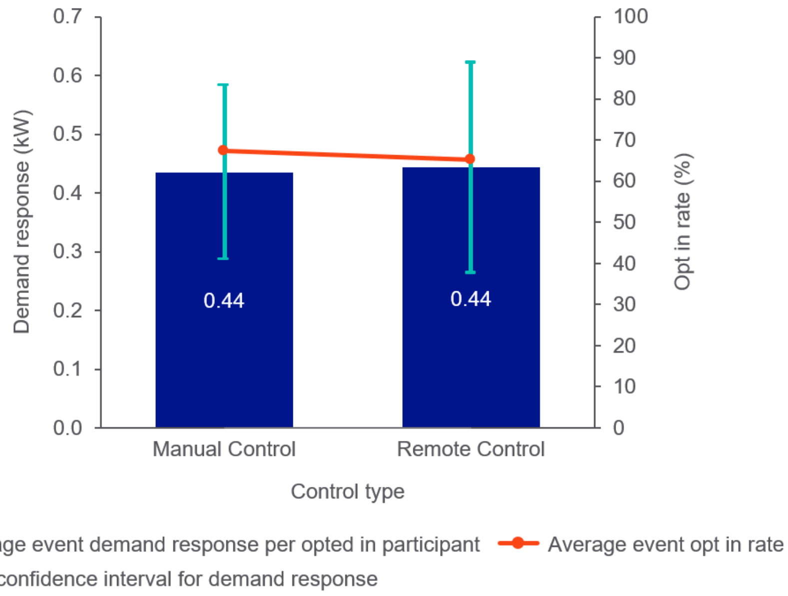

Figure 17. Average demand response per opted in participant and participant opt in rate by heat pump control method.

Despite these findings, 72% of manual control customers indicated via survey responses that they would find it easier to take part in events if they were able to use an app to remotely control their heat pump (Figure 18 left). These results show that automated control over the heat pump is not necessary for the delivery of flexibility.

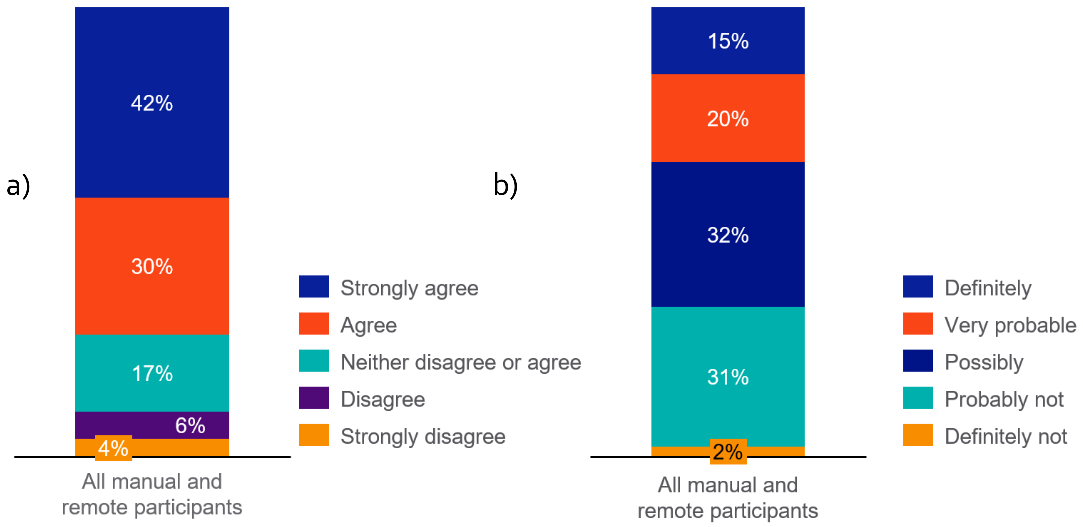

Figure 18. Trial two participant responses to the question a) 'The ability to control my heat pump remotely would make it easier to participate in EQUINOX events' (n=436), and b) 'What is the likelihood that you would consider allowing a trusted third-party to control your heat pump?' (n=619)

EPC rating

No statistically significant difference in demand response magnitude was observed for participants in homes with different EPC ratings, as shown by the overlapping confidence intervals in Figure 19. The figure also shows that opt in rates were around 60% for all EPC groupings. From these findings, we can conclude that EPC group was not a driver of demand response magnitude in trial two.

Since EPC ratings are an imperfect measure of energy efficiency, trial three may explore alternative indicators to more definitively determine whether home energy efficiency correlates with the frequency and magnitude of domestic heat pump demand response.

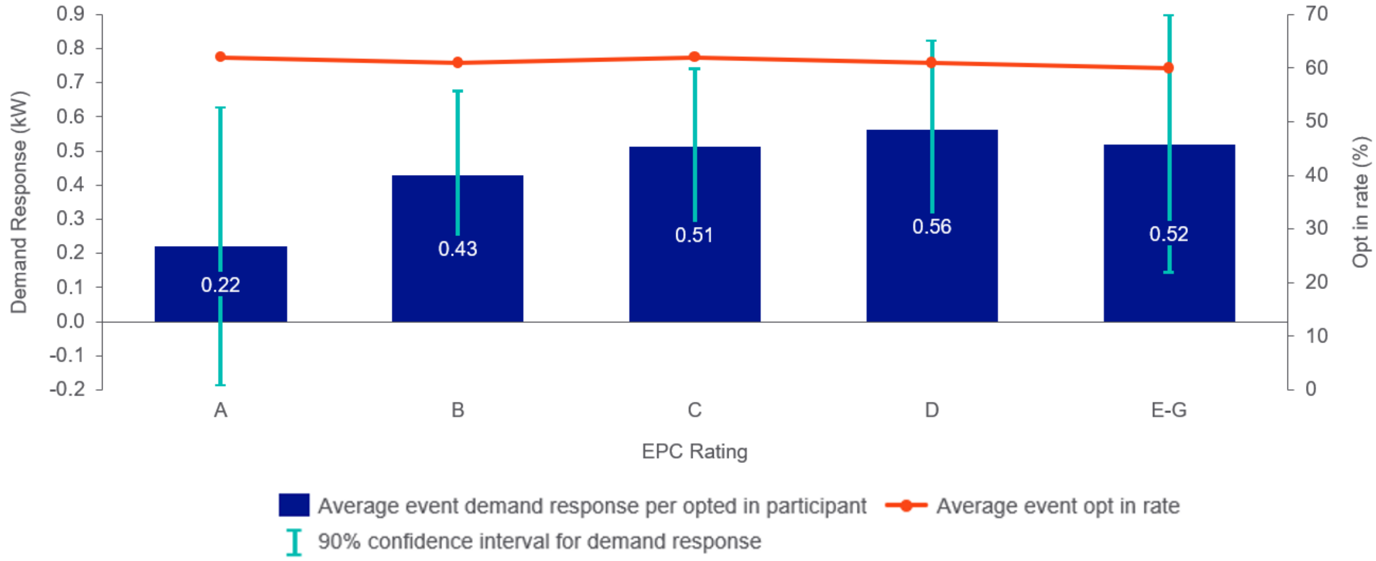

Figure 19. Average demand response per opted in participant and participant opt in rate by EPC rating.

6.4. Aggregator control

All aggregator control participants were on the M3 commercial arrangement. This group was the only one to experience no-notice events (as they rely on a third party controlling the heat pumps). All of these participants lived in EPC A rated homes, were on Tariffs of Interest, and had advanced home energy management systems which enacted heat pump turndown on their behalf during events. A small sample size of 23 households and their high degree of uniformity meant this group could not be compared directly with other groups. They are therefore explored separately here and there are interesting findings which increase understanding of the interaction of leading technologies with heat pump demand response.

Figure 20 highlights the average experience of these participants. The graph shows the demand profile of opted in aggregator control participants relative to their own baseline and control group profiles. Like in Figure 7, participants showed a visible decrease in demand across the event periods. In keeping with these participants being on tariffs of interest, Figure 20 also shows demand peaks across atypical periods of the day (4am – 7am and 1pm – 4pm) as well as demand dips during events. Their tariff was therefore likely already incentivising these participants to load shift from peak times, leaving them with limited additional demand response to offer through EQUINOX events.

Reflecting the difficulty in creating a matching control and treatment group with a small sample size, the control and participant demand profiles are not well aligned in magnitude across the 4am – 7am demand peak (though this is not thought to impact event results). Comparing Figure 20 with Figure 9 and Figure 10 above, it can also be observed that the overall demand across an average day was also far lower for the aggregator control cohort than for other EQUINOX participants. This is thought to reflect a much lower rate of home charging of EVs amongst these households compared to the wider trial two cohort, and perhaps the increased home energy efficiency of this cohort.

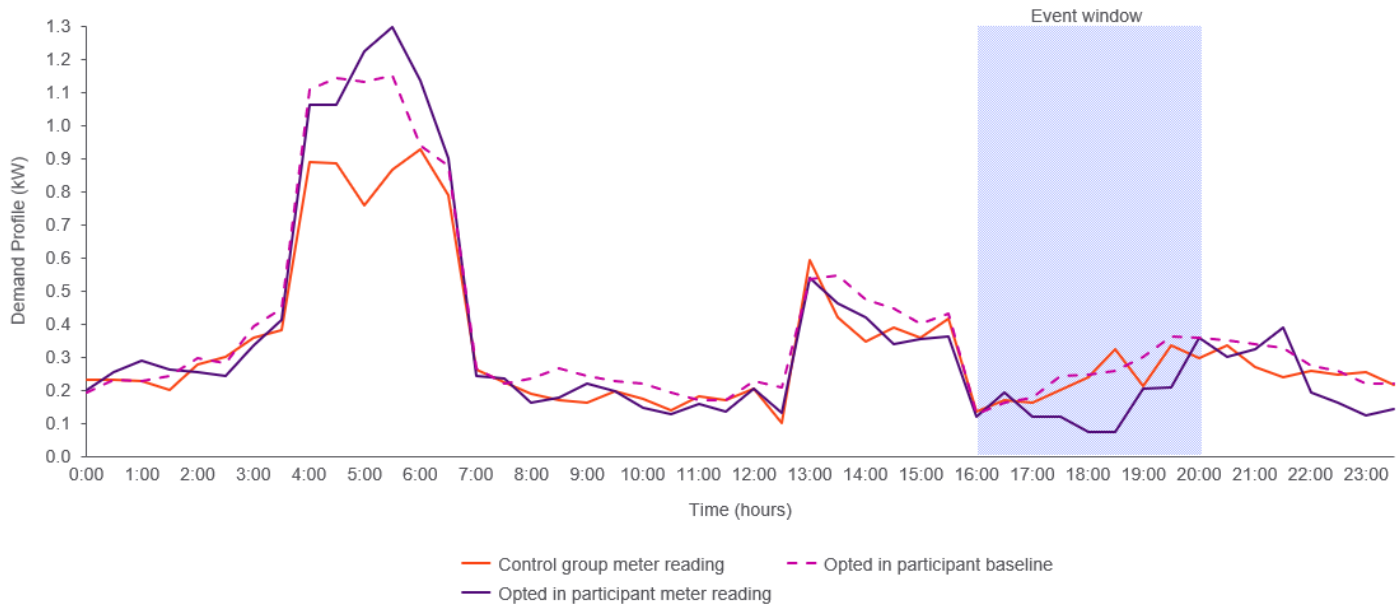

Figure 20: Average demand profile for opted in aggregator control participants relative to their control group, aggregated across all events for all start times of 4pm, 5pm or 6pm.

The small and uniform sample size of the aggregator control group means we cannot make any statistically significant conclusions about these results. Nevertheless, these technologically advanced households appear to be peak load shifting during trial two, albeit in a manner less measurable through EQUINOX events.

7. Overall participant experience findings

7.1. Participant feedback and preferences

Domestic flexibility is a relatively new sector that is growing quickly, with strategic importance in DNO and ESO future energy scenarios. Consumer engagement in managing electricity demand is critical the meeting net zero ambitions on time. Although great than a million customers are engaging in domestic flexibility via DFS and time and type of use tariffs, heat flexibility is a particularly complex area that requires an intentional balance between flexible behaviour, convenience and most importantly, ongoing customer comfort. To better understand these areas, customer research was conducted via surveys, focus groups, and interviews. This research helped us to understand customer satisfaction, trial design preferences, customer comfort, and impacts on potentially vulnerable participants. This section presents the key findings. More details can be found in the EQUINOX Trial Two Customer Engagement Report.[25]

Satisfaction

Customer satisfaction is important as customers must be willing to engage in flexibility if we are to use domestic assets at scale. A mark of success for trial two was the high levels of satisfaction with the trial. As demonstrated in Figure 21, nearly 80% of participants were satisfied with their experience of trial two.

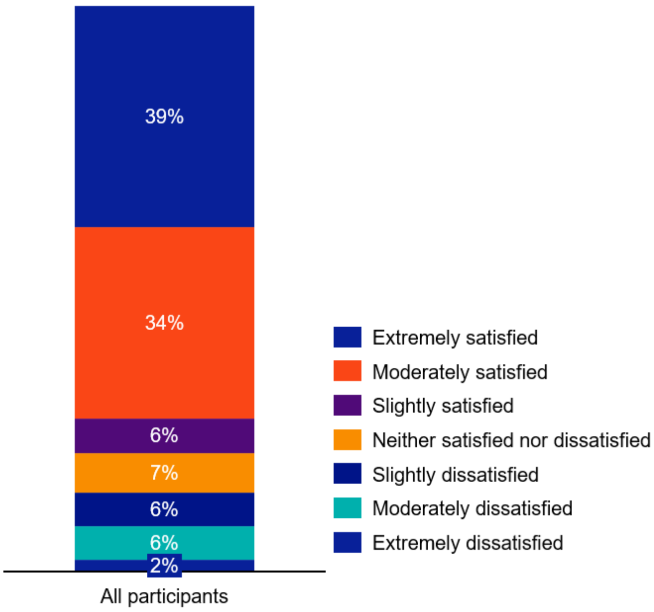

Figure 21. Trial two participant responses to the question 'how satisfied are you with the overall EQUINOX trial so far?' (n=489)

[25] Trial 2 Customer Report

Only 14% of participants reported being dissatisfied, primarily due to financial reasons. Based on customer interviews, customers receiving lower total payment amounts were more likely to be dissatisfied, particularly those on tariffs of interest who could offer little additional demand response via EQUINOX events.

Figure 22 captures participant survey responses on satisfaction with trial payments, showing that 61% of participants were satisfied or neutral on payments in trial two. These findings could suggest most participants felt payment amounts were sufficient, although it is important to acknowledge EQUINOX participants received other rewards for their participation (such as rewards for participating in surveys, focus groups, and interviews) that may have encouraged them to opt into events, and other non-payment factors may have motivated their participation.

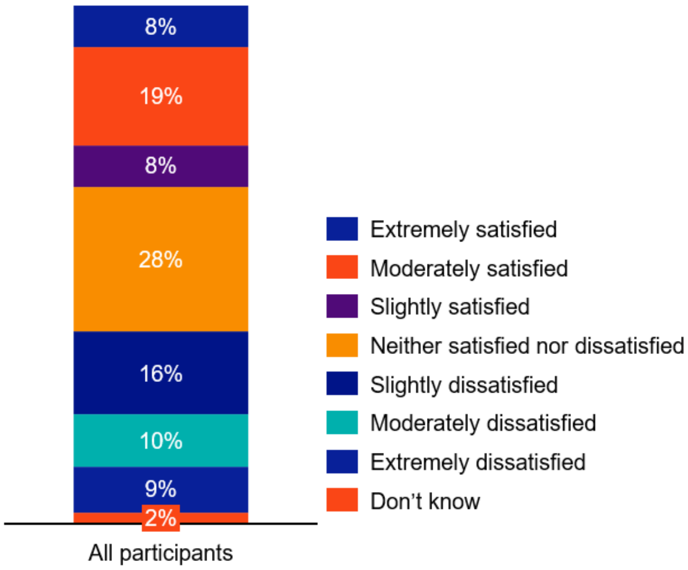

Figure 22. Trial two participant responses to the question 'how satisfied are you with the payment amounts for participating in EQUINOX events?' (n=636)

Trial design

Although DNO flexibility requirements are driven by network needs, flexibility service providers have discretion in which services they tender for and how they use their assets to deliver that flexibility. For example, a flexibility service provider may choose to only tender for flexibility services at particular times of day, or for particular lengths of service.

In the context of domestic flexibility where distributed assets provide that service and customers may be engaged in service provision (either directly through active behavioural changes or indirectly through consenting to aggregator control of their assets), it is important to understand how event design elements impact customer experience.

As discussed in 4.2. Trial two factors of interest, several design factors were tested throughout trial two. The end of trial survey captured participant preferences on trial design factors like event duration and heat pump control type.

As demonstrated in Figure 23, 86% of participants felt that the two-hour duration of events was about right. However, 85% of participants also indicated that they would be willing to try participating in a three-hour event. 78% reported that the zero to three EQUINOX events a week was the right frequency. Of the participants who indicated the frequency of events was slightly too few or far too few, about 50% of participants indicated they would be willing to participate in events multiple times a week, and another 29% daily.

Of participants who could not control their heat pump remotely, most participants (72%) felt being able to control their heat pump remotely would make participating in events easier.

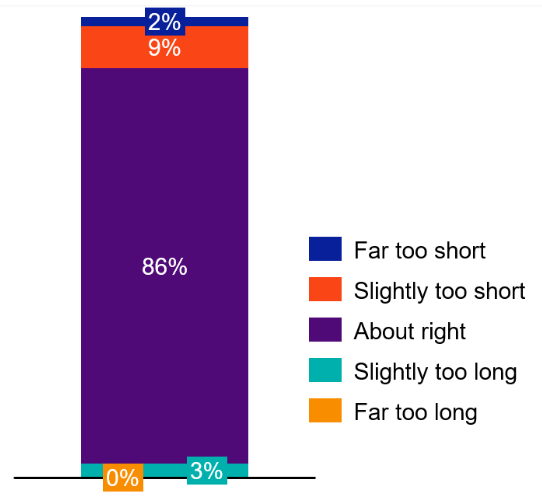

Figure 23. Trial two participant responses to the question 'what do you think about the two-hour duration of EQUINOX events?' (n=636)

Customers were unable to stack flexibility offerings during trial two but opportunities to stack flexibility services are being considered for trial three. However, approximately two thirds of participants (63%) wanted to participate in another flexibility offering during trial two or reported being interested in participating in more than one flexibility offering at the same time in future (69%).

These findings indicate that the design of demand response events in trial two was widely acceptable to participants, but that there are areas for further exploration that could expand the options that flexibility service providers have in delivering domestic flexibility through heat pumps, particularly event length, event frequency and stacking flexibility offerings.

Customer comfort

In the context of domestic flexibility provided by low carbon heating, it is paramount that customer comfort is prioritised. Customers must be able to engage with their heating system in a way that makes sense for their household, including in how they deliver demand flexibility.

To centralise this aim, trial two was designed without penalties for failing to deliver demand flexibility once opted into an event and to avoid unduly incentivising underheating of participating households. Recognising that 'comfort' is complex and subjective, surveys were used to collect self-reported information on participant comfort. This surveying was done in two ways. We used a post-event survey to collect immediate responses after each event. We later asked participants to consider their overall experience during the trial in the end of trial survey.

Considering the post-event survey data first, Figure 24 shows that over all events, on average 85% - 94% of participants reported no change or a slight change in comfort. Events occurring on the coldest days had more reports of change in comfort compared to events on milder days. This corroborates an expectation that colder external temperatures would induce more customers to experience a change in thermal comfort. However, the results are very promising for the feasibility of domestic heat pump flexibility; they indicate that the majority of participants in the majority of events found that the experience of participating in demand response events did not change their comfort level.

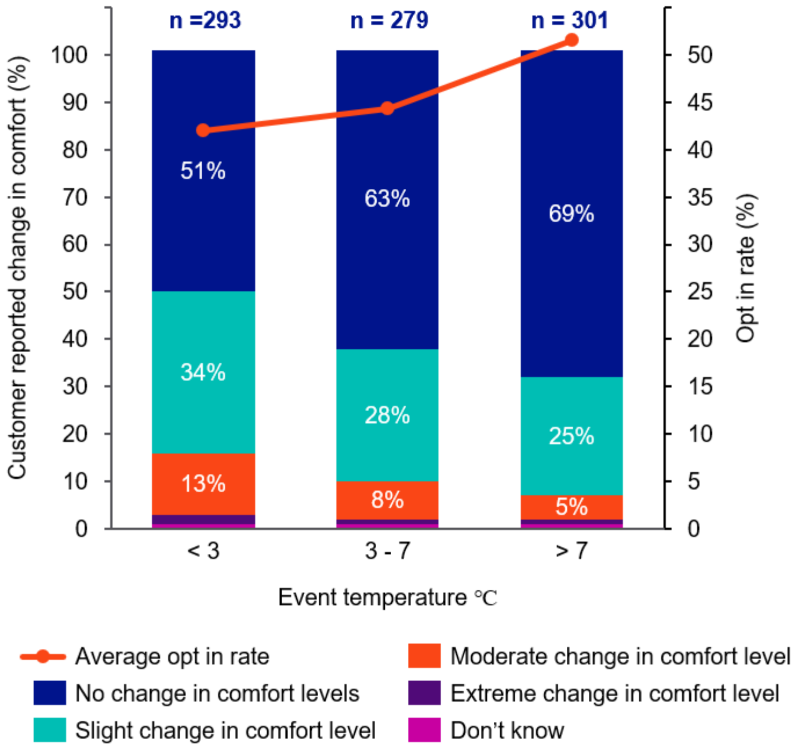

Figure 24. Comfort level and opt in by event temperature band.

Taking a broader perspective in the end of trial survey, we found that 92% of participants either never or only sometimes experienced some measure of discomfort. Exploring this topic more deeply, participants who indicated that they had ever experienced a measure of discomfort during EQUINOX events (42%) were asked to quantify that discomfort as mild, medium or high. The overwhelming majority of respondents (91%) indicated that they had experienced mild discomfort, more closely aligning the results we saw in the end of trial survey with the data we had originally collected in post-event surveys. Further exploring this experience of mild discomfort, participants were asked if they had acted in response to the experience, with most indicating that they had added layers (e.g. jumpers, blankets) or had used alternative heating methods.

Taken alongside high ongoing participation rates throughout the trial, we conclude that many participants do not notice any thermal impact of participating in EQUINOX events, and that for those who do experience a decrease in warmth, the effect is mild and is not sufficient to impact willingness to engage in further trial events.

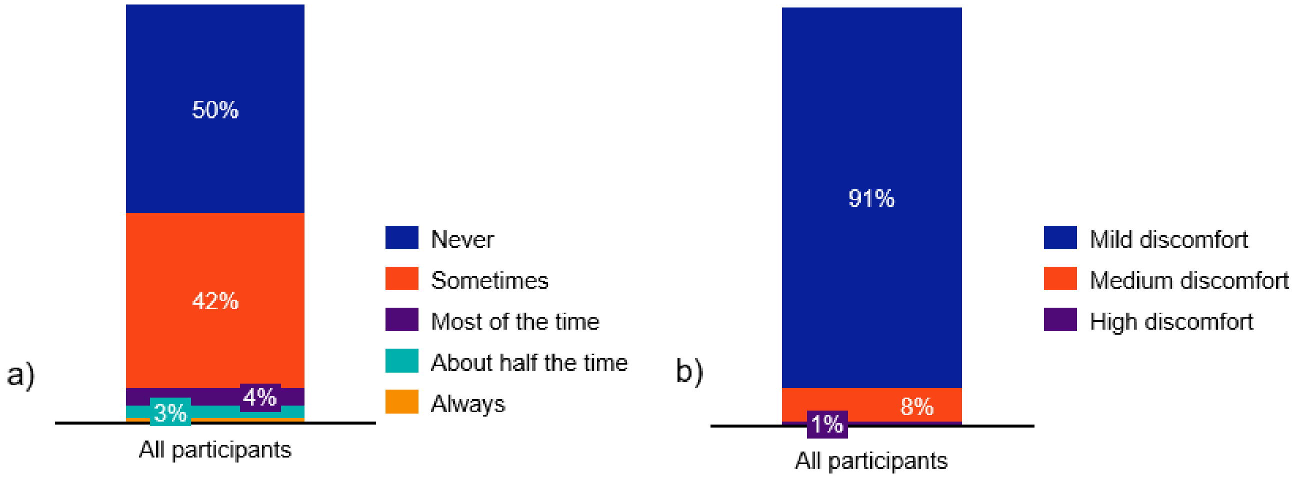

Figure 25. Trial two participant responses to a) 'how frequently did participating in EQUINOX events cause any discomfort for you or someone else in the household?' (n=636) and b) 'if you felt discomfort, what level of discomfort have you felt from participating in EQUINOX events?' (n=318)

Moving away from the average results, some participants indicated that they had experienced discomfort that did impact their willingness to participate in further events, particularly on colder days. These experiences were impacted by material factors such as home insulation standards and overall efficacy of their heat pump installation, but also by personal factors such as health conditions that could be worsened by the cold. These personal factors are discussed further below in Section 7.2.

Individual factors that make participating in regular heat pump flexibility undesirable for some customers do not preclude them from benefitting from the overall energy bill savings that domestic flexibility could provide via reduced network reinforcement costs.

How thermal comfort is captured is being assessed for trial three, considering self-reported or other forms of measurement in addition to strengthening safeguards for customers who may be potentially vulnerable to the cold. Understanding that while participation is an individual choice, the trial does not want to incentivise customers to underheat their home.

7.2 Focus on customers with potential vulnerabilities

Although most trial two customers showed continuing participation and generally high comfort levels during events, it is important to consider the experience of sub-groups of customers who may have barriers to accessing the benefits of demand flexibility in an equitable way. To explore this topic, potentially vulnerable participants were segmented based on self-reported characteristics from the start of trial survey to assess how events impacted them. Potential vulnerability was determined via participants meeting at least one of these three self-reported criteria:

- Responding that they were sometimes, often, and/or rarely/never able to afford their energy bills and other household bills.
- Responding with a non-zero answer to the question, 'including yourself, how many people in your household has a disability or long-term health condition?'
- Responding yes to the question, 'do you feel this disability or long-term health condition is made worse or more difficult to cope with when it's cold?'
- 206 potentially vulnerable participants were identified through this method. It is recognised that vulnerability is a broad and complex concept. There are therefore challenges to categorise, identify, and account for different vulnerabilities. Trial three plans to consider additional individual and combined potential vulnerability factors to explore further impacts of demand side flexibility on potentially vulnerable customers. These considerations are discussed further in Section 11 Appendix B: Vulnerability factors to further explore

The section below presents the participant research findings and themes from surveys, focus groups, and interviews held with participants categorised as potentially vulnerable.

Satisfaction

Surveys indicated similar levels of trial satisfaction across the non-vulnerable and potentially vulnerable participant groups. 79% and 78% were satisfied, respectively, and 14% of both groups were dissatisfied.

Trial design

End of trial survey responses also showed little variation in experiences and preferences between the potentially vulnerable participants and non-vulnerable participants on trial design factors like notice period and event length.

When asked about automation, both groups noted a similar desire to be able to control their heat pump remotely to make participating in EQUINOX events even easier.
In general, it is encouraging that across trial satisfaction and trial design, customers with potential vulnerabilities appeared to have similar preferences and experiences as compared to non-vulnerable participants.

Payment satisfaction

Satisfaction with trial two payment amounts was similar between vulnerable and non-vulnerable participants, as shown in Figure 26.

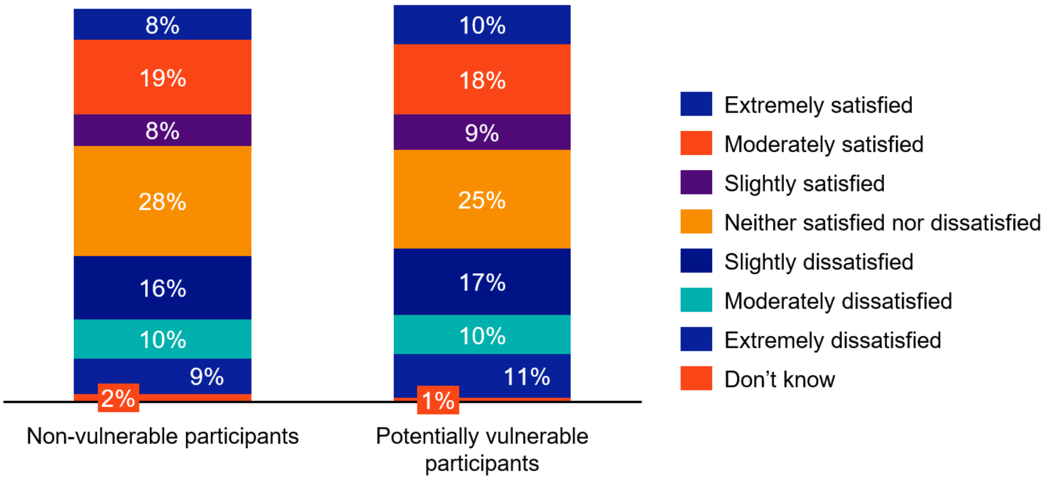

Figure 26. Trial two participant responses to the question 'how satisfied are you with the payment amounts for participating in EQUINOX events?' split by non-vulnerable participants (n=636) and potentially vulnerable participants (n=147).

A major theme from our participant research was the impact of tariffs; a large majority of participants aligned their heating practices to fit into tariff schedules.

Two participants did report underheating their homes, with one noting in a focus group that they have a three-day rule, whereby they don't put their heating on until the fourth day of a cold snap and their thermostat is generally set below ten degrees. While underheating to this extent was not widespread among those engaged in the qualitative research, it does perhaps point to an area of caution for demand-side flexibility. Both in terms of ensuring participant wellbeing is optimised through tailored support and guidance, and any potential risks are mitigated that could incentivise underheating. It is important to ensure flexibility offerings are inclusive of all customers including potentially vulnerable customers.

Customer comfort

Across the four potentially vulnerable focus groups and five interviews conducted, most participants reported no change or only a small difference to comfort levels during trial events. There were a small number of participants, however, who reported feeling a significant difference in comfort levels during very cold weather or when trial events ended at 8pm. This was often attributed to the fact that participants on tariffs of interest tariffs had their heat turned off from 4pm. For those participants, an EQUINOX event from 6-8pm meant having their heat pump turned down for four hours in total.

One participant reported a health condition that was impacted by the cold. Their comfort levels would decrease when events took place during cold weather or when trial events ended at 8pm. Trial events impacted their health condition during these periods, and they altered their behaviour during events such as staying downstairs due to their bedrooms being colder than other parts of their home.

Despite this one experience that was shared during an interview, Figure 27 shows that potentially vulnerable participants and non-vulnerable participants reported similar changes to comfort across the trial.

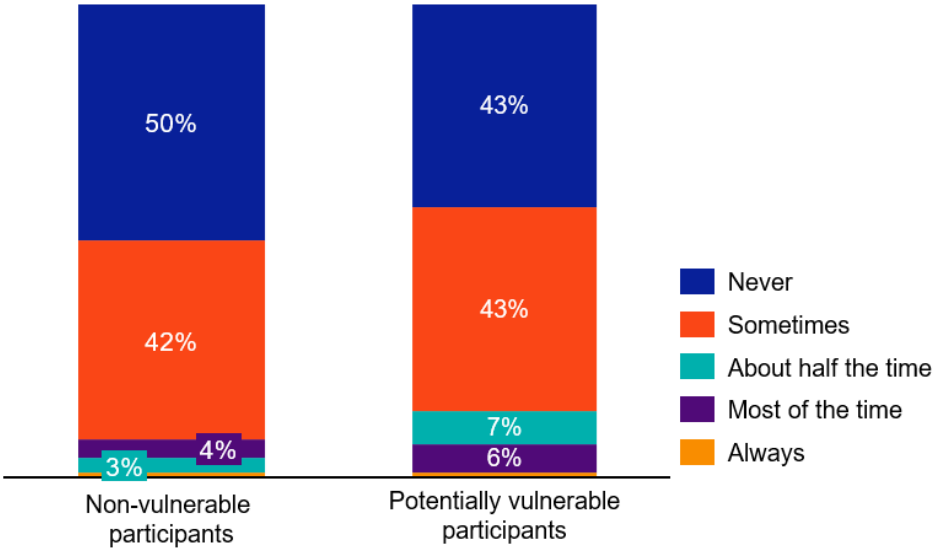

Figure 27. Trial two participant responses to the question 'how frequently did participating in EQUINOX events cause any discomfort for you or someone else in the household?' split by non-vulnerable participants (n=636) and potentially vulnerable participants (n=147).

Considering the potential impact of demand response requests on participants who have a pre-existing health condition and/or disability that is further impacted by the cold, is a focus area in trial three to further understand potential impacts and put safeguards in place. This could include careful consideration of the timing of events, particularly during periods of cold weather, excluding customers on time-of-use tariffs, and reminding customers they should not turn down their heat pump below a temperature that impacts their individual comfort levels.

Fuel poverty

While risk of fuel poverty was not included in the vulnerability indicators defined at the beginning of this section, identifying and understanding the impact of the trial on fuel poor customers was an area of interest. During trial sign-up, M1 and M2 participants were asked about the affordability of their energy bills, which was used as a proxy for fuel poverty and segmented for further analysis.[26]

This analysis showed that participants with a fuel poverty indicator provided an average 0.47 kW of demand response when opting into events, relative to 0.46 kW for participants who did not have a fuel poverty indicator. The opt in rate for participants with fuel poverty indicators was only 3% lower than those participants without. There is no statistically significant difference between the two groups. Drawing clear conclusions on demand response is further complicated by the fact that the analysis does not control for tariff type, so could be skewed as a result. We will continue to explore this area in trial three.

[26] Question asked was "Do you anticipate any issues being able to stay comfortably warm over winter?". Participants who responded "Yes" were classified as at risk for fuel poverty.

8. Network impact

A key consideration for EQUINOX is understanding how DNOs can best utilise aggregated domestic heat pump flexibility in BaU. Increasing volumes of LCTs, such as heat pumps, will be connecting to the National Grid network as the UK transitions to net zero greenhouse gas emissions. Over 360,000 heat pumps are forecasted to be installed across National Grid's four license areas by 2028, up from 106,000 in 2023.[27] These heat pumps make up approximately 20% of all flexible LCT's forecasted on National Grid's distribution network in 2028, down from 24% in 2023.[28] These LCTs will likely contribute to an increase in peak demand in certain areas, leading to future network constraints. Constrained areas are highlighted through National Grid's investment planning process, and if appropriate, denoted as CMZs and managed using flexibility.

This section uses the trial two demand response results from Section 6 to model the theoretical flexibility potential of heat pumps to mitigate the network constraints within the Hayle-Camborne CMZ. This zone was chosen as there was a cluster of EQUINOX participants within the zone and as such it was the most representative location to inform a case study.

The case study results suggest that when participating for 2 hours a day under each scenario, heat pumps alone will not be able to deliver the peak reduction required to mitigate the Hayle-Camborne CMZ, or the zone's full utilisation energy requirements for the winter months. However, the analysis does indicate that heat pumps are well placed to meet a proportion of the CMZ's base weekday flexibility need, reaching close to 20% of the CMZ's projected peak demand in 2028. This demonstrates the need for additional assets for shorter periods to meet the remaining peak demand. The results also show that if a proportion of the heat pumps could sustain a response for longer than 2 hours, fewer heat pumps would be required to meet the CMZ's energy requirements as suppliers would not have to stagger assets across the four-hour daily flexibility window. Trial three looks to test both hypotheses in earnest, with multiple periods of daily flexibility events (Sustain), as well as a period of longer 3- to 4-hour duration flexibility events.

8.1. Hayle-Camborne case study

Introduction to Hayle-Camborne

The purpose of this case study is to combine demand response, event opt in rate, and commercial arrangement preference results from trial two with predicted heat pump volumes to assess how far domestic heat pumps could meet the power and energy flexibility requirements of a representative CMZ.

[27] Under the Best View scenario of National Grid's latest DFES.
[28] Flexible LCTs include heat pumps, battery storage, domestic solar, and EV charging. Note the proportion of forecasted heat pumps varies between National Grid's different regions.

28 of the 1,048 participants recruited for trial two were located within the Hayle-Camborne CMZ[29]. Heat pumps make up a large proportion of the flexible LCTs that National Grid believe are currently installed in Hayle-Camborne (> 60%) and forecasted to connect by 2028 (> 45%). As such, they could play a key role in providing the flexibility required in that CMZ to defer reinforcement. Table 4 shows the number of different flexible LCTs that are connected in the Hayle-Camborne CMZ in 2023, and the predicted numbers across 2026, 2027 and 2028. It also shows the proportion of heat pumps to other flexible LCTs in the CMZ.

Table 4. Current (2023) and forecasted (2026-28) numbers of flexible LCTs in Hayle-Camborne CMZ

	Current	**Forecasted**		
LCTs	**2023**	**2026**	**2027**	**2028**
Heat pumps	2,380	4,332	5,481	8,489
Domestic solar & battery storage	455	714	818	2,378
EV charge points	1,020	3,844	5,405	7,357
Total flexible assets	3,855	8,890	11,704	18,224
Heat pump proportion	**62%**	**49%**	**47%**	**47%**
Other proportion	38%	51%	53%	53%

Table 5 shows the forecasted yearly flexibility requirements for Hayle-Camborne. The yearly estimated utilisation energy is the amount of flexibility declarations (in kWh) National Grid expects to dispatch over the calendar year in this CMZ. The apportioned energy requirements have been calculated by multiplying the energy requirement by the fraction of LCTs made up by heat pumps within Hayle-Camborne each year (see Table 4). Table 6 splits these requirements out per month based upon the expected number of hours of flexibility required each month.

Table 5: Hayle-Camborne flexibility requirements per year

Year	Peak capacity required [kW]	Yearly estimated utilisation energy [kWh]	Yearly estimated utilisation energy apportioned to heat pumps [kWh]
2026	9,290	98,110	47,808
2027	14,700	156,280	73,186
2028	18,240	219,200	102,106

[29] The CMZ of Hayle-Camborne includes the following Electricity Supply Areas (EASs): St Buryan, Mousehole, Newlyn, Geevor, Penzance Heamoor, St Ives, Hayle, Marazion, Cambrone Holmans, Camborne Can Brea, and Redruth.

Table 6: Hayle-Camborne flexibility requirements per month

Year	Month	Peak capacity required [kW]	Potential number of hours per month	Estimated utilisation energy per month [kWh]	Estimated utilisation energy apportioned to heat pumps per month [kWh]
2026	February	7,980	12	3,148	1,534
	March	8,300	72	18,887	9,204
	April	6,340	42	11,018	5,369
	August	1,520	4	1,049	511
	October	6,640	84	22,035	10,738
	November	7,330	48	12,592	6,136
	December	9,290	112	29,381	14,317
2027	January	14,700	168	23,739	11,117
	February	12,660	96	13,565	6,353
	March	12,880	140	19,782	9,264
	April	10,840	150	21,195	9,926
	August	5,360	20	2,826	1,323
	October	10,880	126	17,804	8,338
	November	11,870	98	13,848	6,485
	December	14,040	308	43,521	20,381
2028	January	18,240	266	31,483	14,665
	February	16,140	210	24,855	11,578
	March	16,290	322	38,111	17,753
	April	14,170	220	26,039	12,129
	May	2,040	30	3,551	16,53.99
	August	8,210	90	10,652	4,962
	October	14,030	210	24,855	11,578
	November	15,250	126	14,913	6,947
	December	17,560	378	44,740	20,840

Case study Methodology

The average EQUINOX trial two participant provided demand response of 0.61 kW sustained over the two-hour event duration (1.21 kWh). The average participation rate was 47%.

We used the forecasted growth of LCTs and the average demand response from trial two participants to model the theoretical flexibility potential of heat pumps within Hayle-Camborne, and their ability to meet the flexibility requirements outlined in Table 6. We first compared the theoretical maximum peak power that can be delivered from the projected heat pumps to the peak capacity required in Hayle-Camborne.

Next, we tested three scenarios to simulate what proportion of the forecasted heat pumps would need to participate to meet the full and apportioned energy requirements within the CMZ. These scenarios cover credible future flexibility participation levels by heat pump customers:

- Scenario 1: Heat pumps participate for two hours a day, five days a week.
- Scenario 2: Heat pumps participate for two hours a day, two days a week.
- Scenario 3: An informed mix of Scenarios 1 and 2.

The following assumptions have been applied across all scenarios:

- Heat pump demand response is capped at two hours to replicate trial conditions.
- Suppliers can successfully stagger their heat pumps to fulfil a flexibility requirement that lasts longer than two hours.
- The heat pump control method (customer vs automated control) has no impact on demand response magnitude, as is consistent with available trial two results.
- Suppliers can procure daily flexibility from heat pumps for the DNO.
- Heat Pumps can provide their percentage share of required flexibility based on number of units rather than rating.

Note that all results tables from this point will only show winter months as they have the highest demand.

Peak Capacity

The blue curve in Figure 28 shows the MW exceedance within Hayle-Camborne for a representative day in February 2023, which highlights when and how much flexibility National Grid would need to procure each day. The red blocks represent National Grid's Sustain product blocks, which are procured up to a year beforehand and are designed to provide a daily base load reduction during two four-hour windows. The yellow blocks represent the long-term Dynamic and Secure product blocks which are also procured up to a year ahead of need in increments of 30 minutes. The combination of the different flexibility products allows National Grid to utilise different assets effectively. For example, National Grid may schedule a larger unit for the 30-minute window at the centre of the exceedance period at the week ahead stage. The reduction would not be as effective during the first or last 30-minute window. Instead, Sustain would cover those shoulder requirements. Flexibility will also be procured at the week ahead stage to cover the remaining area under the blue curve, using both Dynamic and Secure products. These flexibility windows will be similar in shape to the yellow blocks in Figure 28.

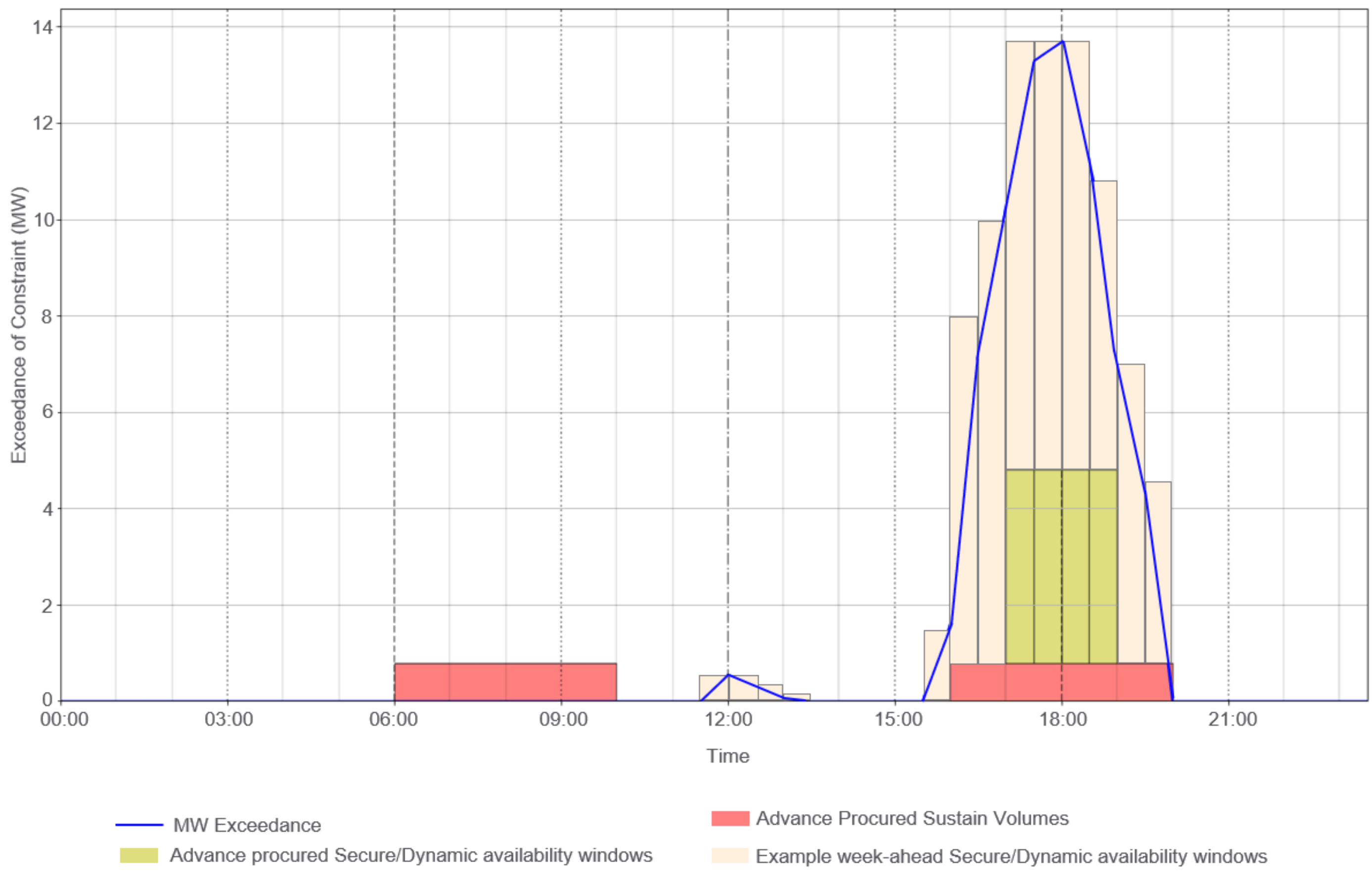

Figure 28. Half-hourly MW Exceedance for Hayle-Camborne CMZ from February 2023, with actual and example procured flexibility

Table 7 shows the theoretical maximum peak power values that could be provided if 100% of projected heat pumps in the Hayle-Camborne CMZ participated in a trial two-style EQUINOX event. It also shows the same for the 47% trial two participation rate. The monthly average temperature in the UK between 2000 and 2024 combined with the temperature/turndown relationship observed in Trial 2 (Figure 12) to adjust the average expected demand response per heat pump for each month.

The table shows that at trial two participation rates, less than 20% of the peak capacity requirement can be met through Secure/Dynamic-style heat pump demand response. Even if 100% of heat pumps opted into the event, this would still only meet a maximum 41% of peak capacity requirements (in February 2026). This shows that heat pumps alone are not suitable for a peak capacity reduction product (yellow blocks) as they cannot reach the peak demand response magnitude required. It also shows that heat pumps cannot meet the entire flexibility requirement from Hayle-Camborne without the dispatch of additional flexibility assets. However, this does not make them unsuitable for providing a baseload reduction style product (red blocks). This is explored further in Scenarios 1 through 3.

Table 7. Peak capacity calculations

Year	Month	Average monthly UK temperature 2000-2024 (°C)[30]	Temperature-adjusted demand response per heat pump (kW)	Total demand response assuming 100% opt in (kW)	Total demand response assuming 47% trial two opt in (kW)	Peak capacity required (kW)	% of peak capacity met (100% heat pump opt-in)	% of peak capacity met (47% heat pump opt-in)
2026	February	4.38	0.75	3,249	1,527	7,980	41%	19%
2026	November	6.65	0.61	2,643	1,242	7,330	36%	17%
2026	December	4.40	0.75	3,249	1,527	9,290	35%	16%
2027	January	3.99	0.75	4,111	1,932	14,700	28%	13%
2027	February	4.38	0.75	3,343	1,571	12,660	26%	12%
2027	November	6.65	0.61	4,111	1,932	11,870	35%	16%
2027	December	4.40	0.75	4,111	1,932	14,040	30%	14%
2028	January	3.99	0.75	6,367	2,992	18,240	35%	16%
2028	February	4.38	0.75	6,367	2,992	16,140	39.45%	19%
2028	November	6.65	0.61	5,178	2,434	15,250	33.96%	16%
2028	December	4.40	0.75	6,367	2,992	17,560	36.26%	17%

Scenario 1: Heat pumps participate for two hours a day, five days a week.

Table 8 shows:

- The estimated utilisation energy requirements split by month.
- The monthly demand response achieved if 100% of projected heat pumps participate for 2 hours a day, 5 days a week. This represents an intensive participation requirement from the homes involved, which shares characteristics with the Sustain flexibility product.
- The percentage of heat pumps that would need to participate to meet the energy requirements under this scenario.
- The apportioned utilisation energy requirements and the percentage of heat pumps that would need to participate to meet the apportioned requirements. The apportioned energy requirements have been calculated by multiplying the energy requirement by the percentage of heat pumps in relation to other LCTs within Hayle-Camborne (Table 4).

[30] Taken from the Met Office UK Climate series

Table 8. Scenario 1 results. Green cells represent heat pump percentages below the average opt in rate seen in trial two (<47%), and therefore indicate a realistic percentage of heat pumps in Hayle-Cambourne that could be procured. Gold cells represent heat pump opt in rates between 47% -100% which could theoretically meet the energy requirements. Orange cells represent heat pump opt in rates above 100%, which are not possible.

Year	Month	Estimated utilisation energy required [kWh]	Estimated apportioned utilisation energy required [kWh]	Heat pump demand response provided through scenario 1 assuming 100% opt in [kWh]	% of homes needed to meet utilisation energy (max 2 hrs per home)	% of homes needed to meet utilisation energy apportioned to heat pumps (max 2 hrs per home)
2026	February	3,148[31]	1,534[32]	129,960	5%[33]	2%[34]
2026	November	12,592	6,136	105,701	24%	12%
2026	December	29,381	14,317	129,960	45%	22%
2027	January	23,739	11,117	164,430	43%	20%
2027	February	13,565	6,353	133,736	20%	10%
2027	November	13,848	6,485	164,430	17%	8%
2027	December	43,521	20,381	164,430	159%	74%
2028	January	31,483	14,665	254,670	62%	29%
2028	February	24,855	11,578	254,670	39%	18%
2028	November	14,913	6,947	207,132	22%	10%
2028	December	44,740	20,840	254,670	123%	57%

Table 8 shows that at most 45% of projected heat pumps will need to participate to meet the full utilisation energy requirements for the 2026 winter period. In 2027 and 2028, heat pumps can meet the requirements for January, February and November, but are insufficient for December.

Of course, heat pumps are not the only flexible LCT, so it would be unwise to assume they need to cover the full utilisation energy requirements. Using the figures in Table 4 we can apportion the utilisation energy requirements and see how the percentage of heat pumps needed to meet the requirements changes. With a reduced energy target, heat pumps can meet the energy requirements for all the winter months between 2026 and 2028. December 2027 and 2028 require ~74% and ~57% respectively, which is above the 47% average participation rate seen in trial two.

[31] Per day: 120 kWh.

[32] Per day: 60 kWh.

[33] i.e., 2.5% of heat pumps installed in 2026 are needed per 2-hour block to meet the utilisation energy requirement spread across a 4-hour block every day of the month.

[34] i.e., 1% of heat pumps installed in 2026 are needed per 2-hour block to meet the utilisation energy requirement apportioned to heat pumps spread across a 4-hour block every day of the month.

This scenario will be explored further in trial three to see how this modelling translates into a real-world trial.

Scenario 2: Heat pumps participate for two hours a day, two days a week.

Scenario 1's intensive participation requirement from homes will not be a suitable arrangement for all homes. Therefore, additional analysis is required to determine whether flexibility requirements can be met if households participate less regularly. Scenario 2 undertakes the same analysis as scenario 1, but heat pumps are now only required to provide flexibility for two hours a day, two days per week. This is a similar schedule to trial two. Heat pumps are assumed to be evenly spread across all days of the week to meet the utilisation energy requirements.

Table 9 shows the same analysis summary for scenario 2 as Table 8 showed for scenario 1. Outside the months of December and January, heat pumps could theoretically meet the utilisation energy requirements with their projected numbers. If using the more realistic opt in rate of 47% from trial two, only the requirements of February 2028 and November 2027 could be met using heat pumps alone. Taking the apportioned energy requirements shows that the December needs for 2027 and 2028 still cannot be met, as the percentage of heat pumps required is larger than 100%. December 2026 and January 2027 and 2028 theoretically could be covered if opt in rates were higher than 47%. Utilisation energy requirements could be met in all other months.

Table 9. Scenario 2 results. Cells are coloured as in Table 8.

Year	Month	Estimated utilisation energy required [kWh]	Estimated apportioned utilisation energy required [kWh]	Heat pump demand response provided through scenario 2 assuming 100% opt in [kWh]	% of homes needed to meet utilisation energy (max 2 hrs per home)	% of homes needed to meet utilisation energy apportioned to heat pumps (max 2 hrs per home)
2026	February	3,148	1,534	51,984	12%	6%
2026	November	12,592	6,136	42,280	60%	29%
2026	December	29,3813	14,317	51,984	113%	55%
2027	January	23,739	11,117	65,772	108%	51%
2027	February	13,5659	6,353	53,495	51%	24%
2027	November	13,848	6,485	65,772	42%	20%
2027	December	43,521	20,381	65,772	397%	186%
2028	January	31,483	14,665	101,868	155%	72%
2028	February	24,855	11,578	101,868	98%	45%
2028	November	14,913	6,947	82,853	54%	25%
2028	December	44,740	20,840	101,868	307%	143%

Scenario 3: An informed mix of Scenarios 1 and 2.

Scenarios 1 and 2 demonstrate possible flexibility offerings from individual domestic heat pump owners. A mixture of both scenarios is more likely across a large population. This is based on customer findings from trial two, which suggest an appetite for both. As outlined in Section 7, 78% of participants agreed that the 0-3 event per week cadence for trial two was 'neither too many nor too few' and 22% felt that there were 'slightly or far too few' EQUINOX events. Encouragingly, no participants reported that there were too many EQUINOX events. Using these percentages as a proxy, we can determine the percentage of homes that would need to behave flexibly to meet the required utilisation energy for the CMZ.

Table 10 repeats analysis from the first two scenarios for a scenario in which 78% of the projected heat pumps participated for 2 days a week (following scenario 2), and the other 22% participated for 5 days a week (following scenario 1).

The analysis shows that heat pump numbers would need to increase by a minimum of 200% to provide sufficient flexibility in the month with the highest utilisation energy requirement (December 2027). January and December 2028 also cannot be met using current projected heat pump numbers. December 2026, January 2027, and February 2028 requirements can only be met with an opt in rate higher than that observed in trial two.

As expected, using the apportioned energy requirements improves on the above results. Now, only requirements in December 2027 and 2028 can still not be met by heat pumps alone, necessitating procurement of other flexible LCTs. Heat pumps can meet the apportioned utilisation energy across all other months with opt in rates below or similar to trial two rates.

Table 10. Scenario 3 results. Cells are coloured as in Table 8.

Year	Month	Estimated utilisation energy required [kWh]	Estimated apportioned utilisation energy required [kWh]	Heat pump demand response provided through scenario 3 assuming 100% opt in [kWh]	% of homes needed to meet utilisation energy (max 2 hrs per home)	% of homes needed to meet apportioned utilisation energy (max 2 hrs per home)
2026	February	3,148	1,534	69,139	9%	4%
2026	November	12,592	6,136	56,233	45%	22%
2026	December	29,381	14,317	69,139	85%	41%
2027	January	23,739	11,119	87,477	81%	38%
2027	February	13,565	6,353	71,148	38%	18%
2027	November	13,848	6,485	87,477	32%	15%
2027	December	43,521	20,381	87,477	299%	140%
2028	January	31,483	14,665	135,484	116%	54%

2028	February	24,855	11,578	135,484	73%	34%
2028	November	14,913	6,947	110,194	41%	19%
2028	December	44,740	20,840	135,484	231%	108%

Conclusion

The above scenarios suggest that heat pumps alone will not be able to meet the peak capacity required to mitigate the entire constraint seen in the Hayle-Camborne CMZ. This indicates that heat pumps are not best placed to meet sudden peaks in DNO flexibility needs. Heat pumps alone also cannot meet the zone's full utilisation energy requirements across all winter months, even when those requirements are apportioned to heat pump numbers relative to total flexible LCT numbers.

However, heat pumps may be better suited to providing a daily base weekday flexibility need similar to the Sustain flexibility product (Figure *28.* Half-hourly MW Exceedance for Hayle-Camborne CMZ from February 2023, with actual and example procured flexibility – red blocks), which would reduce the peak and the volume of flexibility that the DNO would have to procure at the week-ahead or closer stage. Additionally, if a proportion of the heat pumps were able to sustain a response for longer than 2 hours, fewer heat pumps would be needed to meet the energy requirements as suppliers would not have to stagger homes across the flexibility window.

This case study therefore suggests that heat pump flexibility can help to resolve distribution network CMZs when combined with other assets.

9. Looking ahead to trial three

Trial two has provided key learnings on domestic heat pump flexibility that deepen our understanding of how customers will accept and respond to requests for demand response, and how much networks can rely on demand response to manage constraints in a net zero future. As we look ahead to the third and final EQUINOX trial in 2024/25, we continue to look for new ways to innovate and advance the conversation on domestic heat pump flexibility.

Trial two activities have informed our preliminary thoughts on trial three and highlighted the following areas we will look to explore:

- **Sustain-type commercial arrangement:** The Hayle-Camborne CMZ network impact analysis indicates that heat pumps will make a useful contribution to de-loading the network but need to be paired with other flexible assets to fully mitigate peak demand in CMZs. The findings suggest that heat pumps could be most beneficial when providing a regular daily reduction in base peak demand, rather than as dynamic flexible assets used to meet sudden network needs. This is indicative of a Sustain-type commercial arrangement for domestic customers. Trial three will therefore prioritise the incorporation of a Sustain-type commercial arrangement to measure heat pump households' capability to provide demand response when advance notified, throughout the winter during periods of peak demand. Tracking the behavioural response of participants through this Sustain arrangement will provide great value in informing the future flexibility role for domestic heat pumps.

- **Longer events:** The Hayle-Camborne CMZ analysis also highlighted that meeting four-hour DNO flexibility requirements with domestic heat pump households is more challenging if each heat pump only offers two hours of flexibility. This means available households have to be spread into cohorts, each dispatched to cover half of the four-hour flexibility window. This effectively halves the total number of households available to provide demand response in MW terms. If participants can provide flexibility for a longer time window, this would increase available MW demand response peak, which would be highly beneficial to DNOs. Given most surveyed participants (85%) suggested they were open to trying longer three-hour events, we will test longer events in trial three. We will test in practice if participants would be willing to opt in for longer events and assess any potential implications for the demand response they provide and their thermal comfort.

- **Flexibility product stacking:** Considerable benefits for GB may be unlocked if DNOs and the ESO can procure flexibility from the same assets at the same time. Flexibility service providers stand to benefit since they could layer additional contracts on the same assets, while households also stand to benefit since they could be rewarded through additional incentives. Since 69% of surveyed customers reported they would be interested in participating in more than one flexibility offering concurrently, stacking EQUINOX with an additional ESO offering is a key ambition for trial three. In stacking with either an existing or simulated flexibility service/trial, we will test how participants respond, and how the process can be optimised for flexibility service providers and networks.

- **Morning events:** We found that demand response levels did not vary with event start time during the evening peak. However, we would like to test whether this holds for events held during the morning demand peak. This is based on anticipated network needs and expectations that customers have differing heating behaviours in the morning versus the evening.

- **Vulnerability:** Alongside trial two, an Equitable Participation Framework (EPF, summarised in Section 11) was developed. It identified factors that increased the likelihood of a participant being in a vulnerable situation regarding their home heating. By considering how these factors compounded and interacted, the EPF has assessed the obstacles to unlock the benefits of flexibility. It also considered which factors were most relevant to target and segment potentially vulnerable participants. These have helped us define hypotheses to test in trial three. We are encouraged that so many customers reported never feeling discomfort in trial two. Nevertheless, we will also review safeguards for customers who may be more vulnerable to the cold. While participation is an individual choice, we never want to incentivise customers to underheat their home.

- **Broader demographic spread:** Demographic data from trial two showed progress towards a pool of participants that is representative of the UK more broadly. While we may be limited by the pace of the heat pump rollout, we will continue to consider ways to enrol a more diverse pool of participants in trial three that is more representative of the UK in terms of home ownership status, average household income, and other metrics.

- **Alternative efficiency metrics:** There was no statistically significant relationship between demand response and EPC (used as a proxy for insulation) in trial two. We will consider using alternative metrics for home efficiency such as size of home in trial three to allow us to extract more nuanced learnings.

- **Additional license area:** Trial two investigated demand response solely with participants across the NGED license area. In trial three we are planning to onboard a second network, SP Energy Networks, which would enable EQUINOX trial arrangements to be tested across a wider area.

Trial two's analysis also highlighted several factors that likely will not be a focus for trial three. These include:

- **Participants on tariffs of interest:** We saw that opted in participants on tariffs of interest already provided demand response based on the price signal built into their tariff. They therefore had limited additional flexibility to offer through EQUINOX events. We will accordingly evaluate if the eligibility criteria for trial three should include these households, or if it would be more useful to focus on households not yet providing demand response via a tariff.

- **Potentially excluding participants with aggregator-controlled heat pump households.** The experiences of aggregator-controlled participants could not be properly evaluated in trial two, due to the small size of the group, and due to all members of the group being on tariffs of interest. An ambition for trial three is to recruit a larger aggregator-controlled cohort to more thoroughly assess whether there are any statistically significant differences relative to participants who control their heat pumps themselves. However, if this larger group is still dominated by customers on tariffs of interest, it will be challenging to determine whether their heating behaviours are a response to the price signal built into their tariff or a result of EQUINOX events. In this case it would not add value to trial three to enrol this aggregator-controlled cohort. It may be the case that aggregator-controlled heat pump households all have arrangements permitting their supplier to heat their home dynamically according to when prices are lowest. A higher penetration of these heat pumps would therefore mean they can provide demand response, though the specifics of such automation will determine whether or not they are compatible with events-based flexibility procurement initiatives like those tested in EQUINOX trial two.

- **Variable event notice periods:** We found that demand response levels did not vary significantly with event notice period. Notice period is therefore not currently a priority for further testing in trial three.

- **Customer heat pump control types:** We saw that opted in participants provided statistically insignificant variations in demand response across manual and remote customer control methods. Customers controlling their own heat pumps can therefore reasonably be treated as a single group.

Overall, we are extremely encouraged by the results and findings from trial two and believe it has offered unique insights into how much networks can rely on customer demand response through domestic heat pump flexibility. We are looking forward to further refining trial two outcomes in the upcoming winter 2024/25 trial.

10. Appendix A: Event scheduling and operations

10.1. Event Scheduling

Trial two ran 36 events between 3rd November 2023 and 13th March 2024.

As described in above, there were a number of trial variables which needed to be tested proportionally. To aid with scheduling events, an event timetable depicted in Figure 29. Trial two event timetable was created which assigned a specific combination of trial group, event time, and notice period to each event over the trial period. This meant that the only variable that needed to be chosen on a weekly basis was the days the events took place on.

Trial 2 Timetable

		Event by Event Set-up (2023 events)													
	Week	1		2		3		4		5		6		7	
	Dates for Weekdays	30/10 - 3/11		6/11 - 10/11		13/11 - 17/11		20/11 - 24/11		27/11 - 1/12		4/12 - 8/12		11/12 - 15/12	
	Event days provided by	25/10		1/11		8/11		15/11		22/11		29/11		6/12	
	Event Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Notice Period (M1A/B, 2A/B)	D	M	2	D	2	M	D	2	M	D	2	M	D	2
	Notice Period (M3A/B)	D	M	P	D	P	M	D	P	M	D	P	M	D	P
	Event Start Time (pm)	4	5	6	4	5	4	5	6	4	5	4	6	6	4
Trial Group	M1 Treatment	A	A	A	B	B	A	A	B	B	B	A	A	A	B
	M1 Control	B	B	B	A	A	B	B	A	A	A	B	B	B	A
	M2 Treatment	A	A	A	B	B	A	A	B	B	B	A	A	A	B
	M2 Control	B	B	B	A	A	B	B	A	A	A	B	B	B	A
	M3 Treatment	A	A	A	B	B	A	A	B	B	B	A	A	A	B
	M3 Control	B	B	B	A	A	B	B	A	A	A	B	B	B	A

		Event by Event Set-up (2024 events)																					
	Week	8		9		10		11		12		13		14		15		16		17		18	
	Dates for Weekdays	8/1 - 12/1		15/1 - 19/1		22/1 - 26/1		29/1 - 2/2		5/2 - 9/2		12/2 - 16/2		19/2 - 23/2		26/2 - 1/3		4/3 - 8/3		11/3 - 15/3		18/3 - 22/3	
	Event days provided by	3/1		10/1		17/1		24/1		31/1		7/2		14/2		21/2		28/2		6/3		13/3	
	Event Number	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	Notice Period (M1A/B, 2A/B)	M	D	2	M	D	2	M	D	2	M	D	2	M	D	2	M	D	2	M	D	2	M
	Notice Period (M3A/B)	M	D	P	M	D	P	M	D	P	M	D	P	M	D	P	M	D	P	M	D	P	M
	Event Start Time (pm)	5	4	5	6	6	5	6	5	4	6	4	5	4	6	6	4	5	6	5	6	4	5
Trial Group	M1 Treatment	B	A	A	B	B	B	A	A	A	B	B	A	A	A	B	B	B	A	A	B	B	B
	M1 Control	A	B	B	A	A	A	B	B	B	A	A	B	B	B	A	A	A	B	B	A	A	A
	M2 Treatment	B	A	A	B	B	B	A	A	A	B	B	A	A	A	B	B	B	A	A	B	B	B
	M2 Control	A	B	B	A	A	A	B	B	B	A	A	B	B	B	A	A	A	B	B	A	A	A
	M3 Treatment	B	A	A	B	B	B	A	A	A	B	B	A	A	A	B	B	B	A	A	B	B	B
	M3 Control	A	B	B	A	A	A	B	B	B	A	A	B	B	B	A	A	A	B	B	A	A	A

KEY			
M1	Low utilisation payment, stratified by notice	P	Phantom event (no notice)
M2	High utilisation payment, stratified by notice	2	Customer informed 2 hours ahead
M3	Availability payment, flat utilisation payment	M	Customer informed morning of
		D	Customer informed day ahead

Figure 29. Trial two event timetable

Similarly to trial one, EQUINOX events were scheduled based upon a week ahead weather forecast from the Meteo Group. The forecast was collected in the form of hourly external temperature. Bristol was chosen for the main forecasting location, given it was reasonably central across National Grid's license areas. Weather stations in Plymouth and Birmingham were also tracked to see whether there were large temperature variations across the license areas. Hourly temperatures for the weekdays of the following week were extracted for these three weather stations and stored on a tracking spreadsheet. The average temperature at the Bristol weather station between 4-8pm was calculated in addition to the average temperature for the whole day.

On each Wednesday, National Grid:

- Used the tracking spreadsheet to gauge which temperature range(s) required more event days and look for temperatures within this range in the following week's Monday to Friday forecast.
- Used the average 4-8pm forecast temperatures to choose two event days which met this criterion.
- Ensured that the non-event days chosen were ensuring a proportional balance between event days and non-event days at similar temperatures.
- Made any adjustments to the chosen days as needed.

On each Thursday before noon, National Grid:

- Accepted the availability windows on the chosen event days at the times stated on the event timetable, for the chosen trial groups.

The suppliers were then informed of the chosen event days for the following week via email.

10.2. Event Operations

The Flexible Power platform was used to schedule and dispatch the EQUINOX events in Trial 2. To interface with Flexible Power, a supplier is required to have an Application Programming Interface (API) which receives the dispatch signals sent by Flexible Power. The API was already implemented for both Octopus Energy and Sero for trial one, whereas the API for ScottishPower was implemented during the trial two preparations phase.

The EQUINOX Constraint Managed Zone (CMZ) set up in the Flexible Power Portal for trial one was altered for trial two to accommodate changes in trial design, notably:

- Creating two Dispatch Groups (DGs) for each supplier.
- Changing the flexibility product from Sustain to Long-Term Dynamic to allow availability to be inputted for the whole trial period and allow for scheduling after the standard gate closure (Thursday 12:00).

To reduce operational complexity during the trial, availability declarations were made for 4-8pm every weekday for every supplier for the entire trial period, prior to the trial period starting. This enabled the chosen event day(s) and time(s) to be selected at the week ahead stage. This also enabled contingency events to be scheduled at much shorter notice if the forecast drastically changed after the initial set of events had been chosen.

11. Appendix B: Vulnerability factors to further explore

Table 11: Vulnerability factors to further explore

Factor	How it has been captured in Trials to date	Issues that should be investigated
Income level	Trials one and two have not had high participation from households with relatively low incomes or which could be classed as fuel impoverished. Household composition has also not been analysed to enable data segmentation according to relative household income.	Low-income households may: • Find it harder to engage in heating flexibility offerings, especially if they are already heating to a minimum. • Be able to offer greater demand response, relative to dwelling size. • Be more satisfied by [lower] payment amounts than more well-off households. They may also be more at risk of underheating, if flexibility offerings act as an incentive to do so.[35]
Insulation level	EPC data has not so far been correlated with significant differences in demand response. It is not clear if EPC correlated with actual temperature loss during events.	Poorly insulated households may find it harder to engage effectively with heating flexibility offerings and may have to opt out of events earlier or more often, resulting in lower payment amounts.
Age	Trial one and two identified if households had members over the age of 65, observing no effect on participation in events.	The effects of age on thermoregulation may only become significant in older age groups. Whether households with members over the age of 75 demonstrate any reduced capacity to engage with heating flexibility offerings should be explored.
Caring responsibilities and young children	Trial one and two identified households with children under 5 years old and have identified some small, potential effects on participant experience.	Given demands on schedules, possibly higher stress, and the higher risks for young children to experience changes in their comfort, it would be valuable to explore whether households with young children, and especially households where there is only one parent, face challenges to take

[35] It is worth noting that initial data for the first 1,000 respondents from the WMCA February 2024 Environmental Attitudes Survey, which surveyed views from residents across the West Midlands, found that 32% of the 344 respondents who reported taking part in energy saving schemes responded 'Always' to the question, "Do [energy flexibility] schemes encourage you to use less energy than you feel you need to be comfortable or for your wellbeing?" Only 12% of respondents responded 'Never'.

		part in events, especially when those events take place during sensitive time periods for these households, such as when children are eating, bathing or preparing for bed.
Households where at least one member suffers from a health condition exacerbated by the cold, or which increases home heating needs	Trial two focused on three primary determinants of potentially vulnerable; if participants self-reported that they were sometimes, often, and/or rarely/never able to afford their energy bills and other household bills, reported either themselves or someone in their household having a disability or long-term health condition, and indicating that this disability or long-term health condition is made worse or more difficult to cope with when it's cold. 206 potentially vulnerable participants were identified from the start of trial survey. 71% identified a household member who suffers from a disability or long-term health condition reported that it was made worse or more difficult to cope with when it is cold.	While the data from Trial two indicates a potentially small higher risk of discomfort among these groups, it would be valuable to test this further, notably on whether they would prefer to take part in earlier or shorter events. It would also be worth investigating whether these and other potentially vulnerable households are more or less likely to take part in EQUINOX events in the morning. 32% of Trial two potentially vulnerable respondents versus 36% of all households indicated they would consider taking part in morning events. Households where at least one member suffers from a health condition exacerbated by the cold, or which increases home heating needs may be more likely to experience difficulty in the morning if the house is already cooler from less heating overnight.
Digital exclusion and communication challenges	This has not been analysed in the trials to date. Lack of access to the internet, or smart technology, or lack of confidence in using either of these independently could undermine access to demand flexibility offerings for households, as could communication challenges. However, as many of these limits relate to the ability to engage with the heat pump itself, rather than with heating flexibility offerings, it may be out of scope to investigate this further under EQUINOX.	

12. Appendix C: Key learnings from trial two

Project EQUINOX is organised into five workstreams (WS):

- **WS1**: Commercial arrangement design.
- **WS2**: Technical integration and automation.
- **WS3**: Customer engagement.
- **WS4**: Trials coordination.
- **WS5**: Project management and knowledge dissemination.

Through these workstreams the project has delivered on its deliverables and objectives. In the spirit of continuous improvement, we regularly capture and update a learning log during monthly programme meetings.

This section presents a summary of key learnings from trial two organised by project workstream. In order to not reiterate the content shared previously in the report, this section provides a non-exhaustive list focusing on key process learnings and items.

The learnings described are being actively utilised by our teams to improve the EQUINOX project and upcoming trial three. Our hope is that they can also be helpful to other similar projects, flexibility trials, and customer focused programmes. As part of our commitment to knowledge sharing, we are happy to further discuss any of these learnings with industry stakeholders. If interested, please reach out to nged.innovation@nationalgrid.co.uk.

12.1. Workstream 1 – Commercial Arrangements

Workstream 1 is responsible for designing the commercial arrangements tested throughout the EQUINOX trials. Building off the commercial arrangements tested in trial one and flexibility offerings in the market, the workstream led the design and development of the commercial arrangements outlined in this report, which were tested in trial two. In the development of these commercial arrangements, key learnings included:

- Existing financial incentives to foster flexibility (ToU tariffs) are very successful. Hence, there was minimal additional flexibility that could be accessed via EQUINOX events. This effect was more pronounced for "tariffs of interest" that directly incentivise load shifting from the evening peak period. Ultimately, this indicates that treating all tariffs equally is inappropriate in trial circumstances.
- Although we could reasonably expect that heat loss rate of a home would impact customer comfort and potentially their flexibility volume, we were only able to see this interaction when considering external temperature and not when considering the EPC rating of a home. It is not known whether the heat loss rate of a home (independent of the external temperature) has a demonstrable effect on flexibility volume, but we will explore alternative measures or proxies to EPC in trial three.
- Although we were able to show that customers do respond to a financial incentive for flexible behaviour in the form of ToU tariffs, we were not able to determine any significant impact of varying £/kWh utilisation rates on volume of flexibility delivered. It is unclear whether there is a general absence of price sensitivity in the range of tested utilisation rates; or whether confounding factors such as non-financial motivations of

customers could overshadow price effects. Trial three will further explore alternative incentive structures rather than examining price sensitivity directly.
- Additional areas for investigation emerged later in the project cycle after trial two goals were completed in the Q3 2023. Trial three goals should be finalised in greater depth ahead of the trials in 2024/5 to ensure more comprehensive preparedness for the analysis which will be undertaken in the second and third quarters of 2025.

12.2. Workstream 2 – Technical Integration and Automation

Workstream 2 is responsible for operationalising the technical integrations and automation between National Grid and the suppliers that support flexibility procurement. In trial two, this workstream successfully onboarded a third supplier, ScottishPower, enabling their customers to participate in the trial. In enabling the technical integrations and automation, key learnings included:

- The structure and capabilities of commercial arrangements are limited by the technical integration and setup which must enable them. Therefore, it is essential for WS1 and WS2 to coordinate and collaborate in parallel to avoid any unforeseen scope changes in work.
- Developments implemented for trial two that focussed on reducing the snapback effect experienced in trial one were successful; no abnormal load increase was observed during the trial two events.
- Testing windows should be scheduled a minimum of four weeks prior to the beginning of the trial window to give sufficient time to fix issues with the testing regime (should there be any).

12.3. Workstream 3 – Customer Engagement and Experience

Workstream 3 is responsible for defining and implementing the customer engagement approach for the EQUINOX trials. In trial two, this workstream successfully led the recruitment of customers and the evaluation of customer perceptions through quantitative and qualitative research. In coordinating the customer engagement, key learnings included:

- Recruiting a participant pool that is representative of the UK population is difficult as heat pumps are not yet widespread, so current heat pump owners tend to be early adopters. It is, therefore, important to actively pursue key groups like organisations that serve underrepresented groups, local authorities, and other relevant organisations to promote the trial which can help to recruit harder-to-reach customers.
- Determining potential customer hypotheses prior to the start of trial is helpful in ensuring that the surveys and focus groups are most appropriate to capture relevant data. This will reduce the time for data analysis.
- When surveying customer perspective and experience it is helpful to allow for additional free text responses in order to capture the nuances of individual responses and capture context which allows for a more holistic interpretation of the results.
- Customer vulnerability is broad and complex; there are challenges to categorise, identify, and account for vulnerabilities. It is important to consider the multi-dimensional factors associated with vulnerability and identify them from the outset of customer recruitment.
- Many vulnerability factors identified are indicative of wider societal challenges. Income inequality, digital exclusion, societal exclusion, and poorly insulated homes are not only barriers to unlocking the full potential

of heating flexibility, but they are also barriers to the energy transition as a whole. Any measures to facilitate the engagement of households in these vulnerable situations with heating flexibility offerings will only ever serve to partially mitigate the risks of inequitable access and unsafe participation.

12.4. Workstream 4 – Trials

Workstream 4 is responsible for the overall coordination of the EQUINOX trials. In trial two, this workstream successfully scheduled the EQUINOX events and analysed the trial results. In leading the implementation and analysis of trial two, key learnings included:

- The configuration used for the EQUINOX zone on the Flexible Power portal should be retained for trial three as it enables the scheduling and dispatch of all the different types of events.
- When setting up the scheduling process, it is important to have the capability to schedule and remove events at short notice to respond to weather/external factors.
- Clearly allocating trial variables to specific events helped enable the delivery of a complex trial design, as it allowed suppliers to plan ahead. It also reduced operational complexity for the DNO.
- It is important that research questions are clearly constructed with a direction in mind, as it enables for the trial to be designed based on a clear set of goals.
- There needs to be clear communication on where data is being shared.

12.5. Workstream 5 – Project management & knowledge dissemination

Workstream 5 is responsible for the overall coordination of the EQUINOX programme and supporting the dissemination of learnings to industry and other stakeholders. During trial two, this workstream successfully shared project learnings and updates through numerous public conferences and forums. In leading the project management & knowledge dissemination, key learnings included:

- Signing off external communications can be time consuming. Thus, when coordinating external project updates, such as press releases and video interviews with participants, it is important to allow enough review time for each partner involved. This is particularly relevant when coordinating across a large consortium/multiple organisations as on the EQUINOX project.