BEIS Electrification of Heat Demonstration Project

Home Surveys and Install Report

Written by LCP Delta

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This report has been funded by BEIS on their behalf

Catapult Energy Systems · LCP Delta · Oxford Computer Consultants

Contents

Glossary

ASHP	Air Source Heat pump (air-to-water heat pump)
BEIS	Department for Business, Energy and Industrial Strategy
DC	Delivery Contractor
DNO	Distribution Network Operator
EoH	Electrification of Heat
EPC	Energy Performance Certificate
ESC	Energy Systems Catapult
GSHP	Ground Source Heat Pump (ground-to-water heat pump)
HT ASHP	High Temperature Air Source Heat pump (air-to-water heat pump)
Hybrid	Hybrid heat pump system (this is an air source heat pump coupled with a gas, oil or LPG boiler)
MCS	Microgeneration Certification Scheme
AB, C1, C2, DE	Socio-economic status groupings (see Table 1)
PCM	Phase Change Material (thermal storage)

1. Executive summary

1.1 Project background

The Electrification of Heat (EoH) Demonstration project is funded by the Department for Business, Energy and Industrial Strategy (BEIS) and seeks to better understand the feasibility of a large-scale rollout of heat pumps across the UK. It aims to demonstrate that heat pumps can be installed in a wide variety of homes and deliver high customer satisfaction across a range of customer groups. It is also evaluating products and services that increase the appeal of heat pumps and identify optimal solutions for a wide range of homes.

The project had a target to install heat pumps in up to 750 homes across Great Britain in a representative range of housing archetypes, with the majority on the gas grid. The project recruited participants from the public to go through a customer journey including home suitability survey and heat pump design. Not all recruited participants went through to installation. Overall, 742 heat pumps were installed as part of the project.

The project is ongoing but the survey and installation stages – to which this report refers – were completed by winter 2021. A report covering the Participant Recruitment stage has been produced covering how participants were recruited to the project, motivations for involvement in the project, the demographics of participants, prior heat pump awareness and consumer barriers to heat pump installation.

1.2 About this report

This report provides insights and data from the home survey, design and installation stages of the project. The report is based on data collected from these stages of the project and the findings reported by the three Delivery Contractors (DCs): E.ON, OVO and Warmworks. It should also be noted that the findings in this report are in the context of the knowledge, skills and experience of the surveyors, designers and installers who carried out relevant stages of this project. The three DCs took different approaches to the project stages, and these differences impact the comparability of some results. There are also a few instances where the results are subjective as the associated questions may have been interpreted differently by contractors.

The aims of this report are to provide a view of:

- The homes involved in the project e.g. property type, age, size, etc.;
- Types of heat pumps installed and additional measures required;
- Costs of installations;
- Barriers to heat pump installations; and
- Lessons from the home survey, design and installation stages.

1.3 Key findings

The report provides the following findings:

1.3.1 Properties involved in the trial

One aim of this project was to demonstrate that heat pumps can be installed in a wide range of domestic properties across the UK, and it has been successful in achieving this. Heat pump designs and installations have been achieved across a wide range of property types, sizes and ages, both on and off the gas grid, and in both rural and urban environments.

The mix of properties and households involved in the project were driven mainly by project quotas. Each DC was required to install a certain number of heat pumps in their trial area within the project timescales. Different approaches were taken by each of the DCs to achieve their installation targets. Properties 'triaged out' of the project or not recommended for a heat pump installation were not necessarily unsuitable for heat pumps, but were less attractive candidates for installation within this project. Suitability of the wider UK housing stock for heat pumps should therefore not be inferred based on this data.

1.3.2 Heat pump types installed

A range of different heat pump types were installed in line with project target quotas. Of the 742 heat pumps installed, 41% were low temperature air source heat pumps (ASHP), 33% were high temperature air source heat pumps, 21% were hybrid heat pumps, 1% were individual ground source heat pumps (GSHP) and 4% were shared ground source heat pumps. The GSHP target of at least 6% of properties was hardest to achieve because only about 10% of properties had suitable ground space, and some of these participants were not willing to have a ground array installed. The minimum requirement of 6% for high temperature heat pumps was far exceeded mainly because of how high temperature heat pumps are defined. Heat pumps are defined as "high temperature" if they are capable of heating to over 65 degrees Celsius, whether or not this functionality is used in practice. Some high temperature units installed in this project were chosen because the higher temperatures were necessary to meet the heating demands, but in many cases the high temperature heat pumps installed were configured to operate as low temperature heat pumps. These products were chosen for their efficient performance rather than their high temperature functionality. Hybrid heat pumps were mainly installed by E.ON because properties in E.ON's area were smaller on average and lacked space for the hot water cylinder, making hybrids more appropriate. E.ON also took a more conservative design approach that favoured hybrid heat pumps in order to guarantee that heat demands would be met and running costs would not increase.

1.3.3 Additional measures installed

New heat emitters were needed with 93% of the heat pumps installed as the existing radiators would have been too small to achieve the necessary heat output. A new thermal store was installed in 81% of homes, either because the property had a combi boiler before and no thermal store, or because the original cylinder did not have a suitably sized coil for a heat pump. Energy efficiency upgrades were only made for 15% of properties where a heat pump was installed – in the majority of cases this was loft insulation, and a few properties received cavity wall insulation or door replacements. Many of the properties that had a heat pump installed already had suitable levels of loft and wall insulation, in part because harder to insulate properties were 'triaged out' at earlier stages of the project.

A range of ‘innovation measures’ were made available in the project with the aim of overcoming consumer barriers to heat pumps. These included phase change material (PCM) thermal stores, noise enclosures, aesthetic impact reduction solutions and cooling systems. PCM thermal stores were installed in 33 homes, many of which were flats that lacked space for a hot water cylinder. Noise barriers or enclosures were used at 27 properties to keep within noise limits, though often low noise heat pump models were used instead. DCs reported that participants did not raise concerns around aesthetics and there was very little interest in cooling functionality.

1.3.4 Costs of heat pump systems installed

Costs recorded for the installation of heat pump systems were based on the costs quoted by DCs in their project proposals for the trial. The average total cost per property was about £14,800 including the heat pump unit, additional measures and installation. However, it should be noted that these costs may not be representative of typical costs of heat pump installations outside a trial environment. For example, in some cases there could be a reduced cost due to the benefits of bulk buying and economies of scale. On the other hand, costs could be higher as a result of overheads relating to the trial.

Hybrid heat pumps were the lowest cost option with an average total cost of £10,200 per system. Low temperature ASHPs were the second lowest cost option, with an average installed cost of £13,700. High temperature ASHPs were more expensive than other types of ASHP, with an average total cost of around £17,400. The higher cost is partly because the high temperature heat pumps installed are more expensive modern units. GSHPs were the most expensive type of heat pump system installed. The 10 individual GSHP installations carried out by Warmworks cost £47,400 per property on average, including the cost of the ground works. The shared GSHP installations carried out by E.ON and OVO cost £16,400 per property because the heat pump units installed were smaller and the cost of ground works was shared by multiple properties. Some of the variability in costs was due to differences in the prices quoted originally in project proposals and the mix of heat pump types installed by DC.

The costs above include additional measures such as heat emitters and thermal stores. Heat emitter costs ranged broadly depending on the number of emitters installed. The average cost per property was £2,800 in total, including installation. The most common number of emitters installed was 8-10. Thermal storage costs were mostly between £1,500 - £2,000 or £3,500 - £4,000, depending on the DC and the size of store installed.

1.3.5 Barriers to heat pump installation

The project seeks to understand how to overcome barriers to the widescale roll-out of heat pumps for domestic heating. Participant barriers are discussed further in the Participant Recruitment report. A commonly reported reason for participants not wanting to proceed with a heat pump installation was the disruption that the installation would cause to their home. This includes replacement of pipework, impact on décor, etc.

This report looked at the barriers to installing heat pumps as reported by surveyors / designers / installers in the project. Only 12% of properties surveyed were considered unfeasible based on technical constraints (as detailed in the bullet points below). This broadly matches findings from unpublished BEIS analysis[1] which indicates that that low-temperature air source heat pump suitability in UK homes might be approximately 90%, without accounting for insulation and space and noise constraints[2]. In this project, 66% of the eligible properties assessed were recommended a heat pump based on project constraints[3]. Barriers were recorded as reasons a heat pump was not recommended for a property in the context of this trial – for example, the contractors were working within project time and budget constraints to install a target number of heat pumps in a range of different properties. This may have impacted the assessments of whether or not heat pumps were recommended for properties.

The main non-participant barriers were:

- **Practical – external or internal space constraints:** For 8% of properties assessed, a lack of external space for an outdoor unit was cited as the reason a heat pump could not be installed. For 5% of properties, although there was space for the outdoor unit, it would have been too close to a neighbouring property to meet noise limits, even if noise abatement measures were applied, and would therefore require planning permission. Planning permission applications were made in some cases, but none were approved. For 2% of properties, a lack of internal space for a thermal store or larger radiators was given as the main reason.
- **Technical – heating capacity constraints:** For 7% of properties assessed, the size of heat pump required to meet the heat losses of the property was larger than products available within the scope of this project. For 4% of properties, designers were concerned that the comfort requirements could not be met, either because of the heat pump capacities available in the project scope, or as noted above because large enough radiators could not be installed in some rooms.
- **Economic – cost of upgrades required:** For 4% of properties assessed, the cost of the installation and/or additional measures would have been too high for the DC to accommodate within its project budget. This reason was given most often by OVO, which set a cap of £15,000 per property. The explanations provided suggest this was often due to the need for additional insulation, and in some cases the replacement of microbore piping or a large number of radiators.

Overcoming these barriers was explored in the project as far as possible. For example:

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[1] The BEIS analysis draws upon previous a Delta-EE research methodology (https://www.gov.uk/government/publications/electric-heating-in-rural-off-gas-grid-dwellings-technical-feasibility) with some parameter changes scaled to the National Housing Model and applied to on-gas housing.

[2] It should be noted that this trial investigated various types of heat pump, whilst the specific finding being referred to from the previous BEIS research relates to low temperature air source heat pumps only

[3] Project constraints mainly consisted of project specific targets relating to property archetypes and types of heat pump, as well as time and funding constraints.

- Engagement with the local planning authority helped to facilitate discussions around noise and permitted development. Noise enclosures were a viable solution for some properties to meet permitted development.
- Contractors spent considerable effort finding ways to minimise disruption for customers.
- Product alternatives such as hybrid systems with no outdoor unit (sometimes known as 'compact hybrid heat pumps') and compact phase change material thermal storage were introduced to overcome issues of space constraints and high heating demands.
- The local DNO was engaged to try and speed up the processing of connection applications and find solutions to processing bulk applications.

However, overcoming all barriers was not within the control of the project. For example, exploring solutions to microbore piping issues, such as installation of low loss headers, was beyond the scope of this project. Further analysis would be required to understand the financial implications of larger heat pump sizes or substantial energy efficiency upgrades needed for those properties where the measures required fell outside the scope of this project.

1.3.6 Lessons from the survey, design and installation stages

The key lessons learned from these project stages are as follows. Recommendations related to these lessons are provided in the following section.

- **Design standards, tools and assumptions:** Through the project it emerged that there are different understandings and interpretations of MCS standards and how to achieve compliance. Feedback from project delivery partners is that there is an overall industry trend towards surveyors being overly cautious in their design assumptions for calculating the heat demand of a property, leading to over-sizing of heat pumps. There was also uncertainty about how to account for particular circumstances, such as kitchens with no heat emitters, or where renovations were planned but the full design details not yet known. Another issue that emerged was around updates to manufacturer design tools having 'bugs' that impacted the design calculation results. This raised the question of whether design tools should be accredited by MCS, and the requirement for better industry understanding of MCS standards.
- **Use of desktop audits:** As the project progressed, DCs refined their recruitment approaches to minimise customer drop out after the site survey stage by collecting more information at an earlier stage. Desktop audits using publicly available information such as Google Street View were found to be a useful tool in the project triaging process and will continue to be used by DCs in a commercial context.
- **Manufacturer documentation and guidance:** DCs have noted that the guidance from manufacturers on installation of their heat pump units can be lacking or

inconsistent. This was even the case where installers had undertaken recent manufacturer training. In some cases, contacting the manufacturer to resolve queries through the technical support was also time consuming.

- **Customer expectation management:** On average, heat pump installations took 2-4 days to complete by a team of two installers and one electrician, including the installation of new heat emitters and thermal storage but excluding installation of any energy efficiency measures. Most installations involved heat emitter replacements and installation of a new thermal store. To maintain customer satisfaction, DCs found it was important to discuss the potential disruptions early on in the engagement process, clearly communicate how long installers would be in their home, and provide an alternative heat source for the installation period.
- **Managing and auditing subcontractors:** The project has been delivered by three DCs and several subcontractors. Overall, this worked well, but the number of parties involved did make it more difficult to plan for installer availability, communicate learnings between installers and DCs, and manage installation quality and safety. A concern was raised by one DC that MCS certification does not ensure the ongoing competency of all installers working for those organisations.
- **Quality of heat pump installations:** A number of issues have been identified from the installation quality assurance audits done to date, particularly around insulation of pipework and having appropriate clearances from components. None of these issues are considered to be unusual for the heat pump industry as a whole, or indeed the wider heating industry.
- **Supply chain constraints:** Product shortages were experienced during the trial that delayed heat pump installations. These were attributed to supply chain disruptions including Covid-19 impacts, but do point to potential challenges for the mass roll out of heat pumps. Some issues with installer capacity were also reported, particularly due to Covid-19, although these were very localised.
- **Noise limits and planning permission:** Technical solutions such as low noise heat pumps and noise enclosures can enable designs to meet noise requirements. However, where these solutions are not viable, planning permissions could be a barrier to the wider uptake of heat pumps.
- **DNO approvals:** For properties where load checks were required by the local Distribution Network Operator (DNO), these checks sometimes took several months to complete, delaying heat pump installations. Lack of standardisation in decision-making and inability to handle batch requests within the DNO organisation was also reported as issues by some DCs. If these challenges are not resolved, DNO approvals could become a significant barrier to the mass roll out of heat pumps.

1.3.7 Best practice and recommendations

Recommendations and best practice guidance from these project stages are as follows:

- **Support and training for heat pump design and installation:** The project has demonstrated a range of understandings and interpretations of the MCS design rules, some of which could result in oversizing of heat pumps. Further, non-conformance issues with some heat pump installations were raised in quality assurance audits – these point to a lack of understanding of design requirements and a need to upskill installers in this area. This important issue needs to be addressed to ensure heat pumps are designed and installed correctly, ensuring efficient performance and consumer expectations are met. Suggested ways this could be addressed are:
    - Having experienced designers within organisations supporting new designers.
    - One DC also suggested that there should be a formal qualification for heat pump design, as there is for installation. MCS have since announced that the existing Heat Pump Standard will be split into two standards – one for Heat Pump Design and one for Heat Pump Installation[4].
    - Further training for designers and installers to understand the MCS design rules. Support from an independent advice organisation was well received in this trial – ways of providing similar support for the wider heat pump industry should be considered.
    - Continuation of QA audits in design and installations
- **Recognition of competence:** It was suggested that surveyors, designers and installers should be required to hold a competency card ensuring they understand the fundamental principles of designing heat pump systems. This could be similar to the Gas Safe ID card carried by Gas Safe registered engineers certifying that they have the necessary qualifications to carry out gas work.
- **Sharing of learnings from the trial:** In addition to the dissemination reports and case studies published from this project, it is recommended that all relevant learnings from this trial for the heat pump industry are summarised and shared with designers/installers through appropriate channels.
- **Review of MCS requirements and guidance:** DCs noted a number of instances where there was uncertainty or disagreement on how to comply with MCS requirements – for example, how to meet heat losses in kitchens that do not have heat emitters. Findings from DCs and GTEC relating to the MCS requirements and guidance should be collated and shared with MCS so that these can be reviewed and updated if necessary.
- **Review of MCS ongoing quality assurance:** Concerns were raised by DCs about whether MCS certifications of organisations were adequate to ensure the ongoing

[4] MCS announces key changes to its Heat Pump Standard, 26/01/2022, MCS: https://mcscertified.com/mcs-announces-key-changes-to-its-heat-pump-standard/

competence of the installers working for those organisations. It was suggested that MCS lacks the resources to provide ongoing compliance enforcement. The MCS certification process should be reviewed and enhanced to ensure it delivers high quality installations and increased confidence in the industry.

- **Auditing and standardisation of design tools:** MCS does not audit or accredit design tools – instead it is up to MCS accredited organisations to check that design tool calculations are MCS compliant. It was suggested by DCs that producers of design tools should have some obligation to confirm they are MCS compliant, or that they be audited by MCS. It would be useful for the heat pump industry to have all design tools and product recommendations centralised under MCS – this would also help in providing confidence in the industry.
- **Automation of desktop audits:** In this trial DCs made use of publicly available information and data provided by participants to 'triage out' properties not suitable for a heat pump in the context of this project before conducting a site survey. Learnings from the triage process and suitability assessments could be used to inform the development of heat pump assessment algorithms to automate initial survey stages and reduce the overall costs of installing a heat pump.
- **Customer support and expectation management:** Through this trial DCs have learned how to more effectively engage and support households through the transition to a heat pump. Additional ways of sharing these learnings with the wider industry might be considered. We recommend, for example, that organisations:
    - Have dedicated (non-technical) customer support staff who can explain the implications of having a heat pump installed at the appropriate stages in the customer journey. This is discussed further in the Participant Recruitment report.
    - Take customer preferences in to account from early on in the process to ensure the best system for their needs is installed.
    - Set clear expectations for customers of how long installers will be in their property and what works will be carried out.
    - Provide an alternative heat source for the duration of the installation.
- **Summarising of key facts for customers:** Customers can be overwhelmed by the volume of documents provided to them in the process of designing and installing a heat pump. It was suggested that customers should also be provided with a simple "key facts" document summarising the main assumptions for their property, such as estimated running costs.
- **Review and improvement of DNO approval processes:** Options to speed up and streamline DNO approval processes for heat pumps should be urgently explored and implemented. New connection protocols and tools are needed so that specific approval is not required for installation. More standardised processes that are able to

process bulk applications would help. There may also be a need to upskill staff within DNOs around understanding heat pump loads.

- **Review of pipework requirements in new building regulations:** Building regulations should be reviewed to ensure that all new buildings can easily have a heat pump installed without the need for solutions to overcome microbore piping issues or heat emitter upgrades.
- **Review of noise requirements for heat pumps:** Local Planning Authority requirements for heat pump planning permissions should be re-assessed to determine whether any of these requirements could be revised to encourage wider uptake of heat pumps.
- **Innovative solutions to practical and technical barriers:** This trial has demonstrated the need for innovative solutions to practical and technical barriers to installing heat pumps, such as locating outdoor units and replacing microbore pipework. These should be encouraged through future innovation trials and support mechanisms.
- **Demonstrating solutions for properties with high heat demands:** Properties with very high heating demands were effectively excluded from heat pump installations in this trial because of product and budget limitations. It is worth quantifying how prevalent these properties are and potentially conducting a separate analysis on what it would cost to install heat pump systems in these homes.

2. Introduction

This report provides interim findings on the home survey, design and installation stages of the BEIS Electrification of Heat (EoH) Demonstration project. The project has installed 742 heat pumps across the UK through three Delivery Contractors (DCs) to understand the feasibility of a mass rollout of heat pumps.

2.1 Aims

The aims of this report are to provide data and insight on:

- The characteristics of homes involved in the EoH demonstration project, including age, type, size and whether they are 'on' or 'off' the gas network. Note that the number of homes involved at the survey, design and installation stages differs as not all homes proceeded to the following stage.
- Basic details of the heat pumps and accompanying measures installed.
- Costs of the heat pump systems installed into homes within the project, including how this varies between different heat pump types and additional measures installed as part of the system.
- Lessons from the home survey, design and installation stages:
  - An overview of the barriers to heat pump installation at these stages in the project.
  - Lessons around reducing barriers to uptake.
  - Best practice around the home survey, design and installation processes.

A separate report will be produced by the project's Evaluation Contractor (ICF) looking at how the project activities were delivered, how the project performed against delivery targets, and what lessons can be learned for the heat pump market. This report will include findings from interviews with heat pump installers involved in the project.

More details on the participant recruitment stage, including lessons from customer engagement, are contained within the Participant Recruitment report.

2.2 Sources of data used for this report

Data provided in this report derive from four sources:

- **The Electrification of Heat project Database (stored in USmart):** this is the central database used for the project where all participant, survey, design and installation data are held.
- **Qualitative lessons arising from meetings with DCs:** meetings were held throughout the recruitment, survey, design and installation stages. Meetings included: initial interviews with DCs about their approaches, monthly Operation Meetings throughout the trial, and final one-to-one calls focused on lessons from these stages of the project.

- **DC triage reports:** Reports were provided by each of the DCs detailing the results of their recruitment and triage stages of the project, including their recruitment strategies, triage processes, triage statistics and a discussion of how recruitment barriers could be overcome.
- **Qualitative lessons arising from quality assurance audits:** Key findings from the quality assurance audits done to date were provided by the Energy Systems Catapult (ESC), the project's Management Contractor. These were based on regular meetings with GTEC, the company providing the audits.

2.3 Project stages

The project is delivered by three DCs: E.ON, OVO and Warmworks. Figure 1 below shows the key stages of the EoH demonstration project. Participants were recruited to the project through a variety of means. Eligible householders were then taken through to a home survey and technical survey to assess the feasibility of different heat pumps and any energy efficiency upgrades required to make the home more suitable for a heat pump. Customer communication happened throughout to ensure they were happy to proceed, and their preferences were considered in the design of the system. Following a successful design, the heat pump system was installed. Once installed, the heat pump performance is monitored in the monitoring phase.

The boxes below the flow diagram show the key databases where data from the project has been captured. This report is based on the home survey, technical survey & design, and system installation stages. Property data contained in this report is based on the home survey information database (as this is the stage at which property data is collected). Participants drop out at each stage of the journey and therefore the number of properties in each database is different. The combined dataset used in this report is a combination of datasets 1 to 4.2.

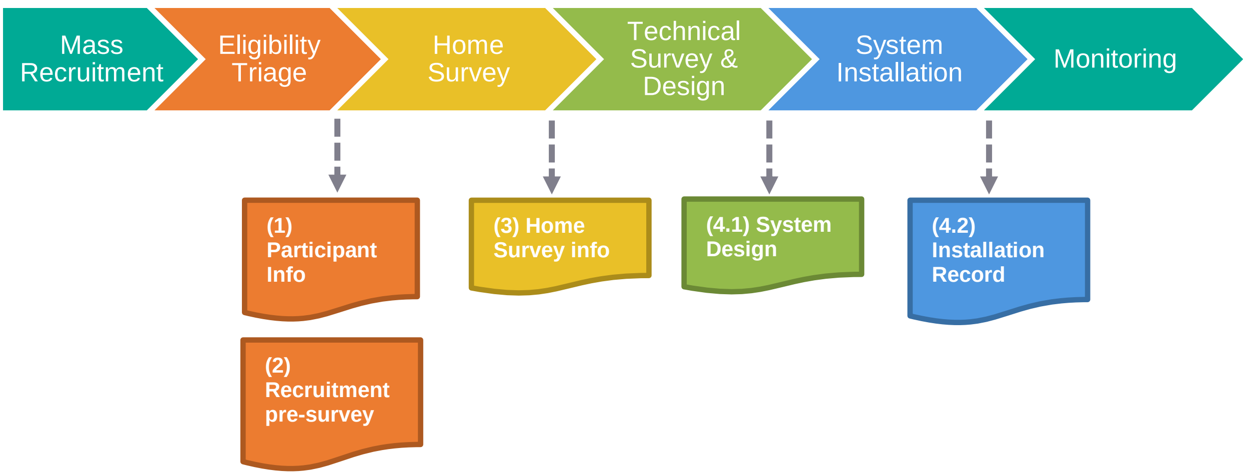


Figure 1: Flow chart of key project stages and databases

2.4 Understanding the data

The quantitative results presented in this report are based on data entered into USmart throughout the project by DCs. Much of this data was provided to DCs by participants and the surveyors / designers / installers contracted by DCs. The data has been audited to ensure all available information has been captured and accurately recorded.

When interpreting the data presented in this report, it is important to understand who the data was provided by, at what stage of the project, and for which participants. The three DCs took different approaches to the project stages, and these differences impact the comparability of some results. There are also a few instances where the results are subjective as the associated questions may have been interpreted differently by contractors.

These contextual circumstances are noted throughout the report and should be read alongside the quantitative results. Qualitative insights from the project contractors are also included to explain what is shown in the data, as well as any findings that are not evident from the data.

2.5 Other caveats

The following caveats apply to the data and findings provided in this report:

- Project context: All findings should be interpreted in the context of the design and structure of the project. Relevant contextual issues have been noted in the main body where required. For example:
  - DCs had target quotas on the mix of property types, demographics and heat pump types involved in the project – the quotas and the extent to which they are met are outlined in subsequent sections of this report. Each DC also worked in a specific geographic region of the UK.
  - Costs of installations were influenced by budgets each of the DCs hold for the installation of heat pumps and additional measures, which are based on the installation costs that DCs quoted in their project proposals. OVO set a budget cap of £15,000 per property and was more likely to not recommend a heat pump on cost grounds than E.ON or Warmworks, which did not apply a budget cap pre property. This is explained further in Section 7.
  - Barriers to heat pump installation contained in this report are those reported by the surveyor / designer / installer, and not participants. Participant barriers to heat pump installation are discussed in the Participant Recruitment report.
- Insights reflect industry experience and expertise: much of this report is based on data from the survey, design and installation stages of the project. The survey and design stages were carried out by surveyors and designers, and so the findings in this report are based on the skills, knowledge, expertise and experience of these contractors.
- Each DC had a different approach to the home survey and design process with differently skilled and experienced individuals making the suitability decision. As an

example the Warmworks decision was taken by a Warmworks employed PAS2035 trained retrofit coordinator, whereas the E.ON decision was taken by an assessor from a heat pump design/installation organisation. This means that the decisions made by one Delivery Contractor are not directly comparable to the decisions of another without accounting for the differences in approach.

3. Delivery contractor approaches

3.1 Introduction

One key aim of the project was to demonstrate that heat pumps can be installed in a wide variety of property types in the UK. Each DC was required to install a certain number of heat pumps in their trial area within the project timescales. Project quotas were set for the types of properties and households that were to be involved and the types of heat pumps installed. These quotas are given in Table 1 and Table 2 below.

Different approaches were taken by each of the DCs to achieve their installation targets. The approaches taken by each DC are described in this section of the report. In total, the DCs received expressions of interest from 8,807 households. Applicants were not recruited to the project if they were not within the DC trial area, if quotas for that customer type had already been met, or if an installation was unlikely to be possible within the project timescales or constraints. Customers who were recruited to the project went on to have a home survey done to assess whether a heat pump installation was recommended within the project constraints.

It is important to understand the triaging and survey processes when interpreting the results of the project. Properties 'triaged out' of the project or not recommended for a heat pump installation were not necessarily unsuitable for heat pumps, but were less attractive candidates for installation within this project. Suitability of the wider UK housing stock for heat pumps should therefore not be inferred based on this data.

Project quotas

Table 1: Target quotas for property types to be recruited in the project and final installed mix

Criteria	Group	Target quota	Final installed mix	Within permitted variance (±5%)
House Type	Detached	40%	41%	Yes
	Semi-detached / end terrace	40%	43%	Yes
	Mid terrace	15%	11%	Yes
	Flats	5%	6%	Yes
House Age	Pre-1919	10%	8%	Yes
	1919 to 1944	20%	14%	No
	1945 to 1964	20%	24%	Yes
	1965 to 1980	20%	22%	Yes
	1981 to 1990	10%	9%	Yes
	1991 to 2000	10%	10%	Yes
	2001+	10%	13%	Yes
Socio-economic status of the household reference point	AB. Higher and intermediate managerial, administrative or professional occupation	25%	25%	Yes
	C1. Supervisory, clerical and junior managerial, administrative or professional	30%	35%	Yes
	C2. Skilled manual workers	20%	17%	Yes
	DE. Semi and unskilled manual workers, state pensioners, casual or lowest grade workers, unemployed with state benefits only	25%	23%	Yes

Table 2: Target quotas for heat pump types to be installed in the project

Heat pump types	Short name	Target quota	Final installed mix	Within permitted variance
Air-to-water heat pump	ASHP	No specific target	41%	N/A
Ground-to-water heat pump	GSHP	Minimum 6% of homes	5%	Yes
Hybrid Heat Pump Systems	Hybrid	Between 20% – 60% of homes	21%	Yes
High temperature Air-to-water Heat Pump	HT ASHP	Minimum 6% of homes	33%	Yes

3.2 E.ON approach

Figure 2 shows the number of E.ON participants who progressed from the application stage through to installation. It illustrates how the number of participants involved at each stage decreased as:

- Customers opted out of the trial; or
- A heat pump installation was not recommended within the project constraints; or
- The application was cancelled by the DC because a programme target had already been met or the installation would not be possible within the project timescales.

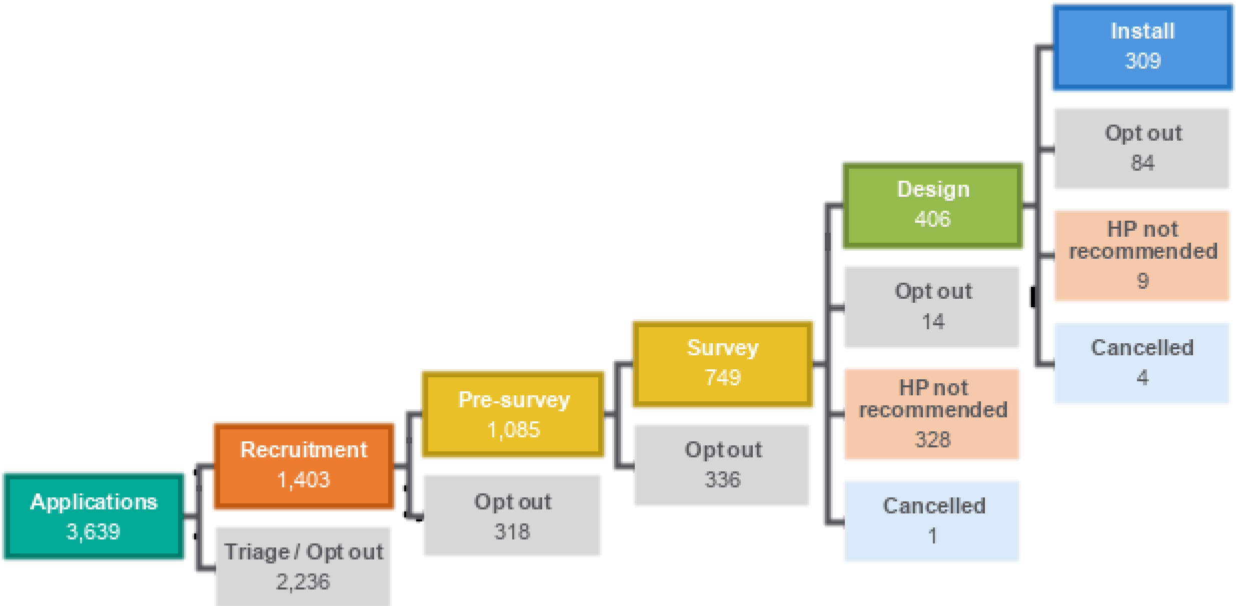


Figure 2 E.ON customer journey flow diagram

3.2.1 Recruitment and eligibility triage

After an expression of interest was received, E.ON conducted a pre-qualification call to gather basic information about the customer and their property. Customers were not recruited to the project if:

- They were outside the DC target area;
- They lacked broadband/wifi to support monitoring or would not accept the monitoring requirements;
- They were on pre-payment meters and could not change to credit meters;
- The quota had been met for that property, household or heat pump type;
- They changed their mind and cancelled the application;

- E.ON cancelled the application due to customer vulnerability (e.g. very elderly); or
- They were not contactable.

After two months of recruitment, E.ON introduced additional desktop assessments as part of the triage process using publicly available information such as aerial/street view imagery and EPCs. The desktop assessment criteria evolved over time as E.ON fed back learnings from the survey and design stages. Checks included whether:

- There was likely to be suitable external space for an outdoor heat pump unit;
- How close the outdoor unit would be to neighbouring properties;
- Heat demand was very high due to low thermal efficiency or the property being particularly large (e.g. 5+ bedrooms).

Most properties (72%) passed the desktop assessment stage. The most common cancellation reasons at the desktop stage were lack of outdoor space (43% of those who were cancelled), quota met (23%), or heat demand too high (8%).

A few months later, E.ON also began doing ‘Energy Expert’ calls with customers before recruiting them to the project. These calls were to help customers understand the process of installing a heat pump and the potential disruption involved. E.ON also asked about the following to identify any potential barriers to installing a heat pump within the project constraints:

- Property size;
- Heat distribution system (pipework, radiators and underfloor heating);
- Insulation requirements;
- Possible cylinder locations; and
- Preferred technology.

Customers were not recruited to the project if they cancelled proactively at this stage or if E.ON determined that the candidate was unlikely to be suitable for the project. Most customers (71%) proceeded after the Energy Expert pre-survey call. For those that did not progress, the most common reason was the customer cancelled because they felt the installation would be too disruptive (46%).

3.2.2 Home survey and technical design

Customers that passed the eligibility triage were recruited to the project. Some of the customers recruited to the project did not proceed to the home survey stage – often this was because they simply could not be contacted to arrange the survey.

For the customers who did proceed, a home survey was then conducted on site by a heat pump designer. Typically, the designer first discussed the implications of installing a heat pump with the customer (as indicated by the Pre-survey stage in Figure 2 above). Based on this discussion, some customers decided that they did not want to take part further in the trial – the reasons they gave are explored in the Participant Recruitment report. In these cases, the designer did not continue with the home survey and a heat pump installation recommendation was not made.

If customers were happy to proceed after the discussion, the designer then assessed whether to recommend a heat pump installation within the project constraints. If a property was considered suitable for recommending a heat pump within the project, the designer then conducted a full technical survey and MCS design calculations. In a few cases, it was only decided to not recommend a heat pump *after* doing the technical design. The reasons provided for not recommending a heat pump installation are discussed in Section 8.

If a viable design was possible within the constraints of the project, and the customer was still willing to proceed with the installation, E.ON then subcontracted an installer to carry out the installation. Before the installation, the subcontracted installer conducted a pre-installation visit to ratify the design. Any changes to the data resulting from the pre-installation visit were recorded in USmart.

3.3 OVO approach

Figure 3 shows the number of OVO participants that progressed from the application stage through to installation. It illustrates how the number of participants involved at each stage decreased as:

- Customers opted out of the trial; or
- A heat pump installation was not recommended within the project constraints; or
- The application was cancelled by the DC because a programme target had already been met or the installation would not be possible within the project timescales.

The stages in OVO's approach were slightly different to E.ON's and these are described below.

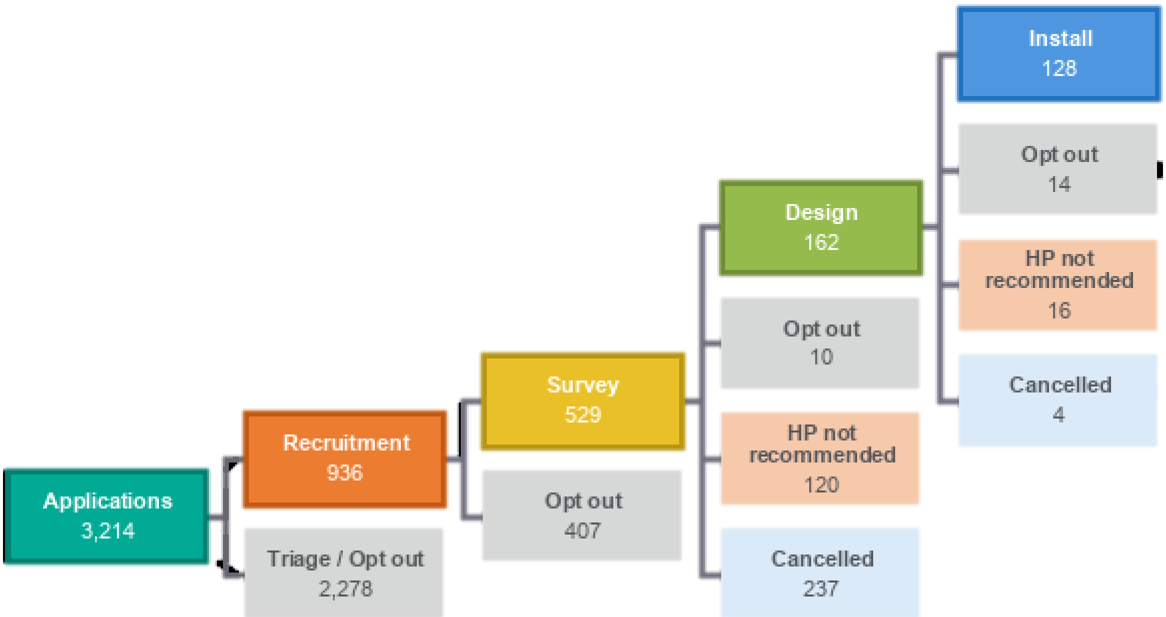


Figure 3 OVO customer journey flow diagram

3.3.1 Recruitment and eligibility triage

When customers registered an interest in the project, OVO asked them to fill in an initial web registration form to check their eligibility for the project. Initial eligibility checks included:

- If properties were in the trial area;
- If customers owned the property and it was their primary home;
- If the property had any external space;
- If the property was listed; and
- If the customer had wifi for monitoring the heat pump.

By far, the most common reason customers did not the pass initial eligibility screening was because their property was outside the OVO trial area (97%).

Customers who passed the initial eligibility screening were then sent a more detailed questionnaire about their property and heating system, which also asked them to provide photos and floor plans if possible. The questions evolved as the project progressed and OVO learned of more potential issues to check for at the recruitment stage. Customers that completed the questionnaire were recruited to the project

3.3.2 Home survey and technical design

After participants were recruited to the project by OVO, they were passed to RetrofitWorks for the survey stage. RetrofitWorks cancelled a number of applications at this stage because a project quota for the household or property type had already been met.

For customers who were eligible, RetrofitWorks checked the information provided by customers in the detailed questionnaire. Heat pumps were not recommended at this stage for a variety of reasons, such as lack of space for a heat pump, quality of window glazing, or because the cost was likely to be too high for the project. These reasons are detailed in Section 8.

If properties met the project quota and passed the RetrofitWorks checks, a Whole House Plan was then produced by a Retrofit Coordinator estimating the property's heating requirements and outlining the possible improvements. The majority of surveys for the Whole House Plans were done remotely due to Covid-19 restrictions.

If customers chose to proceed after receiving the Whole House Plan, a technical survey and MCS design calculations were then done on-site by a heat pump installer. In a few cases a heat pump was not recommended at this stage because, for example, it was found the property had microbore piping or the cost of radiator upgrades would be too high for the project.

3.4 Warmworks

Figure 4 shows the number of Warmworks participants who progressed from the application stage through to installation. It illustrates how the number of participants involved at each stage decreased as:

- Customers opted out of the trial; or
- A heat pump installation was not recommended within the project constraints; or
- The application was cancelled by the DC because a programme target had already been met or the installation would not be possible within the project timescales.

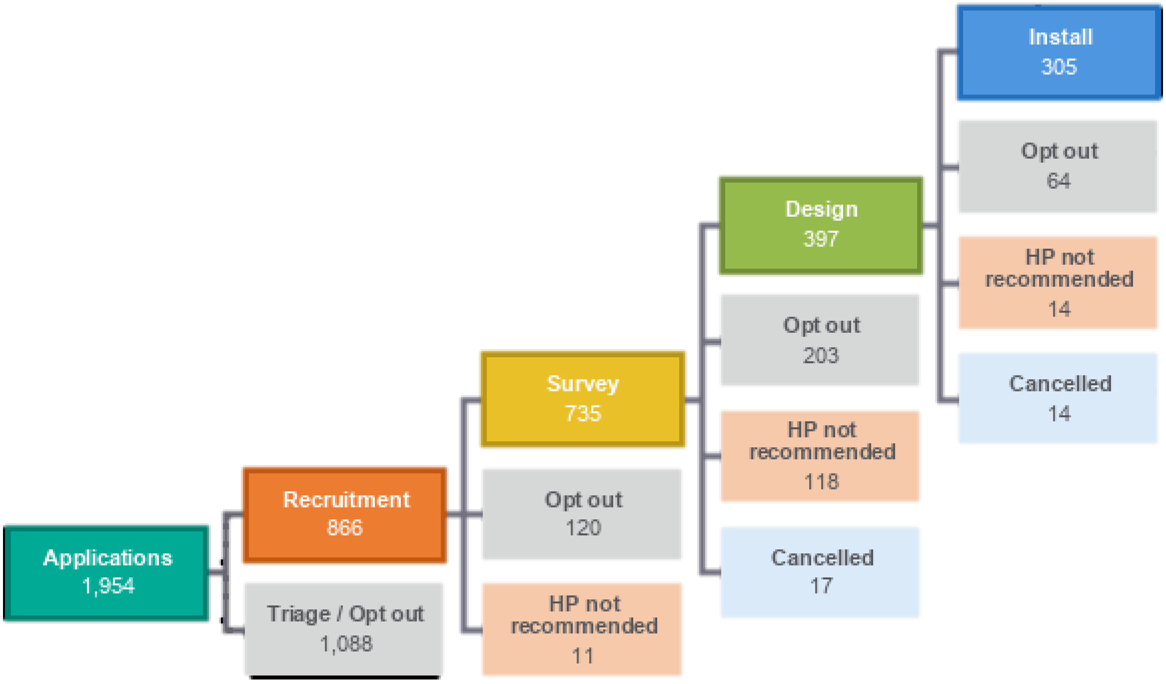


Figure 4 Warmworks customer journey flow diagram

3.4.1 Recruitment and eligibility triage

Recruitment was carried out by Changeworks. Interested customers filled out an initial web application questionnaire and were then called by Changeworks. During the call, Changeworks explained the typical process and potential disruption associated with installing a heat pump, which resulted in a proportion of candidates deciding to withdraw at that stage. In addition, Changeworks used publicly available information like EPCs and online 'street views' to assess whether the property was likely to be a suitable candidate for the project. Factors considered in the triage process included:

- Meeting the project quotas;
- Whether the property was in the trial area;
- Participant motivation and willingness to tolerate disruption;
- Property construction type and insulation levels;
- Likely heat demand; and
- Available space for a heat pump and/or water cylinder.

The most common reason properties were excluded was because they were considered unsuitable for a heat pump within the project constraints. This was typically due to a combination of construction type, insulation levels and likely heat demand.

Properties that were expected to be suitable for the project were recruited and progressed to Warmworks for the survey stage.

3.4.2 Home survey and technical design

After participants were recruited by Changeworks, a Warmworks PAS2035 trained Retrofit Coordinator conducted a home survey to determine whether a heat pump was recommended within the context of the project. Reasons for not recommending a heat pump installation are explored in Section 8. In a few cases, Warmworks made a recommendation against installing a heat pump before conducting the home survey – in several instances this was because customers had a building extension planned and the property heat demand could not be estimated until the extension design was finalised.

At the end of the home survey, the Retrofit Coordinator discussed the implications of installing a heat pump with the customer and asked whether they wanted to proceed. A number of customers decided against a heat pump installation at this stage – reasons for this are explored in the Participant Recruitment report.

If the customer was willing to proceed, a technical survey and MCS design calculations were then carried out by a subcontracted heat pump installer. In a few cases, it was only decided after doing the technical design to not recommend a heat pump.

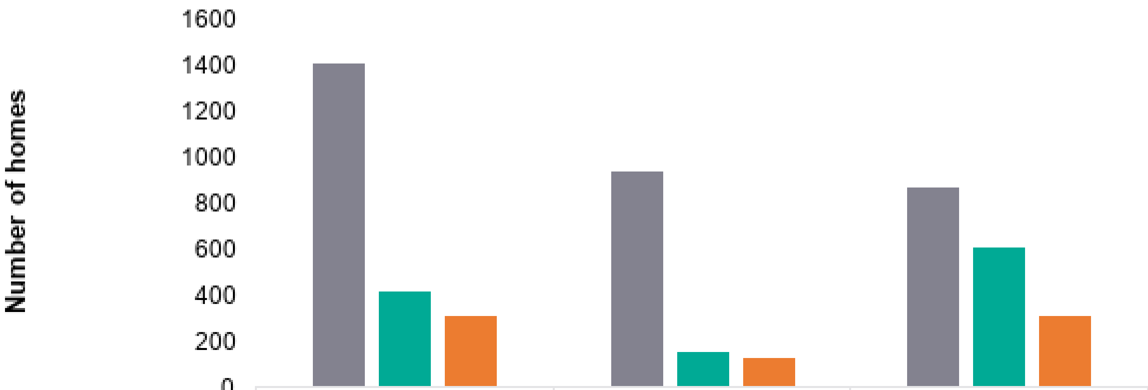
4. Properties involved in the trial

4.1. Introduction

This section provides an overview of the properties involved in the EoH demonstration project. The charts in this section show the number of properties involved at the recruitment stage, those that had a heat pump recommended, and those that had a heat pump installed. The data presented in this section should be interpreted in the context of this project. Each DC had target quotas to install a range of heat pump types in a range of properties, as shown in Section 0.

4.2. Overview of properties involved by delivery contractor

Each of the three DCs had an initial target to install heat pumps in 250 homes. Individual DC targets were amended when it became apparent that OVO would not be able to meet the original target within the project timeframes. Figure 5 shows that of the 742 heat pumps installed by the end of the project, E.ON accounted for 309, OVO accounted for 128 and Warmworks accounted for 305. To achieve these installations, E.ON recruited 1,403 participants to the project, OVO recruited 936 and Warmworks recruited 866. It should be noted that the reduction in OVO's target part way through the project led OVO to cancel some of the applications it already had progressed in order to meet its original target.



	E.ON	OVO	Warmworks
Recruited	1403	936	866
HP Recommended	412	153	605
HP Installed	309	128	305

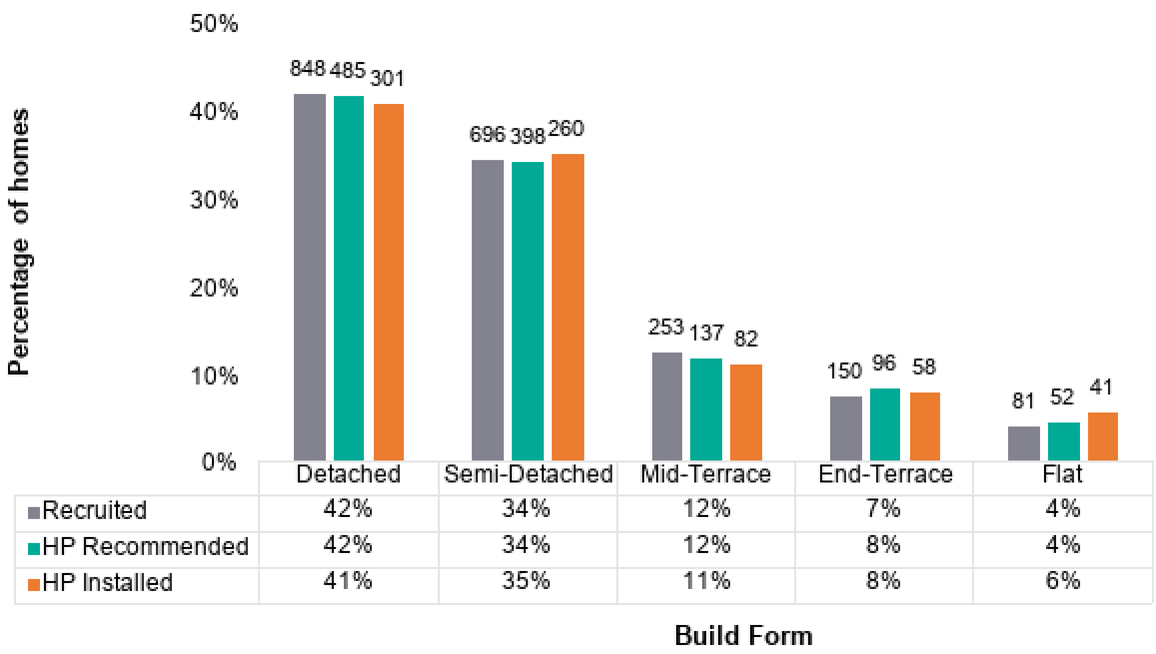
Delivery Contractor (DC)

Figure 5 Homes involved in trial, broken down by DC

4.3. Properties involved by property type

4.3.1. Build form

The mix of property types involved in the project is shown in Figure 6. The majority of homes involved in the trial were detached or semi-detached houses (76%) and terrace properties (19%). Only 6% of homes that had a heat pump installed were flats. The mix of properties involved was driven by the target quotas set for the project. Compared to national averages[5,6], this trial recruited a significantly higher proportion of detached and semi-detached properties and a much lower proportion of flats.



	Detached	Semi-Detached	Mid-Terrace	End-Terrace	Flat
Recruited	42%	34%	12%	7%	4%
HP Recommended	42%	34%	12%	8%	4%
HP Installed	41%	35%	11%	8%	6%

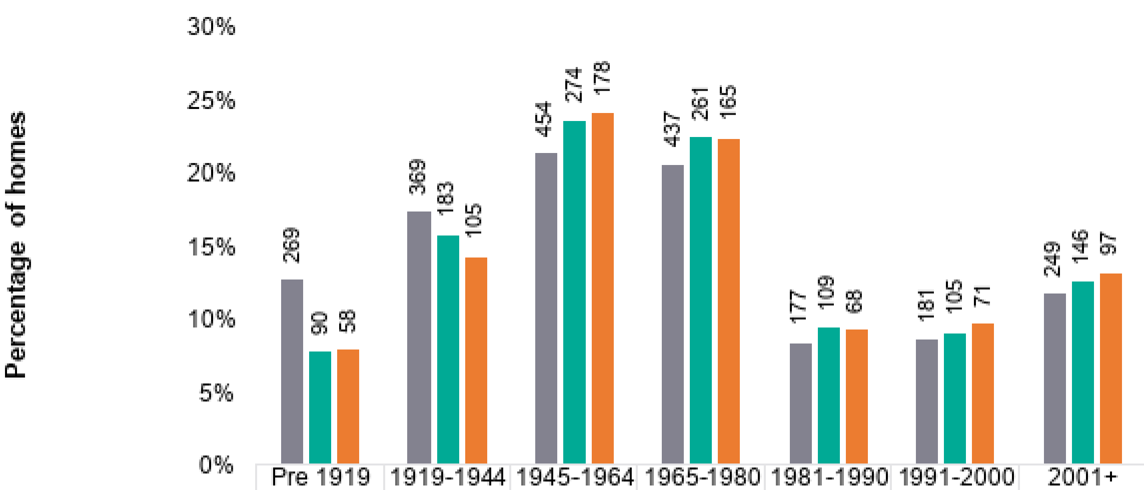
Figure 6 Homes involved in trial, broken down by build form; absolute numbers at each stage shown above bars; excludes properties for which data was not recorded

[5] DLUHC and MHCLG, English Housing Survey Data on stock profile, 2021. In England, 26% of properties are detached houses (including bungalows), 25% are semi-detached, 28% are terraced properties and 21% are flats.

[6] Scottish Government, Scottish house condition survey: 2019 key findings, 2020. In Scotland, 23% of properties are detached houses, 20% are semi-detached, 21% are terrace properties and 37% are flats (including tenement buildings).

4.3.2. Property age

The project successfully involved properties from a range of age bands, as shown in Figure 7. Pre-1919 homes were more challenging to progress as the heat load of these properties was more likely to be too high for the heat pump capacities available, or the measures needed to make the property suitable would be too expensive within the context of the project. These were closely aligned with national averages for England and Scotland[7,8], though the proportion of pre-1919 homes recruited (13%) was slightly below the national proportion (20%).



	Pre 1919	1919-1944	1945-1964	1965-1980	1981-1990	1991-2000	2001+
Recruited	13%	17%	21%	20%	8%	8%	12%
HP Recommended	8%	16%	23%	22%	9%	9%	13%
HP Installed	8%	14%	24%	22%	9%	10%	13%

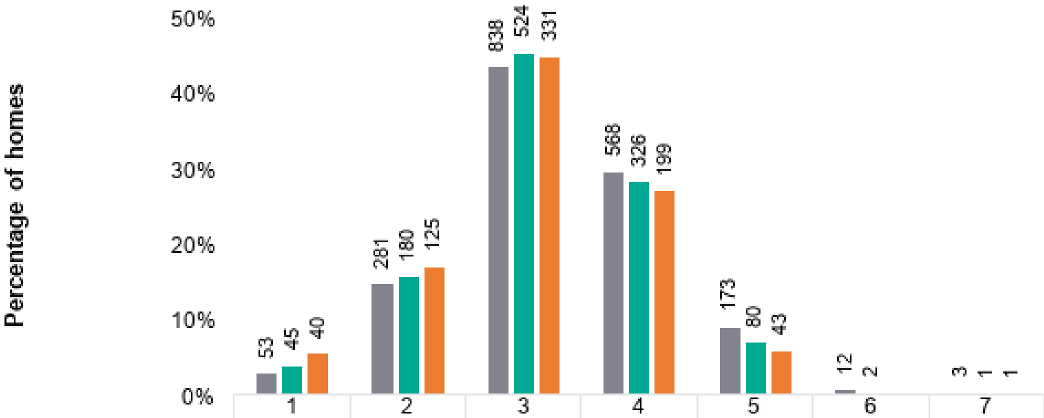
Figure 7 Homes involved in trial, broken down by year of construction (age bands are approximate for E.ON participants as different age bands were used in their data capture); absolute numbers at each stage shown above bars; excludes properties for which data was not recorded

[7] DLUHC and MHCLG, English Housing Survey Data on stock profile, 2021. In England, 20% of all properties were built before 1919, 15% were built between 1919-1944, 18% were built between 1945-1964, 20% were built between 1965-1980, 8% were built between 1981-1990, and 19% were built after 1990.

[8] Scottish Government, Scottish house condition survey:2019 key findings, 2020. In Scotland, 19% of all occupied dwellings were built before 1919, 11% were built between 1919-1944, 21% were built between 1945-1964, 22% were built between 1965-1982, and 27% were built after 1982.

4.3.3. Property size

Almost three-quarters of properties (72%) that had heat pumps installed have 3 or 4 bedrooms (Figure 8). The majority (62%) of homes have a floor area between 65 and 125 m2 (Figure 9). Very large properties were more often difficult to progress because their heat demand was more likely to be too high for the products and measures available within the context of this project. The trial recruited a higher proportion of 4 bedroom homes and a lower proportion of 1 and 2 bedroom homes compared to national averages[9,10]. The average floor area of homes recruited to the project (around 115 m^2) was also higher than national averages[11,12].



	1	2	3	4	5	6	7
Recruited	3%	15%	43%	29%	9%	1%	0%
HP Recommended	4%	16%	45%	28%	7%	0%	0%
HP Installed	5%	17%	45%	27%	6%	0%	0%

Number of bedrooms

Figure 8 Homes involved in trial, broken down by number of bedrooms; absolute numbers at each stage shown above bars; excludes properties for which data was not recorded

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[9] Office for National Statistics. Number of rooms by number of bedrooms – Merged local authorities, 2018. In England, 12% of homes have 1 bedroom, 28% have 2 bedrooms, 41% have 3 bedrooms, 14% have 4 bedrooms and 5% have 5 or more bedrooms.

[10] Scottish Government, Scottish House Condition Survey: 2017-2019 Local Authority Tables. In Scotland, 50% of homes have 1 or 2 bedrooms and 50% have 3 or more bedrooms.

[11] English Housing Survey data on stock profile, 2021. In England, 9% of all properties had a usable floor area below 50 m^2, 22% had a floor area between 50-69 m^2, 29% had a floor area between 70-89 m^2, 15% had a floor area between 90-109 m^2, and 25% had a floor area above 110 m^2.

[12] Scottish Government. Scottish house condition survey: 2019 key findings, 2020. In Scotland, old dwellings (pre-1919) have an average floor area of 107 m^2. Properties built between 1919-1982 have an average floor area of 88 m^2. New dwellings (built from 1982-onward) have an average floor area of 102 m^2.

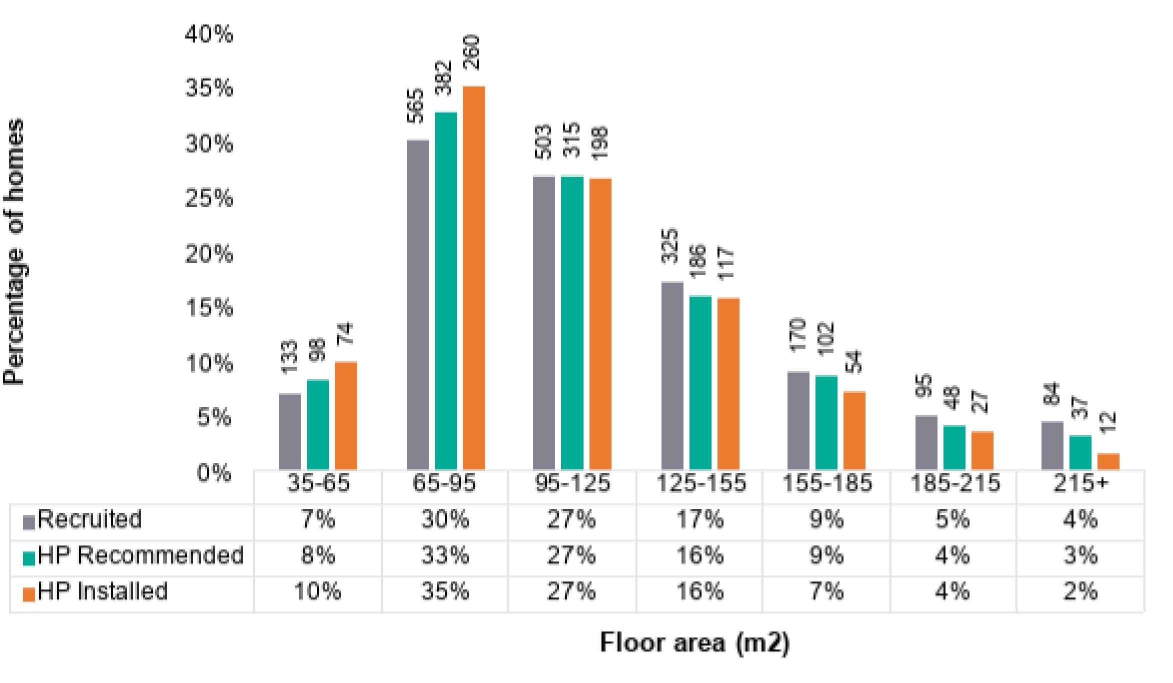


Figure 9 Homes involved in trial, broken down by floor area; absolute numbers at each stage shown above bars; excludes properties for which data was not recorded

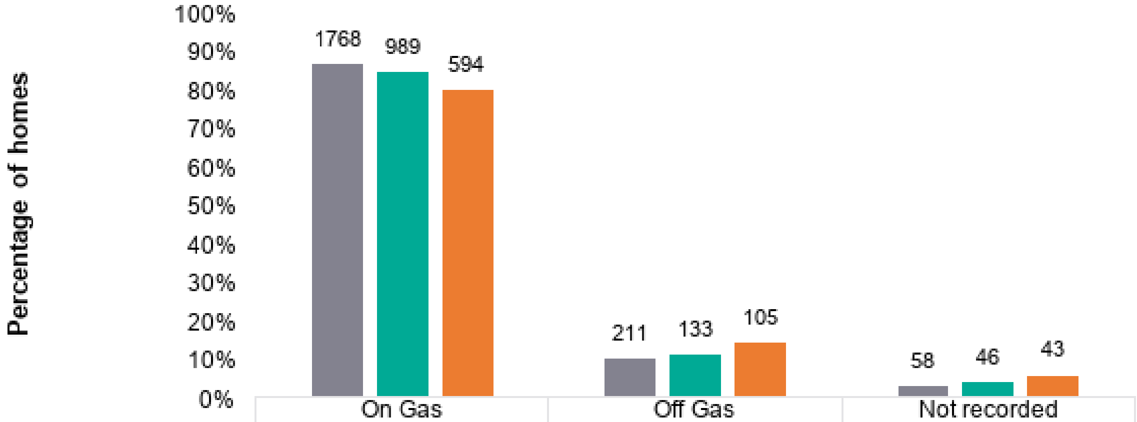
4.3.4. Heating systems and on/off gas

The project focused on fitting heat pumps into properties on the mains gas network. This focus is reflected in Figure 10 which shows that at least 80% of heat pump installations were in homes that were 'on-gas'.

Figure 11 provides a breakdown of the primary heating fuels in homes when they were recruited. Most on-gas properties had a gas boiler. Of those off-gas, most homes had an oil or LPG boiler, or electric heating system, the majority of which were direct electric or storage heaters. These proportions were approximately in line with national averages[13,14].

[13] Office for National Statistics, Energy efficiency of housing in England and Wales: 2021. In England, 79% of dwellings used mains gas to fuel central heating, 12% used electricity, and less than 4% used oil. Combined, other heating fuels were used in less than 5% of all dwellings.

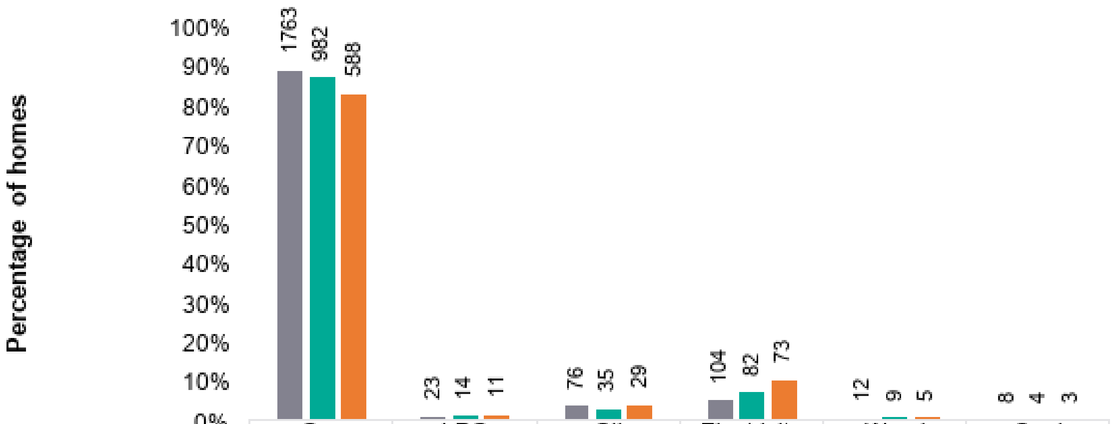
[14] Scottish Government, Scottish house conditions survey: 2019 key findings, 2020. In Scotland, 81% of households used mains gas to fuel central heating, 11% used electricity and 5% used oil. Biomass, solid mineral fuel, LPG and communal heating are each used in 1% of households.



	On Gas	Off Gas	Not recorded
Recruited	87%	10%	3%
HP Recommended	85%	11%	4%
HP Installed	80%	14%	6%

Gas grid connection

Figure 10 Homes involved in trial, broken down by whether the homes have a gas grid connection; absolute numbers at each stage shown above bars



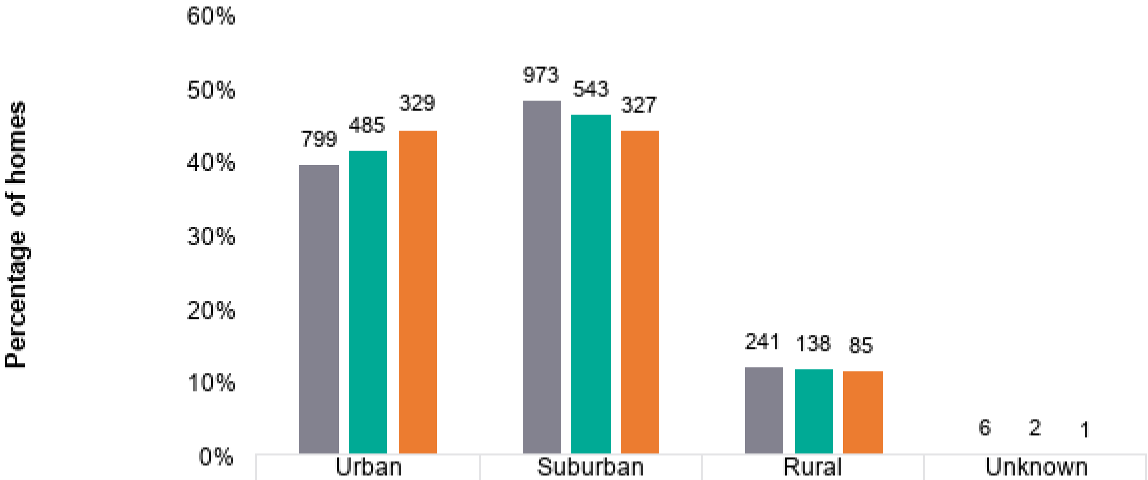
	Gas	LPG	Oil	Electricity	Wood	Coal
Recruited	89%	1%	4%	5%	1%	0%
HP Recommended	87%	1%	3%	7%	1%	0%
HP Installed	83%	2%	4%	10%	1%	0%

Primary heating fuel

Figure 11 Homes involved in trial, broken down by primary heating fuel when recruited; absolute numbers at each stage shown above bars

4.3.5. Property environment

There was an even split in heat pump installations between properties in urban (44%) and suburban (44%) environments as shown in Figure 12. Only about 11% of homes were located in a rural environment because fewer rural properties are connected to the gas network. About 17% of the population in England and Scotland live in rural areas15,16.



	Urban	Suburban	Rural	Unknown
Recruited	40%	48%	12%	0%
HP Recommended	42%	46%	12%	0%
HP Installed	44%	44%	11%	0%

Property environment

Figure 12 Homes involved in trial, broken down by location of property; absolute numbers at each stage shown above bars

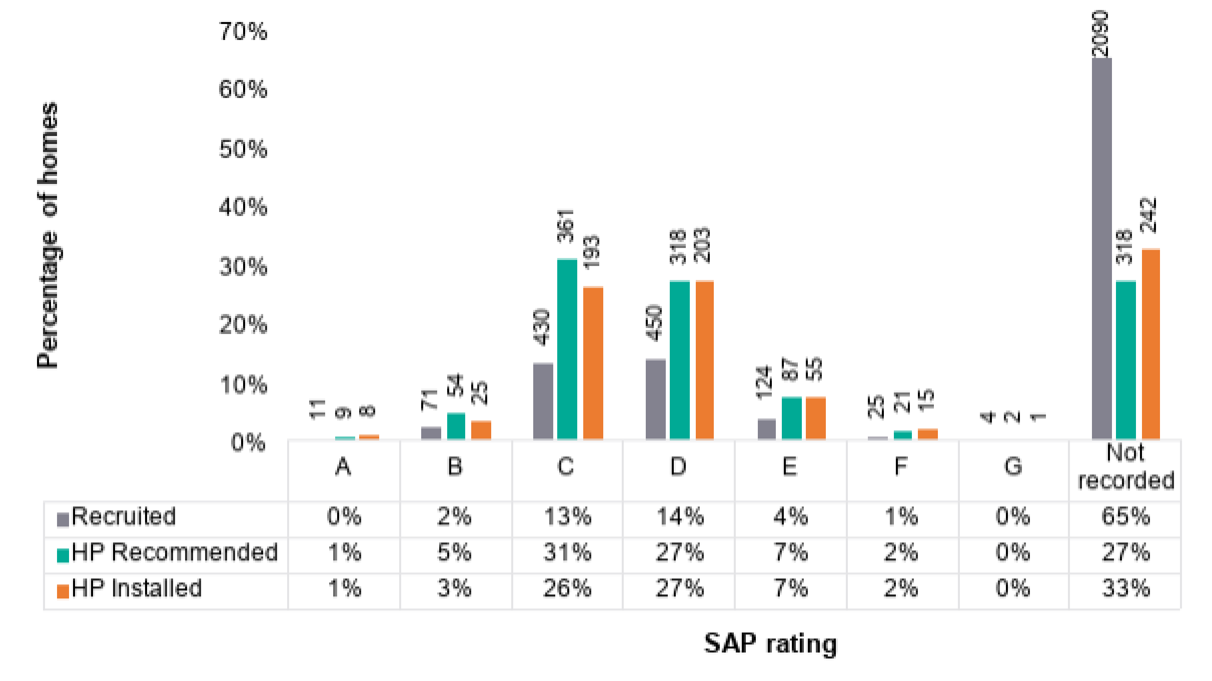
4.3.6. Energy efficiency rating

Figure 13 shows that at least 53% of homes involved in the trial had an energy efficiency rating of C or D before the heat pump installation. SAP ratings17 were not recorded for a significant number of properties involved in the trial, including a third that had a heat pump installed.

[15] Department for Environment, Food & Rural Affairs, Rural population and migration: 2021

[16] Scottish Government, Rural Scotland Key Facts: 2021

[17] A SAP rating of A is a high efficiency home; G is a home with poor energy efficiency..



	A	B	C	D	E	F	G	Not recorded
Recruited	0%	2%	13%	14%	4%	1%	0%	65%
HP Recommended	1%	5%	31%	27%	7%	2%	0%	27%
HP Installed	1%	3%	26%	27%	7%	2%	0%	33%

Figure 13 Homes involved in trial, broken down by Standard Assessment procedure (SAP) energy efficiency rating.; absolute numbers at each stage shown above bars

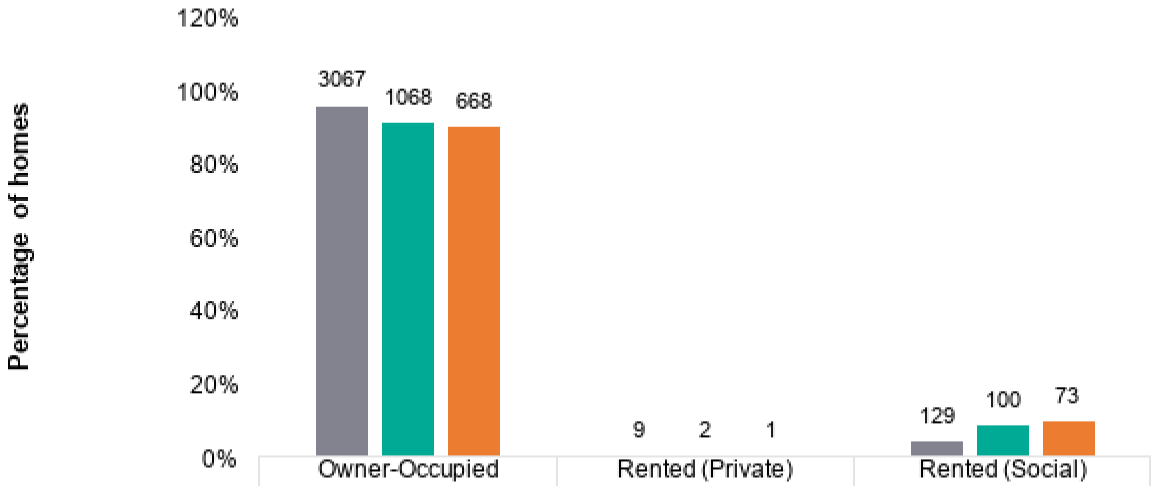
4.4. Properties involved by household attributes

This section details the attributes of households involved through each stage of the project from recruitment to installation. More information about the participants recruited to the project is contained in the Participant Recruitment report.

Figure 14 shows that the majority of participants involved the project are owner-occupiers (96% of those recruited and 90% of those with a heat pump installed through the project). This is a significantly higher proportion than the national average18,19. The remaining 10% of heat pump installations are for those living in social housing. Only one heat pump was installed for a private rented house. Again, this is reflective of the project design, which sought to install the majority of heat pumps in private homes.

[18] English Housing Survey data on tenure trends and cross tenure analysis, FA1221 (S108): household type by tenure, 2019-2020. In England, 64% of all households are owner occupiers, 17% are social renters and 19% are private renters.

[19] Scottish Government, Housing statistics: Stock by tenure, 2018. In Scotland, 59% of all dwellings are owner-occupied, 14% are privately rented and 23% are social rented dwellings.



	Owner-Occupied	Rented (Private)	Rented (Social)
Recruited	96%	0%	4%
HP Recommended	91%	0%	9%
HP Installed	90%	0%	10%

Tenure

Figure 14 Homes involved in trial, broken down by tenure type; absolute numbers at each stage shown above bars

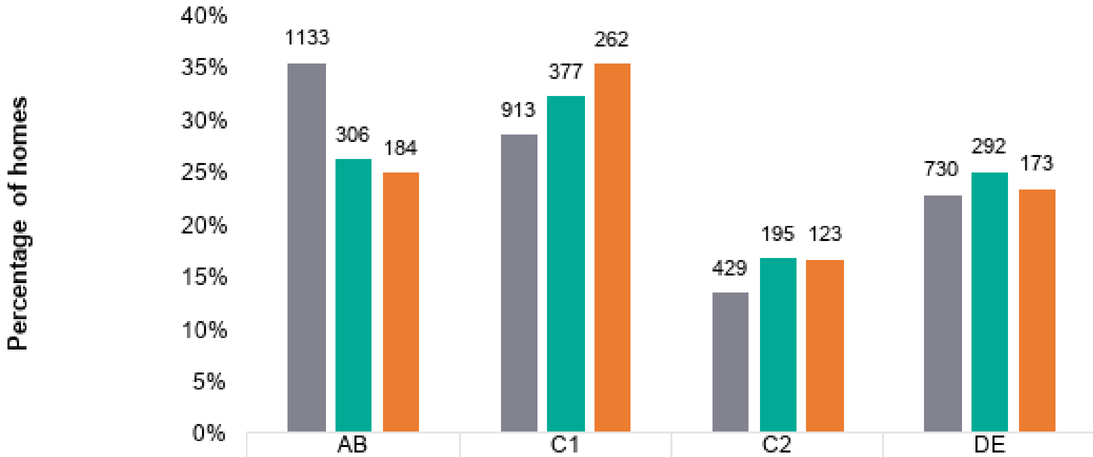
Figure 15 shows that participants from a range of socio-economic groups were recruited to the project, as per the project quotas. Compared to national averages, the proportion of AB participants recruited to the project was higher and the proportion of C2 participants was lower 20,21.

A large proportion (at least 35%) of households with a heat pump installed through the project have a household income over £50,000, as illustrated in Figure 16. Participant incomes were therefore higher than the national average for the UK, where only about 29% of households earn over £50,000 per year before tax22.

[20] Office for National Statistics, Approximated Social Grade, 2013. In England, 22% of the household reference persons aged 16 to 64 fall into social grade AB, 31% fall into social grade C1, 21% fall into social grade C2, and 26% fall into social grade DE.

[21] Scotland's Census, Scottish Council Area 2011 by Social Grade (approximated) by Term-time Address (Indicator), Age, Residence Type and Household Reference Person, 2013. In Scotland, 18% of the household reference persons aged 16 to 64 fall into social grade AB, 32% fall into social grade C1, 22% fall into social grade C2, and 28% fall into social grade DE.

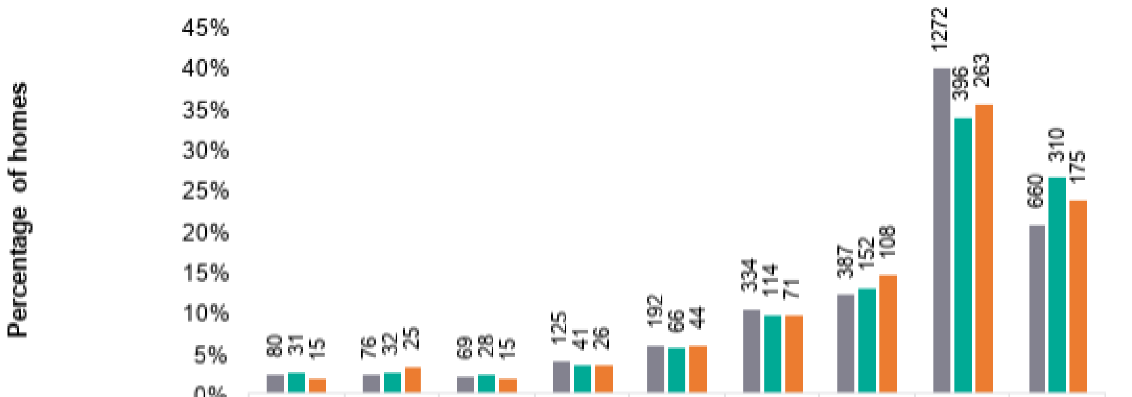
[22] Ethnicity facts and figures, Household income, 2021



	AB	C1	C2	DE
Recruited	35%	28%	13%	23%
HP Recommended	26%	32%	17%	25%
HP Installed	25%	35%	17%	23%

Social group

Figure 15 Homes involved in the trial, broken down by socio-economic group; absolute numbers at each stage shown above bars

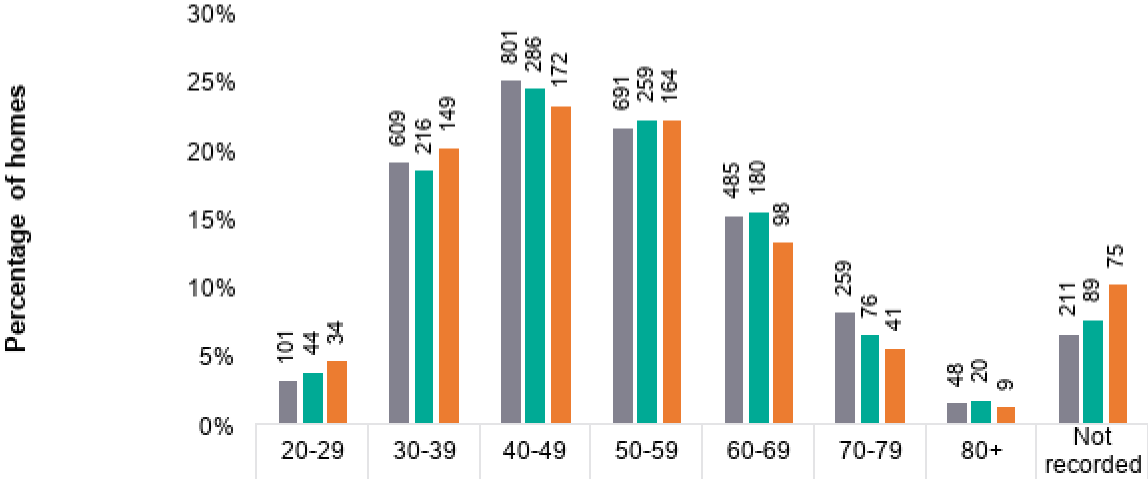


	0 - 12,500	12,501 - 16,200	16,201 - 20,000	20,001 - 25,000	25,001 - 30,000	30,001 - 40,000	40,001 - 50,000	50,001+	Prefer not to say
Recruited	3%	2%	2%	4%	6%	10%	12%	40%	21%
HP Recommended	3%	3%	2%	4%	6%	10%	13%	34%	26%
HP Installed	2%	3%	2%	4%	6%	10%	15%	35%	24%

Household income (£ annual)

Figure 16 Homes involved in trial, broken down by reported household income; absolute numbers at each stage shown above bars

Figure 17 shows the most common age range for the main participant was between 30–60 years old. Participants were older on average compared to national averages[23],[24].



	20-29	30-39	40-49	50-59	60-69	70-79	80+	Not recorded
Recruited	3%	19%	25%	22%	15%	8%	1%	7%
HP Recommended	4%	18%	24%	22%	15%	6%	2%	8%
HP Installed	5%	20%	23%	22%	13%	6%	1%	10%

Figure 17 Homes involved in trial, broken down by age of main participant; absolute numbers at each stage shown above bars

[23] Office for National Statistics, Population estimates by marital status and living arrangements, England, 2021. In England, in the population over 16 years of age, 13% were 16-24 years old, 32% were 25-44, 32% were 45-64, and 23% were 65+.

[24] Scotland's Census, Scottish Council Area 2011 by Age by Term-time Address (Indicator), 2013. In Scotland, in the population over 18 years of age, 12% were 18-24 years old, 33% were between 25-44%, 34% were between 45-64, and 21% were 65 or older.

5. Types of heat pumps installed

5.1. Introduction

The project required a range of different heat pump types to be installed. The target quotas and installation figures achieved are given in Table 2. The minimum requirement for high temperature heat pumps was far exceeded (33% of installs versus a minimum target of 6% of homes). This was mainly because of how high temperature heat pumps are defined. Heat pumps are defined as “high temperature” if they are capable of heating to over 65 degrees Celsius, whether or not this functionality is used in practice. Some high temperature units installed in this project were chosen because the higher temperatures were necessary to meet the heating demands, but in many cases the high temperature heat pumps installed were configured to operate as low temperature heat pumps. These products were chosen for their efficient performance rather than their high temperature functionality. The ground source heat pump target was hardest to achieve (5% of installs versus a minimum target of 6%).This was because only about 10% of properties had suitable ground space, and some of these participants were not willing to have a ground array installed.

5.2. Size of heat pumps installed

The average (mean) size of heat pump installed in the project was 7.7kW. Figure 18 shows the average size (mean, median and mode) for each type of heat pump, and Figure 19 shows the ranges of heat pump size installed. The ASHPs installed were on average the largest, with the most common size (mode) being 8.5 kW (27%), although the sizes varied widely from 5 kW to 16 kW. High temperature ASHPs were next largest on average with the most common size being 7 kW (40%) and most others were either 5 kW (21%) or 12 kW (26%). 74% of GSHPs were 3kW – these were those installed as part of a shared loop GSHP system. Most (87%) hybrid heat pumps were 4 kW.

As highlighted previously in the report, the costs of installations – and therefore the size of heat pumps that could be installed in the project were influenced by budgets each of the DCs held. These were based on the installation costs that DCs quoted in their project proposals for the installation of heat pumps and additional measures. OVO set a budget cap of £15,000 per property and was more likely to not recommend a heat pump on cost grounds than E.ON or Warmworks, which did not apply a budget cap pre property. This is explained further in Section 7.

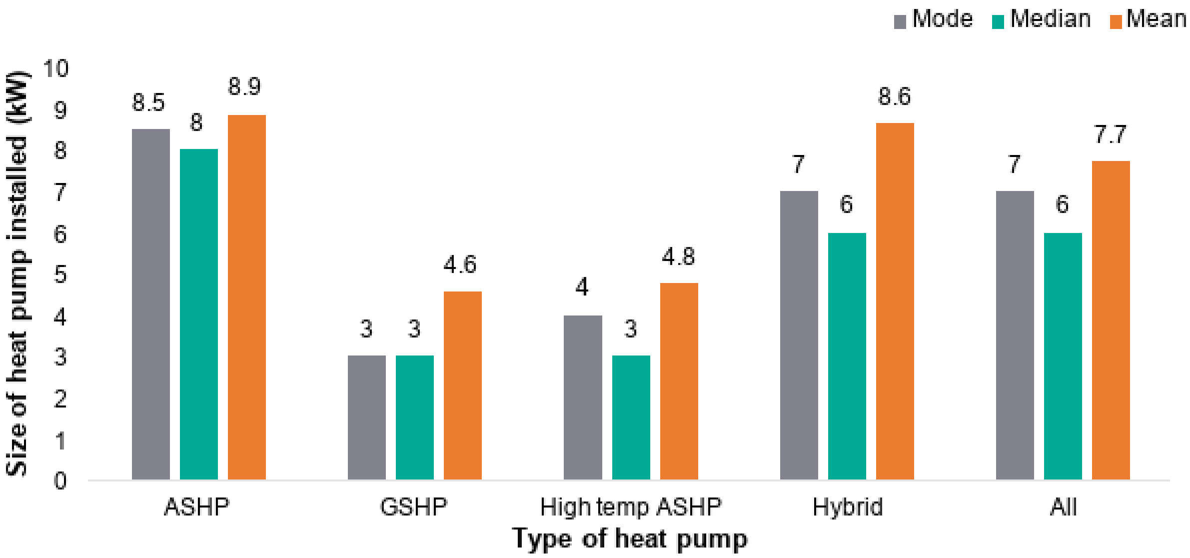


Figure 18 Average size of heat pump by heat pump type

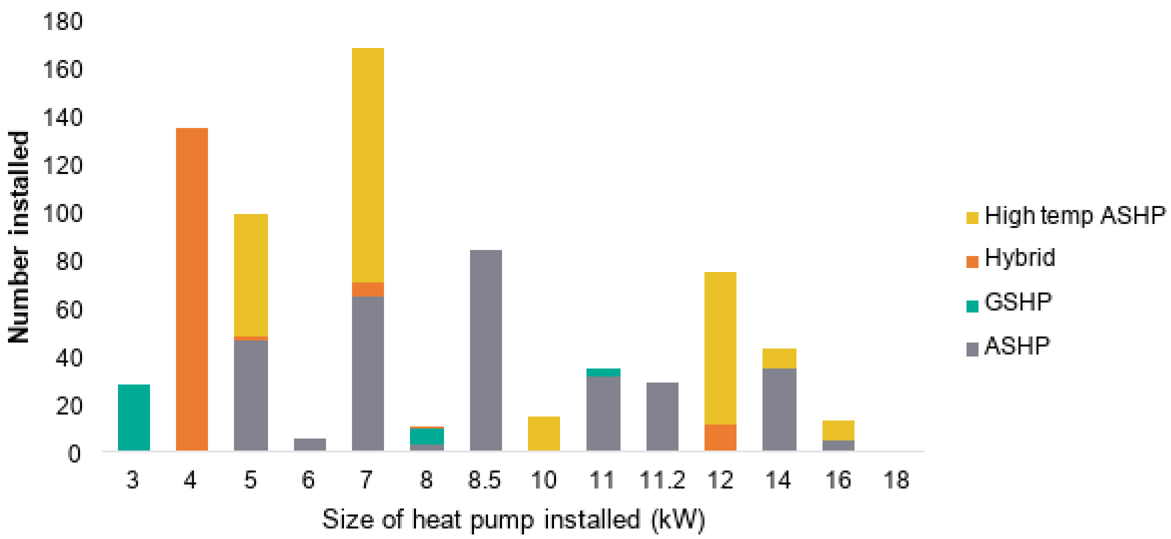
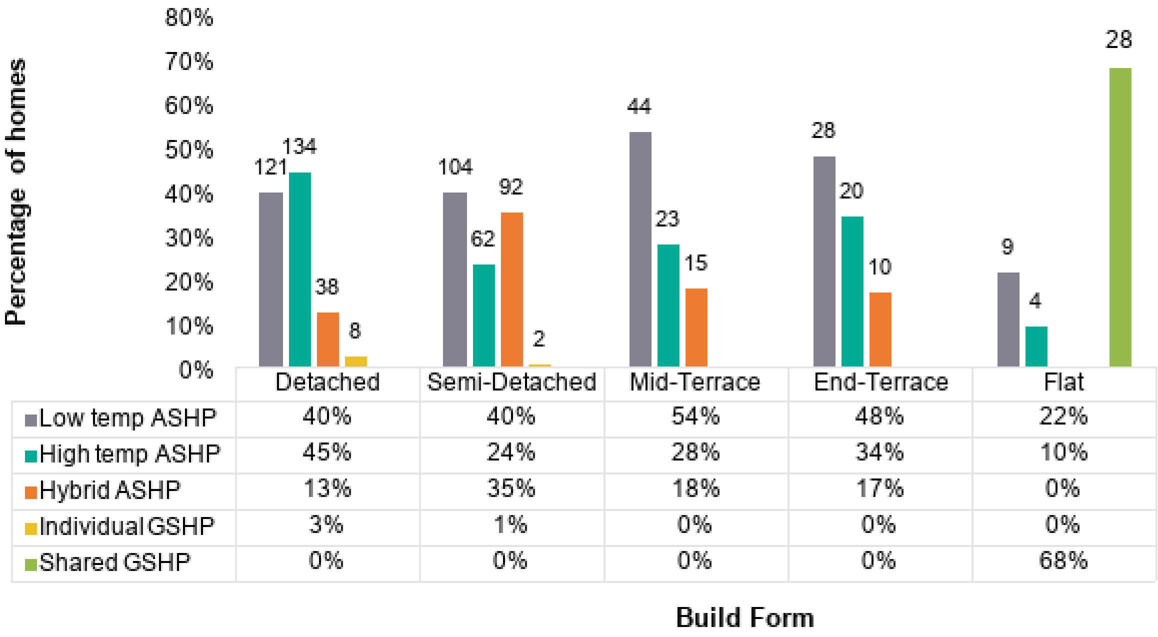


Figure 19: Size of heat pumps installed in the project (kW)

5.3. Heat pump types installed by property type

Figure 20 shows the type of heat pump installed by build form. Hybrid heat pumps were more commonly installed in semi-detached properties, where there was less likely to be space for a hot water tank than in detached properties. High temperature air source heat pumps (high temp ASHP) were installed mostly in detached properties, where higher space heating and hot water requirements made high temperature units better suited to meeting the heat demands. Only 38 homes had ground source heat pumps installed, the majority of which were flats connected to shared ground arrays or boreholes. The individual homes that had ground source heat pumps installed were either detached or semi-detached.

Other property characteristics, such as property age and size, had no significant impact on the types of heat pumps installed.



	Detached	Semi-Detached	Mid-Terrace	End-Terrace	Flat
Low temp ASHP	40%	40%	54%	48%	22%
High temp ASHP	45%	24%	28%	34%	10%
Hybrid ASHP	13%	35%	18%	17%	0%
Individual GSHP	3%	1%	0%	0%	0%
Shared GSHP	0%	0%	0%	0%	68%

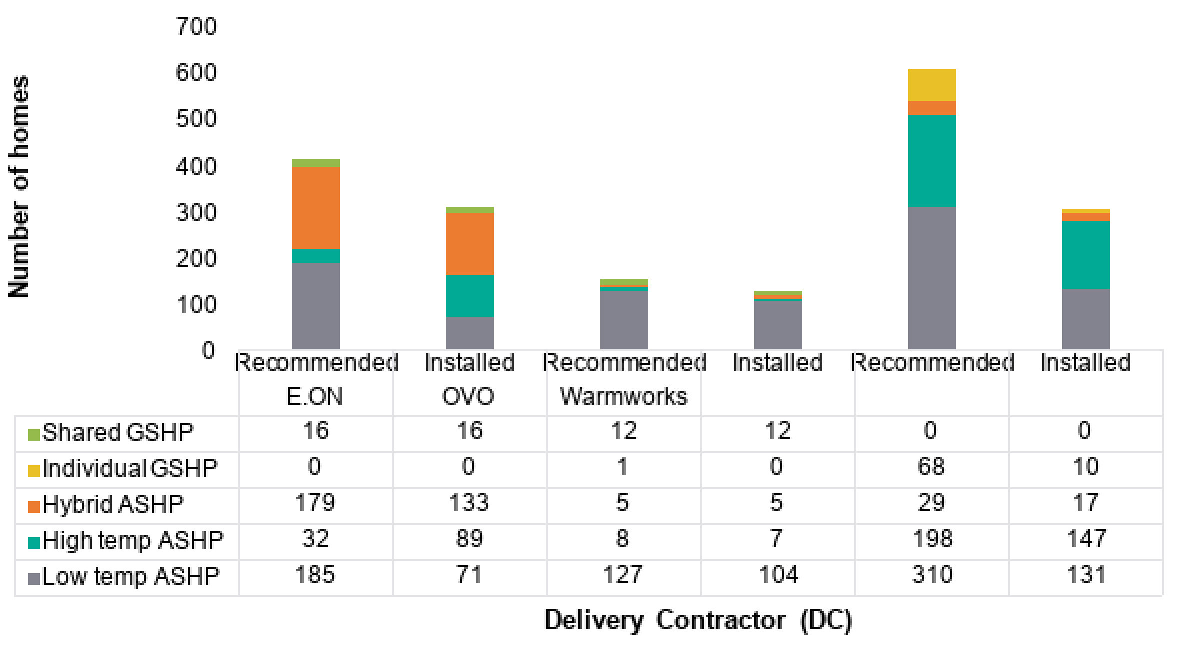
Figure 20 Type of heat pump installed by property type; absolute numbers shown above bars

5.4. Heat pump types in installed by delivery contractor

The types of heat pumps recommended and installed by each DC are shown in Figure 21. E.ON installed more high temperature heat pumps than it had recommended. This was because of a change in the heat pump products E.ON had planned to install to ones which have high temperature functionality, though often these were configured to operate as low temperature heat pumps. Warmworks installed fewer ground source systems than it had recommended. In many instances where Warmworks recommended a GSHP this was said to be the customers preference, though some customers then elected not to proceed due to the disruption of the GSHP installation works. It may be that these customers had not fully appreciated this earlier on in the process. The private homes where Warmworks did proceed with GSHP installations were of a large size and required the installation of a three-phase electricity supply, which Warmworks found to be an expensive and complicated process that became a barrier for further GSHP installations in the project.

E.ON recommended and installed a higher proportion of hybrid heat pumps (42% of installs) than the other two DCs. Warmworks recommended and installed a higher proportion of high temperature units (48% of installs). OVO installed mostly ASHPs. There are a number of reasons for these differences:

- **Target quotas:** All DCs were originally required to ensure that between 20-60% of installs were hybrid heat pumps. E.ON was the only DC that achieved this original target.
- **Property types:** Properties in E.ON's area were smaller on average and lacked space for the hot water cylinder, making hybrids more appropriate. Where Warmworks recommended high temperature ASHPs, it was often because properties were older, less well insulated, and/or lacking internal space for a large hot water cylinder.
- **Design culture:** Another reason cited for E.ON's preference for hybrid systems was a culture of low-risk designs, where the aim is to ensure running costs are very unlikely to increase and heat demands will definitely always be met.
- **Installer preferences:** The choice of heat pump was also related to installer preferences – for example, OVO reported that many installers in their networks preferred ASHPs to hybrids due to the complexity of hybrid installations. Installers will typically work with specific brands of heat pumps and are trained by this manufacturer to install these systems. This makes installers more familiar with these systems and biased towards recommending them. Part of the reason that E.ON elected to bring the design process in house was to have more control over which heat pump types it recommended. This way it could ensure that the heat pump type selected was the best fit for the customer's needs, rather than the installer's preference.
- **Customer preferences:** OVO reported many customers wanting to transition to a 'full' heat pump (rather than hybrid) in order to reduce their carbon footprint as far as possible. Conversely, E.ON reported many customers preferring a hybrid as it was perceived to be less of a transition or risk than moving to a 'full' heat pump. Warmworks sometimes recommended high temperature heat pumps where customers said they wanted to keep their existing radiators, or wanted to be sure their home could be maintained at about 21°C.



	Recommended E.ON	Installed	Recommended OVO	Installed	Recommended Warmworks	Installed
Shared GSHP	16	16	12	12	0	0
Individual GSHP	0	0	1	0	68	10
Hybrid ASHP	179	133	5	5	29	17
High temp ASHP	32	89	8	7	198	147
Low temp ASHP	185	71	127	104	310	131

Figure 21 Types of heat pumps recommended and installed by delivery contractor

6. Additional measures required

6.1 Introduction

This section details the additional measures installed alongside heat pumps in the trial.

6.2 Project quotas

The additional measures are defined in Table 3 alongside the target quotas for the project and the actual numbers installed. This section focuses only on the following types of measures:

- **Energy efficiency measures** required to make the property heat pump ready e.g. loft insulation, cavity wall insulation, door and window replacement, draught proofing.
- **Heat emitter** upgrades or additions to make the property heat pump ready, including standard radiators, low temperature radiators, and innovative fan assisted heat emitters.
- **Thermal storage** upgrades or additions, including hot water tanks and innovative phase change material (PCM) thermal storage.
- **Noise abatement** technology including noise barriers or enclosures and low noise heat pump models to be within noise limits.

Other measures such as cooling and aesthetic improvements were intended to overcome consumer barriers such as aesthetics concerns, but DCs reported few customers raising these concerns and, as a result, they offered these technologies to only a few customers.

Table 3: Target quotas and definitions for secondary systems/additional measures to be installed in the project

Technology	Description in project specification	Target quota	Number installed
Smart control systems and monitoring equipment		All homes	
Thermal storage	A new standard hot water tank, or an equivalent sized innovative space-saving thermal store, capable of delivering instantaneous hot water	Water tanks expected in all homes except for hybrids. Minimum 10% of homes to be fitted with innovative thermal storage	33 homes (4%) were fitted with phase change material thermal storage batteries

Technology	Description in project specification	Target quota	Number installed
Heat emitters	Where required, new heat emitters should be installed such as fan-assisted or other innovative heat emitters	Minimum 10% of homes (with fan assisted)	18 homes (2%) were fitted with fan assisted heat emitters
Cooling system and components	Additional components required to provide cooling, to include necessary pipework insulation to avoid condensation issues	Minimum 6% of homes	Installed for 1 property
Noise reduction technology or components	Innovative application of noise reduction technology to reduce external and/or internal noise levels	Minimum 6% of homes	27 homes (4%) were fitted with noise enclosures or barriers. 46% of heat pumps (342) installed were low noise models – generally this was by default based on the product rather than to comply with planning regulations.
Aesthetic impact reduction technology or components	Additional components required to improve the visual impact of the heat pump system such as the use of internal and/or external ducting, visual camouflage or enclosures	Minimum 6% homes	Installed for 1 property
Energy tariff advice / info		Offered to all	N/A
Disconnection from gas supply	Provision for appropriate upgrades or replacements for other gas fed equipment such as: gas fires and gas ovens and hobs	Offered to all, except hybrid systems	N/A

Technology	Description in project specification	Target quota	Number installed
Energy efficiency measures	Provision should be made to cover the cost of insulation in poorly insulated homes to ensure compliance with the recommended maximum U-values for refurbishment of existing domestic buildings These additional building upgrade measures may include, but are not limited to: • Insulation upgrades, e.g. loft insulation, external wall, internal wall, underfloor. • Upgrades / replacements of windows and doors. • Draught-proofing.	Where required	Loft insulation: 102 homes (14%) Replacement doors: 3 homes (<1%) Wall insulation: 7 homes (1%)

6.3 Overview of additional measures

6.3.1 Energy efficiency measures

Most properties (85%) that had a heat pump installed did not require any energy efficiency upgrades, as shown in Figure 22. Of those that did, the most common measure required was loft insulation (14%). Cavity wall insulation was installed in 7 properties, and 3 properties had doors replaced to reduce drafts. It was noted by DCs that some types of properties would have required more substantial upgrades before a heat pump was appropriate because of high heat losses e.g. solid wall insulation in pre-1919 stone built properties such as tenements, pre-1991 timber frame properties, or window replacements for single glazed sash windows. Usually, these measures have not been recommended within the project because of associated costs which, whilst possible within the project scope, would limit the available budget for other measures or homes. There were also planning/conservation area constraints that limited what measures could be used in some instances.

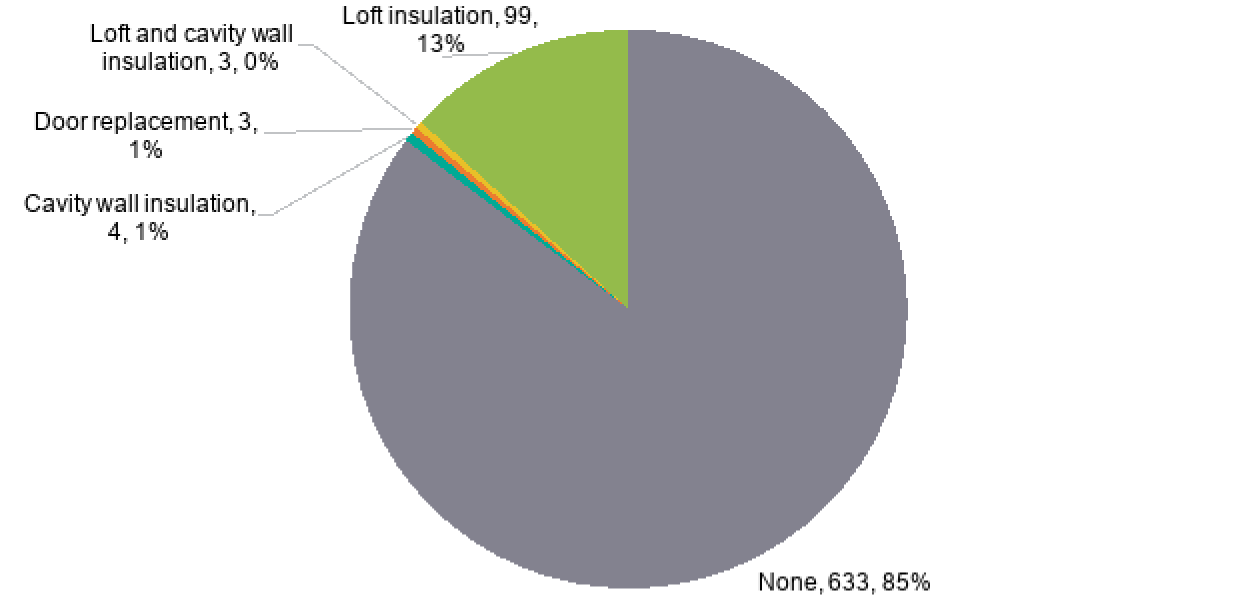


Figure 22 Energy efficiency measures installed with heat pumps

6.3.2 Heat emitter upgrades

Heat emitters are often replaced during a heat pump installation, normally by replacing existing radiators with larger ones. This is to account for the lower flow temperatures that heat pumps typically run at compared to other heating systems. Larger radiators mean that the property will be adequately warmed by the heat pump and the heat pump will be running more efficiently - although replacing them may not always be necessary.

The majority of homes in the trial (93%) had new heat emitters installed as part of the heat pump installation, as shown in Figure 23. In most cases these were either standard (33%) or low temperature radiators (57%), though 18 properties had fan assisted radiators installed. Standard radiators were more often installed with high temperature heat pumps and low temperature radiators with low temperature heat pumps. Anecdotal evidence from contractors suggests that in properties where new heat emitters were fitted, it tended to be that all existing heat emitters in the property were replaced – however, data on the number of existing radiators was not recorded so this cannot be verified.

There was also a strong influence of customer preference around the types of heat emitters installed, mainly for aesthetic or space reasons. For example, vertex or fan assisted radiators were used in small rooms to overcome space constraints. Customers often preferred towel rails for bathrooms, even though these are less efficient. Under MCS, electric radiators in bathroom or kitchen must be omitted from design.

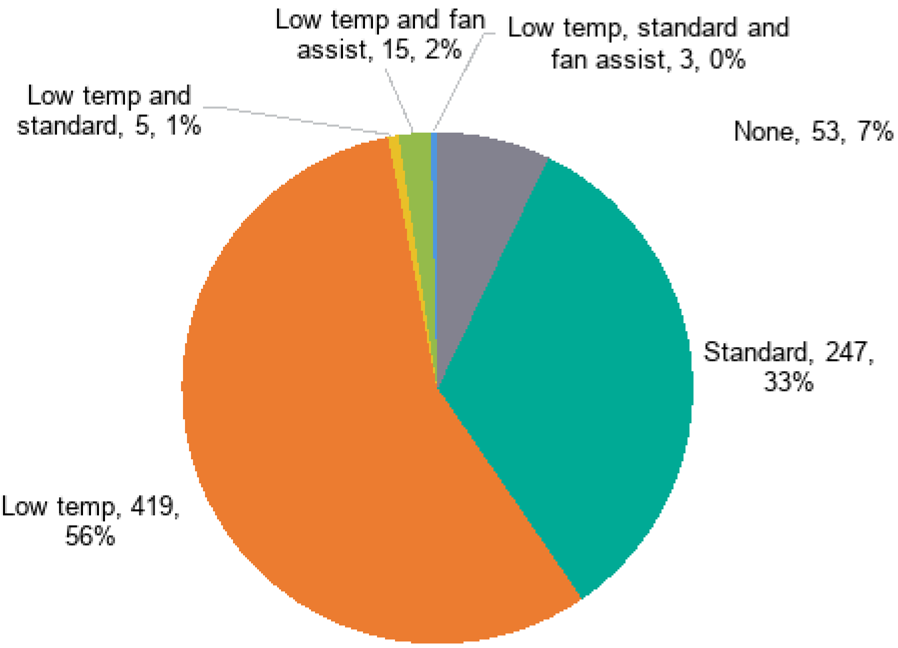


Figure 23 Heat emitters installed with heat pumps

6.3.3 Thermal storage

Most homes (81%) that had a heat pump installed also had a thermal store fitted, as shown in Figure 24. The majority of hybrid heat pumps installations did not require a thermal store as they had combi boilers, but those with standard boilers required a thermal store to be installed. With other heat pump types, existing domestic hot water cylinders were generally replaced because the original cylinder did not have a suitably sized coil. Where customers had an existing combi boiler, the new hot water cylinder had to be acceptable to the customer. Often it required space to be made available, but could sometimes be put in a loft, though this may have required remedial work such as hatch widening and finishing to airing cupboards. Phase change material (PCM) heat batteries were installed in a range of property types to limit the amount of space required for thermal storage.

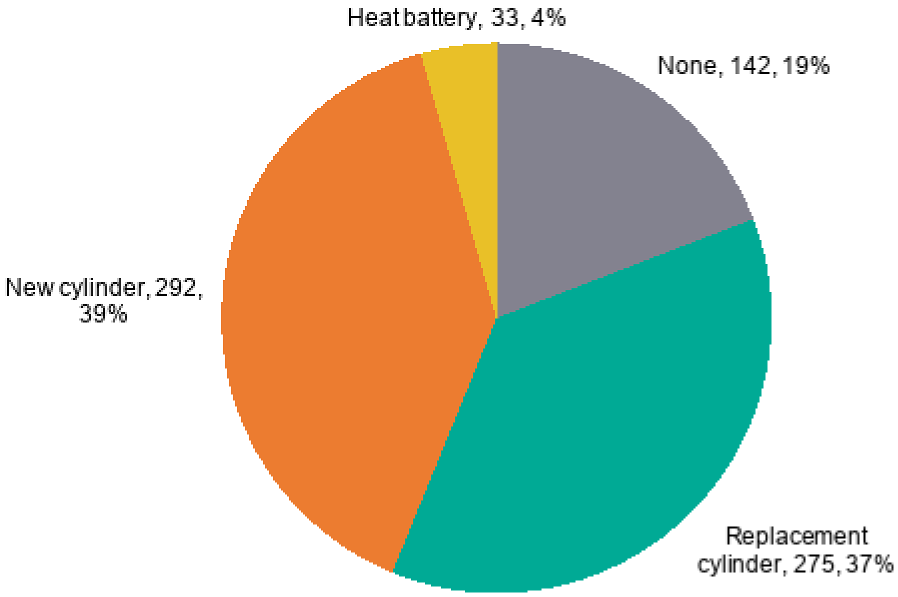


Figure 24 Thermal storage installed with heat pumps

6.3.4 Noise abatement

Barriers or enclosures to limit noise were only necessary with 4% of heat pump installations, as shown in Figure 25. Many models of heat pumps are now built with noise reduction and therefore do not require this. Almost half (46%) of the heat pumps installed in the trial were low noise models.

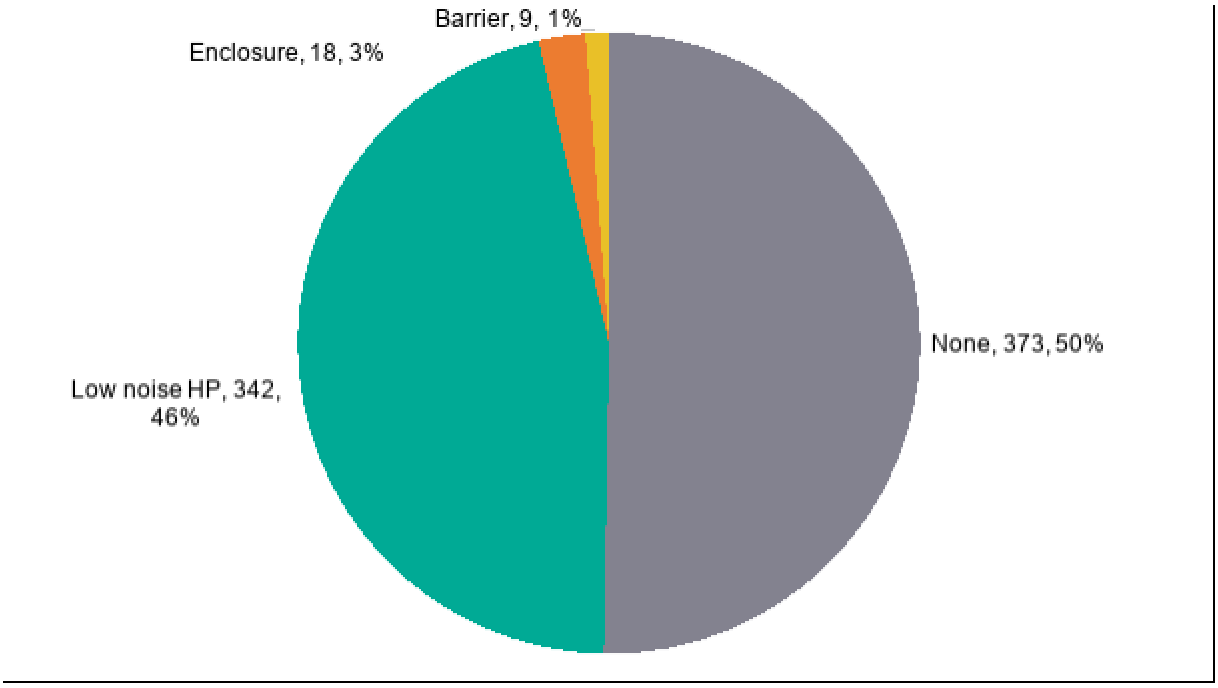


Figure 25 Noise abatement measures installed with heat pumps

7. Costs of systems installed

7.1 Introduction

This section presents costs of the heat pump systems and additional measures installed in the project. The figures in this section must be taken in context of the project:

- The heat pumps are being installed by DCs at economies of scale; these may be lower costs than an individual householder is likely to be able to purchase for a single heat pump. However, these are reflective of industry costs / those a contractor would pay to deliver a project.
- The cost of the systems installed are reflective of the design of the project. DCs had an overall project budget based on costs quoted in their project proposals, and it was up to each DC how this budget was managed – for example, OVO set an internal budget cap of £15,000 per home. Whilst higher cost heat pumps or additional measures *could* be installed within the project scope / budget, this would impact available budget for other homes.
- All cost information represents the costs incurred by the project at a point in time. They are not necessarily fully representative of the range of costs in the market and have not been adjusted to account for changes such as inflation since they were incurred.

The costs quoted are consistent with those quoted by each DC in their tender response – i.e. they are the costs charged to BEIS, not necessarily the cost incurred by the DC. It has been confirmed with each contractor that the costs are based on typical market rates and are representative of the cost of equipment and installation, however generally they are based on rates/contracts agreed with their sub-contractors and hence may represent “fixed price” arrangements in many cases. This is clearly evident in the data with often very little difference (if any) between the heat pump costs for the same heat pump make/model/size by a particular installer. Thermal storage costs were based on the type and size of cylinder installed and heat emitter costs were based on the number of emitters installed.

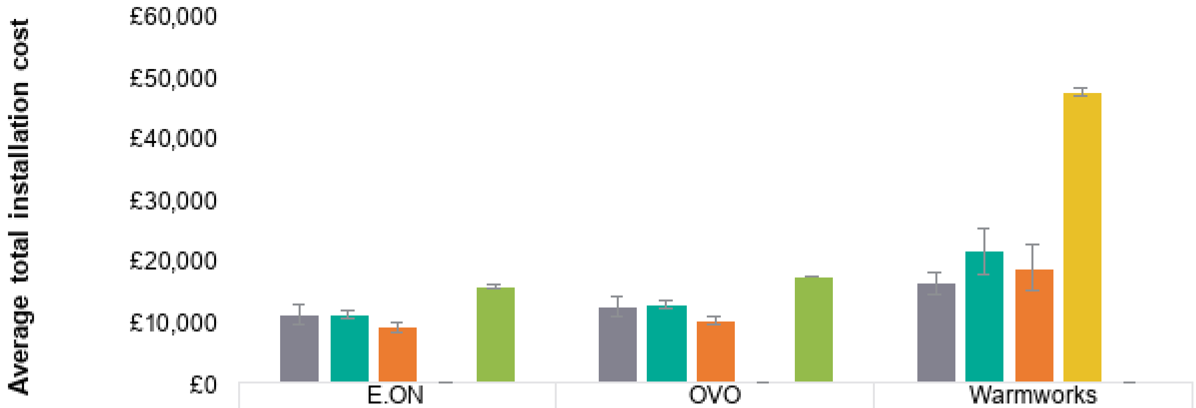
7.2 Total costs of heat pump systems

The total installation costs by heat pump type are given in Table 4. These include the cost of the heat pump, additional measures, and labour costs. The average cost per property was £14,800.

Figure 26 shows how the average total installation costs by heat pump type varied by DC.

Table 4: Total costs of heat pump installations by heat pump type, including additional measures

Heat pump type	**Number of installations**	**Average cost per property and standard deviation**	**Maximum cost**	**Minimum cost**
Low temp ASHP	306	£13,700 ± £2,800	£26,900	£9,000
High temp ASHP	251	£17,400 ± £5,900	£28,400	£8,700
Hybrid ASHP	147	£10,200 ± £3,300	£27,300	£8,000
Individual GSHP	10	£47,400 ± £600	£48,200	£46,400
Shared GSHP	28	£16,400 ± £800	£17,300	£15,400
Average	742	£14,800 ± £6,200	£48,200	£8,000



	E.ON	OVO	Warmworks
Low temp ASHP	£11,100	£12,300	£16,300
High temp ASHP	£11,100	£12,800	£21,400
Hybrid ASHP	£9,100	£10,200	£18,700
Individual GSHP	£0	£0	£47,400
Shared GSHP	£15,700	£17,300	£0

Delivery Contractor (DC)

Figure 26 Average total costs of heat pump installations by DC, including additional measures

Comparing the costs by heat pump type it can be seen that:

- **Hybrid heat pumps** were the lowest cost option with an average total cost of £10,200 per system. The lower cost is in part due to the fact that most hybrid systems (92%) did not require the installation of thermal storage. Most hybrids were 4kW units installed by E.ON. OVO installed four 4kW units and Warmworks installed a few 7kW and 12kW hybrid systems.

- **Low temperature ASHPs** were the second lowest cost option, with an average installed cost of £13,700 per system, including additional measures. The most commonly installed sizes were 8.5kW units (27% of low temperature ASHP installs) and 7kW units (21% of low temperature ASHP installs).
- **High temperature ASHPs** were, on average, more expensive than other types of ASHPs, with an average total cost of around £17,400. This is partly due to a higher proportion of these units being installed by Warmworks (83%), which quoted a higher average cost for all heat pump systems (see Figure 26). E.ON and OVO both reported similar total installed costs for high temperature ASHPs as for low temperature ASHPs. The most commonly installed sizes of high temperature ASHPs were 7kW (41%) and 12kW (25%). It should be noted that the majority of high temperature heat pumps installed in this trial (99%) still required new heat emitters to be installed as the flow temperatures were lower than in the original heating system or the old emitters were inefficient. The choice of high temperature heat pump was often based on product performance rather than high temperature functionality.
- **GSHPs** were the most expensive type of heat pump system to be installed. Warmworks installed 10 GSHPs in individual properties at an average total cost of £47,400 per property. These were either 8kW or 11 kW models. E.ON and OVO installed shared ground array or borehole systems in blocks of flats (16 flats in E.ON's case and 12 flats on OVO's case). Each flat had a 3kW GSHP installed. The average total cost of the shared GSHP systems was £16,400 per property. The cost per property was lower for shared GSHP systems than individual GSHP systems because the cost of the ground works was shared by multiple properties.

7.3 Breakdown of total costs

Table 5 gives the heat pump and installation labour costs by heat pump type, excluding additional measures. The heat pump and installation costs generally accounted for the majority (55-75%) of the total installation costs. Labour costs were reported separately from equipment costs by OVO and Warmworks, whereas E.ON reported the two together. Warmworks recorded labour costs of £1,610 for all installations – these were only the installation costs for the monitoring and control systems. OVO's labour costs ranged from about £1,280-£6,490, with an average of £3,650 per installation – this included the installation of the heat pump, additional measures and annual service. Most of OVO's installations took between 4-5 days, putting its labour costs at about £890 per day on average.

Table 5: Costs of heat pump and installation labour, excluding additional measures

Heat pump type	Number of installations	Average cost per property and standard deviation	Maximum cost	Minimum cost
Low temp ASHP	306	£9,000 ± £2,000	£19,600	£5,300
High temp ASHP	251	£11,700 ± £4,900	£21,300	£5,300
Hybrid ASHP	147	£6,700 ± £2,600	£19,600	£5,200
Individual GSHP	10	£40,300 ± £0	£40,300	£40,300
Shared GSHP	28	£11,500 ± £100	£11,600	£11,400

Table 6 gives the costs of additional measures installed with heat pumps.

Table 6: Costs of additional measures installed with heat pumps – installation costs included for E.ON and Warmworks but excluded for OVO

Measure type	Number of installations	Average cost per property and standard deviation	Maximum cost	Minimum cost
Heat emitters	687	£2,800 ± £900	£6,200	£200
Hot water cylinder	564	£2,700 ± £900	£3,600	£900
PCM thermal store	33	£3,000 ± £800	£3,900	£2,000
Loft insulation	94	£500 ± £50	£850	£350
Cavity wall insulation	8	£800 ± £100	£1,000	£750
Door replacement	3	£6,100 ± £3,000	£9,600	£4,000

Heat emitter costs ranged broadly depending on the number of emitters replaced, from under £200 to over £6,000 in total. The average cost was about £2,800 in total, and the average cost per emitter was about £300, including installation. The most common number of emitters installed per house was 8-10 (38% of all installations), as shown in Figure 27 below.

Hot water cylinders installed by E.ON and OVO averaged £1,800 per home at whereas the average cost of those installed by Warmworks was about £3,600. The most common sizes installed were 200 litres (53% of cylinders) and 150 litres (25% of cylinders). Of the 33 PCM thermal stores installed, most were either 9kWh or 10.5kWh. PCM thermal store prices ranged between about £2,000 and £3,900, although these may not necessarily be the retail prices a customer would pay.

The cost of energy efficiency measures ranged between £350-£850 for loft insulation, £750-£1,000 for cavity wall insulation, and £4,000-£9,600 for new doors, depending on the number replaced.

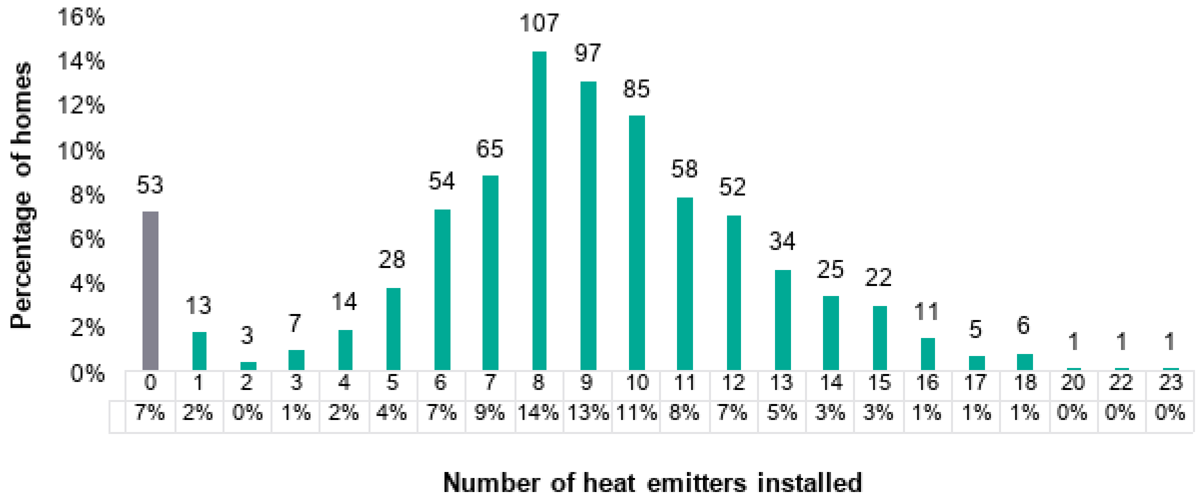


Figure 27 Number of heat emitters installed with heat pumps; absolute numbers of homes shown above bars

8. Barriers to installing heat pumps

8.1 Introduction

This section presents the barriers to installing heat pumps as reported by surveyors / designers / installers in the project. Barriers in this case were largely technical, economic and practical. The reasons that consumers did not wish to proceed with an installation after a heat pump was recommended are explored in the Participant Recruitment report.

Barriers were recorded as reasons a heat pump was not recommended for a property in the context of this trial. Up to two reasons could be selected from the pre-coded options given in Table 7, and an optional explanation could be entered for why that reason was selected. In most cases (over 90%) only one reason was given. The optional explanations provided indicate that there were often multiple reasons why a heat pump was not recommended, even if only one option was selected.

There were 246 cases where a heat pump was not recommended because a programme target had already been met – these cases are not included in the analysis in this section.

The findings should be interpreted in the context of this project, in particular:

- Project constraints and target quotas: DCs were working within time and budget constraints to install a target number of heat pumps in a range of different properties. These constraints were factored into assessments of whether or not heat pumps were recommended for properties in the trial.
- Surveyor/designer/installer judgement: Surveyors made their recommendations based on their knowledge, skills and experience and the information available to them.

Table 7: Reason code options where a heat pump was not recommended

Code category	Code	Definition
Participant	Suitability	Proposed participant is not believed to be suitable for the project - for example they may be in or at risk of fuel poverty, may have an underlying health condition of concern, etc
Economic	Running costs	The projected running costs of the system are believed to be too high for the proposed participant - for example may cause them financial hardship in future.
	Install costs	Expected installation cost of the heat pump system (excluding additional measures) is too high for the project budget.
	Measures costs	The cost of additional measures for the home (e.g., insulation, windows, etc) required to make the heat pump work well, are prohibitive for the scope of this project.
Practical	Additional measures	The scope/scale of additional measures required to make the home suitable for a heat pump is deemed beyond the scope of this project.

Code category	Code	Definition
	Space external	There is no practical external space to site heat pump system components e.g., no space of sufficient size, in the right area to route into the home, secure, etc.
	Space internal	There is no practical internal space to site some of the heat pump system components, e.g., no sensible location for a thermal store
	Routing	Required routing of system components (e.g., pipework) is impractical - for example pipe runs too long, require significant disruption or modifications to the home, etc
	Disruption works	Level of disruption to the home required is judged to be excessive for the DC to undertake or excessive for the Participant to live with
	Noise	It is not possible to site a heat pump in a location that complies with Noise regulations (under Planning regulations).
	Reinforcement	DNO has stated that the local network would require reinforcement to permit this installation, and this cannot be accommodated within the project
	Fabric	There are issues with the building fabric that make a heat pump installation not advisable or risky - e.g., presence of asbestos, poor standard of maintenance.
Programme	Target met	Project targets for a particular home archetype / age / Social group have already been met so home/participant is not required. Note: not included in analysis of following sections
Programme	Cancelled	Installation was cancelled due to project timescales and/or budget
Technical	Comfort	Designer does not believe that comfort requirements can be met for the home in question - e.g., warm-up times too long, some problematic rooms in the home, etc.
	Size	The size / power of the heat pump system required for the home is beyond the scope of the project or no suitable system is available.
Other	Other	Any other reason.

8.2 Overview of barriers to installing heat pumps

Figure 28 provides a summary of the reasons a heat pump was not recommended by surveyors / designers / installers.

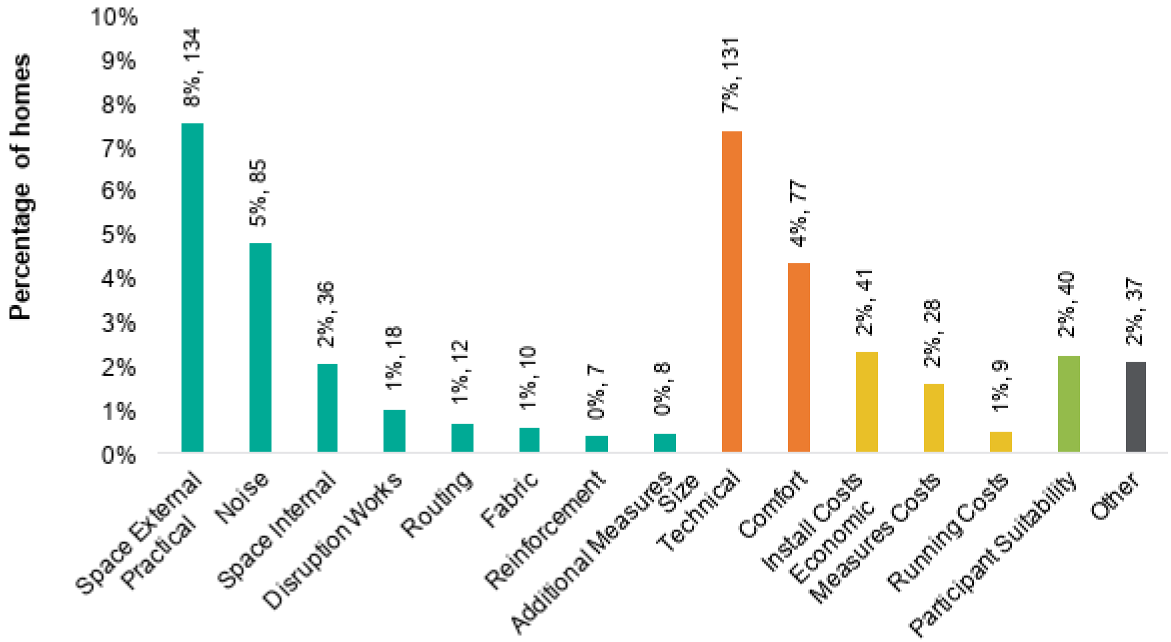


Figure *29* provides the same data as above but broken down into subcategories. Note that percentages sum to over 100% because two reasons were given in a small number of cases.

Figure 28 shows that a heat pump was recommended for 66% of the eligible properties assessed to participate in the trial. The most common reasons that heat pumps were not recommended were practical (17% of properties assessed) and technical (12% of properties assessed). The 12% figure broadly matches findings from unpublished BEIS analysis[25] which indicates that that low-temperature air source heat pump suitability in UK homes might be approximately 90%, without accounting for insulation and space and noise constraints[26].

Further details of all the barriers are given below:

- **Practical – external or internal space constraints:** For 8% of properties, a lack of external space for an outdoor unit was cited as the reason a heat pump could not be installed. For 5% of properties, although there was space for the outdoor unit, it would have been too close to a neighbouring property to meet noise limits, even if noise abatement measures were applied, and would therefore require planning

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[25] The BEIS analysis draws upon previous a Delta-EE research methodology (https://www.gov.uk/government/publications/electric-heating-in-rural-off-gas-grid-dwellings-technical-feasibility) with some parameter changes scaled to the National Housing Model and applied to on-gas housing.

[26] It should be noted that this trial investigated various types of heat pump, whilst the specific finding being referred to from the previous BEIS research relates to low temperature air source heat pumps only

permission. Planning permission applications were made in some cases, but were not approved. For 2% of properties, a lack of internal space for a thermal store or larger radiators was given as the main reason. For 1% of properties, locations were possible, but the routing of pipework would have been too complex to implement. The disruption of installation works was only given as a reason in 15 cases (1% of properties) – pipework replacements and wooden flooring in particular were cited as problems in a few instances. However, disruption of installation works was by far the most common reason that participants elected not to proceed with installations where a heat pump was recommended – this is discussed in detail in the Participant Recruitment report.

- **Technical – heating capacity constraints:** For 7% of properties, the size of heat pump required to meet the heat losses of the property was larger than products available within the scope of this project. For context, the highest capacity heat pumps installed in this trial were 14kW (44 properties), 16kW (12 properties) or 18kW (1 property), depending on the DC. For 4% of properties, designers were concerned that the comfort requirements could not be met, either because of the heat pump capacities available in the project scope, or because large enough radiators could not be installed in some rooms (as highlighted above). Kitchens and bathrooms were most often cited as problem areas in the explanations provided by designers.
- **Economic – cost of upgrades required:** For 4% of properties assessed, the cost of the installation and/or additional measures would have been too high for the DC to accommodate within its project budget. This reason was given most often by OVO, which set a cap of £15,000 per property. The explanations provided suggest this was often due to the need for additional insulation, and in some cases the replacement of microbore piping or a large number of radiators. The 1% of properties classed as having ‘Practical – Fabric’ or ‘Practical – Additional Measures’ issues could also have been classes as Economic barriers. The presence of asbestos was noted in three of the explanations provided in these cases.
- **Participant – unsuitable circumstances for trial:** In several of the 40 instances (2% of properties) where participant suitability was given as a reason, it was explained that building works/extensions were planned and an MCS design could not be done until the building plans were finalised. There were also a few cases where the property was being sold or rented.
- **Other barriers:** Other barriers (2% of properties) included a variety of reasons such as planned building work, lack of communication from the customer, health and safety concerns about accessing property, electricity supply upgrades not possible in project timescales, or solar thermal systems being incompatible with a heat pump in the context of this trial because of the monitoring requirements.

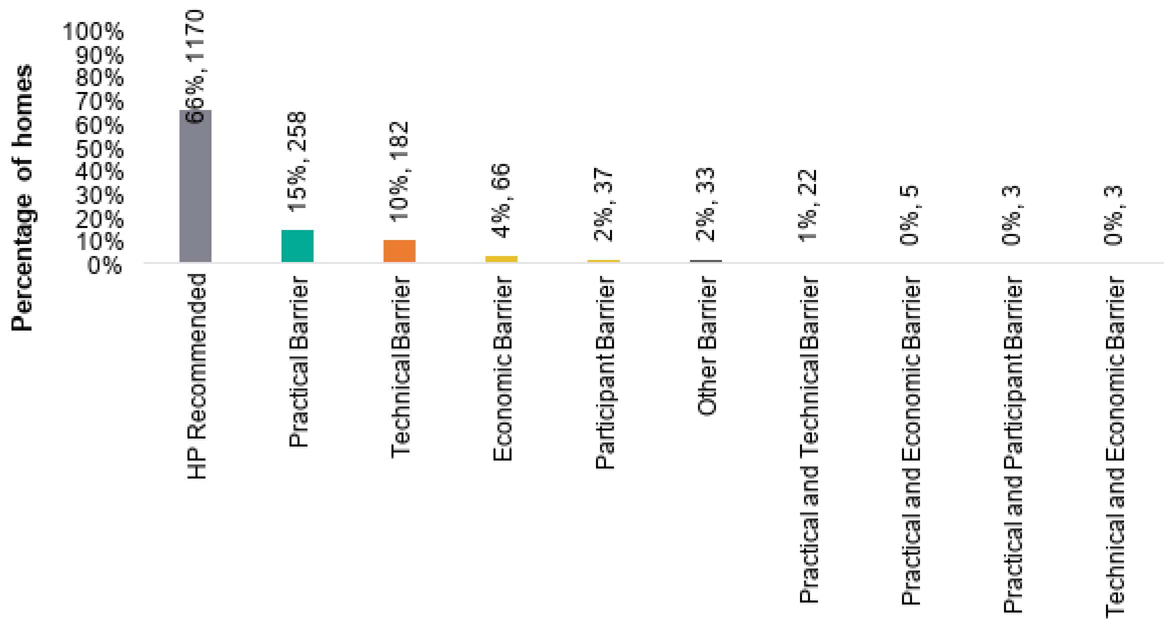


Figure 28 Reason type given for heat pump not being recommended; absolute number of homes shown above bars

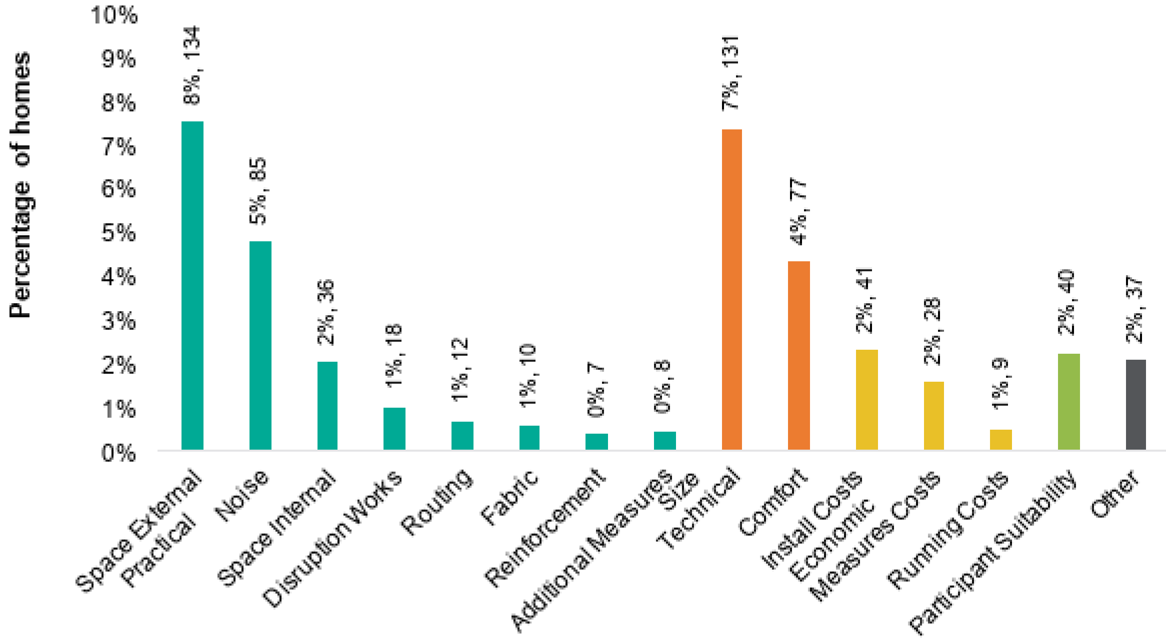


Figure 29 Reason given for heat pump not being recommended; absolute number of homes shown above bars

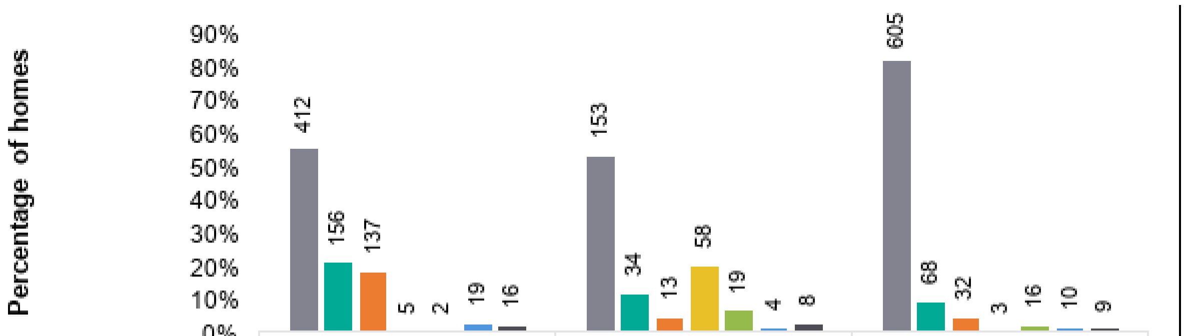
8.3 Barriers by delivery contractor

Barriers to installing heat pumps are broken down by DC in Figure 30 and Table 8.

Noise restrictions were a major barrier for E.ON in particular due to their trial area being mostly urban (Newcastle) and the prevalence of terraced housing in this area. Proximity of properties meant that installations did not meet permitted development rules. Noise solutions, such as acoustic enclosures and fencing barriers were part of the design process – E.ON included noise enclosures where this might enable the heat pump to reach permitted development under the planning process, but these were not always sufficient.

OVO mainly cited high costs as a barrier (22% of properties assessed) because of the additional measures required to make properties heat pump ready. OVO had set a £15,000 budget cap per property that it aimed to keep within, whereas the other DCs worked within a total project budget. E.ON more often cited heat pump capacity as an issue. In all cases this points to the same problem – high heat losses – which either need to be a) reduced with insulation or b) met with a higher capacity heat pump and/or larger radiators.

Participant suitability issues were cited more often by OVO and Warmworks than by E.ON. This is likely because E.ON's triaging process was very comprehensive and would have picked up on these suitability issues at an earlier stage in the project.



	E.ON	OVO	Warmworks
HP Recommended	55%	53%	81%
Practical Barrier	21%	12%	9%
Technical Barrier	18%	4%	4%
Economic Barrier	1%	20%	0%
Participant Barrier	0%	7%	2%
Multiple Barriers	3%	1%	1%
Other Barrier	2%	3%	1%

Delivery Contractor (DC)

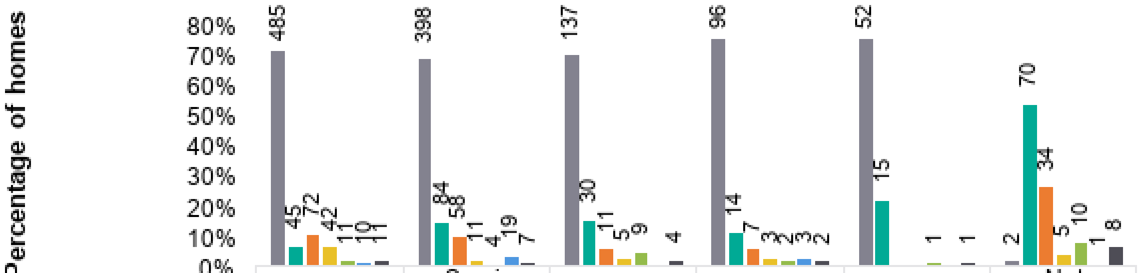
Figure 30 Reason type given for heat pump not being recommended, broken down by delivery contractor; absolute number of homes shown above bars

Table 8 Breakdown of reasons given for heat pump not being recommended, broken down by delivery contractor; percentage of properties assessed

Barrier		E.ON	OVO	Warmworks
HP recommended		55%	53%	81%
Practical	Space External	9%	8%	6%
	Noise	11%	1%	0%
	Space Internal	1%	2%	3%
	Disruption Works	0%	1%	2%
	Routing	1%	0%	1%
	Fabric	1%	0%	1%
	Reinforcement	1%	0%	0%
	Additional Measures	0%	1%	0%
Technical	Size	12%	5%	4%
	Comfort	9%	0%	1%
Economic	Install Costs	0%	14%	0%
	Measures Costs	1%	8%	0%
	Running Costs	0%	1%	1%
Participant	Suitability	0%	7%	3%
Other	Other	2%	3%	2%

8.4 Barriers by property types

Figure 31 shows that heat pumps were recommended for a similar share of all types of properties. Practical barriers like lack of space were less common for detached properties and more common for flats. Detached properties were more likely to be rejected because of the size of heat pump required or the cost of installing the heat pump and additional measures.

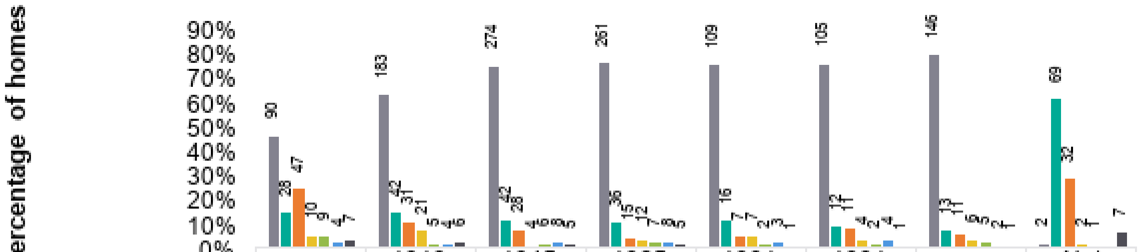


	Detached	Semi-Detached	Mid-Terrace	End-Terrace	Flat	Not recorded
HP Recommended	72%	69%	70%	76%	75%	2%
Practical Barrier	7%	14%	15%	11%	22%	54%
Technical Barrier	11%	10%	6%	6%	0%	26%
Economic Barrier	6%	2%	3%	2%	0%	4%
Participant Barrier	2%	1%	5%	2%	1%	8%
Multiple Barriers	1%	3%	0%	2%	0%	1%
Other Barrier	2%	1%	2%	2%	1%	6%

Build Form

Figure 31 Reason type given for heat pump not being recommended, broken down by delivery contractor; absolute number of homes shown above bars

Figure 32 shows that heat pumps were recommended for properties of all ages, though were less likely to be recommended for older properties built before 1944. Practical and technical barriers were more often cited for these properties.

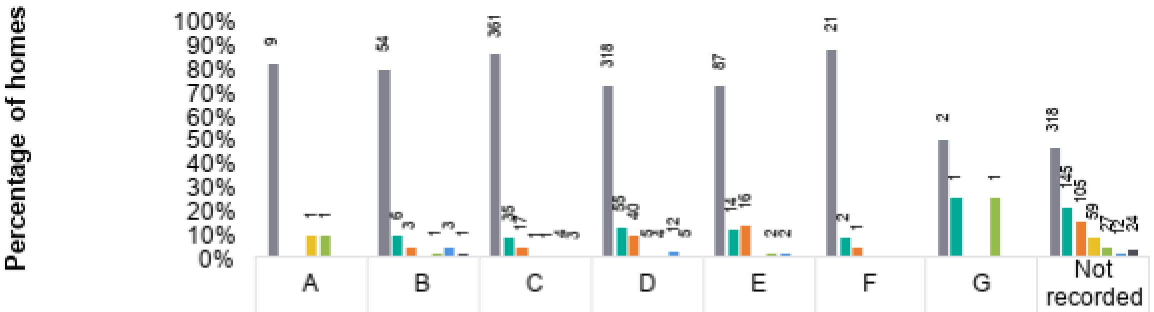


	Pre 1919	1919-1944	1945-1964	1965-1980	1981-1990	1991-2000	2001+	Not recorded
HP Recommended	46%	63%	75%	76%	75%	76%	79%	2%
Practical Barrier	14%	14%	11%	10%	11%	9%	7%	61%
Technical Barrier	24%	11%	8%	4%	5%	8%	6%	28%
Economic Barrier	5%	7%	1%	3%	5%	3%	3%	2%
Participant Barrier	5%	2%	2%	2%	1%	1%	3%	1%
Multiple Barriers	2%	1%	2%	2%	2%	3%	1%	0%
Other Barrier	4%	2%	1%	1%	1%	1%	1%	6%

Year of construction

Figure 32 Reason type given for heat pump not being recommended, broken down by delivery contractor; absolute number of homes shown above bars

Figure 33 shows that heat pumps were recommended for homes of all energy efficiency ratings, including E/F/G rated properties, but were more likely to be recommended for homes with a SAP rating of A/B/C.

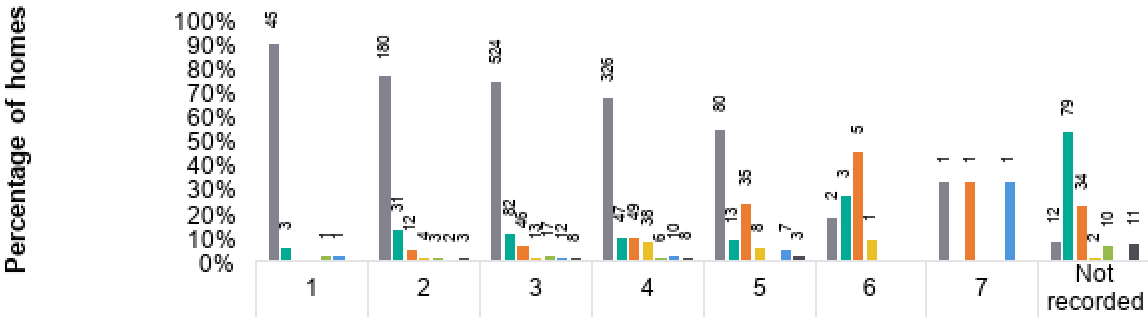


	A	B	C	D	E	F	G	Not recorded
HP Recommended	82%	79%	86%	72%	72%	88%	50%	46%
Practical Barrier	0%	9%	8%	13%	12%	8%	25%	21%
Technical Barrier	0%	4%	4%	9%	13%	4%	0%	15%
Economic Barrier	9%	0%	0%	1%	0%	0%	0%	9%
Participant Barrier	9%	1%	0%	1%	2%	0%	25%	4%
Multiple Barriers	0%	4%	1%	3%	2%	0%	0%	2%
Other Barrier	0%	1%	1%	1%	0%	0%	0%	3%

SAP rating

Figure 33 Reason type given for heat pump not being recommended, broken down by SAP energy efficiency rating; absolute number of homes shown above bars

Figure 34 shows that larger properties with 5 or more bedrooms were less likely to have a heat pump recommended because the size of heat pump required would have been larger than the units available in the trial.

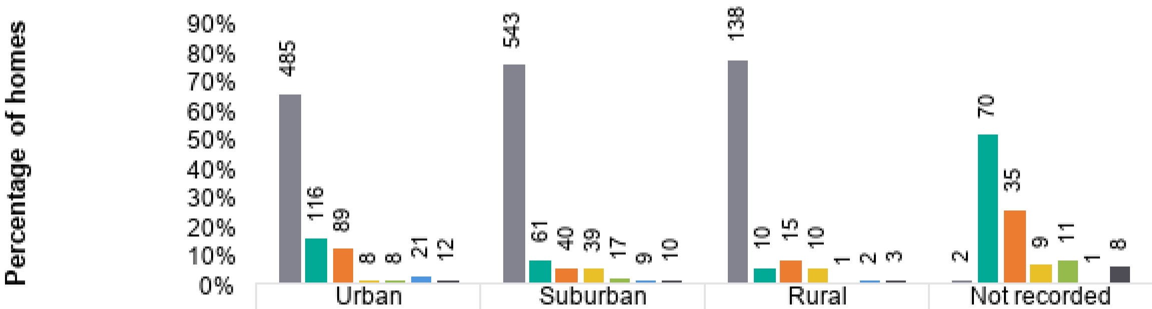


	1	2	3	4	5	6	7	Not recorded
HP Recommended	90%	77%	75%	67%	55%	18%	33%	8%
Practical Barrier	6%	13%	12%	10%	9%	27%	0%	53%
Technical Barrier	0%	5%	7%	10%	24%	45%	33%	23%
Economic Barrier	0%	2%	2%	8%	5%	9%	0%	1%
Participant Barrier	2%	1%	2%	1%	0%	0%	0%	7%
Multiple Barriers	2%	1%	2%	2%	5%	0%	33%	0%
Other Barrier	0%	1%	1%	2%	2%	0%	0%	7%

Number of bedrooms

Figure 34 Reason type given for heat pump not being recommended, broken down by number of bedrooms; absolute number of homes shown above bars

Figure 35 shows that heat pumps were recommended for properties in all environments, though were slightly less likely to be recommended in urban environments where space and noise constraints were more often a barrier.

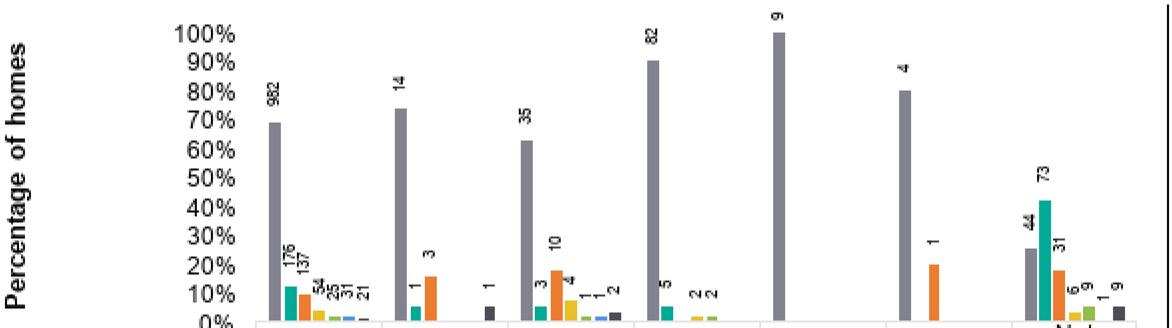


	Urban	Suburban	Rural	Not recorded
HP Recommended	66%	76%	77%	1%
Practical Barrier	16%	8%	6%	51%
Technical Barrier	12%	6%	8%	26%
Economic Barrier	1%	5%	6%	7%
Participant Barrier	1%	2%	1%	8%
Multiple Barriers	3%	1%	1%	1%
Other Barrier	2%	1%	2%	6%

Property environment

Figure 35 Reason type given for heat pump not being recommended, broken down by property environment; absolute number of homes shown above bars

Figure 36 shows that heat pumps were recommended for both on-gas and off-gas properties. Practical barriers were more often an issue for on-gas properties, which tended to be smaller and more likely to have space or noise constraints.



	Gas	LPG	Oil	Electricity	Wood	Coal	Not recorded
HP Recommended	69%	74%	63%	90%	100%	80%	25%
Practical Barrier	12%	5%	5%	5%	0%	0%	42%
Technical Barrier	10%	16%	18%	0%	0%	20%	18%
Economic Barrier	4%	0%	7%	2%	0%	0%	3%
Participant Barrier	2%	0%	2%	2%	0%	0%	5%
Multiple Barriers	2%	0%	2%	0%	0%	0%	1%
Other Barrier	1%	5%	4%	0%	0%	0%	5%

Primary heating fuel

Figure 36 Reason type given for heat pump not being recommended, broken down by primary heating fuel; absolute number of homes shown above bars

9. Lessons

This section presents lessons from the survey, design and installation stages of the project as reported by DCs.

9.1 Lessons from home surveys and design

9.1.1 Design tools

The design of a heat pump system can be carried out using a variety of software tools. Many manufacturers have their own specific design tools for their product range and there is often an expectation from manufacturers that these will be used. Tools can be web based or in MS Excel. Some of these manufacturer tools were used within the project and they were generally found to be useful and suitable. However, some issues were experienced:

- Tool upgrades: new versions of tools were sometimes released with several ‘bugs’. This created inaccuracies in the design and made the tool difficult to use. On occasions, new versions of the tool changed the results of calculations. This indicates a quality issue in the tool design or a lack of checking/testing. It also points to a potential compliance issue with Microgeneration Certification Scheme (MCS). MCS do not accredit any tools and manufacturers do not appear to have any obligation to “prove” their tool is compliant. A question arises as to how manufacturers can ensure their design tools are MCS compliant and provide this confidence to contractors. One DC suggested it would be useful to have all tools and product recommendations centralised under MCS.
- Conservative default assumptions: For example, high default U-values[27] for windows or walls, reflecting older standards of construction. These can result in potential over-sizing of heat pumps to minimise the risk that a heat pump provides insufficient heat for the occupant. Tools need to encourage the user to make a good assessment and pick a value that is appropriate, not set a ‘worst case’ default as this can result in significantly oversized systems that do not operate efficiently, or properties being rejected where a solution is possible. It also points to a need for better default assumptions for design tools.

9.1.2 Limitations of working with certain products and manufacturers

Contractors will generally work with specific heat pump manufacturers and products. Heat pump designs are therefore done with a limited selection of potential products, rather than all heat pump products on the market – this was the case in this trial and reflects how industry works more widely.

[27] U-values are the rate of heat loss in a building element, such as walls or windows

9.1.3 Understanding of MCS design standards

All designs must be MCS compliant, but through the project it emerged that different understandings or interpretations of MCS design rules exist. For example, one issue was found with how to account for kitchens with no heat emitters. Another issue was around meeting individual room heat loss requirements where rooms were non-habitable but have a quantifiable background ambient heat demand. Guidance was provided by GTEC, a training company with expertise in MCS that is providing quality assurance audits for the designs and installations in the project. With this guidance, it was found that there was more flexibility within MCS guidelines than previously understood on this issue: flow temperatures could be increased within the COP (Coefficient of Performance[28]) guidance and adjustments made to the internal design requirements and room temperatures.

Overall, there was found to be a trend of ‘over caution’ in heat pump design in the industry i.e. over-sizing and adding more than the required number of radiators. This is partly due to MCS standards/audits that will not pass under-designed systems.

A lesson that emerged from the project is that a greater understanding of MCS design standards and the flexibility within them would be very useful for the industry. There are already training paths and qualifications for installing heat pumps, and it was suggested by one DC that there should also be a formal qualification for heat pump design.

The key findings of the Quality Assurance audits done to date are summarised in Section 9.2.4.

9.1.4 Design assumptions

One issue encountered at the design stage was the use and accuracy of default values (such as U-Values) by installers. Like the design tools, installers often overestimated heat loss from a building compared to the actual U-values, which can lead to inaccurate designs.

Two DCs reported that some of the design assumptions were omitted or could not be validated. For example, distance measurements for noise calculations appeared inconsistent with other information provided, or no supporting evidence was supplied e.g. photos.

Errors in designs were also reported by DCs, such as radiators being incorrectly sized or DNO approval being flagged as necessary when it was not. One DC said there were instances where it was unclear what design assumptions to use, as the installer, manufacturer and auditor on site could not agree on which approach was correct.

Better training for designers, as well as having more experienced designers supporting new designers, will help to address these types of issues.

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[28] The efficiency of a heat pump which measures the ratio of electrical input compared to heat output

9.1.5 Desktop audits and site surveys

Each DC took different approaches to the survey and design stages of the project, and processes were refined as the project progressed. Generally, a first stage of desktop audit took place, followed by a full design involving a site survey.

Whilst desktop audits were found to be very helpful, there were some limitations of this stage:

- Some practical and technical issues can only be picked up during a site survey. For example, practical problems of where to fit the heat pump unit or radiators were only picked up when the designer was surveying the home. This means that contractors must assume a certain % drop out following the site survey due to practical and technical constraints.
- A small number of assumptions made during the desktop survey can have a big impact on the design and suitability of the home. For example, the presence of cavity wall insulation (CWI) can usually only be determined during a site survey for many homes, but the contractor must have an assumption at the initial desktop audit stage of whether it is likely to be fitted that cannot be verified until the survey stage. In these cases, contractors do not wish to spend too much time and resource on designing a system that may be quickly identified as unsuitable at survey stage – if for example, the customer is unwilling to install CWI.
- Accounting for customer preferences is another challenge during the initial desktop audit. For example, customers may have preferences around the number, sizing and type of radiators – perhaps for aesthetic reasons – which impacts the technical design. The full design could not be fully determined until the site survey, yet assumptions need to be made at the initial audit stage as to what the customer may be willing to accept.

The approach of starting with an initial desktop survey and moving onto the site survey is logical and the most cost-effective approach. However, the risk remains of spending resources on site surveys where the property is unsuitable. To mitigate this as far as possible, the DCs continually reviewed and refined their approach to the design and survey stage – particularly in trying to add other elements into the initial design, or to make this more accurate. One example of this is using publicly available information such as Google Street View during the desktop audit to enable contractors to measure the garden area and identify potential problems of finding space for the heat pump outdoor unit.

Triaging and audits were necessary in this project because of the project target and quotas. However, the DCs all said that a similar process would be applied in a commercial context, albeit with more lenient triaging criteria. E.ON had previously been recruiting heat pump customers with only a site survey, but with customer volumes growing it has now made desktop audits a standard part of their recruitment process.

9.1.6 Differences between EPCs and PAS 2030 design

Another challenge of the design process is communicating differences between Energy Performance certificates (EPCs) and PAS 2030[29] designs to customers. Projected running costs, for example, are calculated at each stage, but can produce quite different results. EPCs are based on high-level assumptions and tend to assume higher energy consumption and therefore result in higher running costs (and lower savings, where applicable) compared to PAS 2030, which is based on bespoke room by room calculations. It can sometimes be challenging to explain to customers the reasons for these differences and ensure they have confidence in the figures that are provided to them, particularly since heat pumps are not recommended in EPCs. DCs generally found this was not an issue for most customers though, provided the differences were explained upfront.

9.1.7 Property extensions and renovations

A strong driver for some householders to install heat pumps was to upgrade their heating system at the time of a major property renovation or addition of an extension. Given major building works would be going on at this stage, this approach would minimise the overall level of disruption for the householder and be the ideal stage at which to install a heat pump. However, there can be challenges around designing a heat pump solution in these circumstances. Under MCS, a heat pump can be designed for a property as it would be after the extension is built, but not without sufficient knowledge of the extension's physical characteristics. This meant that many properties undergoing a renovation or preparing an extension had to be excluded from the project.

9.1.8 Customer drop out

Customer barriers to heat pump installs are not the focus of this report and are covered in the Participant Recruitment report. However, DCs did report the following qualitative lessons around drop-out rates at the survey stage:

- Drop-out rates were particularly high amongst social housing tenants.
- When the EoH project first commenced, DCs found the drop-out rate at survey stage was higher than anticipated. Through changing their processes to identify potential barriers earlier on in the process, this drop-out rate reportedly decreased through the course of the project. The DCs also reported that this helped improve customer satisfaction and reduced time spent on surveys that did not proceed to installs.

[29] PAS 2030 is a standard that provides a specification for the installation of energy efficiency improvements

9.2 Lessons from installation

9.2.1 Time required for installations

On average, heat pump installations took 2-4 days to complete, including the installation of new heat emitters and thermal storage but excluding installation of any energy efficiency measures. The range of installation times for heat pumps and measures are shown in Figure 37 and Figure 38. The installation time depended on factors such as property size and the existing pipework – for example, where microbore pipework had to be replaced the installation could take around 8-10 days. GSHP installations took longer because of the ground works – for example, the time recorded for the installation of E.ON's shared GSHP system for 16 flats was 84 days. Installations also took longer in some cases because of Covid-19 health and safety measures (e.g. social distancing).

Installations were typically carried out by a team of two engineers and one electrician. The time spent by the electrician depended on the nature of the property – the wiring and commissioning could generally be done on the last day, but would take longer if a property already had solar panels and/or batteries that needed connecting.

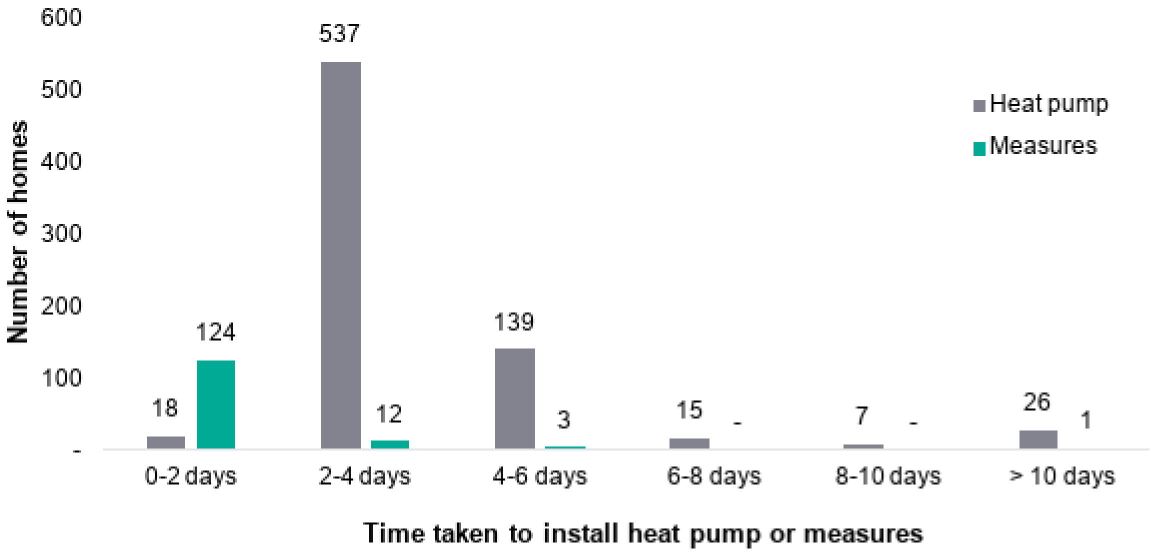
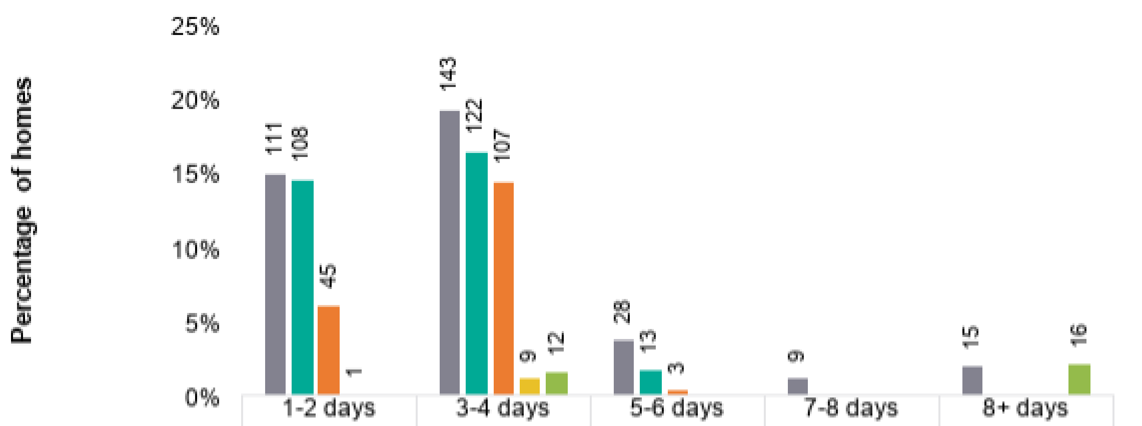


Figure 37 Time taken for installation of heat pump and accompanying measures (data for time taken is only reported for 20% of measures which were installed)



	1-2 days	3-4 days	5-6 days	7-8 days	8+ days
Low temp ASHP	15%	19%	4%	1%	2%
High temp ASHP	15%	16%	2%	0%	0%
Hybrid ASHP	6%	14%	0%	0%	0%
Individual GSHP	0%	1%	0%	0%	0%
Shared GSHP	0%	2%	0%	0%	2%

Time taken to install heat pump

Figure 38 Time taken for installation of heat pump, broken down by heat pump type; absolute number of homes shown above bars

9.2.2 Managing customer expectations and minimising disruption

An important element of the installation was to manage customer expectations about what the installation would entail and the impact on the household occupants. DCs found that, generally, customers were satisfied with the installation process when:

- It was made very clear how intrusive the works were likely to be e.g. replacement of pipework.
- Customer communications were clear on how long installers would be in their home.
- Householders were provided with an alternative source of heat for the installation period.

It should be noted that most installations were not distress purchases i.e. where households purchase a new heating system to replace a faulty / broken heating system. This could have an impact on customer expectations as they had time to prepare for the replacement and were not in a hurry to fit a new heating system.

9.2.3 Manufacturer guidance

DCs have noted that the guidance from manufacturers on installation of their heat pump units can be lacking or inconsistent. This was even the case where installers had undertaken recent manufacturer training. In some cases, contacting the manufacturer to resolve queries through the technical support was also time consuming.

9.2.4 Quality assurance

Quality assurance (QA) audits are being conducted by training provider GTEC for a selection of properties that had a heat pump installed. As of January 2022, the audit process was still in progress, though the majority of visits have been completed. Findings from the QA audits will be detailed in a separate report and learnings for installers will be provided. The most common issues from the audits done to date are as follows:

- **Participant awareness of documentation:** Participants that had a heat pump installed should have been provided with several documents, including design documents, running cost predictions, electrical certificates, commissioning documentation and handover packs. These were either provided by email or as hardcopies. When asked by GTEC to provide these documents, many participants either believed they had not received them, were unaware they had received them, or were unable to locate them. Without the documentation, GTEC was unable to audit against the specific design for the particular property. This also points to potential issues around providing documents electronically (e.g. going into spam folders), and/or households not understanding what had been provided to them.
- **Insulation of pipework:** Another common problem was pipework not being adequately insulated, particularly outdoors and in lofts. Inadequate insulation causes heat to be wasted and reduces the performance of the system. This has been raised with installers to ensure they understand why insulation of pipework is required and how to properly apply it.
- **Appropriate clearances from components:** Certain clearances are needed from heat pump outdoor units for air circulation, discharge safety valves and removal of condensation or defrost water. These were not observed for a number of installations, the most common error being insufficient clearance from the base of the unit to the ground. GTEC suggested that some installers need a better understanding of why it is necessary to have these clearances.
- **Electrical safety and compliance:** Early on in the audit process it was found that many of the installations done by one installation company had electrical safety issues such as live wires or components not properly isolated or tested. The DC had these issues addressed and no further installations were carried out by the installation company. This was especially concerning to the DC as the installation company had been recommended to them by a manufacturer. The DC suggested that MCS certification does not ensure the ongoing competency of all installers working for those organisations. Removing the installation company from the MCS register also took several months after the issue was raised because it had to first be referred to the relevant MCS installer certification body.
- **DNO notifications:** Earlier on in the trial GTEC was asked by DCs to assist with the DNO notification process for heat pump connections, as the process is relatively technical to understand. It is an issue for installers that the database of heat pumps

they must reference in the application process is based in Microsoft Excel, as many installers do not have Excel access.

- **Manufacturer documentation:** Accessing up to date and correct documentation for products can be a challenge when manufacturers have thousands of product lines. This was highlighted when a number of installs were found to have used a particular component not shown in manufacturer documentation online and it was realised that an additional release of the documentation had been sent only to registered installers.

It should be noted that all of the issues encountered in this project were not considered to be unusual for the heat pump industry as a whole, or indeed the wider heating industry.

9.2.5 Problems with monitoring equipment installation and set up

Several issues were encountered in setting up the monitoring equipment used for this trial. These resulted in monitoring data being transmitted incorrectly or not being transmitted at all. The issues were mainly attributed to wiring issues on the part of the installer as well as errors in the installation instructions.

9.2.6 Managing and auditing subcontractors

The project has been delivered by three DCs and several subcontractors. There were some challenges with managing subcontractors where DCs were several steps removed from the people actually carrying out the heat pump installations. For example, a DC may have subcontracted out the survey, design and installation stages to another organisation, which itself acted as a project manager of subcontracted installation companies employing a number of installers. This made it more difficult to plan for installer availability, communicate learnings between installers and DCs, and manage installation quality and safety.

9.2.7 Specific lessons to heat pump types

There were some installation issues reported around specific heat pump types:

- Shared ground loop/borehole GSHPs: installations required a certain amount of logistical organisation, disruption and customer support. For example, one installation required six boreholes to be drilled – requiring access to the outdoor area, water supply/water pressure for the drilling rig and parking spaces for several days. Shared loop GSHPs installations were installed by two out of three DCs in social housing and contractors spent considerable time supporting and liaising with the customers to reassure and keep them updated.
- ASHPs in coastal environments: required additional coats of paint to the units due to the corrosion caused by sea air.
- Siting of heat pumps for their refrigerants: for the refrigerant R290 (propane), used in the high temperature ASHPs models deployed in the project, the heat pump has to

be installed away from any drains and this is not always possible within the layout of properties.

9.3 Other challenges encountered

Other challenges encountered in the process from home suitability survey to installation are as follows.

9.3.1 DNO approvals

Heat pumps can require approval from the local Distribution Network Operator (DNO) for connection. The size of the heat pump and local network constraints will determine how much impact a potential connection may have – DNOs will first undertake a load check and then the impact can be assessed. Whilst some heat pumps can be connected straight away, others will have implications of local network area reinforcement. Where heavy engineering works are required, these can take weeks to progress.

The main impact the DNO approvals process had on the project were delays in progressing applications. One DC was told that load checks would normally take around 4–6 weeks, but many were taking up to 11 weeks and longer over the winter period. DCs had to manage this pipeline and it can also have an impact on keeping customers engaged and interested, especially if customers have already experienced delays from the planning approvals process.

Other issues were encountered with the DNO process. For example, one DC was required to make payments for each individual household separately, resulting in higher administrative time and inefficiencies for the DC. Other DCs did not experience this, with one DC being able to submit batches of applications, thereby speeding up the process.

Lack of standardisation in decision-making within the DNO organisation was also reported as an issue by DCs. There was also found to be differences in opinions between individual staff at the same DNO, with differing levels of knowledge and risk, and therefore a degree of subjectivity in the decisions being made.

To overcome this barrier, the DCs engaged with the DNOs, and this was successful to a degree – especially where this engagement was with senior staff. However, there are improvements that could be made to the approval processes, and these are provided in the recommendations section.

The DNO approvals process was challenging for DCs to manage within the project but also has significant impacts for the mass rollout of heat pumps where greater volumes of heat pumps are expected to be installed over a short timeframe. Applications were easier for DNOs to manage where heat pump installations were focused in one geographical area rather than scattered. Therefore, the impact of large volumes of individual households applying for approvals needs to be considered and managed.

DNO improvements since EoH

Following the installation phase of the project, BEIS gave feedback to various DNOs concerning issues experienced during the DNO approvals process. As a result, the Energy Networks Association, an industry body who represents UK and Ireland energy infrastructure companies, have provided the following response, assuring BEIS that improvements have been made to the DNO approvals process.

"DNO approvals play an important role in ensuring that the network is not overloaded and that heat pump installations don't cause unacceptable disturbances to other customers. Since the installs under the Electrification of Heat Demonstration project took place, DNOs have made improvements to their processes to speed up connection times and streamline approvals including digitising processes and making it easier to go through the connect and notify process."

9.3.2 Supply chain

There have been issues encountered with the availability of several products during the project, including the heat pumps themselves and heat emitters. Manufacturers reported to DCs a shortfall in heat pump units in late 2020 due to supply chain disruptions including Covid-19. A later shortage of heat emitters meant a 2-3 week lead time, causing some delay in installations. One DC also reported issues getting the necessary heat metering equipment. In some instances, DCs could substitute products or components with alternatives, but in other cases product shortages caused delays of several weeks or months.

Some issues with installer capacity were also reported, although these were very localised.

9.3.3 Impact of the Covid-19 pandemic

The project was carried out during 2020-2021, during which the UK was going through periods of lockdown due to the Covid-19 pandemic. This had multiple impacts including:

- Lack of access to participants' homes for surveying and installation.
- Availability of installers e.g., there were some reports of smaller installation firms closing
- General turbulence in the market due to uncertainty.

10. Conclusions

This report provides findings from the home survey, design and installation stages of the Electrification of Heat project. It should again be noted that the findings in this report are in the context of the knowledge, skills and experience of the surveyors, designers and installers who carried out relevant stages of this project, and that the findings should be viewed within the context of the project.

Properties involved in the trial One aim of this project was to demonstrate that heat pumps can be installed in a wide range of domestic properties across the UK, and it has been successful in achieving this. Heat pump designs and installations have been achieved across a wide range of property types, sizes and ages, both on and off the gas grid, and in both rural and urban environments.

The mix of properties and households involved in the project were driven mainly by project quotas. Each DC was required to install a certain number of heat pumps in their trial area within the project timescales. Different approaches were taken by each of the DCs to achieve their installation targets. Properties ‘triaged out’ of the project or not recommended for a heat pump installation were not necessarily unsuitable for heat pumps, but were less attractive candidates for installation within this project. Suitability of the wider UK housing stock for heat pumps should therefore not be inferred based on this data.

10.1 Heat pump types installed

A range of different heat pump types were installed in line with project target quotas. Of the 742 heat pumps installed, 41% were low temperature air source heat pumps (ASHP), 34% were high temperature air source heat pumps, 21% were hybrid heat pumps, 1% were individual ground source heat pumps (GSHP) and 4% were shared ground source heat pumps. The ground source heat pump target of at least 6% of properties was hardest to achieve, because only about 10% of properties had suitable ground space, and some of these participants were not willing to have a ground array installed. The minimum requirement of 6% for high temperature heat pumps was far exceeded mainly because of how high temperature heat pumps are defined. Heat pumps are defined as “high temperature” if they are capable of heating to over 65 degrees Celsius, whether or not this functionality is used in practice. Some high temperature units installed in this project were chosen because the higher temperatures were necessary to meet the heating demands, but in many cases the high temperature heat pumps installed were configured to operate as low temperature heat pumps. These products were chosen for their efficient performance rather than their high temperature functionality. Hybrid heat pumps were mainly installed by E.ON because properties in E.ON’s area were smaller on average and lacked space for the hot water cylinder, making hybrids more appropriate. E.ON also took a more conservative design approach that favoured hybrid heat pumps in order to guarantee that heat demands would be met and running costs would not increase. There are also other potential reasons for this difference, such as demographics and motives of participants in different areas – this is explored in the Participant Recruitment Report.

10.2 Additional measures installed

New heat emitters were needed with 93% of the heat pumps installed as the existing radiators would have been too small to achieve the necessary heat output with the lower flow temperatures. A new thermal store was installed in 81% of homes, either because the property had a combi boiler before and no thermal store, or because the original cylinder did not have a suitably sized coil for a heat pump. Energy efficiency upgrades were only made for 15% of properties where a heat pump was installed – in the majority of cases this was loft insulation and a few properties received cavity wall insulation or door replacements. Many of the properties that had a heat pump installed already had suitable levels of loft and wall insulation, in part because harder to insulate properties were 'triaged out' at earlier stages of the project.

A range of 'innovation measures' were made available in the project with the aim of overcoming consumer barriers to heat pumps. These included phase change material thermal stores, noise enclosures, aesthetic impact reduction solutions and cooling systems. Phase change thermal stores were installed in 33 homes, many of which were flats that lacked space for a hot water cylinder. Noise barriers were used at 27 properties to keep within noise limits, though often low noise heat pump models were used instead. Overall, DCs reported that trial participants did not raise concerns around aesthetics and there was very little interest in cooling functionality.

10.3 Costs of heat pump systems installed

Costs recorded for the installation of heat pump systems were based on the costs quoted by DCs in their project proposals for the trial. The average total cost per property was about £14,800 including the heat pump unit, additional measures and installation.

Hybrid heat pumps were the lowest cost option with an average total cost of £10,200 per system. Low temperature ASHPs were the second lowest cost option, with an average installed cost of £13,700. High temperature ASHPs were, on average, higher cost than other types of ASHP, with an average total cost of around £17,400. The higher cost is partly because the high temperature heat pumps installed are more expensive modern units. GSHPs were the most costly type of heat pump system to be installed. The 10 individual GSHP installations carried out by Warmworks cost £47,400 per property on average. The shared GSHP installations carried out by E.ON and OVO cost £16,400 per property because the heat pump units installed were smaller and the cost of ground works was shared by multiple properties. Some of the variability in costs was due to differences in the prices quoted originally in project proposals and the mix of heat pump types installed by DC.

The costs above include additional measures such as heat emitters and thermal stores. Heat emitter costs ranged broadly depending on the number of emitters installed. The average cost per property was £2,800 in total, including installation. The most common number of emitters installed was 8-10. Thermal storage costs were mostly between £1,500 - £2,000 or £3,500 - £4,000, depending on the DC and the size of store installed.

10.4 Barriers to heat pump installation

The project seeks to understand how to overcome barriers to the widescale roll-out of heat pumps for domestic heating. Participant barriers are discussed further in the Participant

Recruitment report. A commonly reported reason for participants not wanting to proceed with a heat pump installation was the disruption that the installation would cause to their home. This includes replacement of pipework, impact on décor, etc.

This report looked at the barriers to installing heat pumps as reported by surveyors / designers / installers in the project. A heat pump was recommended for 66% of the eligible properties assessed to participate in the trial. Barriers were recorded as reasons a heat pump was not recommended for a property in the context of this trial. The main non-participant barriers were:

- **Practical – external or internal space constraints:** For 8% of properties, a lack of external space for an outdoor unit was cited as the reason a heat pump could not be installed. For 5% of properties, although there was space for the outdoor unit, it would have been too close to a neighbouring property to meet noise limits, even if noise abatement measures were applied, and would therefore require planning permission. Planning permission applications were made in some cases but were not approved.
- **Technical – heating capacity constraints:** For 7% of properties, the size of heat pump required to meet the heat losses of the property was larger than products available within the scope of this project. For 4% of properties, designers were concerned that the comfort requirements could not be met, either because of the heat pump capacities available in the project scope, or because large enough radiators could not be installed in some rooms.
- **Economic – cost of upgrades required:** For 4% of properties assessed, the cost of the installation and/or additional measures would have been too high for the DC to accommodate within its project budget. This reason was given most often by OVO, which set a cap of £15,000 per property. The explanations provided suggest this was often due to the need for additional insulation, and in some cases the replacement of microbore piping or a large number of radiators.

Overcoming these barriers was explored in the project as far as possible. For example:

- Engagement with the local planning authority helped to facilitate discussions around noise and permitted development. Noise enclosures were a viable solution for some properties to meet permitted development.
- Contractors spent considerable effort finding ways to minimise disruption for customers.
- Product alternatives such as hybrid systems with no outdoor unit (sometimes known as ‘compact hybrid heat pumps’) and compact phase change material (PCM) thermal storage were introduced to overcome issues of space constraints and high heating demands.
- The local DNO was engaged to try and speed up the processing of connection applications and find solutions to processing bulk applications.

However, overcoming all barriers was not within the control of the project. For example, exploring solutions to microbore piping issues, such as installation of low loss headers, was beyond the scope of this project. Further analysis would be required to understand the financial implications of larger heat pump sizes or substantial energy efficiency upgrades needed for those properties where the measures required fell outside the scope of this project.

10.5 Lessons from the survey, design and installation stages

The key lessons learned from these project stages are as follows. Recommendations related to these lessons are provided in the following section.

- **Design standards, tools and assumptions:** Through the project it emerged that there are different understandings and interpretations of MCS standards and how to achieve compliance. Feedback from project delivery partners is that there is an overall industry trend towards surveyors being overly cautious in their design assumptions for calculating the heat demand of a property, leading to over-sizing of heat pumps. There was also uncertainty about how to account for particular circumstances, such as kitchens with no heat emitters, or where renovations were planned but the full design details not yet known. Another issue that emerged was around updates to manufacturer design tools having 'bugs' that impacted the design calculation results. This raised the question of whether design tools should be accredited by MCS, and the requirement for better industry understanding of MCS standards.
- **Use of desktop audits:** As the project progressed, DCs refined their recruitment approaches to minimise customer drop out after the site survey stage by collecting more information at an earlier stage. Desktop audits using publicly available information such as Google Street View were found to be a useful tool in the project triaging process and will continue to be used by DCs in a commercial context.
- **Manufacturer documentation and guidance:** DCs have noted that the guidance from manufacturers on installation of their heat pump units can be lacking or inconsistent. This was even the case where installers had undertaken recent manufacturer training. In some cases, contacting the manufacturer to resolve queries through the technical support was also time consuming.
- **Customer expectation management:** On average, heat pump installations took 2-4 days to complete by a team of two installers and one electrician, including the installation of new heat emitters and thermal storage but excluding installation of any energy efficiency measures. Most installations involved heat emitter replacements and installation of a new thermal store. To maintain customer satisfaction, DCs found it was important to discuss the potential disruptions early on in the engagement process, clearly communicate how long installers would be in their home and provide an alternative heat source for the installation period.

- **Managing and auditing subcontractors:** The project has been delivered by three DCs and several subcontractors. Overall, this worked well, but the number of parties involved did make it more difficult to plan for installer availability, communicate learnings between installers and DCs, and manage installation quality and safety. A concern was raised by one DC that MCS certification does not ensure the ongoing competency of all installers working for those organisations.
- **Quality of heat pump installations:** A number of issues have been identified from the installation quality assurance audits done to date, particularly around insulation of pipework and having appropriate clearances from components. None of these issues are considered to be unusual for the heat pump industry as a whole, or indeed the wider heating industry.
- **Supply chain constraints:** Product shortages were experienced during the trial that delayed heat pump installations. These were attributed to supply chain disruptions including Covid-19 but do point to potential challenges for the mass roll out of heat pumps. Some issues with installer capacity were also reported, particularly due to Covid-19, although these were very localised.
- **Noise limits and planning permission:** Technical solutions such as low noise heat pumps and noise enclosures can enable designs to meet noise requirements. However, where these solutions are not viable, planning permissions could be a barrier to the wider uptake of heat pumps.
- **DNO approvals:** For properties where load checks were required by the local Distribution Network Operator (DNO), these checks sometimes took several months to complete, delaying heat pump installations. Lack of standardisation in decision-making and inability to handle batch requests within the DNO organisation was also reported as issues by some DCs. If these challenges are not resolved, DNO approvals could become a significant barrier to the mass roll out of heat pumps.

MCS improvements since EoH

BEIS and project partners have engaged with MCS throughout the EoH project and reported and discussed some of the issues that emerged from it. As a result, MCS has looked at how the guidance could be improved to enable the uptake of heat pumps.

The following is a response from MCS.

"MCS welcomes the findings of this report. Through our process for Standards development and maintenance, we are asking our independent technical working groups to consider the report's conclusions and recommendations.

The report underlines the sector's need for a skilled workforce, working to industry standards, for the delivery of quality installations for customers. For example, the undertaking of accurate heat loss calculations goes beyond design tools and highlights why, as a heating industry, we need well-trained, competent heat pump system designers.

Over the last 6 months MCS has:

- *Rewritten MCS 025 - The Competency Standard - to describe the sector's competencies which form the basis for MCS accreditation of quality training provision. The revised MCS 025 requires the appropriate supervision of those that can't evidence competency. It also introduces for the first time a reassessment policy to ensure an individual's skills and knowledge are kept up to date.*
- *Split the MCS Heat Pump Standard (MIS 3005) into two parts – one focussed on installation, and one focussed on design, reflecting two distinct skill sets.*
- *Supported industry in bringing new design and installation courses to market.*

During 2023, MCS will:

- *Launch the 'MCS Hub', a tool for gaining and maintaining certification which will also document and clearly identify competent individuals that a Contractor has.*
- *Reset MCS compliance assessments undertaken by MCS and Certification Bodies, to focus on capturing evidence of delivered quality in the field and less on "back-office" compliance.*
- *Launch an electronic link between MCS installation and manufacturer's warranty through integration with Digital Benchmark. This will form the start of resolving issues with providing a customer with the documentation associated with their installation."*

11. Best practice and recommendations

Recommendations and best practice guidance from these project stages are as follows:

- **Support and training for heat pump design and installation:** the project has demonstrated a range of understandings and interpretations of the MCS design rules, some of which could result in oversizing of heat pumps. Further, non-conformance issues with some heat pump installations were raised in quality assurance audits – these point to a lack of understanding of design requirements and a need to upskill installers in this area This important issue needs to be addressed to ensure heat pumps are designed and installed correctly, ensuring efficient performance and consumer expectations are met. Suggested ways this could be addressed are:
    - Having experienced designers within organisations supporting new designers.
    - One DC also suggested that there should be a formal qualification for heat pump design, as there is for installation. MCS have since announced that the existing Heat Pump Standard will be split into two standards – one for Heat Pump Design and one for Heat Pump Installation[30].
    - Further training for designers and installers to understand the MCS design rules. Support from an independent advice organisation was well received in this trial – ways of providing similar support for the wider heat pump industry should be considered.
    - Continuation of QA audits in design and installations.
- **Recognition of competence:** it was suggested that surveyors, designers and installers should be required to hold a competency card ensuring they understand the fundamental principles of designing heat pump systems. This could be similar to the Gas Safe ID card carried by Gas Safe registered engineers certifying that they have the necessary qualifications to carry out gas work.
- **Sharing of learnings from the trial:** In addition to the dissemination reports and case studies published from this project, it is recommended that all relevant learnings from this trial for the heat pump industry are summarised and shared with designers/installers through appropriate channels.
- **Review of MCS requirements and guidance:** DCs noted a number of instances where there was uncertainty or disagreement on how to comply with MCS requirements – for example, how to meet heat losses in kitchens that do not have heat emitters. Findings from DCs and GTEC relating to the MCS requirements and

[30] MCS announces key changes to its Heat Pump Standard, 26/01/2022, MCS: https://mcscertified.com/mcs-announces-key-changes-to-its-heat-pump-standard/

guidance should be collated and shared with MCS so that these can be reviewed and updated if necessary.

- **Review of MCS ongoing quality assurance:** concerns were raised by DCs about whether MCS certifications of organisations were adequate to ensure the ongoing competence of the installers working for those organisations. It was suggested that MCS lacks the resources to provide ongoing compliance enforcement. The MCS certification process should be reviewed and enhanced to ensure it delivers high quality installations and increased confidence in the industry.
- **Auditing and standardisation of design tools:** MCS does not audit or accredit design tools – instead it is up to MCS accredited organisations to check that design tool calculations are MCS compliant. It was suggested by DCs that producers of design tools should have some obligation to confirm they are compliant with MCS or some other platform, or that they be audited by MCS. It would be useful for the heat pump industry to have all design tools and product recommendations centralised under MCS – this would also help in providing confidence in the industry. The design process could also be simplified if manufacturers were required to publish thermal outputs under certain conditions, as some manufacturers already do. This would make it easier to assess and compare whether heat pumps are capable of meeting the design heat losses.
- **Automation of desktop audits:** in this trial DCs made use of publicly available information and data provided by participants to 'triage out' properties not suitable for a heat pump in the context of this project before conducting a site survey. Learnings from the triage process and suitability assessments could be used to inform the development of heat pump assessment algorithms to automate initial survey stages and reduce the overall costs of installing a heat pump.
- **Customer support and expectation management:** through this trial DCs have learned how to more effectively engage and support households through the transition to a heat pump. Additional ways of sharing these learnings with the wider industry might be considered. We recommend, for example, that organisations:
    - Have dedicated (non-technical) customer support staff who can explain the implications of having a heat pump installed at the appropriate stages in the customer journey. This is discussed further in the Participant Recruitment report.
    - Take customer preferences into account from early on in the process to ensure the best system for their needs is installed.
    - Set clear expectations for customers of how long installers will be in their property and what works will be carried out.
    - Provide an alternative heat source for the duration of the installation.
- **Summarising of key facts for customers:** customers can be overwhelmed by the volume of documents provided to them in the process of designing and installing a

heat pump. It was suggested that customers should also be provided with a simple "key facts" document summarising the main assumptions for their property, such as estimated running costs.

- **Review and improvement of DNO approval processes:** options to speed up and streamline DNO approval processes for heat pumps should be urgently explored and implemented. New connection protocols and tools are needed so that specific approval is not required for installation. More standardised processes that are able to process bulk applications would help. There may also be a need to upskill staff within DNOs around understanding heat pump loads.
- **Review of pipework requirements in new building regulations:** Building regulations should be reviewed to ensure that all new buildings can easily have a heat pump installed without the need for microbore piping replacements or heat emitter upgrades.
- **Review of noise requirements for heat pumps:** Local Planning Authority requirements for heat pump planning permissions should be re-assessed to determine whether any of these requirements could be revised to encourage wider uptake of heat pumps.
- **Innovative solutions to practical and technical barriers:** This trial has demonstrated the need for innovative solutions to practical and technical barriers to installing heat pumps, such as locating outdoor units and replacing microbore pipework. These should be encouraged through future innovation trials and support mechanisms.
- **Demonstrating solutions for properties with high heat demands:** Properties with very high heating demands were effectively excluded from heat pump installations in this trial because of product and budget limitations. It is worth quantifying how prevalent these properties are and potentially conducting a separate analysis on what it would cost to install heat pump systems in these homes.

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