Leeds City Council

Leeds RHINOS - Heat Pump Ready Project Report

Stream 1, Phase 1 Feasibility Study

Issue 3

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Disclaimer - the positions reflected in this report are those of the consortium collectively, and do not necessarily reflect the views of every member of the consortium.

Executive Summary

Introduction to the project and consortium

Leeds City Council (LCC) led a partnership of expert organisations in carrying out this feasibility study into the development of an innovative methodology for deploying domestic heat pumps at a high density within urban communities, in line with the UK Government's ambition of installing 600,000 heat pumps a year by 2028.

In 2021, approximately 85% of UK domestic heating was provided through networked gas. This is not compatible with a net zero future and the way we heat our homes has to change dramatically. Heat pumps can significantly reduce carbon emissions and eliminate harmful local air pollution. Achieving their rapid installation in domestic properties on a mass scale is a technical, logistical, financial and social challenge that the project aims to tackle.

The Renewable Heat Infrastructure Network Operating System (RHINOS) project is part of the Heat Pump Ready Programme Stream 1, Phase 1, funded by BEIS through its £1 billion Net Zero Innovation Portfolio (NZIP), which aims to accelerate the commercialisation of innovative clean energy technologies and processes through the 2020s and 2030s.

The partnership, led by LCC, consisted of; Arup, Kensa Contracting Ltd, Parity Projects, University of Leeds (UoL), Leeds Beckett University (LBU), Otley Energy, Legal & General, Northern Powergrid and IRT Surveys. The aim of bringing all these organisations together was to develop and strengthen partnerships between all stakeholders, several of whom are already involved in cutting-edge retrofit project developments in Leeds, to provide innovative solutions to aid the heat decarbonisation transition.

Low-carbon projects have largely been demonstrated in social housing, the result being rows of renovated properties broken up by private households that weren't able to take part. This project focused predominantly on privately-owned housing.

The wards of Otley and Yeadon, Chapel Allerton and Roundhay were selected within the city of Leeds as part of this study since they comprise high proportions of privately-owned homes currently on the gas network and are made up of a wide range of house types, including a large number of older and densely packed Victorian terraced properties.

The concept and intention

This feasibility project focused on the concept of shared ground borehole arrays connecting to heat pumps in individual private homes. The concept has been developed and tested under current energy prices and subsidy levels available for installation. The project progressed through a set of work packages (outlined in detail in Section 3) consisting of area selection, customer engagement, concept design, business model creation and consideration of the local supply chain and quality assurance processes.

Work package scope and key findings

Within the area selection work package, existing housing stock baseline data and modelling, provided by Parity Projects, was shortlisted using criteria defined collectively within the project team. This helped to identify high concentrations of properties where the deployment of the concept was considered to be most favourable within the three wards of focus. Areas were targeted where there were a high proportion of smaller homes, with a lower energy efficiency, connected to an electrical network that required limited or no reinforcement due to the additional load of a heat pump and were occupied by people who were more likely to be able to pay for the installation. Several scenarios of fabric improvement and heating system installation were then considered and costed as part of further stock modelling, although other areas of the study were limited to considering a single option of light retrofit measures (loft insulation and air tightness where applicable) and deployment of the heat pump solution. Engagement with Northern Powergrid was key to the delivery of this element of work.

The customer engagement work package was led by Leeds Beckett University and carried out in three stages. Firstly, 15 interviews were carried out with members of the public on general experiences, expectations and preferences to do with their existing heating systems and a potential transition to heat pumps. This fed into the definition of the concept solution, which was then tested within four focus group sessions, exploring attitudes towards installing heat pumps, the feasibility of including energy efficiency improvement measures and the acceptability of possible finance solutions among other topics. The findings of the focus groups were used to develop a survey to explore their response to a more-developed proposed solution including attitudes to obtaining heat from a shared ground array heat pump system and preferences for paying for it.

Key findings indicated that people are curious and want to protect the environment, and so would be open to transitioning from their gas boilers but they want a good deal. Numerous nuanced barriers to uptake were displayed from the engagement process which included upfront cost, level of expected benefit, disruption involved, trusted and personalised delivery, timing in relation to personal circumstance and perceived need. With cost and cost savings being of the highest importance to people when deciding about a heat pump, it is crucial to demonstrate how a heat pump will provide good value for money.

A customer journey proposal was developed by Otley Energy, mapping the existing, successful, and complementary Kensa and LCC approaches and comparing these to delivery models across the UK and Europe. The customer engagement work established key design principles to enhance the customer journey design and overcome potential barriers to uptake. These proposals form a sound basis for more detailed operational design and testing to understand the effectiveness of each step in moving customers forward to successful delivery.

An initial generic design concept and costing model was developed as the project progressed which was tested with residents as part of the engagement. A technical design was undertaken by the University of Leeds for a specific street in Chapel Allerton which had a high concentration of homes which met the criteria developed in the area selection work package. This allowed for a technical review of the generic concept in order to verify the assumptions in this initial design and to evaluate the heat demands, electrical demands and system monitoring that may be required. Opportunities for diversifying demand on the power network may exist, although this is sensitive to the timing and magnitude of heat demand peaks between homes. An overall seasonal efficiency of 3.17 was predicted which was slightly lower than our initial concept and cost modelling.

Business and finance modelling was undertaken concurrently for the combination of light fabric measures and the shared ground array plus individual heat pump system being proposed.

A split ownership business model was developed by Kensa and Legal & General whereby the costs for elements outside the home, i.e. the shared ground array infrastructure, and the costs associated with the home, i.e. the heat pump and any retrofit measures could be funded separately.

The consumer could pay for the infrastructure element via a standing charge, whilst the home-integrated elements could be paid for upfront or via a loan, which was estimated to require an additional £6,000 after the eligible government contribution of £6,000. This compares to a typical cost of a replacement gas boiler of £3-4,000.

For a typical solid wall mid-terraced house, it was demonstrated that running costs for the proposed solution would be similar to the pre-improvement running costs with a gas boiler.

The supply chain for the delivery of such a scheme was considered and the need to address certain constraints was identified. These constraints relate to the availability of products such as manifolds, pumps, heat exchangers and glycol, installation equipment including drilling rigs, accredited and competent professionals for delivery and other services such as aftercare. This is of particular importance when considering deployment at a greater scale than the immediate project.

Existing guidance on Quality Assurance and Customer Protection was gathered and assessed. Kensa is already delivering shared ground array schemes and energy efficiency measures aligned to the Microgeneration Scheme (MCS) and PAS 2035 processes, through survey, design, installation (including post-completion), and handover. Leeds City Council also has experience in delivering retrofit schemes using these quality assurance frameworks, as well as the use of accredited contractors for delivery and aftercare. Standards for Consumer Protection frameworks and measures were also explored and Kensa's approach compares favourably to these.

Reflections

The project has benefitted from valuable collaboration between local project partners and stakeholders where many viewpoints and experiences were shared, particularly during regular cross-work package meetings.

Several challenges persisted throughout the project, however. Contracting and data sharing arrangements between parties affected initial mobilisation and general data accessibility and availability slowed early progress.

The single cost model developed consisting of light retrofit measures alongside the shared ground array and heat pump solution was tested with consumers, indicating a low likelihood of customer take up. This pointed to a need to improve the offer significantly through either further measures and/or additional funding support.

Despite the significant reduction in primary energy demand[1] from installation of heat pumps, heating cost savings do not come from the installation of the heat pump system due to the high cost of electricity (34p/kWh) compared to natural gas (10p/kWh). It is clear that cost savings are instead delivered by fabric efficiency measures and self-generation and storage.

The inclusion of further measures to upgrade homes, improve comfort, reduce heat demand and/or some self- generation and energy storage was identified as an area of development to potentially provide a more compelling offer.

Uncertainty about energy cost savings was identified as a significant risk. The business model rests upon several specific assumptions. Of particular note are assumptions around the applicability and the real benefit, including comfort, of the specific light retrofit measures included in the base model, given the known[2] unreliability of information on EPCs.

[1] BRE (2019) Briefing Note – Derivation and use of Primary Energy factors in SAP. https://www.bregroup.com/wp-content/uploads/2019/10/Briefing-note-on-derivation-of-PE-factors-V1.3-01-10-2019.pdf

[2] Adam Hardy & David Glew, Leeds Beckett University (2019). An analysis of errors in the Energy Performance certificate database
https://www.researchgate.net/publication/333537101_An_analysis_of_errors_in_the_Energy_Performance_certificate_database

Next steps and further work

The RHINOS project team decided not to apply for Phase 2 of the Heat Pump Ready Programme in light of its initial findings, identified challenges and further work needed to develop a compelling offer for private homeowners to decide to commit. The timing and requirements of the application part way through Phase 1 meant that findings and proposition were not fully formed, and the partnership was not in a position to present a confident plan for Phase 2 trial delivery on this basis.

The project partnership would like to carry out further work to iterate the customer offer, taking our initial business model and understanding of customer attitudes and preferences to develop it into a solution that is more likely to gain take up and succeed.

LCC remain committed to playing an active role in developing business and finance models to accelerate the decarbonisation of the housing stock and wider economy including exploring their own involvement in delivery models. The financial and resource constraints they and other Local Authorities face make this form of collaborative and government funded development project of critical importance.

Contents

Glossary

Term	Definition
ASHP	Air Source Heat Pump
BEIS	Department for Business, Energy & Industrial Strategy
DHW	Domestic Hot Water
DNO	Distribution Network Operator – company licenced and responsible for electricity distribution to end users, separate from transmission network
EPC	Energy Performance Certificate – provides rating of domestic property energy efficiency and fuel costs
GSHP	Ground Source Heat Pump
HPR	Heat Pump Ready – BEIS programme
PCM	Phase Change Material
RHINOS	Renewable Heat Infrastructure Network Operating System – Leeds HPR project name
SAP	Standard Assessment Procedure - methodology used to assess and compare the energy and environmental performance of domestic properties
SBRI	Small Business Research Initiative – UK government programme to procure research & development services
Shared ground array	Ground source heating system where at least two or more properties are connected to a communal ground loop and have individual heat pumps
SME	Small Medium Enterprise
SPF	Seasonal Performance Factor – measure of heat pump efficiency
SPV	Special Purpose Vehicle – subsidiary company that is formed to undertake a specific business purpose or activity
WP	Work Package

1. Introduction

This report summarises the feasibility study carried out by the Leeds Renewable Heat Infrastructure Network Operating System (RHINOS) project as part of Stream 1, Phase 1 of the Department of Business, Energy & Industrial Strategy (BEIS) Heat Pump Ready (HPR) Programme.

The RHINOS project ran from June-November 2022 and sought to develop a method for the coordinated deployment of heat pumps at a high density in domestic properties within Leeds (classed as an urban location within HPR) as well as for future, wider deployment. Leeds City Council (LCC) were the lead organisation of a consortium involving multiple companies, each with designated roles and work package responsibilities but collaborating towards the common goal - see Figure 1 and Section 3. Another key stakeholder was the local Distribution Network Operator (DNO), Northern Powergrid.

Figure 1 – Leeds RHINOS Consortium

The overall project cost of £198,000 was wholly funded through the Small Business Research Initiative (SBRI), predominantly covering staff time from each organisation and some project expenses.

Section 2 covers the aims of the feasibility study in more detail and Section 3 describes the structure of the project and roles of each organisation. Sections 4-9 detail the analysis & findings from each work package.

Key findings from the work packages are summarised in Section 10, with Sections 11-13 describing the overall methodology and steps for practical heat pump deployment at high density. Sections 14 & 15 cover the recommendations and conclusions from this feasibility study.

Whilst efforts have been made to present a consistent consortium position throughout this report, Sections 4-9 focus on the specific work packages produced by independent authors, some elements of thought and commentary may therefore not precisely align across the report. The executive summary and concluding sections have however been developed collectively across the consortium.

1.1. Heat Pump System Choice

As a founding member of the consortium, Kensa's existing shared ground array system (described further in Section 1.2) was used as the technical basis for developing a coordinated methodology for high density heat pump deployment in Leeds. This feasibility study did not consider a holistic approach to determine the 'optimal' heat pump system for high density deployment for several reasons:

- Emphasis on a single system allowed for focused consumer engagement, technical analysis and commercial development on this solution.
- LCC has deployed the shared ground loop array and shoebox heat pump system in various social housing projects, including the Clustering for Warmth project providing low carbon heat to 26 tower blocks. It is a cost-effective and high-performing solution that bypasses some of the limitations of traditional heat pumps. LCC were keen to build on their experience with this technology and the existing relationship with Kensa to understand its potential for wider deployment, especially in the able-to-pay sector.
- Having the system developer and heat pump manufacturer as part of the consortium ensured data sharing and communication on key areas was maintained throughout the project.
- The areas where the shared ground array system is most suitable (high densities of homes, e.g. terraced streets) are also those where individual air source heat pump (ASHP) and ground source heat pump (GSHP) systems may be most difficult to install and so this was considered a valuable sector of housing to target.
- It was assumed that the shared ground array system would be viable within sufficient areas of Leeds to facilitate installation at a sufficient scale for the HPR project. Several characteristics of the system complement the HPR project criteria as it is inherently high-density and has a lower impact on the electrical network than an equivalent number of individual ASHPs.
- It was expected that other HPR feasibility studies would be investigating the suitability of other technologies – important given that there is no 'one size fits all' solution to high density heat pump deployment in the UK.

The use of a single system does mean that elements of the methodology developed in this feasibility study are specific to the shared ground array, however, a number of the opportunities and issues identified also overlap significantly with high density deployment of heat pumps in general.

1.2. Technical Information – Shared Ground Array & Heat Pump System

The RHINOS project proposed using a shared ground array (also referred to as shared loop) system that has previously been deployed by Kensa, and this is referred to throughout the report.

In this system, a 'cluster' of homes (typically comprising 30+ properties on one or more streets) would be connected to a shared ground array, consisting of deep boreholes (~200m) and shallow distribution pipework that is installed in a communal location (e.g. the road) – see Figure 2. The shared ground array is equivalent to utility infrastructure, with consumers able to obtain a heat connection for their property in a similar way to existing electricity & water networks.

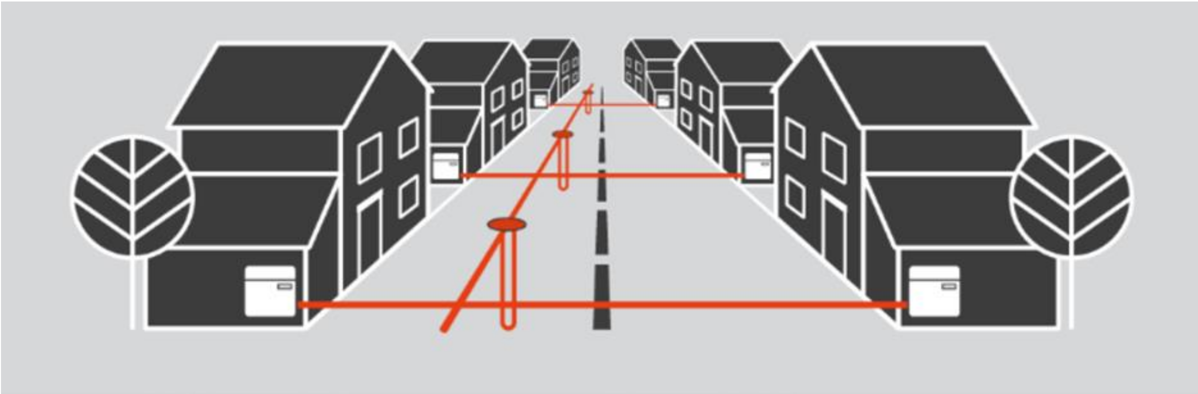


Figure 2 - Shared ground loop array diagram

The shared loop is a closed system, heat is extracted from the ground in the deep boreholes but no further centralised heating is provided and so it is defined as an ambient loop system (with typical temperatures of 5-10°C). GSHPs within each dwelling then extract heat from this shared loop and generate hot water for space heating or domestic hot water (DHW) at a high and consistent efficiency due to the relatively constant temperature from the ground. The dwelling heat pumps also provide all pumping of the shared loop, and no centralised energy centre/pumping station is required. For each dwelling, a range of Kensa heat pump models are available with selection based on the expected heat demand. DHW storage can be provided by Phase Change Material (PCM) thermal stores as these have a higher energy density and lower spatial footprint than traditional DHW vessels.

Key benefits of this system design are:

- The shared array is in effect a mini heat network for each cluster of homes and therefore benefits from diversity of demand, reducing the number/depth of boreholes required per property, compared to individual ground source systems
- Minimal noise or visual impact during operation
- High and consistent efficiency year-round that is largely unaffected by cold weather or humid conditions

Constraints of the system include:

- The space and additional upfront cost required for the boreholes and heat network
- The need for demand density to economise on the cost of the infrastructure

Further information on the performance, ownership model and cost of the system is provided in subsequent sections.

2. Aims, Expected Outcomes & Objectives

The BEIS HPR guidance states that the aim of Stream 1 (Phase 1) feasibility studies is to “support the deployment of heat pumps through the development and trial of innovative solutions and methodologies for the optimised deployment of domestic heat pumps, at high-density”. The RHINOS project followed this aim, with a specific heat pump system (individual heat pumps connected to a shared ground array) and focussed on Leeds as the trial area.

As stated in the RHINOS project proposal, the objectives for the feasibility study were:

1. Confirm the reduction of the lifetime costs of domestic heat pumps (including capital equipment costs, installation costs and operating costs.)
2. Develop communication strategies and effective approaches for community engagement to build a suitable consumer offer.
3. Enable a more flexible storage system that enables a shift of energy demand away from peak periods.
4. Inform policies that support the finance and deployment of shared ground arrays as a new utility, similar to broadband, water, electricity and gas networks.
5. Develop and strengthen partnerships between all stakeholders involved in the domestic heat pump, energy infrastructure and domestic housing stock sectors.
6. Provide confidence in the scaling up of demand for shared ground loop heat pump solutions so that UK companies can invest in opportunities for manufacturing and installation.
7. Inform planning policies to encourage local authorities and regional heat planners to prioritise opportunities for shared loop heat pump solutions.
8. Establish an evidence base to enable investment pathways to replicate high density heat pump deployment across the UK

The expected outcome from the feasibility study was to identify a number of suitable property clusters in Leeds where the shared ground loop array could be deployed in order to achieve the BEIS high density deployment criterion. LCC has pledged to achieve carbon neutral status by 2030 and this feasibility study forms an important element of how emissions from domestic heating could be reduced whilst also improving air quality and the comfort of homes for residents.

Alongside this, the consortium would develop a robust methodology and business model that would be applicable to other urban areas in the UK and further developed in Phase 2 of the HPR program.

3. Work Package Summary

The Leeds RHINOS project was organised into seven work packages (WPs). WP1 and WP7 covered project management and reporting, WP2-5 focussed on specific elements that would contribute to the development of a methodology for high density heat pump deployment and were led by different consortium partners to best utilise their specialisms and knowledge. Outputs from each WP fed into others, with an iterative approach intended to develop the methodology and supporting consumer offer through successive rounds of research & engagement, analysis, and design. A simplified diagram of the programmed interactions and key deliverables between WPs is shown in Figure 3 and the work packages are described briefly below.

WP1 – Project Management

Led by Arup, this WP provided day-day project management across the multiple consortium partners and other stakeholders. Key activities were preparation and monitoring of the project plan & risk register, organising whole-project meetings and ensuring that the other work packages had the required resource and data. WP1 also managed the interface with BEIS through the monitoring officer reviews and the preparation of invoices and deliverables.

Key deliverables - Project plan, risk register and status updates.

WP2 – Buildings & Network Mapping

Led by Arup with significant collaboration between Parity Projects, Northern Powergrid and Kensa, this WP provided the analysis, visualisation, and selection of suitable clusters of properties within Leeds, which was a key input for the progression of other work packages (particularly WP4 and WP5). The analysis considered the numerous technical criteria, based on requirements from BEIS, the DNO, and the shared ground array system to ensure a high-density deployment was feasible.

Key deliverables – Methodology for property selection and shortlist of viable Leeds clusters.

WP3 – Consumer Research

Led by LBU, this WP provided high quality data on the attitudes of Leeds residents to the proposed heat pump system and consumer offer, which was a key data input for WP5 and WP6, but also set the context for the whole consortium. Key activities were recruitment of Leeds residents for engagement, preparation of interview/survey questions (utilising supporting data from other WPs on specifics of the RHINOS offer), and interpretation of results. Three rounds of engagement with residents were undertaken.

Key deliverables – Findings and data from the three rounds of engagement.

WP4 – Detailed Design

Led by UoL, this WP provided a more detailed analysis of the shared ground array system for clusters of properties identified in WP2 to provide confidence in the expected system performance, and to validate design assumptions for high density deployment, which fed back into the WP5 business model analysis. Key activities were assessing the property heat demands in detail, understanding the implications for borehole and shared ground array design, and proposing a monitoring strategy for consideration in deployment. WP4 was originally intended to also cover analysis of the impact on the local grid, however during the course of the project these assessments predominantly took place as part of WP2.

Key deliverables – analysis model of shared loop array and monitoring strategy.

WP5 – Funding & Business Model

Led by Kensa and Legal & General, this WP provided the development of the consumer offer (for residents) and financial model (for business) for the shared ground array system in the private owner/occupier market. Key activities were development of a whole-life cost model, assessing the role of private finance and using the model to understand the sensitivity of consumer costs and financial returns to a range of scenarios (as informed by WP3 research).

Key deliverables – 'Cost to Consumer' calculations and overall consumer offer.

WP6 – Supply Chain & Quality Assurance

Led by Otley Energy and UoL, this WP provided investigation into the current supply chain (specific to the needs of the shared ground array system) to understand risks and opportunities with both immediate and wider deployment. This WP also provided research into processes and standards that cover all stages of heat pump deployment, to establish a holistic proposal for a customer journey to ensure quality assurance and customer protection during deployment.

Key deliverables - Supply chain map, diagram of processes and customer journey template.

WP7 – Communication and Dissemination

Led by Arup, this work package predominantly provided the summarising of the feasibility study work at the end of the project into this report. LCC or Arup also attended events and meetings during the project as part of HPR Stream 3 knowledge sharing activities.

Key deliverables – Feasibility study report.

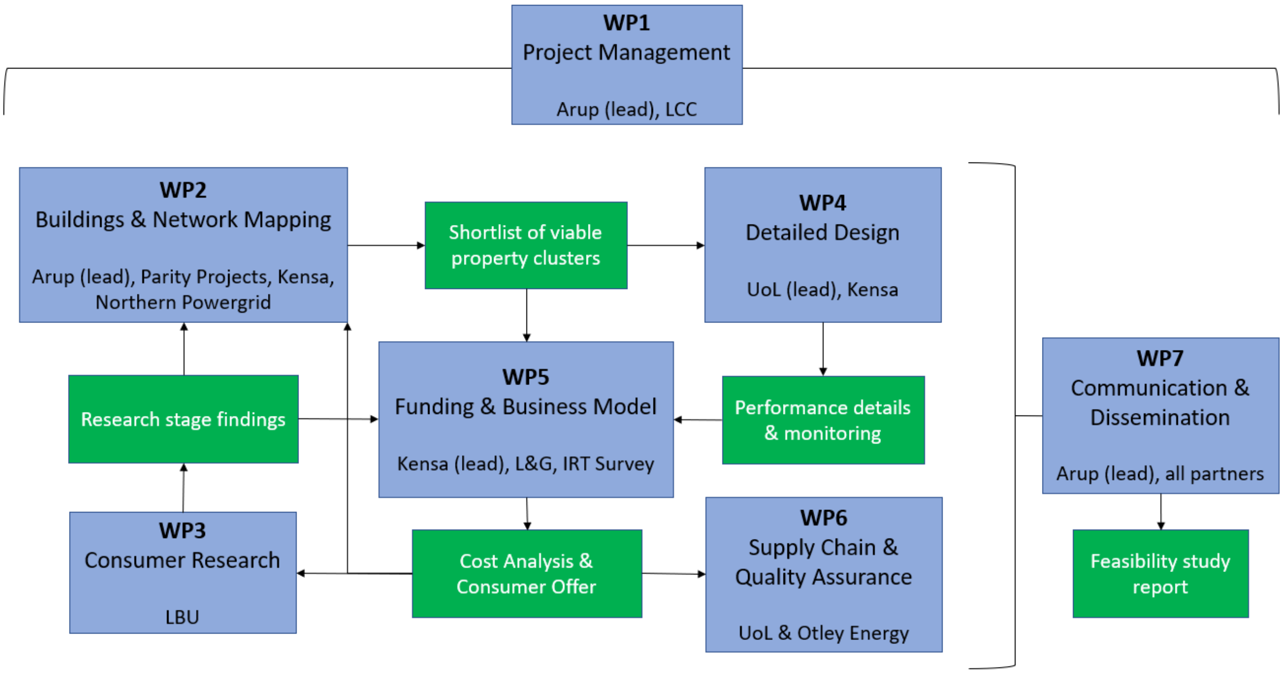


Figure 3 – RHINOS Work Package Interaction

4. WP2 (Buildings & Network Mapping) - Methodology & Findings

WP2 consisted of three principal stages which are described in detail in this section:

1. Gathering information on properties in the Leeds wards and the local electrical networks to assess the quality of data available to the consortium and any gaps – Section 4.1
2. Developing tools and a repeatable process to identify properties where deployment of the shared ground array system could be considered (incorporating rules and filters based on BEIS, Northern Powergrid and Kensa criteria) – Section 4.2
3. Using the developed process to find suitable clusters of homes in Leeds and generate a shortlist of the most promising clusters for assessment by other WPs - Section 4.3

4.1. Information Gathering

Properties

Three Leeds wards were selected by LCC for the feasibility study: Chapel Allerton, Roundhay and Otley & Yeadon. Housing stock in these areas was assessed using Parity Projects' Pathways software. This uses public Energy Performance Certificate (EPC) data on each home, alongside Ordnance Survey data, Light Detection and Ranging (LiDAR) data and other data sources to populate a Reduced Data Standard Assessment Procedure (RdSAP) dataset for each property, with data gaps being filled in from neighbouring properties where required. Alongside the property specific data, the software contains a dataset of potential installation measures (e.g. fabric measures, heating systems, solar PV), as well as a representative price dataset for each.

Electrical Network

The RHINOS project proposal stated that high density heat pump deployment at the low voltage (LV) feeder level would be targeted (each LV network typically supplies around 100 homes). Data on the LV electrical network was required to understand the feasibility of high-density deployment in specific locations, key data being the number of homes connected to a given LV feeder and the current headroom. Northern Powergrid introduced their public, web-based AutoDesign tool which provides an indication of the feasibility of new connections at the LV feeder level, based on existing capacity on each network.

Issues were encountered with the sharing of some data as a non-disclosure agreement (NDA) was originally a Northern Powergrid requirement to obtain network data that was not publicly available. Agreement on the NDA delayed access for 2-3 months and was not resolved, although an alternative solution was reached, with a restricted dataset provided that covered only specific Leeds areas and with individual supplies removed. Access to internal Northern Powergrid tools and other datasets which provide premises and additional LV feeder data was not possible during the project but further collaboration for Phase 2 of HPR was discussed.

Additional data made available by Northern Powergrid included some of the data used by the AutoDesign tool, which contained a table of capacity of each secondary substation and LV feeder as well as the number of connected domestic & non-domestic properties. Northern Powergrid stated that the majority of LV feeders are not monitored, and so the provided capacity values are generally estimates. A higher proportion of secondary substations are monitored, although full monitoring of demand is currently only carried out at the primary substation level. Northern Powergrid are currently in the process of increasing the monitoring of LV networks to provide higher quality data, and it was stated that networks of interest could be prioritised for monitoring as part of heat pump deployment (i.e. HPR Phase 2) if required. Whilst within the scope of HPR, the number of properties supplied by a primary substation, and therefore the quantity of heat pump installations required to meet the high-density criterion, was deemed unsuitable for the Leeds RHINOS project.

Another key dataset obtained at a later point in the project from Northern Powergrid were shapefiles defining the LV network cable layout. Other information on the Northern Powergrid network was provided informally, such as typical locations where triple concentric, twin phase cables may be present (these are from older installations and would require replacement to accommodate any significant additional load).

4.2. Developing tools and processes

Properties

A method was required to reduce the full list of 33,000 properties in the three Leeds wards to those where a shared loop system was technically feasible, whilst also meeting the BEIS project criteria and aligning with local grid constraints.

The full set of criteria was collated and a high level, initial flowchart of this selection process was developed (see Appendix 1 – Property Selection Flowchart), which proposed using the LV feeder data as the first level filter, ruling out areas with limited capacity before addressing other criteria. However due to the delays in obtaining this data from Northern Powergrid, the order of the selection process was altered to maintain the overall feasibility study program, as outputs from WP2 were key dependencies for other WPs.

As a first pass, filters were created in the Pathways software following discussion with the WP2 group (see Table 1), to rule out homes that were judged to be less suitable for the shared loop array and/or for meeting BEIS criteria. These filters could be refined in future assessments; however, they were judged suitable at this feasibility study stage to quickly reduce the number of homes under consideration and produced a list of approximately 1,900 properties.

The Parity Pathways tool encompasses visualisation software to allow for powerful interrogation of the results, which was used to produce an interactive heatmap of the 1,900 properties to assist with identifying high density clusters (see Figure 4).

Table 1 – Initial property selection criteria

Property Criteria	**Rationale**
Not detached	Size of property and proximity to others likely to be an issue for the heat network
Standard Assessment Procedure (SAP) rating < 60	Homes that already have reasonable energy performance (EPC C or greater) less likely to benefit significantly from light retrofit measures and therefore less likely to see significant energy cost savings
Annual heating demand < 420 kWh/m^2	To rule out very poorly insulated or commercial properties
Index of Multiple Deprivation (IMD) Decile > 5	To target homes that are assumed to have a greater ability to pay (upfront or with monthly repayments)
Gas heating	To comply with BEIS criteria, but noting that non-gas properties could be added (up to the allowable proportion) at a later stage if compatible with the heat network
Not social housing or newbuild	To comply with BEIS criteria (<30% of a cluster can be social housing and new build)), but noting that these could be added (up to the allowable proportion) at a later stage if compatible with the heat network

Figure 4 – Heatmap of potentially suitable homes in the Roundhay ward

To provide an indication of post-retrofit energy performance, the Parity Pathways software allows SAP calculations to be run on each home to assess the estimated impact of different combinations of retrofit measures. A set of retrofit scenarios (see Table 2) were developed and run to provide estimates of heat demand, retrofit measure cost, future energy cost and other metrics for use in other work packages, alongside a comparison to the home's current (unimproved) performance. Whilst this is a powerful tool to indicate typical performance at the housing stock level, there are also limitations as to the accuracy of the calculations at an individual building level given the potentially limited and/or incorrect EPC data upon which the RdSAP models are based.

Table 2 - Modelled retrofit scenarios

Scenario	Description	Included retrofit or low carbon technology measures
No fabric measures	To see the impact of only changing the heating systems (i.e. from gas > heat pump)	No fabric measures
'Light' retrofit	Pre-set list of valid measures, i.e. those involving lower cost and disruption or commonly acceptable e.g. windows	- Cavity wall insulation - Loft insulation - Draughtproofing - Window upgrades
'Deep' retrofit	Pre-set list of valid measures, including those involving higher cost and more disruption	- External wall insulation - Internal wall insulation - Internal ceiling insulation - Solid floor insulation - Suspended floor insulation
Photovoltaic (PV)	PV and no-PV options applied to all scenarios	- PV array size estimated based on LiDAR data and allowed on south-facing roofs (no battery storage)
Heat Pump System Options	Restricting the heating system options to compare the impacts, due to different SAP calculation methods. Applied to all scenarios.	- Gas boilers (counterfactual / current scoring) - Individual air source heat pumps - Shared loop ground source heat pumps

Electrical Network

Northern Powergrid's public AutoDesign tool provides a means of assessing new electrical connection applications by taking the required supply size and then colour coding LV feeders on a map to give an indication of their capacity (see Figure 5). However, this is intended for new connection applications rather than as a batch or automated tool for specific demands such as heat pumps, limiting its usefulness to the RHINOS project as an initial method of filtering where a large number of potential clusters needed to be tested. The tool also provides limited additional information on the specific LV feeders; not showing actual capacity or identifying the cable and with no data export. Discussions with Northern Powergrid clarified the assumptions that are made within the tool, which assisted with subsequent assessment of LV feeder capacity:

- Using an option in the tool for a new heat pump connection bases the assessment on a fixed size ASHP, which is not applicable to the RHINOS project shared loop system. The ‘commercial load’ option therefore needs to be used so that an arbitrary demand can be assessed.
- LV feeders are automatically coloured red if there are >100 properties connected (regardless of estimated capacity)
- Approximately 25% of LV feeders have incomplete connectivity data and are therefore shown as orange (indicating a that a connection *may* be feasible)
- From within the tool, capacity on each feeder is not given and individual feeders are not distinguished for cross-reference back to other datasets.

Figure 5 –Typical output from AutoDesign tool for new connection request in Leeds

Further discussions with Northern Powergrid helped to determine a process for assessing the number of heat pumps that could be deployed to each LV feeder within current capacity limits (i.e. before network reinforcement is required), based on the network data that had been provided.

A key parameter is the after diversity maximum demand (ADMD) that could be assumed for heat pumps on the local electrical network. Diversity is used analogously within electrical and heating system design and is a measure of the observed average peak demand per home, as a proportion of the theoretical peak (i.e. a result of the fact that not everyone runs an oven or showers at exactly the same time). Northern Powergrid stated that they apply diversity factors derived from the 2014 Customer Led Network Revolution (CLNR) project to connection requests for multiple heat pumps, where each heat pump is <3.9kWe (if larger heat pumps are installed, no diversity is currently assumed).

The Kensa heat pumps proposed in the RHINOS project have a low peak electricity demand due to the relatively small size and high efficiency, with the larger Shoebox 6kW model expected to have a typical electrical demand of 2kW. The shared loop ground array requires a minimum number of homes to be viable, therefore inherently providing a degree of diversity and Northern Powergrid agreed that 1kW could be assumed as the additional average demand per heat pump for the purposes of the feasibility study assessment when using AutoDesign or the LV feeder data. For reference, for a ‘typical’ non-electrically heated house (i.e. with lighting, appliances and gas heating) Northern Powergrid would assume an ADMD of approximately 2kW.

High demand scenarios or limiting events were not considered in detail during WP2, however it was noted that the Kensa heat pumps automatically apply a random start up delay to mitigate cold start load (when all equipment restarts following a power outage).

Northern Powergrid advised that as well as capacity on a given LV feeder (which is fundamentally related to thermal limits on the cables), voltage drop is also a key design criterion. Northern Powergrid carried out some simple sensitivity studies considering heat pump connections to show that on smaller networks, the capacity limit is expected to be the driving constraint rather than voltage drop. However, voltage drop does become a constraint on physically longer LV feeder cables, which were assumed to be those feeders with >100 homes already connected.

Through collaboration with Northern Powergrid the rules listed in Table 3 were therefore applied to the LV feeder capacity data to assist in property selection.

Table 3 – Initial LV feeder selection criteria

LV feeder criteria	Rationale
Between 10 and 100 properties connected	Avoid very small LV feeders, which tend to be in more rural areas and properties are therefore likely to be unsuitable for the shared loop array system. Avoid longer LV feeders due to voltage drop constraints
> 10% capacity (measured/estimated maximum demand as proportion of cable limit)	Whilst it is recognised that a comprehensive methodology would consider deployment in grid-constrained areas, the specific timescales of the HPR programme (relative to the potential time for local reinforcement) and other deployment constraints meant that it was desirable to not be overly restrictive when initially considering grid capacity
No anomalous values	As noted above, some of the LV feeders have incomplete or poor data, which typically manifests as anomalously high/low values in the table
No commercial supplies (half-hourly meters)	Due to the wide range of potential demands from non-domestic properties, there was greater uncertainty in the estimated capacity on these LV feeders, which also comprised a small number of the total and so it was judged appropriate to rule these out

4.3. Shortlisting process

The first-pass filter on properties described in Section 4.2 produced a heatmap which was then used to identify specific clusters of properties to consider as areas for deployment of the shared loop system. For this feasibility study a manual approach was taken, areas with the highest concentration of eligible properties were considered first and a longlist of potential clusters was built up covering the three Leeds wards. This process was performed collaboratively with WP2 members, with the local knowledge of some project partners providing a useful verification step in corroborating or challenging the selection of specific streets. For future studies an automated/semi-automated approach could be developed to assist in ranking clusters, e.g. by calculating the density quantitatively based on distance between property coordinates.

This manual process predominantly considered whether the properties were in a suitable arrangement, i.e. clustered together on the same street or in an otherwise dense cluster such as a block of flats as this is a key criterion for the shared loop system (with shorter distances between properties reducing the capital cost of the shared loop infrastructure). The longlist contained approximately 800 eligible properties within 18 clusters across the three wards.

Within the identified clusters, there were generally a number of properties in the same street or area that had not met the initial filters defined in Table 1, particularly for terraced streets where homes are of the same construction and may have only marginal differences (e.g. SAP rating slightly over 60 or a slightly different IMD score). These non-flagged homes were recorded, as they represented an opportunity (pending further analysis) to increase the size of the heat network, or offer redundancy on uptake in that area given the typically small differences.

Shortlisting of properties was focussed on the requirements of the HPR Phase 2 application, which allowed the deployment to be broken down into four separate groups (with funding for installation of each group awarded separately). At this point, a decision was made to assess ‘high density’ at the secondary substation rather than LV feeder level, for the following reasons:

- Although secondary substations supply a greater number of homes, enough clusters had been identified that could meet the BEIS density criterion at this level
- Working at the secondary substation level offered more flexibility for the planned Phase 2 trial deployment. The arrangement of LV feeders was often found to not align with the desired heat network for a street (e.g. different parts of the street being supplied by different feeders) meaning that the homes on a single shared loop could be split between multiple LV feeders and not achieving high density on an individual one. Due to the separate density constraint of the shared loop array, it would not be possible to substitute homes from elsewhere on the same LV feeder.
- The number of streets supplied from different secondary substations is considerably smaller and so this reduced this risk of a split cluster, whilst also offering the possibility of increasing the deployment density if other clusters elsewhere in the substation supply area could be identified.
- Data on substation demand and capacity is generally of a higher quality due to increased monitoring.
- Investigation of the Northern Powergrid shapefiles showed difficulties in linking LV feeders back to the table of capacities, therefore not providing a simple ‘one stop’ map in the Pathways software where all filters and criteria could be assessed.

From the longlist, a further set of more detailed selection criteria were applied to identify the most promising clusters and ensure that the BEIS and updated electrical network requirements could be met, see Table 4.

Table 4 - Cluster selection criteria

Cluster Criteria	Rationale
Number of currently eligible homes in the cluster >30	As with all heat networks, the shared loop array benefits from diversity of heat demand with larger numbers of connected properties. 30 homes was stated by Kensa to be a reasonable minimum number of properties to achieve some diversity and reduce the average peak heat demand on the network (thereby reducing the borehole size required and capital cost). This criterion rules out some clusters where a larger number of 'almost eligible' properties are present, but was felt to be conservative at this stage of the feasibility study, and ensured that the most promising clusters were taken forward.
Cluster layout maximises heat network density and minimises length of pipework	A high density of homes maximises the cost-efficiency of the shared loop infrastructure as, shown in Section 7, there is limited scope for the per-home capital cost to increase. e.g. homes on both sides of a street preferred to a single side and networks that avoided 'wrapping' around multiple streets preferred – see Figure 6.
Most homes do not have the proposed light retrofit measures already installed (from Parity Projects dataset)	This is partially captured by the earlier filter for all homes to have a SAP rating < 60, but this acts as an additional check to ensure that homes will see a reasonable reduction in energy demand and therefore energy cost savings. It should be noted that this filter relies on the underlying EPC data to be correct, whereas it is known that assessors cannot always access loft spaces (for example) and so the true level of existing insulation is not always well known.
Home size, construction and SAP modelling show that post-retrofit peak heat demand will be <6kW	This allows the Kensa Shoebox heat pumps to be used (max. 6kWth) which are the default assumption for the heat pump cost within the business model (see Section 7)
Substation with sufficient capacity and where eligible properties reach 25% density, as well as having acceptable LV feeder capacity	To meet key BEIS criterion, and provide some confidence that the local grid will have capacity.
No other significant electrical network constraints	The longlist was reviewed by a Northern Powergrid engineer to identify any clusters with potential issues that could affect deployment (such as presence of triple concentric cables, looped supplies etc.)

Figure 6 – examples of property clustering. Top left - high density with shared ground array encompassing multiple streets possible. Top right – larger semi-detached properties spaced further apart with higher heat demands. Bottom – properties on one side of a street, limiting heat demand density

Following the shortlist process described above, the four most promising clusters were identified and formed the key output of WP2 – see Table 5. A number of other ‘reserve’ clusters were also identified; however, as these were under different secondary substations, they were not considered for the Phase 2 application (where a density target across all homes within a stage subgroup would have to be met, therefore a single substation was preferred). This showed that approximately 300 homes were judged suitable for the deployment of heat pumps with the shared ground array system across the clusters. More detailed design of the individual arrays would then follow alongside home surveys and other analysis to determine the expected heat loads and borehole sizing (see Section 6 as an example). The specific clusters were also used as the basis for the consumer cost calculations in Section 7. However, it is important to note that whilst there is some redundancy within the selected clusters (i.e. there are more than the minimum 30 homes in each) the findings from the WP3 consumer research (Section 5) showed that a low proportion of uptake is expected. This is difficult to incorporate into the selection criteria described in this section due to the unpredictable nature (from the available data) of which homeowners would be willing to take up the consumer offer.

Table 5 – Shortlisted Leeds clusters

Cluster Name	Ward	# homes that met criteria	Total homes in the area	Property type	# homes on secondary substation	Potential deployment density
Pasture Street	Chapel Allerton	86	130	Solid wall brick terrace	235	37%
Northbrook Street	Chapel Allerton	64	83	Solid wall brick terrace	295	22% (with scope to increase)
Bridge Avenue	Otley & Yeadon	47	47	Solid wall stone terraces	75	63%
Orchard Street	Otley & Yeadon	105	120	Solid wall stone terraces	290	36%
Total		302	380		895	

5. WP3 (Consumer Research) – Methodology & Findings

5.1. Background

This work package comprised three stages. First, semi-structured interviews with 15 members of the public were conducted to better understand Leeds consumers. Participants were asked about their heating systems, experiences, expectations, and preferences around heating behaviour, control, and perceptions of affordability. The findings from the interviews were taken and, with WP5 colleagues, used in to generate information for the public about the finance packages that could be made available. This information was tested during the second stage, which comprised four focus groups with members of the public. In these sessions, their attitudes towards heat pumps and their willingness to accept a change away from their gas boilers were explored. This included discussing potential finance scenarios around a switch to heat pumps, how acceptable the disruption caused by connecting to a high-density heat pump network would be, as well as how feasible it was to include energy efficiency improvement measures. The findings from the focus groups were used to develop a survey with the public to explore their response to the proposed heat pump package, their preferences for paying for a heat pump, and their barriers to joining a neighbourhood heat pump.

5.2. Methods

5.2.1. Interviews

Interviews took place between Monday, 22 August and Wednesday, 24 August 2022. They lasted an hour and took place in participants' own homes. Interviews were audio recorded and transcribed verbatim. Data were analysed thematically using the research question: "*What would engage people in taking the next steps in their heat pump journey*."

Interview participants

Fifteen participants were recruited by an independent fieldwork organisation. This small sample is characteristic of qualitative research. Purposive sampling was used to include a wide range of demographics. Potential participants were provided with a summary of the project and asked a set of screening questions relating to both themselves and their homes, plus whether they would be willing to pay to upgrade their heating system.

Participants were recruited from three areas of Leeds. Seven participants live in Roundhay, five in Chapel Allerton and three in either Otley or Ilkley. The majority of participants (eleven) were between 40 and 59 years old (73%), with one being between 30 and 39 and between 60 and 69 years old. The remaining two participants were aged between 70 and 79. Five of the participants were male. Ten were white British, while four were Asian or Asian British. The remaining participant was white European. Three social grades were represented: four were Grade B, seven were Grade C1 and the remaining two were C2. Seven households had children living at the address. Seven homes visited were semidetached (7), four were terraced, three were flats and one was detached. All but one of the participants owned their homes, and one rented. One of the participants, in addition to their own home, had other properties in the selected geographic areas, which they rented out.

5.2.2. Focus groups

The four focus groups took place on Thursday, 06 October and Friday, 07 October 2022. They lasted an hour and took place in a conference venue in Leeds. During the focus groups participants were shown a video, produced by Kensa, which showed a shared ground loop system and how it works. They were also shown an infographic (see Appendix 2 – Focus Group Infographic) to explain two alternative finance packages that were being developed. For ease of participant understanding, the shared ground loop system was referred to in the focus groups as a *neighbourhood heat pump*. Recordings of the groups were transcribed, and the transcriptions analysed using thematic analysis using the research question "*What would make people swap their gas boiler for a neighbourhood heat pump?*"

Focus group participants

Again, together with our recruitment partner, participants were identified. Potential participants were provided with a summary of the project and asked screening questions about themselves and their homes, plus whether they would be willing to pay to upgrade their heating system. To be eligible to take part they needed to be willing to pay to change their heating system to a heat pump. Participants with a range of demographics and a range of willingness to pay responses were selected to gain insight from people with a range of views and experiences.

The 20 participants were recruited from the three areas of Leeds. Seven participants lived in Roundhay, five in Chapel Allerton and 8 in Otley. Most participants (sixteen) were between 30 and 59 years old, with three aged 60-69, and one aged between 80 and 85. Six participants were male. Sixteen participants were White British, two were Asian or Asian British and two were Black British. Five social grades were represented: one was A, four were B, twelve were C1, two were C2 and one was D. Twelve households had children living at the address. Eight participants lived in semidetached homes (eight), five lived in terraced homes, five in detached homes and the remaining two participants lived in flats or bungalows. All but one of the participants owned their homes, and one rented. Two of the participants had, in addition to their own home, other properties, which they rent out. During the screening process, three participants said that they would be willing to pay up to £1,000 for a heat pump, fourteen said they would spend between £1,000 and £3,000, while the remaining three participants said that they would be willing to spend over £5,000.

5.2.3. Survey

An online survey was developed to measure responses to the neighbourhood heat pump offer. Survey items were informed by the findings from the interviews and focus groups, and from the heat pump offer that was developed as part of WP5. During the survey, participants were asked to watch a short video about neighbourhood heat pumps (the same as used in the focus groups). Participants then answered a series of questions about their interest in, and willingness to pay for, a heat pump fed from a shared ground array.

Survey participants

1000 survey participants were recruited via a panel organisation. To meet the project deadline, participants were recruited from across the UK, as recruiting 1000 participants from Leeds would have taken too long. To be eligible to take part they were required to be homeowners living in the UK, age 18 and above.

47% were male and 53% were female, 92% were White British. Most were working (56%), either full time (40%) or part time (16%) and 39% were retired or not working and not seeking work. We included people with a range of ages:

- 0.2% were age 18-24
- 6% were age 25-34
- 13% were age 35-44
- 19% were age 45-54
- 28% were age 55-64
- 24% were age 65-74
- 9% were age 75-84
- 0.8% were age 85+

Half had an undergraduate (36%) or postgraduate (14%) degree. A quarter (24%) had GCSEs or equivalent as their highest qualification, 13% had A levels or equivalent, and 11% had NVQ Level 1-3.

Most (57%) reported living in a suburban area, with 24% reporting living in a rural area and 18% an urban area. They reported living in a detached (38%), semi-detached (32%), terraced (20%) home or flat (10%).

Most had gas central heating (81%), followed by electric heating (6%), oil (6%), heat pump (2%) or solid fuel (1%).

Participants were asked to say how they were managing financially:

- 18% reported they were living comfortably
- 47% reported they were doing alright
- 26% reported they were just about getting by
- 7% reported they were finding it quite difficult
- 3% reported they were finding it very difficult

They were also asked a question about their attitude to new technology:

- 8% reported they like new technology and to be the first to try something new
- 53% reported they are reasonably interested in new technology but prefer not to buy it until they know it's reliable
- 28% reported they are less interested in new technology and prefer to wait until most people they know have got it and they can see the benefits
- 11% reported that they are not interested in new technology and prefer to use what they already have

5.2.4. Ethics

The study was reviewed and approved through the Leeds Beckett research ethics process. Participants were provided with information about the research and had the opportunity to ask questions before providing written informed consent. Participants received an industry-standard incentive for taking part.

The results are presented in three sections that summarise the results from the interviews (5.3), focus groups (5.4) and survey (5.5).

5.3. Results – Interviews

Five themes were identified in the data to answer the question "*What would engage people in taking the next steps in their heat pump journey*." The themes are described below and illustrated with representative quotes.

5.3.1. Cost

The cost of energy was a major concern to all our participants, and they talked about how they are willing, or have started, to take action to try to reduce the cost of their bills. Some had been making efforts to reduce energy costs for some time, while for others, this was new territory. All the participants were acutely aware of the increases in the energy price cap, and all were worried about how much their bills were going to increase. Not all the participants had heard of heat pumps, and those who had usually assumed they would be expensive. The cost of a heat pump was therefore the main question participants asked. They wanted to know about the overall cost of a heat pump, including the cost of the equipment, the cost of installing it, any fabric improvement costs, as well as the cost to run it and maintain it. Their cost baseline was the cost of replacing their gas boiler, which they typically anticipated would be £3,000 including installation. The cost of a heat pump was always compared to this and they would be reluctant to pay much more for a heat pump. Participants talked about how there should be a government incentive to contribute to the cost. Many talked about how this should cover the difference in cost between what they would pay for a heat pump and what they would pay to replace their gas boiler. Several talked about how providing interest-free loans would be a good way to encourage them to pay for a heat pump.

"Say £3,000 paid over, like, two years or something like that. I'd sign up today, literally would. Because, like I say, most of the time, these [finance] schemes are spread out over a ridiculous amount of time. I don't need ten years to pay this off, you know, I just need like a year or two. As always, with ridiculous amount of interest and in the end, you end up paying three or four times back. So, if you could just pay back what you paid out as the cost, that would be amazing."

While most talked about wanting to be environmentally friendly, the *cost* of a heating system was more important than carbon savings.

"I think that the sound of it is good. It's great. And I know it does work in social housing. Because I've seen what Leeds have done already. And it is working. I'd be interested in it. Definitely, it's cost. That's number one."

5.3.2. Payback period

Participants were prepared to “spend money to save money” and talked about how quickly they would expect a heat pump – and other energy saving technologies – to recoup the cost of their outlay. A wide range of payback periods was reported, with many participants claiming they would expect a heat pump to have paid for itself in energy savings within a year. Others would be prepared to wait two, three or five years.

“If it was a few thousand pounds, it probably wouldn’t be at least two years, I think plus two years would be a good figure to pay something back, if it was quite expensive.”

One participant reported that they would expect to recoup the cost “within my lifetime”. They differed from the others in that they had purchased solar panels and were more familiar with the concept of waiting many years to recoup the cost of an energy saving technology.

“The way we looked at it was what we were having to pay out in comparison to the grants we were getting, we wouldn’t see the money back in our lifetime. It’s more of a future proofing for future generations. Not us in particular. Right. If we were passing this house on to our kids, maybe, again, but then you don’t know what’s gonna happen in the future. We got the solars at the time knowing we were going to get our money back. And we were going to outlive the solars. So, we knew sort of what we were looking at there, we would recoup our costs, whereas I don’t think looking at the new [heat pump] systems, we’d actually recoup the costs.”

The landlord participant talked about how it would not be possible to recoup the cost of a heat pump on the properties they rent out, as tenants would be unwilling to pay a higher rent solely because a property has a heat pump. Any energy savings would therefore go to the tenant and would not offset the cost of the heat pump.

“I think they’d [the heat pumps] have to be paid for. I don’t think we’d want to pay for them doing because I don’t think it’d... I know it’s a bit bad, but I know it’d be nice for tenants but they’re obviously not going to pay for anything doing, so when we couldn’t put rent up to cover itself, I don’t think we would.”

The tenant participant held similar views and highlighted that they would object to their rent rising simply because a heat pump was fitted. In contrast, however, they talked about being willing to pay more to *buy* a home with a heat pump.

“if there was a house with a heat pump and one without, you’d want that, I think. I mean, if that was the clincher between the two things, you’d want the one with.”

Some participants talked about potential problems if they sold their house while still paying for the heat pump. They were concerned that there could be legal difficulties, or that a heat pump with outstanding finance would be less attractive to potential buyers.

5.3.3. Crisis management

A new heating system was not an aspirational purchase for our participants, and they usually replaced their boiler when it broke and could not be repaired, or when they were informed that their boiler would no longer be covered by their breakdown policy. This meant that they usually found themselves crisis managing their new heating system, meaning there was no time to research the different options. Participants talked about how boilers usually break down in the winter, and so there is a need to get it repaired or replaced as soon as possible. This means that they want to go for the quickest option possible, which is inevitably a replacement gas boiler. They did not have the time to explore alternatives.

"I would like to think that I am eco-friendly. I do all the right things. But sometimes if I wanted a boiler, and I needed it ASAP, then I might forget about being eco-friendly. And I might just put a new boiler in because it's easy, and it's convenient. I think it's probably more easy and convenient to have that in."

We heard about one other situation in which people often replace their boiler: when they move house, and they believe the boiler in their new home will break soon. A few of our participants had made enquiries about a heat pump but had been told that their home was not suitable or would require a hybrid system. This meant that they returned to the "normal" option of a gas boiler.

"I did consider these heat pumps. Oh, yeah. And I looked at that, but they were at the time, out with my price range. And also, I was advised that they weren't the best for houses like this – older houses – so I was told. So, I thought, I'll just go to the easy route of a combi boiler to be honest."

Some of our participants were nervous of their boiler or didn't understand the controls and preferred not to interact with it. Seven participants controlled their boiler through an app and found this easier.

5.3.4. Disruption

Our participants wanted to minimise any disruption arising from changing their heating system. Because most of our participants were unfamiliar with heat pumps, they didn't know what the installation process would be, although they expected it would be more disruptive than a replacement gas boiler. They wanted to minimise the time they spent without heating and hot water, as well as minimise the disruption from the installation process. They didn't want workers in their home for any longer than necessary. This meant that they were wary of having their road or garden dug up. They were also wary of committing to a heat pump if it requires them to have fabric improvements to their home. They talked about how insulation is relatively easy to install in new homes, but it can be more difficult in older homes. They were also reluctant to do anything that involves lifting floors or disturbing walls.

They were unsure what maintenance a heat pump would require but suspected it would be more involved than maintaining a gas boiler. They were also nervous about how expensive and difficult it would be to repair a broken heat pump. They wondered whether they could get a care/repair policy, similar to their gas central heating system.

Participants were also wary about how a heat pump might disrupt their lifestyle more generally. A few talked about how they wouldn't want to be without their gas hob or gas fire. Some cook in a way that needs a real flame, e.g. to make chapatis. Some wanted the instant heat and the ability to heat just one room, provided by their gas fire.

"What I look forward to in wintertime – just turning this [the gas fire] on and it looking like a coal fire and the flames. And plus, the most important part of my cooking is using a gas flame. So that's why I would never have an electric cooker because it has no flame."

Several raised concerns that if their neighbours used a lot of heating or hot water there wouldn't be enough for them and were worried that this could cause conflict between neighbours. Nevertheless, they talked about being encouraged by groups of neighbours signing up to a heat pump.

5.3.5. Information

This theme is about how people would find out about heat pumps and the questions they have. All our participants expected that they would start with a web search, but they talked about how they are sceptical of a "sales pitch" they are likely to get from a heat pump company website.

"It's very hard to actually get somebody who you can trust to believe. I'm nonplussed by a lot of these so-called experts, you know. Where did you spring from, you know? Last week he was stacking shelves in Tesco and now you're an expert on something. I suppose an acknowledged engineer with no ties to any of anything, either government or manufacturers to give an unbiased appraisal that is believable, showing the rights and wrongs or the good points, bad points – that would help a hell of a lot."

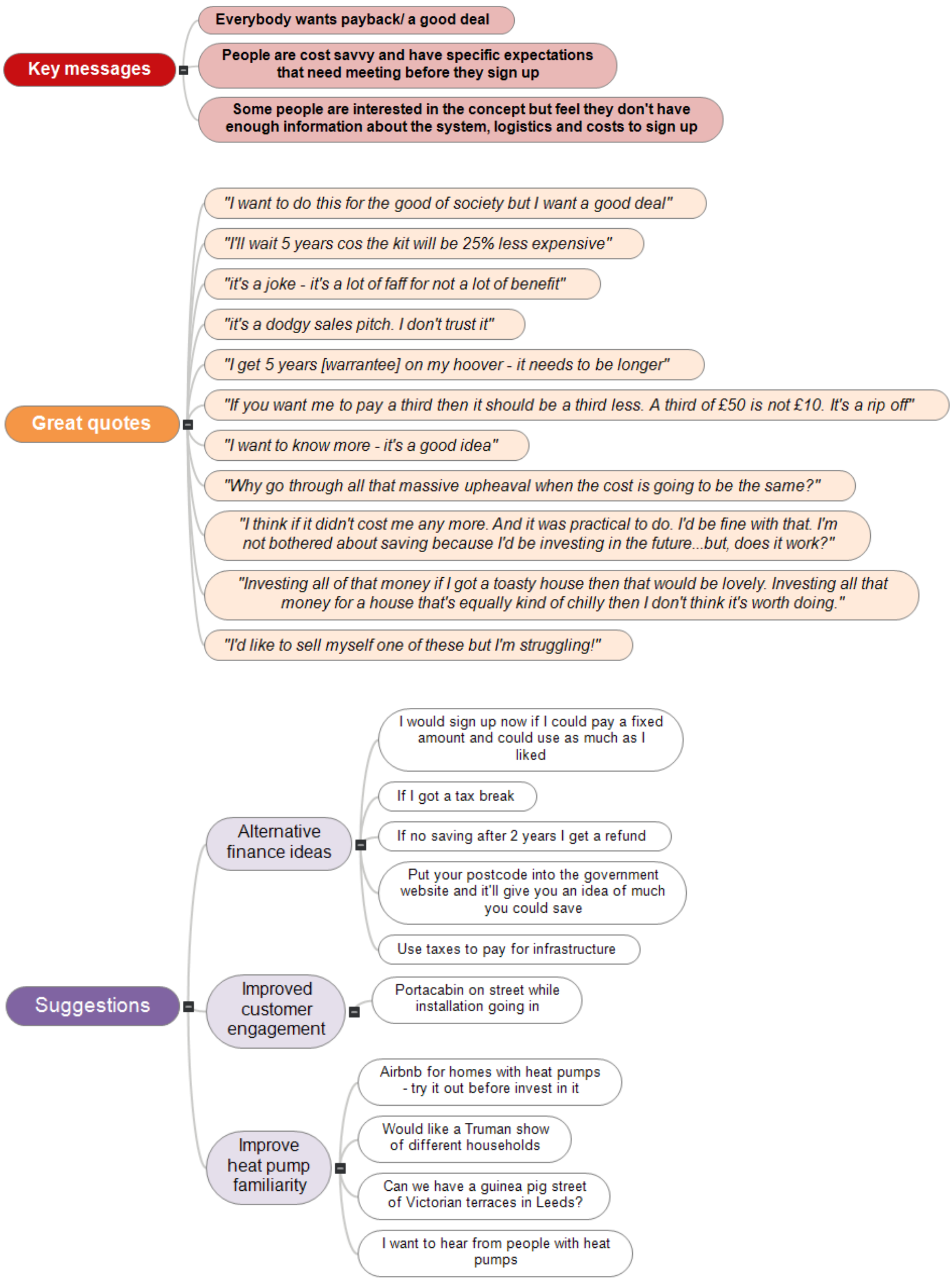
Many talked about how they would normally ask friends and family for advice. However, few of our participants knew anybody with a heat pump. Many would ask a trusted tradesperson, for example a gas engineer who has serviced their boiler. A few talked about how they knew this could mean they get biased advice favouring gas boilers, but nevertheless wanted to hear their opinion.

Participants were interested in visiting a heat pump display home where they could see what a heat pump looks like, sounds like, and how to operate it. However, they would also like to talk to somebody who has a heat pump installed. One of our participants, who had looked into getting a heat pump, talked about searching on a property sale website to try to find one with a heat pump that he could view, ostensibly as a potential buyer, but really to see the heat pump in a real-life situation. They wanted to find out about the reality of using a heat pump.

"It's always nicer to go talk to a client who's got it in the house, and it's working. And they're using it, and they're telling you what they're saving, you know, what their energy costs are. I mean, I promote solar panels to anybody because of what we're saving. And I've got evidence, I can prove it and I can show them my bills."

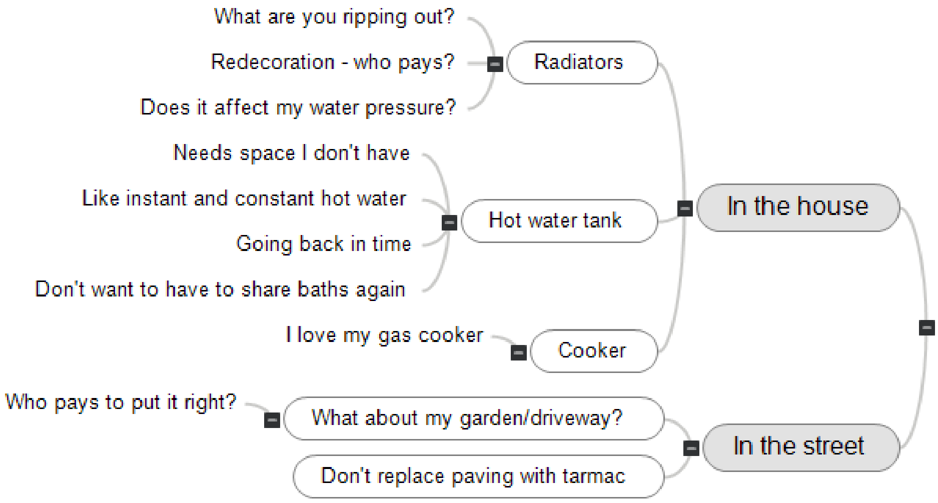
5.4. Results – Focus groups

Our focus group analysis addressed the research question "*What would make people swap their gas boiler for a neighbourhood heat pump?*" The themes we identified are described below and illustrated with representative quotes.



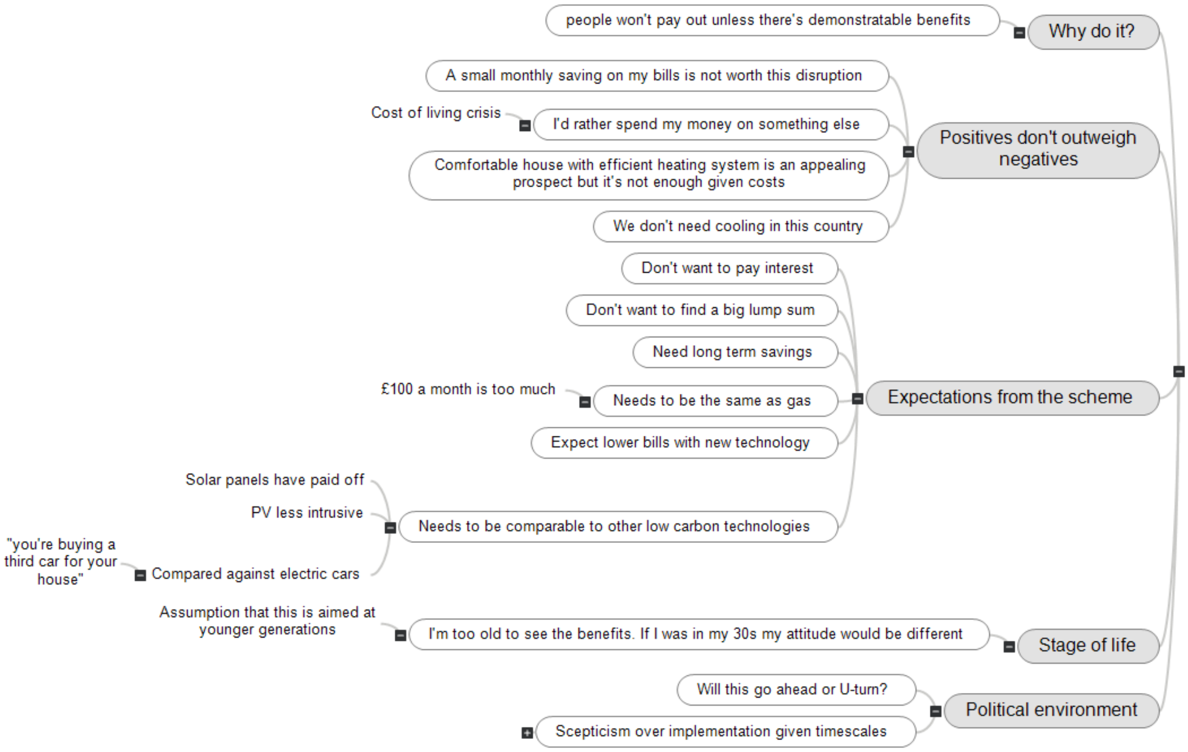
5.4.1. The faff factor

This theme is about the perceived hassle, or “faff” of converting to a heat pump and the possible lifestyle changes it might involve. Participants were wary of the disruption that a heat pump might involve, such as the need to dig up the streets to install a ground array, or their garden or drive to connect to the ground array. Many were unsure about how practical it would be to find space for a heat pump (which may be bigger than their current boiler) and space for a water cylinder. The water cylinder in particular was perceived as an inconvenience. Participants with small homes worried about how much space it would take up. Many talked about how they remember having an Immersion heater before their combi boiler, and sometimes ran out of hot water or had to wait for the water to heat. They perceived having a water cylinder as a backward step. Participants were also wary of the disruption that might arise from having to replace radiators or installing insulation. Some had explored internal or external wall insulation and had rejected it as being impractical, unattractive, or unsuitable for their home.



5.4.2. No perceived benefit

This theme describes how participants did not perceive sufficient benefit in the offer to sign up to a heat pump. While all wanted to make a positive contribution to the environment, they didn’t want to feel they were being penalised for doing so. They talked about how they were being asked to make a large financial commitment for seemingly very little reduction on their bills. The perception that this is a poor deal was compounded by interest being payable on the loan: they expected an interest-free loan. The possibility of their heat pump providing a cooling air conditioning feature was not perceived as sufficiently attractive: they highlighted that there are very few days in the year when this would be useful. Participants contrasted the heat pump offer with those offered by solar panel companies. These were perceived as being much more attractive, with clear financial illustrations that showed how the outlay to purchase the solar panels would be recouped in a reasonable amount of time.

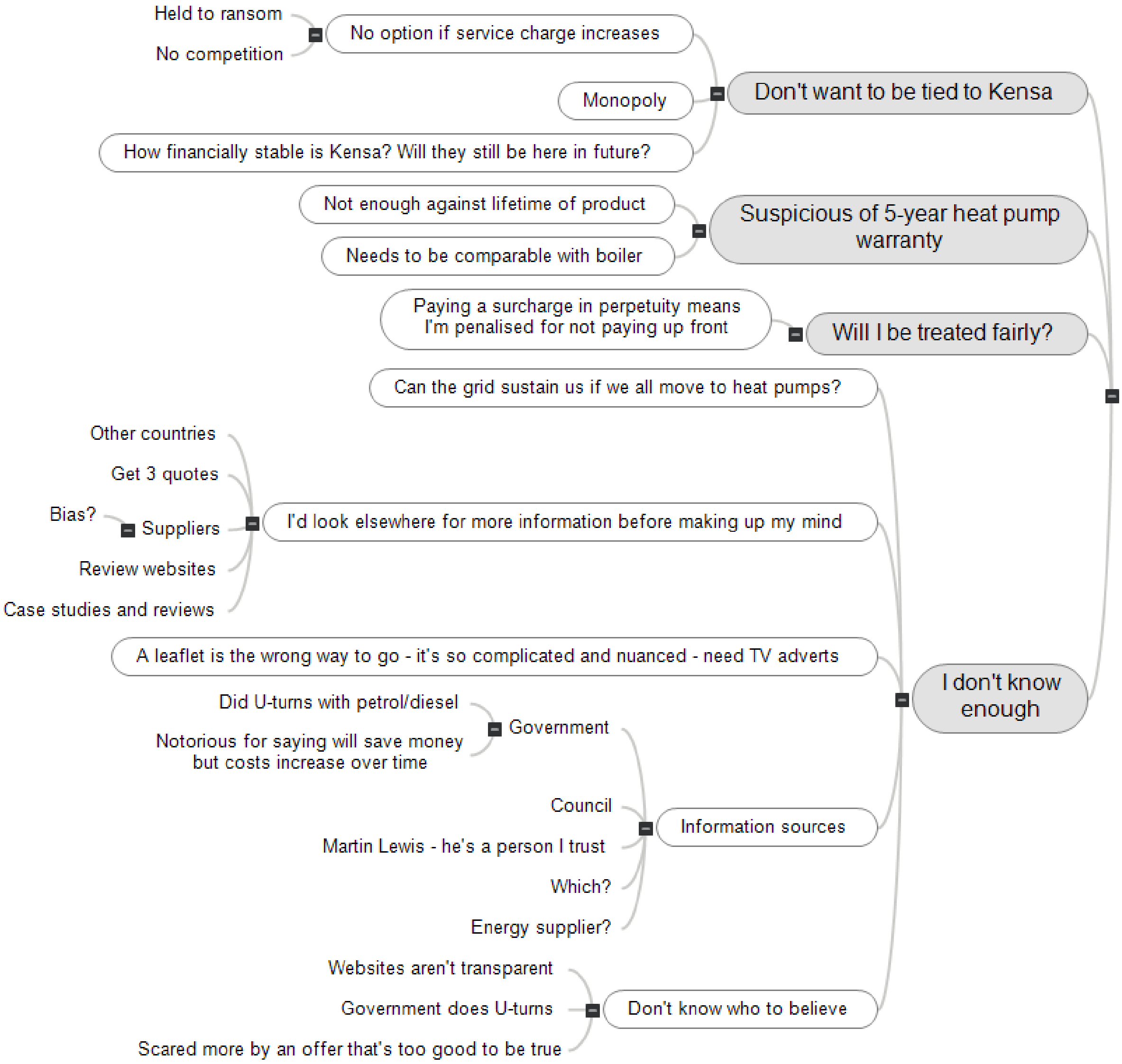


5.4.3. Trust

This theme describes the limited trust that participants had in the heat pump offer. Participants discussed who they would trust with information about heat pumps. While council involvement was reassuring, they wanted independent advice about the advantages and disadvantages of heat pumps and the contracts available. Martin Lewis was suggested by all the groups as a trustworthy information source.

Participants were all very reluctant to sign up to a service that would leave them "hostage" to the company that owns the ground source array. They were concerned that Kensa could increase the cost, or demand repair costs from them, and they would have no option but to pay. There were many aspects of the offer that generated this distrust. Participants believed that the financial alternatives were designed to make a profit for Kensa. The need to pay a bill surcharge in perpetuity was viewed as being unfair. This unease was compounded by being unable to obtain quotes from alternative suppliers. The five-year warranty on the heat pump was considered insufficient, and indicative of poor-quality equipment. Furthermore, participants were unsure about whether the ground array could supply sufficient hot water for the whole neighbourhood, and whether they may find themselves without hot water if their neighbours were heavy consumers.

Participants also lacked trust in government policies. They were concerned that they could go through the cost and disruption of getting a heat pump only to find that there is a policy U turn and heat pumps are no longer considered good for the environment. All the groups talked about how previous recommendations to buy a diesel vehicle to protect the environment were soon replaced by advice to buy petrol.

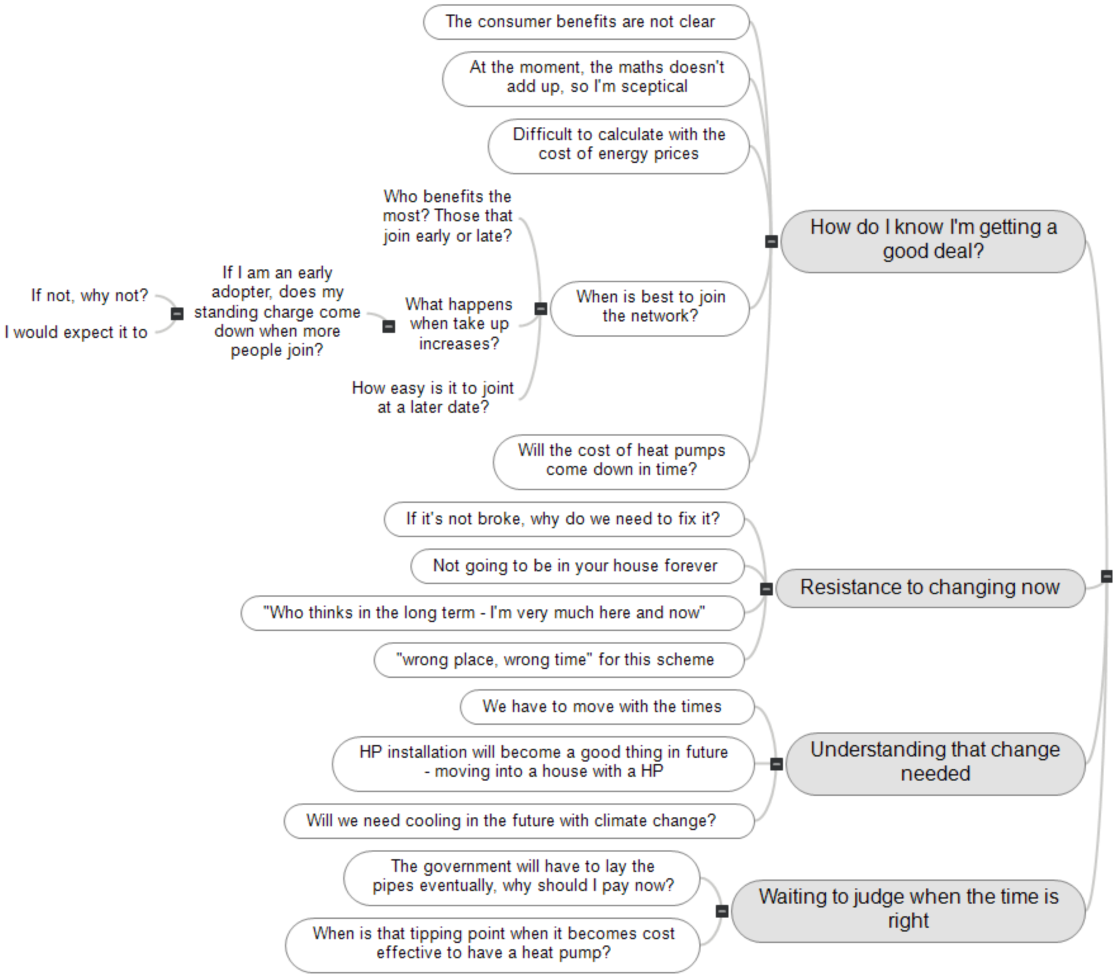

Held to ransom
No competition
No option if service charge increases
Monopoly
Don't want to be tied to Kensa
How financially stable is Kensa? Will they still be here in future?
Not enough against lifetime of product
Needs to be comparable with boiler
Suspicious of 5-year heat pump warranty
Paying a surcharge in perpetuity means I'm penalised for not paying up front
Will I be treated fairly?
Can the grid sustain us if we all move to heat pumps?
Other countries
Get 3 quotes
Bias?
Suppliers
Review websites
Case studies and reviews
I'd look elsewhere for more information before making up my mind
A leaflet is the wrong way to go - it's so complicated and nuanced - need TV adverts
I don't know enough
Did U-turns with petrol/diesel
Notorious for saying will save money but costs increase over time
Government
Council
Martin Lewis - he's a person I trust
Which?
Energy supplier?
Information sources
Websites aren't transparent
Government does U-turns
Scared more by an offer that's too good to be true
Don't know who to believe

5.4.4. Timing

This theme is about participants' concerns that now is not the right time to invest in a heat pump. There were several reasons for this. Some had only recently changed their gas boiler, and others preferred not to replace it until it breaks. For some, this was because they didn't want to pay for a new boiler until necessary, but for some it was because they were concerned about the embodied carbon in their gas boiler.

Another common reason was the belief that if everybody is expected to convert to a heat pump then there will need to be government incentives, and the incentive currently on offer was not viewed as large enough. They believed that incentives would increase over time, so that purchasing a heat pump now would mean they lose out financially. They also believed that the cost of heat pumps will reduce in the future: they highlighted that new technology is always more expensive to begin with and cost rapidly decrease over time.

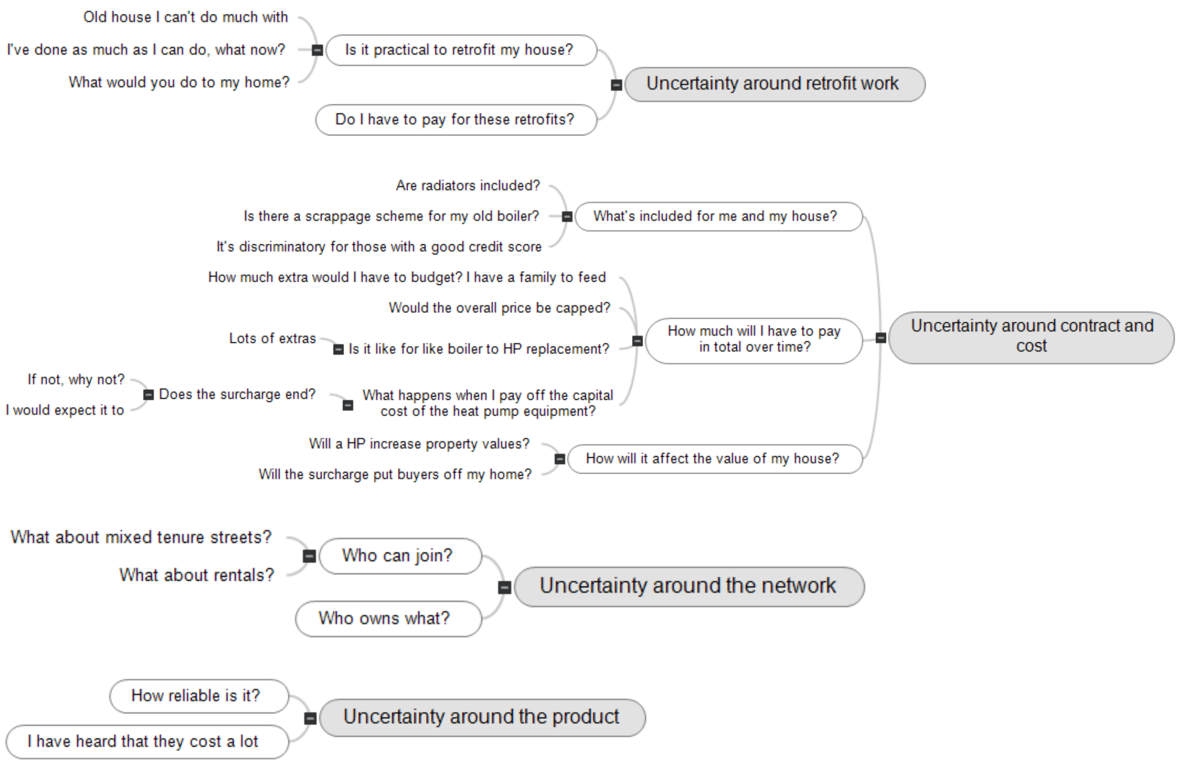
There were also questions about what would happen if more people were to connect to the ground array in the future. They understood the need for a standing charge to pay for the ground array and its maintenance and assumed that the cost would be lower if more people were to connect to it. They reasoned that if the standing charge is to cover costs (rather than make a profit) then in the future people will pay less. They suspected it would be better to wait for a few years until more people had connected, when the standing charge would be lower.



5.4.5. Uncertainty about the offer

This theme is about how participants wanted much more detail – particularly financial detail – than was available. During the focus groups, several of the participants used their calculators to try to work out which of the finance packages provided the more advantageous terms. They did not think that the figures made sense. They wanted personalised projections about how much they would pay and how much they would save. They also wanted much more detail about the retrofit that would be required on their homes, what it would involve, and whether they would be paying for it themselves (either directly or as part of the package) or it is included as a heat pump perk. Some talked about how they had already insulated their home and didn't think there was much more that could be done to make it more energy efficient. In some cases, this was because they have an old home with character features they would not want hidden by internal wall insulation, or that they had been told their home is not suitable for cavity wall insulation. All would expect an individual consultation in which they received a personalised projection for costs, and details of exactly what retrofit measures would be involved. There was also some uncertainty about whether a property that had signed up to a permanent bill surcharge would be more difficult to sell, or whether it would be perceived a bonus that the new owners would not have to undergo the disruption involved in installing a heat pump. Participants also had questions about what would happen on mixed tenured streets in which there were some private homes and some social housing ones: would social housing tenants have a choice? Would privately owned homes pay more?

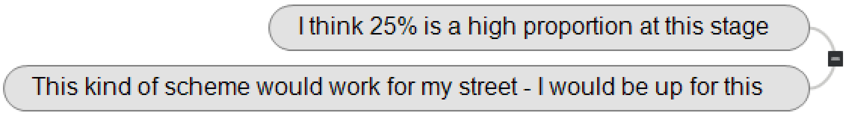
Finally, participants wanted more assurance than currently offered that they would be saving money – that their bills would be sufficiently lower that over time they would recoup the financial outlay.



5.4.6. Willingness to pay

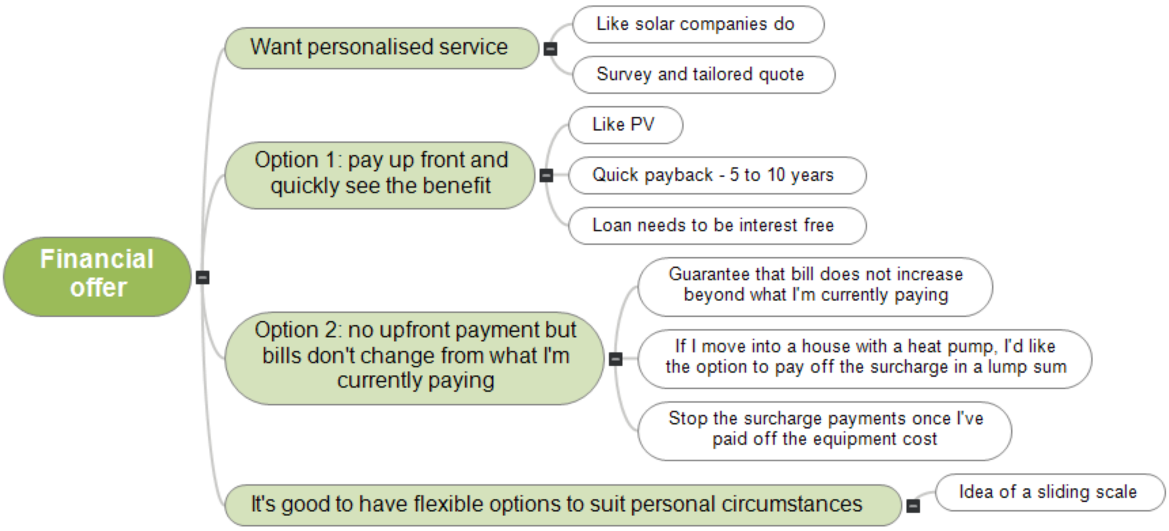
This theme describes how participants would potentially be willing to sign up to the heat pump scheme, providing there is sufficient detail. With the current lack of detail most participants suspected that there would not be 25% of their neighbourhood willing to commit. However, with more detail, and clear financial benefits, they thought that in some areas it could work. They highlighted how this sort of scheme would be much better suited to new builds, so that there is no disruption involved.

The groups included a discussion of an alternative way of framing the offer: a warm, comfortable home (due to better insulation) with no increase in bills. Many of the participants thought that this would be a more attractive offer, but they wanted a guarantee that their bills would not increase. They talked about the financial offers being so unattractive it made them suspicious that there would be hidden financial penalties.



5.4.7. The financial offer

Below we summarise participants' responses to the two finance packages proposed in WP5.



5.5. Results – Survey

Participants were first asked how much they know about heat pumps. The largest proportion (44%) reported that they knew a little, as shown in Figure 7.

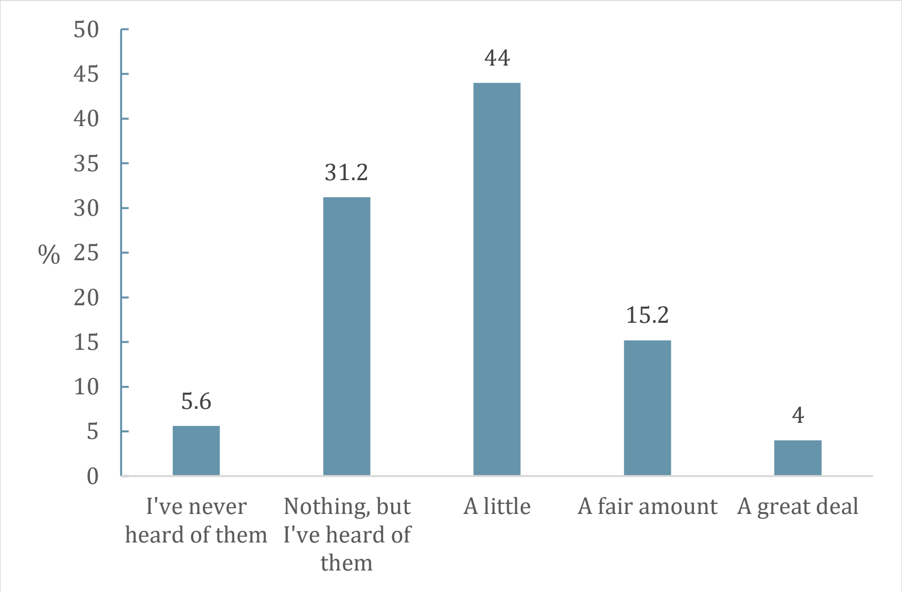


Figure 7 - how much participants had heard about heat pumps.

5.5.1. Who is more interested in getting a neighbourhood heat pump?

Chi squared tests (which tests associations between variables) were conducted to explore how interest in a neighbourhood heat pump varies with demographics. These demographics had a statistically significantly association.

- Age group (chi squared = 21.54, p = 0.003) – the younger age groups – 18-34, 35-44 and 45-54 – were more interested.
- Gender (chi squared = 7.34, p = 0.025) – females were more interested.
- Employment status (chi squared = 21.74, p = 0.16) – those working 30 hours a week or more were most interested.
- Highest level of qualifications (chi squared = 28.82, p < 0.001) – those with a Masters degree or higher were most interested and those with GCSEs/A levels were least interested.
- Financial situation (chi squared = 18.03, p = 0.003) – those who are finding it very difficult to manage financially were least interested.

Type of area (rural, suburban or urban) did not have a statistically significantly association (chi squared = 3.68, p = 0.16).

5.5.2. Payment preferences

After watching a video to explain the Kensa neighbourhood heat pump system, participants were told:

"Imagine that it will cost you £6,000 to install a neighbourhood heat pump in your home (including a discount from a government grant). You can pay this amount up front (Option 1), you can pay it back monthly (Option 2), or you can pay some money up front and the rest monthly (Option 3)."

They were asked to select their preferred option, and they were also able to select that they were not interested in getting a neighbourhood heat pump.

- 16% preferred to pay up front.
- 18% preferred to pay the heat pump company monthly.
- 23% preferred to pay some up front and the remainder monthly.
- 43% reported that they were not interested in getting a neighbourhood heat pump.

Preferences for paying up front (Option 1)

The 16% of participants who preferred this option were asked how they would prefer to pay.

- Most (89%) preferred to pay using their own savings.
- 4% preferred to get a loan from the bank or building society.
- 4% preferred a mix of their own savings and a loan.
- 2% preferred a loan from the heat pump company.
- 1% preferred a mix of their own savings and a loan from the heat pump company.

While only a small number (23) wanted to pay using a loan, most of these (13, or 56%) preferred a personal loan, while the remaining 10 (44%) were split evenly between those who preferred a property-linked loan (i.e. you pay the loan back while you own your home, if you sell your home, the new owner takes over the repayments), and those who preferred an equity loan (i.e. you pay the loan back while you own your home, if you sell your home the loan is repaid).

Preferences for paying monthly (Option 2)

The 18% of participants who preferred this option were asked how much they would prefer to pay each month. The amount varied from £5 to £1,000 with the median amount being £100.

Preferences for paying some up front and the remainder monthly (Option 3)

The 24% of participants who preferred this option were asked how much they would prefer to pay upfront. The modal amount was £2,000. Most (84%) would prefer to use their own savings, with the remainder preferring to use a mix of savings and loan, either from the heat pump company (7%), or a bank or building society (5%). Few wanted a loan to cover all the upfront costs: 3% from a bank or building society and 2% from the heat pump company. The small number of participants (42) who would take out a loan would prefer a personal loan (26), a property-linked loan (10) with the least preferred option being the equity loan (6). The modal amount they would like to pay up front was £100.

Standing charge

The 57% of participants who were interested in a neighbourhood heat pump were told:

> *'To be part of a neighbourhood heat pump network, you also need to pay a monthly standing charge on top of the installation cost and energy bills. This goes to maintaining the network and is similar to the standing charge on your gas or electricity bill. Imagine this standing charge is £50 a month."*

They were asked three questions: whether they could afford to pay; whether the standing charge affects their preferred payment option; and whether the standing charge would stop them wanting to install a heat pump. Their responses are summarised in Figure 8.

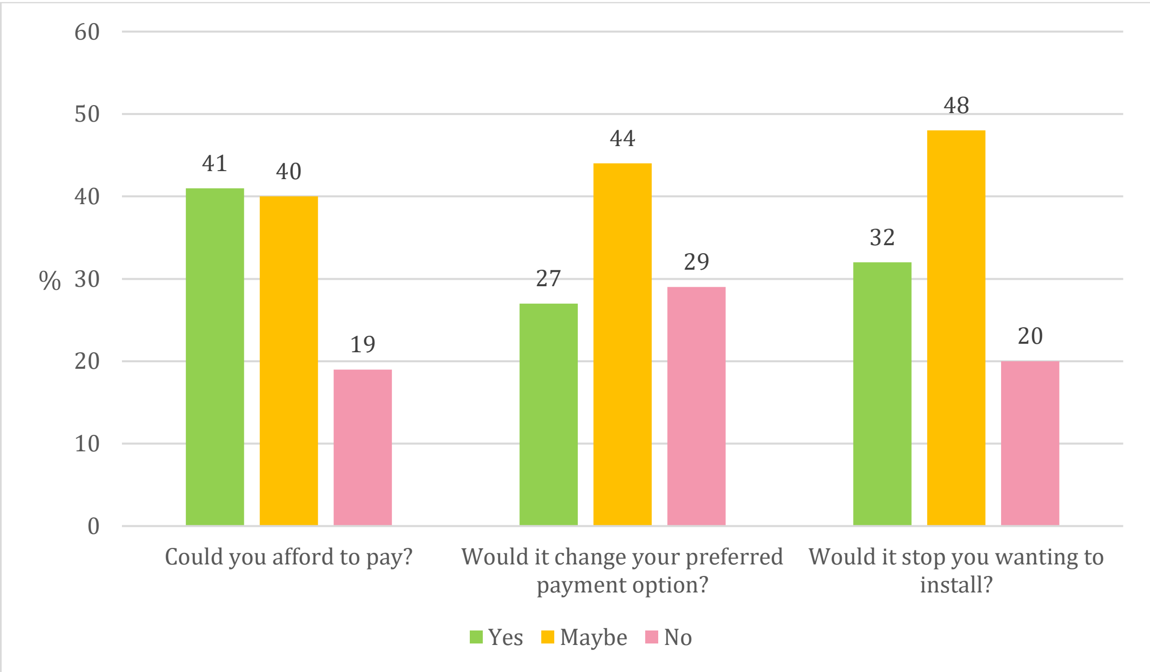


Figure 8 - Responses to the standing charge.

5.5.3. Why are people not interested in a neighbourhood heat pump?

Those who were not interested in a neighbourhood heat pump were asked why. Their responses were content analysed, and the following categories were identified

Cost

Participants noted that heat pumps were too expensive, they do not compare favourably with the cost of a replacement gas boiler, or they do not make financial sense. Some talked about how they were not planning on living in their home long enough for the heat pump to pay for itself in energy savings. Some participants commented that they would prefer to wait for the price of a heat pump to reduce. Some highlighted that they had only recently replaced their gas boiler and would therefore be unwilling to replace it in the near future.

> *"Can't afford it. Many other things priority at the minute."*
>
> *"We only bought a gas combi boiler last year and it is too soon to think about buying a heat pump."*
>
> *"That's far too much money, especially as we had to have our gas boiler replaced last year for around £3.5k."*
>
> *"A new gas boiler would be cheaper."*
>
> *"At my age I shall never save enough to make it worthwhile."*
>
> *"It will take too many years to recoup the cost of the pump."*
>
> *"The costs outweigh the benefits in the current economic climate."*

Concerns about suitability

These responses are about participants being unsure whether a heat pump would be suitable for their homes, or not believing claims about their effectiveness. For example, participants talked about being advised that their home is not sufficiently insulated to have a heat pump. Some noted that a heat pump and water cylinder would take up too much room in their home.

> *"All of the professional advice received suggests a heat pump will not heat the house to an acceptable ambient temperature unless insulation is 100% effective."*
>
> *"This type of heater does not work!"*
>
> *"It looks as though a lot of storage space is needed."*
>
> *"Don't have anywhere for a water tank."*
>
> *"The tank etc will fill my flat, then No Room For ME."*

Concerns about the shared elements

These comments are about not wanting to share a ground array with neighbours. Some concerns are about whether the ground array could supply enough heat for everyone, and others were simply about not wanting to have anything to do with neighbours.

> *"Don't want anything to do with my neighbours."*
>
> *"I would always want total control of my heating costs, and total control of my heating, I may have a heat pump in the future but it would be my own."*

Wanting more information

These responses are about participants wanting more details about heat pumps, or to speak to a friend or family member with experience of using them or being able to see them working before committing.

> *"I don't really know enough about them and I would like to speak to real people who have invested in one and get their opinion once they have been using it for a while."*
>
> *"Would need to know a lot more about it."*

Too much hassle/happy with existing heating

Participants commented that installing a heat pump would be too disruptive, or that they can't face the upheaval of having to insulate their home. Others simply commented that they were happy with their existing heating arrangement and did not see the need to change.

> *"It is too much hassle to install one."*
>
> *"I'm happy with gas."*
>
> *"Happy with my existing system."*

It's not the right way to decarbonise

These responses were about how heat pumps are not the best solution. This could be because people do not believe the technology is sufficiently tested, or that they believe that heat pumps are not the best solution.

> *"Because firstly I have a relatively new oil boiler system, secondly I do not think that a heat pump is the answer to climate problems, ground heat will run out eventually."*
>
> *"Heat pumps are not an efficient method of heating and I am thoroughly fed up with being preached at about what heating system I should have in my own home, this entire green agenda is nothing but a money making scheme."*
>
> *"I don't believe the technology is proven. There aren't enough engineers to support the new technology in case of issue, and it relies a lot on electricity- where does everyone think this electricity will come from?"*

5.5.4. Deciding about a heat pump

Those who were interested in a neighbourhood heat pump were asked who they would prefer to buy it from. They could choose between the heat pump company, the local council, a community energy co-operative, a utility company (e.g. British Gas, E.ON, Npower, EDF), or they could suggest another alternative. The percentage reporting each preference is shown in Figure 9.

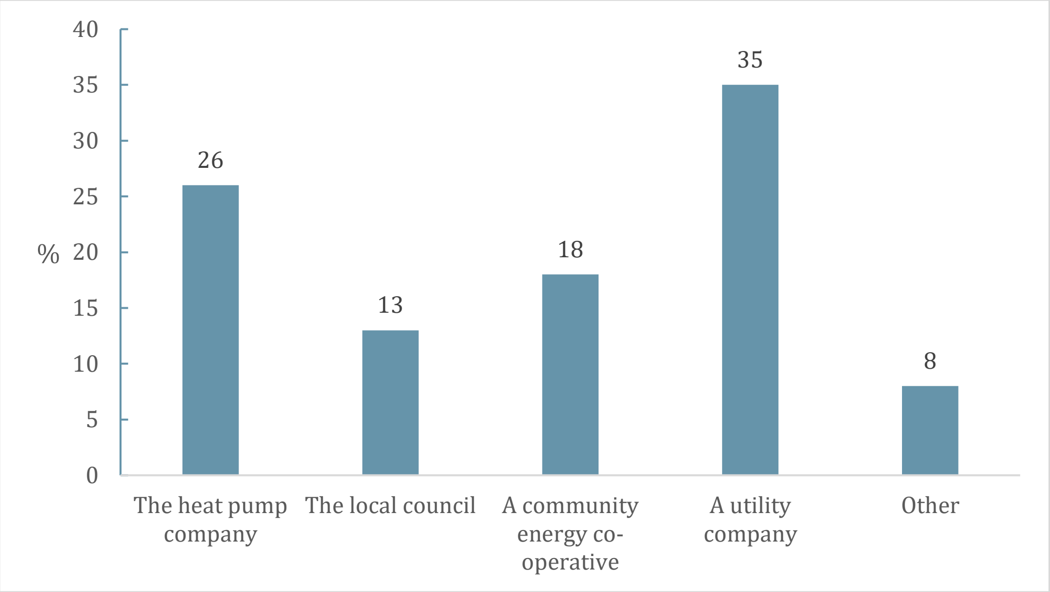


Figure 9 - Preferences for who to buy a heat pump from.

Participants were asked to rank a series of five factors about deciding whether or not to get a heat pump (ranks were from 1 to 5 where 1 is most important and 5 least important). These factors were identified during the focus groups in the previous stage. Mean ranks are shown in Table 6. The most important factor is how much money it saves, followed by how warm and comfortable it makes your home.

Table 6 - Most important factors when deciding about a heat pump.

Factor	Mean rank
Overall, how much money it saves you	2.69
How warm and comfortable it makes your home	2.76
Knowing that a neighbourhood heat pump works and is reliable	2.94
Reducing the amount you pay upfront	3.12
Getting a recommendation from an independent expert	3.48

They were also asked to pick the things that would be most important to them if they were looking to install a neighbourhood heat pump. There were 14 aspects to choose from, which were identified as important during the focus groups. Participants picked and ranked as many as they wished.

The percentage of participants who picked each aspect as important is shown in Figure 10, and the average importance rank they ascribed each one is shown in Figure 11 (in which lower ranks indicate greater importance). The three aspects most commonly selected as important were how much it reduces energy bills, that it gives enough heat and hot water, and waiting until their current system needs replacing. These three were also ranked as the most important.

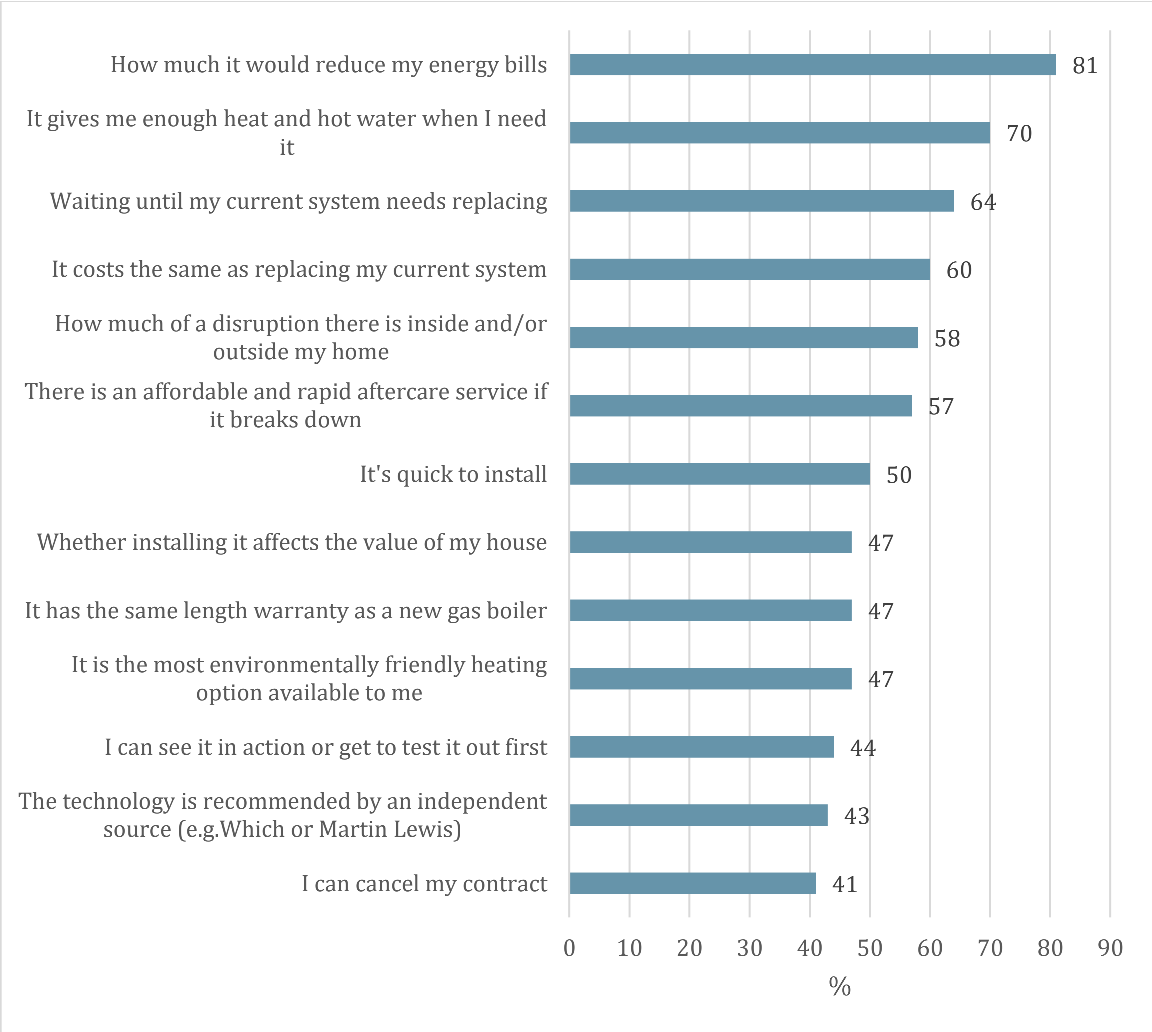


Figure 10 - The percentage of participants who selected each aspect as important.

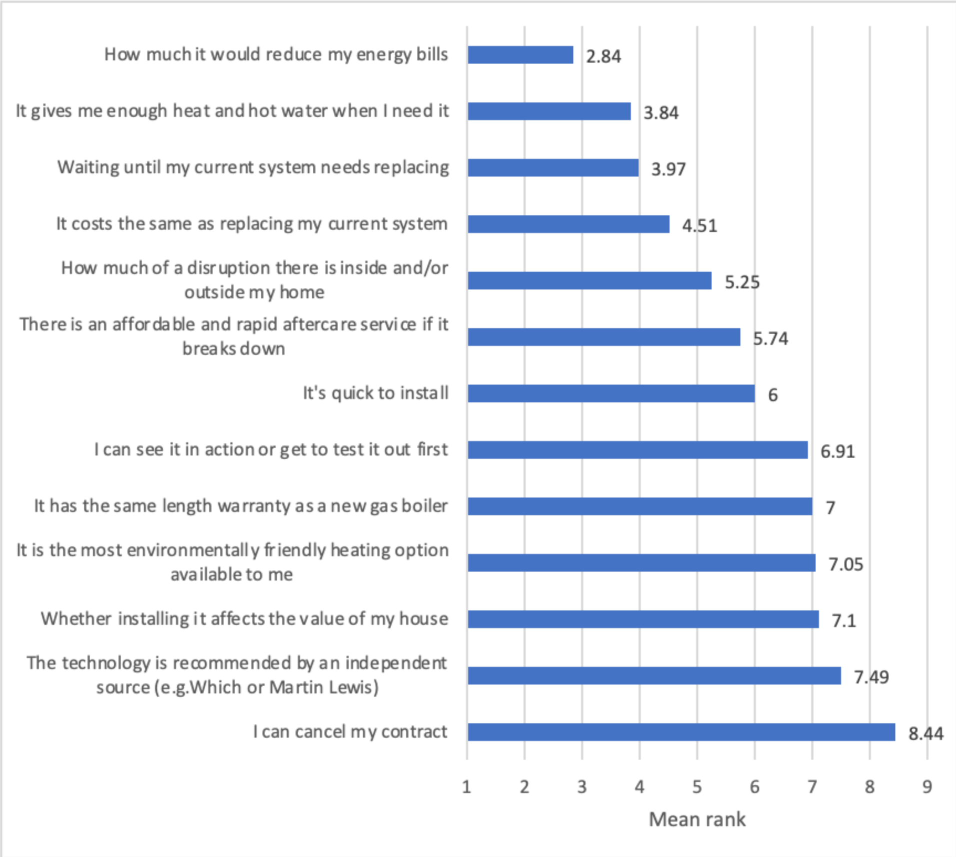


Figure 11 - The average ranked importance of each aspect

Making changes to your home

Participants were told that getting a heat pump sometimes means you need to make changes to your home. They were given a list of changes and asked which ones they were willing to make, which ones they were not willing to make, and which weren't applicable as they had already made this change. Of those who had not already made this change, the percentage who reported they would and would not be willing to make the change is shown in Figure 12. The most acceptable changes are to draughtproof windows and doors, which 59% were willing to do, and insulating the loft, which 53% were willing to do. The least acceptable is to have internal or external wall insulation (24-25%).

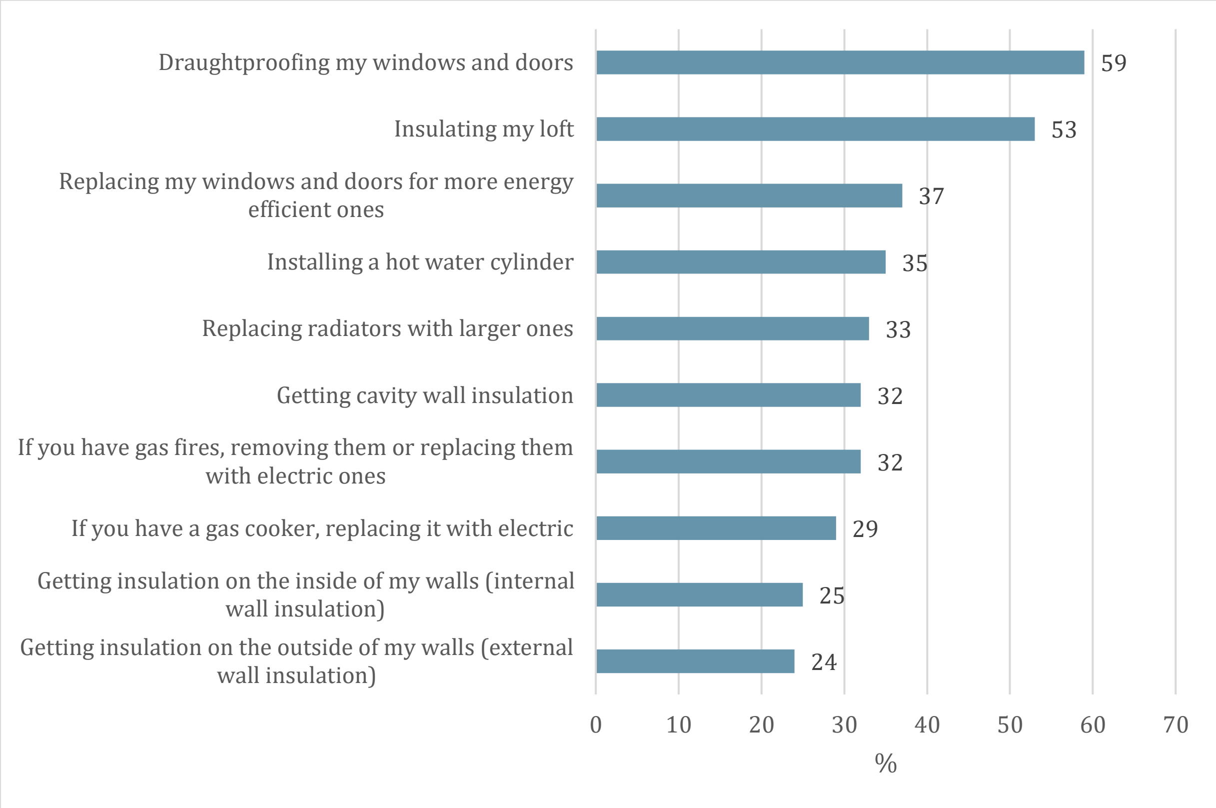


Figure 12 - The percentage of people willing to make changes to their home.

They were asked how long they would be happy for the neighbourhood heat pump installation and/or the changes to your home to take. They were given four options:

- 27% reported one day or less.
- 48% reported 2-3 days.
- 16% reported 4-7 days.
- 8% reported over a week.

5.5.5. The effect of cost on beliefs about heat pumps

To measure the effect of cost on beliefs about heat pumps we told participants that we don't yet know how much it costs to install a neighbourhood heat pump, but they should imagine that it costs a certain amount. They were randomised to one of three conditions: that it costs £6,000; £10,000 or £14,000. They were then asked how much they agree or disagree with five statements. The statements are based on the Theory of Planned Behaviour, which describes how three sets of beliefs (attitudes, norms, and perceived behavioural control) predict behavioural intentions, which in turn predict behaviour. The statements are shown below, with each related theoretical construct shown in brackets.

- People should change to heat pumps to protect the environment (attitudes)
- People should stop using gas in their homes (attitudes)
- My neighbours will be interested in getting a neighbourhood heat pump (social norms)

- I could get a neighbourhood heat pump if I wanted one (perceived behavioural control)
- I will change to a neighbourhood heat pump (intentions)

Mean responses are shown in Figure 13, in which higher scores indicate greater agreement. Cost has an effect on all psychological predictors of behaviour: increasing costs makes attitudes towards heat pumps more negative, reduces social norms, reduces people's beliefs that they could change to a heat pump, and reduces their intentions to do so.

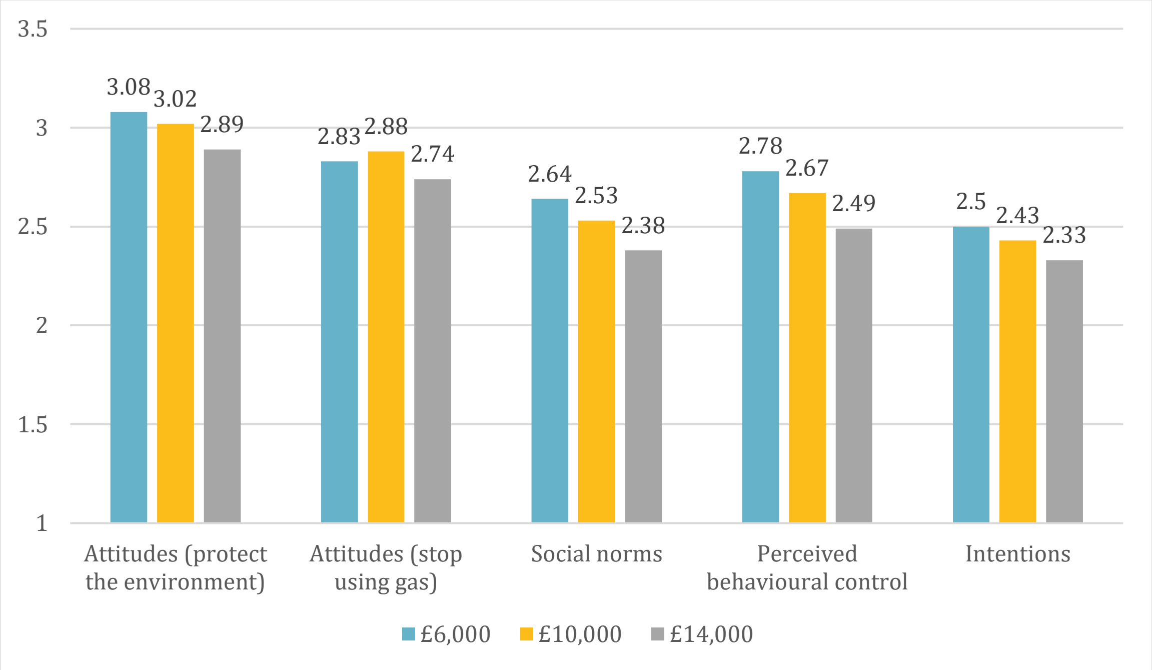


Figure 13 - How the cost of a heat pump affects psychological predictors of behaviour.

5.6. Conclusions

The interview research gives rise to the following conclusions:

1. The cost of heat pump will compare unfavourably against the cost of a replacement boiler and so incentives and interest-free loans need to be in place to offset costs greater than around £3,000.
2. It is important to expand people's "payback horizon" so that they are willing for a technology, such as heat pumps, to take many years to recoup its initial cost.
3. People would be interested in finding out about heat pumps. Some may do this when they move home but most only actually replace their boiler when it breaks, at which point they want the quickest replacement. There would need to be an attractive offer to convince them to replace their boiler while it is working well.
4. Participants want honest information about what is involved in installing and maintaining a heat pump. Disruption should be minimised. For some, it will be important that they can choose to keep a gas supply.
5. There is a need for clear information about heat pumps from a trusted source. People prefer

to ask friends and family, but most don't know anybody with a heat pump. Any misinformation that heat pumps are ineffective, inefficient, or unsuitable for their home can mean that the option of a heat pump is instantly dismissed.

The focus group research gave rise to the following "golden rules" that will help guide the design of finance packages and how to communicate with the public in order to increase heat pump uptake.

1. Create an infographic to clearly show what building works will be involved – inside and outside the home – when a heat pump is installed.
2. Provide a financial modelling service (e.g. personal visit, app, website) that people can use to estimate how much their installation will cost, how much they will save on their bills, and how quickly their financial contribution will be recouped.
3. Be clear about the level of customer service that will be provided, how costs could change, and what options customers have if more people join the network, if they have a dispute or want to leave the heat pump scheme and change back to gas. Also clarify what it will mean for customers if Kensa ceases trading.
4. Design finance packages in a way that benefits customers, not suppliers. This means an interest-free loan, stopping the surcharge once the amount is paid back and a sliding upfront/monthly surcharge scale, so that the amount paid by the customer is the same regardless of how much they pay up front.
5. Provide a guarantee that people will not pay more if they convert to a heat pump now rather than later. This could be a financial incentive, or a future refund, or advantageous terms for "early adopters".
6. Provide a review of the heat pump package by an independent source of advice, such as the Martin Lewis advice page.
7. Frame the "zero cost up front" option as an opportunity to upgrade to a warm, comfortable home at no extra cost. However, this needs to be accompanied by a guarantee that bills will not increase. People who are prepared to pay upfront for their heat pump are usually more interested in making a financial saving.
8. All communication should be designed to promote the belief that the heat pump scheme is trustworthy, set up to enable people to live in warm, energy efficient homes that don't damage the environment.

The survey research gives rise to the following conclusions:

1. People have limited knowledge of heat pumps, with a third knowing nothing about them.
2. Around a half of people are open to the idea of getting a heat pump, and most of these would be prepared to pay for the heat pump (if it cost £6,000) out of their own savings.
3. Of those who would use a loan to pay either partly or in full, the average amount they would be prepared to pay monthly is £100.
4. A standing charge of £50 a month would deter a significant number (up to 80%) from installing a heat pump.

5. Those who were interested in a heat pump would prefer to buy it from their utility company.
6. Reasons why people don't want a neighbourhood heat pump are the cost, especially if they have recently replaced their gas boiler, concerns that their home isn't suitable for a heat pump, not wanting to share infrastructure with neighbours, not knowing enough about heat pumps, finding the installation process too much hassle or being happy with their existing heating system, and not believing heat pumps are the best way to decarbonise.
7. The most important factor when deciding about a heat pump is how much money it will save, followed by how warm and comfortable it makes your home.
8. There is limited willingness to make the changes required for heat pumps to operate efficiently. Most people were willing to draughtproof their windows and doors and to insulate their lofts. Only around a third were willing to replace windows and doors, install a water cylinder, replace radiators, get cavity wall insulation, and replace gas fires and cookers with electric ones. A quarter were willing to get internal or external wall insulation.
9. Three quarters of people were happy for their heat pump installation to take up to three days, and a quarter were happy for longer, although only 8% would be happy with installation taking over a week.
10. The cost of a heat pump affects the psychological predictors of behaviour: attitudes; norms; perceived behavioural control; and intentions. It is important, therefore, to show how a heat pump will provide good value for money.

5.7. Customer journey proposal

5.7.1. Introduction

This section proposes a customer journey for the RHINOS model, with consideration of quality assurance (QA) (Section 9.5) and consumer protection (CP) (Section 9.6) as well as customer engagement, attitudes, and experience.

This work has been informed by the market research work carried out by LBU in WP3 and WP6 on mapping the Kensa, LCC, and the broader sector approach to customer journeys, QA, and CP. It also builds in learnings from knowledge sharing with the LCC Better Homes Leeds (BHL) (formerly Leeds Retrofit Accelerator) project. This project involves multiple members of the consortium and is developing an area-based retrofit model for the able to pay sector.

5.7.2. Methodology

Activity	Notes
Proposal for customer journey	Develop a proposed customer journey from analysis of other models and projects with explanations of the rationale for key steps, discussion of the QA and CP environment and customer engagement, attitudes and experience.
Map WP3 'Golden Rules' to customer journey	Map the 'Golden Rules' developed by LBU through the WP3 customer engagement work to the customer journey as part of its development.
Map supply chain to customer journey	Map WP6 supply chain work to customer journey once customer journey proposal has been developed.
Final customer journey proposal	Finalise the customer journey proposal and write up for WP3 section of report.

5.7.3. The potential role of Leeds City Council

In parallel with this feasibility study, a number of consortium partners have been working with Leeds City Council on the development of the BHL project. This has developed a blueprint for a Local Authority led finance and delivery model for an area-based approach to energy efficient retrofit in the so-called 'able to pay' market.

There are clear overlaps with this project, albeit the starting point in terms of the interventions may differ. This RHINOS project has focused on energy efficiency only to enable heat pumps, whereas the BHL project has focussed on energy efficiency as an offer in its own right, incorporating heat pumps if currently viable, and recognising the importance of energy efficiency in making homes 'Heat Pump Ready'. Both projects have addressed similar questions of neighbourhood selection, housing stock analysis, the nature of the compelling offer, financing arrangements, customer journey, supply chain capacity, and policy enablers. There has been direct knowledge sharing across the two projects and in particular in the context of the consumer research and customer journey design.

A key question that has been addressed in the BHL project, which would have been considered in more detail in the next stage of this project, is the potential role of LCC.

The Kensa business model (see Figure 14) incorporates a Special Purpose Vehicle (SPV) which raises finance, contracts with the supply chain, owns the infrastructure, and charges a standing charge to recover its investment.

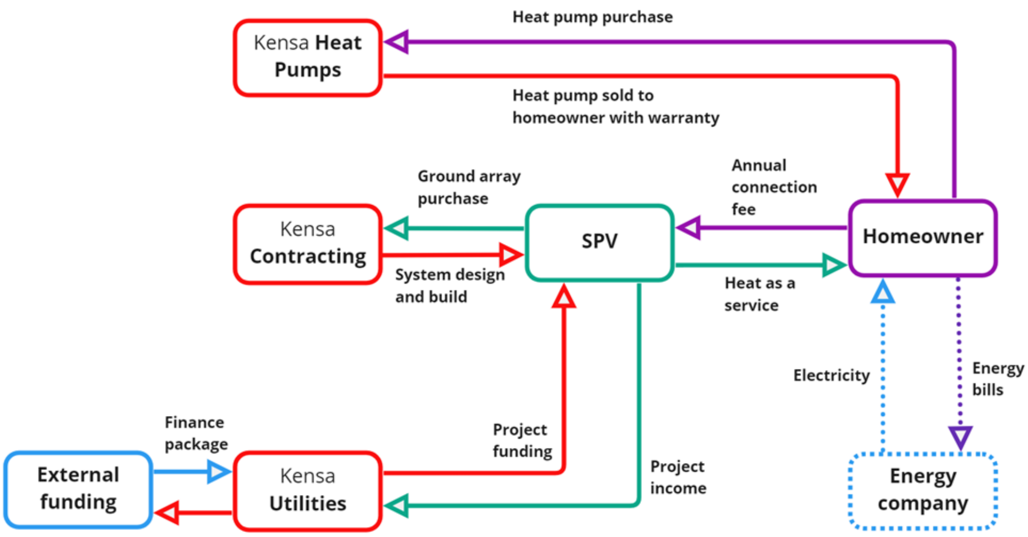


Figure 14–- The Kensa model for deployment of shared ground arrays.

Initial discussions were held with LCC about their involvement in the SPV, specifically in the context of bringing down finance costs. The allocation of risk and rewards and associated legal arrangements would need to be explored in more detail. LCC are open to direct involvement in this kind of project, as they have demonstrated with their investment in the Leeds PIPES district heating system. They also play various roles in area-based fuel poor energy efficiency and regeneration schemes.

The work on BHL is suggesting a direct role for LCC in finance and delivery to stimulate the market (see Figure 15).

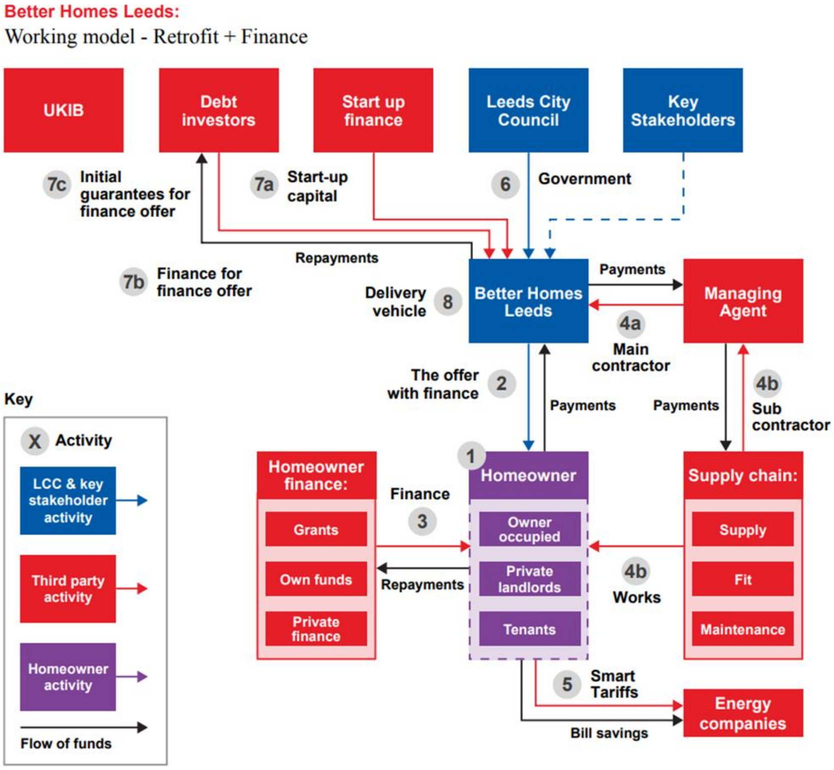


Figure 15–- Outline Better Homes Leeds delivery model

A key working hypothesis in BHL is that LCC should maintain control of the customer journey to maintain the important relationship of trust with homeowners, community engagement, and to protect the customer experience. The supply chain can then be carefully managed within this structure. This approach could be adopted for deployment of shared ground arrays and associated energy efficiency measures, either within direct control of LCC, subcontracting to businesses like Kensa, or through joint venture agreements.

The following proposals for the customer journey do not allocate specific roles at this stage.

5.7.4. Customer journey proposal

Process mapping

Kensa's existing customer journey process has been successful in delivering their heat pump system to customers in the newbuild and social housing sectors, including projects that incorporate fabric energy efficiency measures. LCC also have experience of delivering successful customer journeys across several heating system and energy efficiency projects including area-based schemes of this kind.

There are a number of valuable examples in the retrofit sector of innovation in customer journeys which successfully support homeowners through the process. This includes optimising the balance between digital tools and human contact, to ensure both accessibility for all homeowners and to recognise that behaviour change of this nature requires closer support. This customer journey proposal brings together these approaches with additional analysis around QA frameworks, best practice customer journeys, and the CP landscape.

The work in WP6 focusing on QA provides more detail about the backstage operational process, while this customer journey section focuses more on the front of house, customer-facing aspects.

The customer journey proposal has been developed from the detailed analysis from the Better Homes Leeds project and updated for the focus on heat pump installation. It presents a twelve-stage process, with each stage consisting of a related set of steps and sub-steps. The customer journey proposal process map can be found in Appendix 7 – Customer Journey Proposal Process Map.

Design principles

The market research carried out by LBU identified 'Golden Rules' of the scheme design (see Section 5.6) and these have been incorporated in the customer journey as detailed in the table below.

As discussed above, the potential direct involvement of LCC in delivery of the model and specifically a role in managing the customer journey would lead to responsibility for these elements being split across a number of roles, departments, and organisations. There is a clear overlap in the design principles between different elements of a compelling offer, including the offer itself and how it is delivered.

Golden Rule	Explanation	Inclusion in customer journey
1. Create an infographic to clearly show what building works will be involved.	Helps customers to understand what works are involved – inside and outside the home – when a heat pump and fabric measures are installed.	This has been included in the **consideration step** of the customer journey to feed into building customer confidence in the offer they are buying into and the process of installation which will follow.
2. Provide a financial modelling service (e.g. personal visit, app, website).	Allows customers to estimate how much their installation will cost, how much they will save on their bills, and how quickly their financial contribution will be recouped.	This has been incorporated into the **design stage** as a key element of supporting customers on their finance journey.
3. Clear communication around the level of customer service provided and any built-in CP.	Being clear about the level of customer service that will be provided, how costs could change, and what options customers have if more people join the network, if they have a dispute or want to leave the heat pump scheme and change back to gas. Also, clarify what it will mean for customers if Kensa ceases trading regarding Consumer Protection.	This is present in the customer journey through such elements as a possible walkthrough of the customer journey, and clear upfront communication about the Consumer Protection package which is offered as part of the scheme and installation.
4. Design finance packages in a way that benefits customers, not suppliers.	Providing a finance packaged which includes an interest free loan, stopping the surcharge once the amount is paid back and a sliding upfront/monthly surcharge scale, so that the amount paid by the customer is the same regardless of how much they pay up front.	This has been incorporated into the **design stage** as a key element of supporting customers on their finance journey, complementing the signposting of existing financial options to provide customer confidence in what they are signing up to.
5. Provide a guarantee that people will not pay more if they convert to a heat pump now rather than later.	Giving the customer confidence through the provision of a guarantee. This could be a financial incentive, or a future refund, or advantageous terms for "early adopters".	This has been included in the customer journey as a sub-step of the **Consumer Protection stage**. There is potential for an additional specific guarantee of

Golden Rule	Explanation	Inclusion in customer journey
		this nature to be part of the Consumer Protection package.
6. Provide a review of the heat pump package by an independent source of advice.	Helping to build customer confidence and trust in the offer and planned works through a trusted review from an independent source, such as the Martin Lewis advice page.	This has been incorporated into the **design stage** as a sub-step that will assist with giving customers the confidence to proceed with the proposed package of works.
7. Frame the "zero cost up front" option as an opportunity to upgrade to a warm, comfortable home at no extra cost.	Framing the "zero cost up front" option as an opportunity to upgrade with no additional cost. However, this needs to be accompanied by a guarantee that bills will not increase. People who are prepared to pay upfront for their heat pump are usually more interested in making a financial saving.	This is part of the customer journey at the **consideration and design stages**. Key to uptake will be selling the benefits alongside the financial package which might deliver an attractive "zero cost up front" option.
8. Communications designed to promote the belief that the scheme is trustworthy and has multiple benefits.	All communication should be designed to promote the belief that the heat pump scheme is trustworthy, set up to enable people to live in warm, energy efficient homes that don't damage the environment.	This has been incorporated into the **awareness stage** as a sub-step that will contribute to uptake of the scheme as part of a range of marketing approaches.

These 'Golden Rules' complement design principles developed through the Better Homes Leeds project developed through an analysis of customer journey, best practice, and existing research within the sector. Our current assumption is that to be successful, the customer journey should be:

- **Simple:** Facilitates simple decision making, hassle-free, low-friction processes and low-disruption delivery, allowing customers to move through each step with ease.
- **Understandable:** Provides easy to understand and jargon-free information about the retrofit process and its related benefits, and its reports and plans should be in an accessible format.
- **Attractive:** Communicates the benefits, relevance, and overall attractiveness of the offer successfully to the customer, improving uptake of the compelling offer.
- **Trusted:** Gives customers confidence in the process through local authority involvement, quality assurance, a professional supply chain, and consumer protection.
- **Supportive:** Supports the customer throughout the journey with input from the scheme and gaining confidence from neighbours who come along on the journey with them.

Customer journey stages

This section lays out a brief description of what is involved in each stage of the customer journey.

The key opportunities for innovation in the customer journey lie in both combining cutting edge digital tools and more importantly adopting a deeper, human-centred approach. The consumer research highlights the complexity of the decision-making process and the need for trusted advice. Other sector research shows that homeowners are influenced by multiple people in their social networks and communities, as well as trusted organisations. A hyper-local marketing approach, building on both Kensa and LCC's experience in area-based schemes can work with these networks of influence to build awareness and support for schemes of this nature. A supportive journey that brings neighbours along the journey together will build momentum through normalisation within communities.

- **Preparatory work:** The scheme is set up in a neighbourhood after a process of neighbourhood selection which potentially includes the development of archetype designs, and stakeholder engagement plans and activities.
- **Pre-awareness:** Existing customer awareness and preconceptions around heat pumps and energy efficiency should be factored in around existing renovation plans or gas boilers reaching their end of life. It may also be valuable to tap into life events and trigger points.
- **Awareness:** Customer uptake will be generated for the scheme through a number of marketing channels including a hyper local marketing and engagement approach, trusted community networks, word of mouth, and community-based social marketing (CBSM). Communications should emphasise the climate-friendly and trustworthiness of the scheme.
- **Consideration:** An initial home visit is made, or an initial enquiry is received, whereby the customer is supplied with information and detail about the scheme and process. Initial FAQs or concerns are answered, and the benefits of the installation are communicated.
- **Sign up:** The customer signs up to the scheme and for a home assessment and receive a detailed information pack providing more in-depth information about the scheme and process of installation of internal, external, and fabric measures.
- **Assessment:** A second home visit and initial assessment is undertaken, as well as detailed heat loss calculations and a thorough external geological survey. The customer receives a whole house plan and options for the installation.
- **Design:** A more detailed assessment and design are carried out and the project plan for the installation, and scope of works are delivered. At this point, the scheme might outsource for an independent review of the package of measures offered to ensure customer confidence. Financial modelling and projections are carried out, and support is given to the customer to signpost or provide a financial package. The works are then arranged by Kensa.
- **Installation:** Works proceed on the internal and external heat pump system measures, and fabric energy efficiency measures. The installation is project managed by Kensa on behalf of the customer and checks throughout the process help to ensure customer satisfaction.
- **Post-completion:** The works are signed off by Kensa and the necessary certifications are carried out, with copies supplied to the customer. The heat pump system is commissioned.
- **Handover:** The customer receives a handover pack which includes manuals, certificates, and a dedicated Consumer Protection pack. A handover is carried out with the customer which demonstrates smart controls and behaviour changes, and any customer questions or concerns are addressed. A video walkthrough of the system and its operation is also supplied to assist this handover.
- **Consumer protection (CP):** The customer receives a CP pack which includes workmanship and manufacturer warranties, the registration of the heat pump system with, and potentially an insurance-backed guarantee (IBG). A guarantee of the customer not paying more if heat pump is installed now rather than later might also be included.

- **Loyalty:** The customer signs up as an advocate for the scheme and for potential communications around future maintenance and upgrades, or further measures. A customer satisfaction survey is also completed.
- **Monitoring:** The customer agrees to the ongoing monitoring of energy, comfort, and behavioural data in their home. This data is shared with the customer along with advice to help them optimise their system.

5.7.5. Conclusions

A great customer journey is an essential element of a successful delivery model. Both Kensa and LCC have well established and complementary approaches that are aligned to best practice in the sector.

These approaches include an emphasis on hyper local marketing and community engagement within the neighbourhoods where work is carried out, benefiting from Community Based Social Marketing that promotes support, communication, and positive influence within the community.

The proposals are indicative at this stage and will require a review by all partners to consider roles, deliverability, and any associated cost implications. They represent a sound reflection of emerging best practice in the sector and address the golden rules that have emerged from the LBU research.

6. WP4 (Detailed Design) – Methodology & Findings

The objectives of WP4 have been concerned with the unique ground heat exchange system of the shared loop concept: its design, technical and economic benefits, and the dynamics of the demands on the power network. Primary inputs into the analysis have been details of the properties selected in WP2 and designs have then informed the cost estimates in WP5.

The objectives can be summarized as:

1. Develop an initial shared ground loop design for costing purposes based on each selected area.
2. Verify the assumptions of the initial design and identify opportunities for further optimisation in further deployment.
3. Evaluate heat demand profiles and the consequential distribution circuit power demands.
4. Identify technical system monitoring needs for system deployment.

Design of the shared loop heat pump system requires matching the expected property demands with required heat pump sizes and heating installations, with the distribution network and borehole heat exchanger requirements. The design approach of geothermal heat pump systems is more complex than that of conventional heating systems in that components have to be designed based on annual heating demand profiles and not just property peak conditions. Horizontal pipe network sizes are chiefly related to property and street dimensions. Borehole drilling requirements (a major capital cost component) are determined according to annual demand profiles and ground conditions. There are also trade-offs between capital cost and operating efficiencies/costs to be considered in shared loop design along with design risks to be considered.

6.1. Methodology

Development of initial design data for the shared ground loop system has used current practices for demand evaluation and estimation of the required Borehole Heat Exchanger (BHE) and heat pump sizes (selected products) to meet the demands. This has been done with a view to provide cost data early in the project. The size and extent of the heat pump installations and shared loop components have been estimated for each selected area/street. The technical assessment of the hardware and installation requirements using the approach includes evaluation of:

1. Estimation of building demands based on construction and size data
2. Selection of appropriate heat pump capacity for each property
3. Establishing BHE requirements based on a 2:1 property/BHE ratio, 200m depth and local knowledge of ground conditions
4. Estimation of horizontal pipe and related component costs including trenching costs

Verification of the initial designs and related assumptions has been carried out by application of state-of-the-art thermal modelling tools to examine selected areas/streets and detailed analysis of the thermal behaviour of the system, operating efficiencies and consequential carbon emissions and power demands related to heating operations. This detailed analysis, using high-frequency heating demand data, allows more precise design assessment and identification of opportunities for optimization of operating efficiencies: and hence operating costs and emissions. The steps in the methodology can be summarised as:

- Calculation of property and system heating demand profiles
- Network definition
- Thermal network simulations
- Data analysis

The flow of data through the system modelling process is illustrated in Figure 16 below.

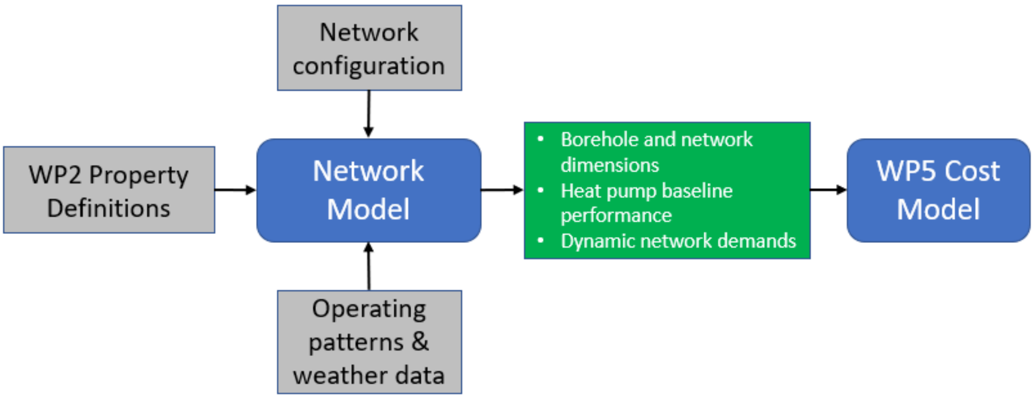


Figure 16 – Shared loop ground heat exchange network model data flows. Outputs from this model were also used to inform the economic analysis.

6.1.1. Heat Demand Profiles

Primary data for the evaluation of shared loop system performance are the collective heat demands of each property connected to the system. The heat loss parameters for each property are available from the tools used in WP2 through the processing of property SAP data. The time-varying heat demands are further dependent on weather conditions and the householder/occupant heat operations.

For the sake of consistency with the SAP modelling process, Typical Reference Year weather data for Leeds has been selected to represent hourly varying external conditions. Similarly, the length of the heating system follows SAP assumptions: operation October through May.

Domestic heating system operating patterns for both hot water and heating are known to be highly dependent on occupant preferences and very variable within a given collection of properties, even when the properties/systems are identical. Operating profiles for heating demand are also known to be different for heat pumps as opposed to boiler heating systems. SAP makes standard assumptions about hours of operation. A more realistic representation of operation has been sought for use in WP4 of the project. Prior UK heat pump trials (e.g., the Renewable Heat Premium Payment programme) have allowed a large data set to be developed that reflects heat pump system operation over a range of property types, forms of ownership and heat emitter types[3].

This demand profile analysis demonstrated some correlation between heating demand profile (variation of demand through typical days of operation) depended on (i) heat pump type (ASHP vs GSHP), (ii) heat emitter type (radiators or underfloor heating), (iii) form of property ownership (owned/rented), (iii) occupant lifestyle. Statistical analysis allowed three types of profile to be identified. These were denoted ‘continuous’, ‘bimodal’ and ‘daytime’ operation and differ in shape according to whether there are prominent morning and evening peaks (see Figure 17). These

[3] Watson, S. D., Lomas, K. J., & Buswell, R. A. (2021). How will heat pumps alter national half-hourly heat demands? Empirical modelling based on GB field trials. *Energy and Buildings*, *238*, 110777. https://doi.org/10.1016/j.enbuild.2021.110777

profiles have further variation according to external temperature conditions. The combination of these profiles being present in a given sample of properties was further found to be dependent on heat pump type, form of ownership and heat emitter type. The explanation for these being correlating factors was the observation that more privately owned properties tend to use GSHP than ASHP systems and are also more likely to have underfloor heating. Conversely, more social housing properties are likely to have ASHP with radiators.

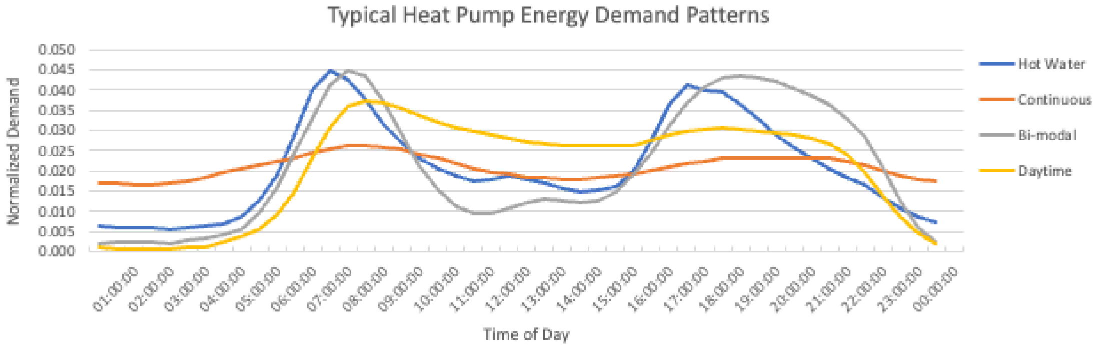


Figure 17 – Daily heating demand profiles derived from heat pump trial monitoring data.

If there was detailed information about heat emitter type and property ownership in a proposed development, demand profiles could be selected for demand analysis on that basis. Such data is not available at the design stage. Since proposed shared loop systems are likely to involve radiator heat emitters, demand profiles are, according to Watson et al., most likely to follow those in the trial data that had ASHP. Accordingly, for analysis in this project the ASHP profiles published by Watson et al. have been used. For such systems the mix of profile type was found to be: 61% continuous, 9% bi-modal, 30% daily. When selected areas/streets have been analysed in detail the profile types have been applied to properties randomly in a way that matches these proportions.

Demand profiles for hot water were identified by Watson et al., based on a combination of heat pump trial and other heating system data – these being found to be less dependent on heating system type. The hot water profile is applied throughout the year (with some daily outside temperature dependency) and becomes the only heat demand in the summer period. Heat demands in the detailed analysis of WP4 are finally calculated based on SAP Heat Loss Parameter (W/K), Hourly typical external temperature, and distributed in the day according to the applied demand profile.

6.1.2. Network Definition

Of the areas selected in WP2, one terraced street was selected for detailed analysis in WP4. This was Northbrook Street in Chapel Allerton, Leeds. This street comprises a total of 83 early 20th century properties with solid wall brick construction mostly in terraced form. The street is further divided by cross streets. The Northeast block consisting of 44 properties was used in the final analysis. The street and proposed network layout are illustrated below in Figure 18 and Figure 19. The street is thought to be typical of many in the selected wards.

Figure 18 – Northbrook Street, Chapel Allerton. Northeast block (44 properties)
Maps data © 2023 Google, Image Landsat / Copernicus.

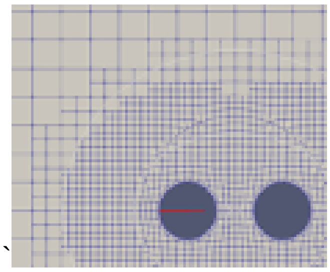
The street layout allows a simple linear network arrangement. The ratio of properties to borehole heat exchangers has initially been modelled as assumed in the initial design – a ratio of 1 borehole to every 2 properties. This has been varied in later studies to verify this assumption and study the effect of varying this ratio. These have initially been assumed to be 200m boreholes but variations around this value have also been simulated. Ground thermal conductivity has been taken to be 2.15 W/m.K. based on experience with other sites in the area. The arrangement of horizontal connections, properties and borehole heat exchangers assumed in the detailed model are illustrated in Figure 19.

Figure 19 – Northbrook Street shared loop design used in detailed simulation studies.

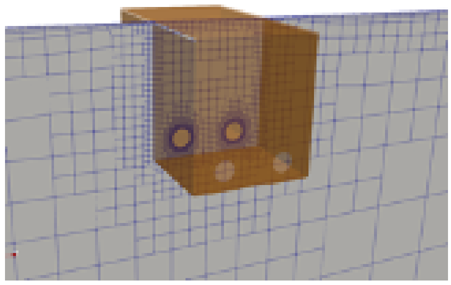
6.1.3. Thermal Network Simulation

The network model that has been implemented and tested allows representation of various configurations of the principal components: (i) properties and their heat pump, (ii) horizontal network pipes, (iii) borehole heat exchangers. The model, in incorporating state-of-the-art component models[4,5], allows the network dynamic performance over short and long timescales to be developed and the full benefits of shared heat exchanger designs to be evaluated.

The first stage in model implementation is to derive detailed heat response data for the various network heat exchange components i.e., horizontal pipes and vertical borehole heat exchangers. This data is derived and stored for each component type and is generated from parametric numerical models – geometric representations illustrated in Figure 20.



Borehole heat exchanger



Horizontal shared loop pipes

Figure 20–- Detailed numerical model used to derive thermal response data.

The network model has been configured with horizontal pipe components to match each property connection and connections between properties and borehole positions along the street. Note that in the preliminary analysis, and in existing design tools, the benefits of the horizontal pipe network are ignored.

The demand transferred to the ground heat exchanger network is driven by the property heat demands and is then dependent on the heat pump power (efficiency) at a given time. This, in turn, is dependent on the heating operating temperature and the fluid temperature in the network connection at any given time. The simulation takes this into account at every step by applying a detailed model of heat pump type. This is derived from manufacturers published test data. The heat pump models evaluated in this study are the Kensa Shoe Box 6kW model and the Kensa EVO 7kW model as these are appropriate to the property peak demands. The characteristics modelled are illustrated in Figure 21.

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[4] Rees, S. J. (2015). An extended two-dimensional borehole heat exchanger model for simulation of short and medium timescale thermal response. *Renewable Energy*, *83*, 518–526.

[5] Meibodi, S. S., & Rees, S. (2020). Dynamic thermal response modelling of turbulent fluid flow through pipelines with heat losses. *International Journal of Heat and Mass Transfer*, *151*, 119440.

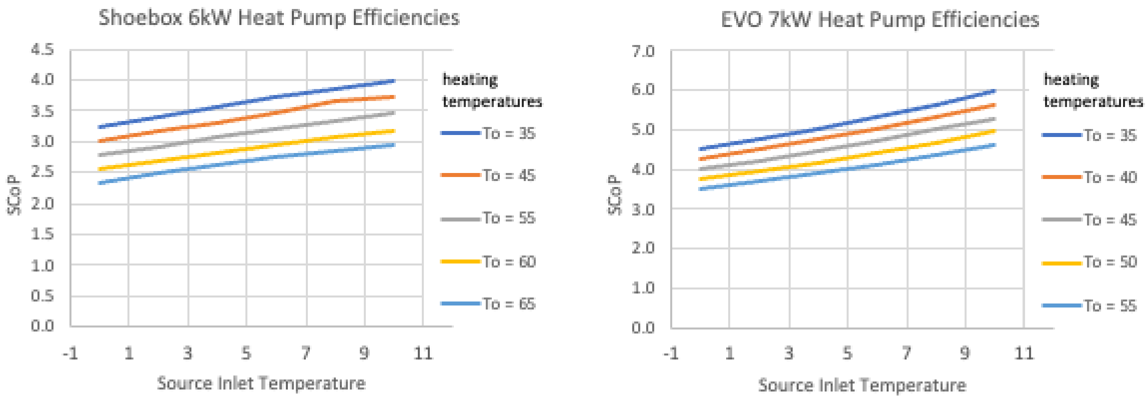

Figure 21–- Heat Pump Characteristics Modelled in WP4.2 (Kensa published technical data).

The heat pump efficiency is strongly dependent on the heating (output) temperature. The common assumption where radiators are to be retrofit is that the most economical option (smallest radiator sizes) is to have a peak heating temperature of 55°C. The simplest form of system controls would keep this temperature constant throughout the year. There are benefits from varying this temperature so that 55°C is only used in the coldest weather conditions and is reduced (as low as 35°C, for example) in warmer weather. This can be automated according to outside temperature in 'Weather Compensation' control systems. Both control options have been modelled in this study.

In evaluating the performance of the shared loop ground heat exchange and heat pump system, the two technical criteria of interest are the Seasonal Performance Factor (heat delivered in the season / energy consumed in the season) and, the minimum borehole fluid temperature. The borehole fluid temperature is fully expected to fall over each season in a geothermal heating system and reach a repeatable minimum value. This should be high enough to avoid risks of freezing or heat pump faults and high enough to ensure good seasonal efficiency. These temperature criteria are typically used in deciding how deep and how many borehole heat exchangers are required. Some variations in borehole length, property/borehole ratio and control system type have been evaluated. Table 7 shows the parameter variations used in the simulation study.

Table 7–- Shared loop network simulation parameters

Borehole length	Property/ Borehole ratio	Heat Pump Model	Control option
200	2	Shoebox 6kW	Fixed Temperature
200	2	Shoebox 6kW	Weather Compensation
200	2	EVO 7kW	Weather Compensation
200	2.7	Shoebox 6kW	Weather Compensation
200	4	Shoebox 6kW	Weather Compensation
225	2	Shoebox 6kW	Weather Compensation
175	2	Shoebox 6kW	Weather Compensation
150	2	Shoebox 6kW	Weather Compensation

In the analysis of the shared loop system thermal behaviour, due consideration has been given to variation in temperatures and efficiencies over multiple seasons. Results reported are extracted from data calculated after five years of simulated operation.

6.2. Results

The shared loop heat exchange performance derived from the detailed system simulations is summarized in Table 8 . The performance indicators are the minimum borehole temperature and seasonal performance factor. These have been verified to correlate with available heat exchanger size for a given heat demand, and the heat pump characteristics. The first results reported are for the intended combination of Shoebox 6kW heat pump and 2 x 200m borehole heat exchangers per 6 properties. Where the temperature of the heating system is constant the seasonal efficiency (SPF_2) is 3.05 and where more sophisticated weather compensating controls were modelled this improved to 3.17. The value 3.07 is lower than the initial target of 3.5 and so in other simulations weather compensating controls were taken to be applied. A value of 3.1 was used in the final operational cost estimates.

The simulation studies have included the case with similar network and heat exchanger configuration but with an alternative heat pump – the Kensa EVO 7kW model. The results suggest the seasonal efficiency could be noticeably improved: predicted SPF2 of 3.94. This implies higher levels of savings and reductions in emissions should be achievable with this option. The barrier to adoption of this particular heat pump model would be its larger physical size, although suitable models from other manufacturers may address this. Hence, although it may be the best option for larger properties in the study, it would not be a practical option for smaller terraced houses. This may not be a general issue for the technology as a manufacturer agnostic approach is intended for larger scale deployment.

Three designs for Northbrook St. NE were simulated with 200m borehole heat exchangers but different ratios of property:borehole – the initial design assumes 2:1. Higher ratios (fewer boreholes in total) showed the expected correlation with both lower seasonal efficiencies and lower minimum borehole temperatures. Although the seasonal efficiency is shown to fall to 3.01 it is more significant that the minimum temperature falls below freezing to -2.28 °C. This temperature is not problematic from the point of view of fluid circulation (20% propylene glycol antifreeze is modelled) but does represent a risk of freezing of soil at shallow locations such as where pipes enter properties. Accordingly, the assumed configuration of 2 boreholes per 6 properties of this terraced form, size and age seems reasonable.

The sensitivity of the design to borehole depth has been investigated by simulating operation of the proposed design but with boreholes between 150 and 225m deep. The predicted efficiencies and minimum temperatures indicated that there would be a small improvement in performance with an increased borehole length (225m). A reduction to 175m may be acceptable but probably 150m in this case would represent an unacceptable design risk.

Table 8 - Shared loop network simulation results. The base case design has been highlighted.

Borehole length (m)	Property/ Borehole ratio	Heat Pump Model	Control option	Minimum Borehole Temperature	Seasonal Performance Factor (SPF_2)
200	2	Shoebox 6kW	Fixed Temperature	1.55°C	3.05
200	2	Shoebox 6kW	Weather Compensation	1.53 °C	3.17
200	2	EVO 7kW	Weather Compensation	0.67 °C	3.94
200	2.7	Shoebox 6kW	Weather Compensation	-0.33 °C	3.09
200	4	Shoebox 6kW	Weather Compensation	-2.28 °C	3.01
225	2	Shoebox 6kW	Weather Compensation	2.373 °C	3.21
175	2	Shoebox 6kW	Weather Compensation	0.563 °C	3.13
150	2	Shoebox 6kW	Weather Compensation	-0.658 °C	3.07

The monthly variation in efficiency and system heat exchange for the proposed network for Northbrook St. NE is shown in Figure 22. The variations are primarily driven by seasonal variation in environmental conditions – the highest efficiencies occurring in the summer periods where demands are minimal. Heat demand can be seen to correspond to a combination of heat pump power and heat extracted from the ground.

Heat exchange with the ground is shown as a combination of that exchanged by the borehole heat exchangers and the horizontal pipes in the network. Behaviour in the summer months suggests heat is being collected by the horizontal pipework (being close to the road surface and able to absorb some solar irradiation) and redistributed to the boreholes. This is possible because the heat pumps circulate fluid around the system but only need to deliver heat for hot water purposes in summer months. This is one aspect of system design that may be an opportunity for further optimisation.

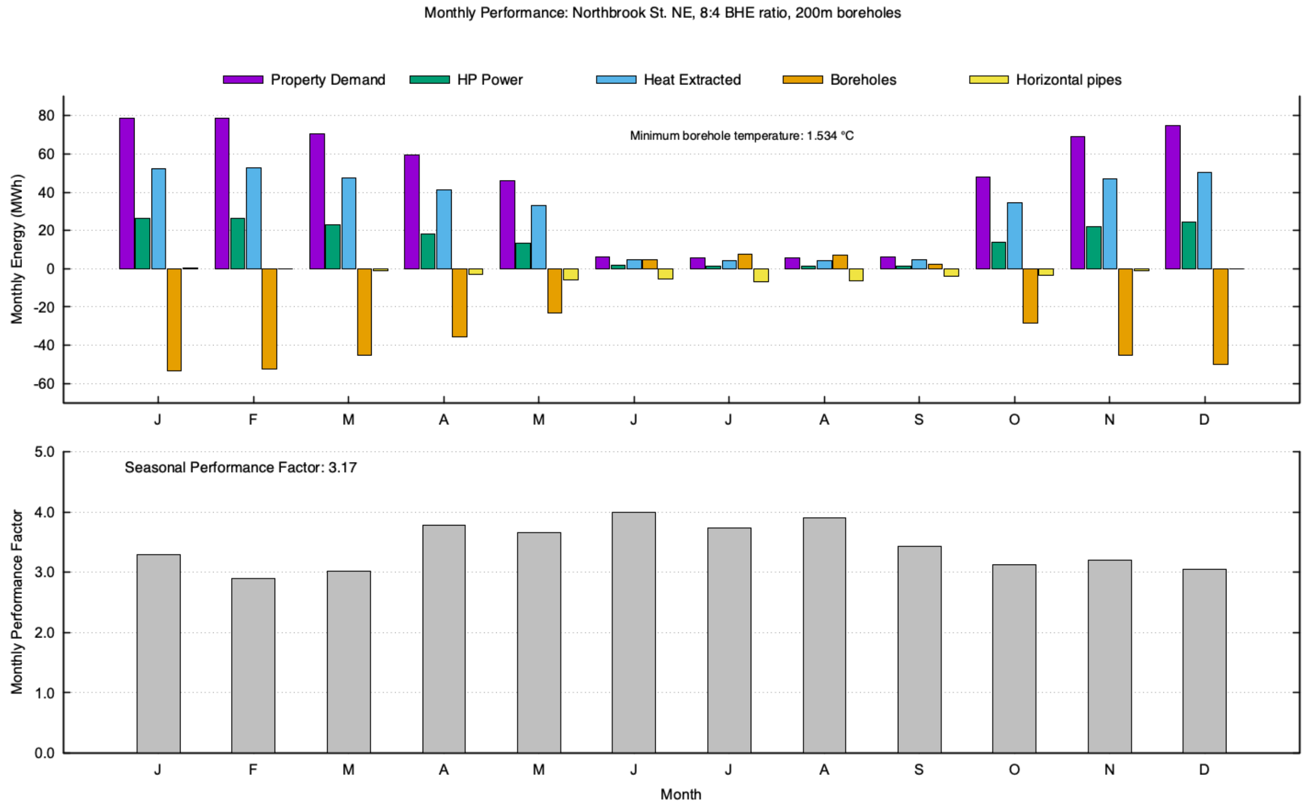

Figure 22 - Simulated monthly performance of the Northbrook St. shared loop heat pump network.

Further details of the base case design for Northbrook St NE predicted system temperatures and heat exchange are shown in **Figure Error**! Unknown switch argument.. These data demonstrate the seasonal variation in fluid temperatures and demands. The fluid temperatures fall towards 2°C in winter but recover in spring and experience modest recharge in summer months. There is a slight downward trend in temperature during the first years of simulated operation. This behaviour is very typical of geothermal heating systems.

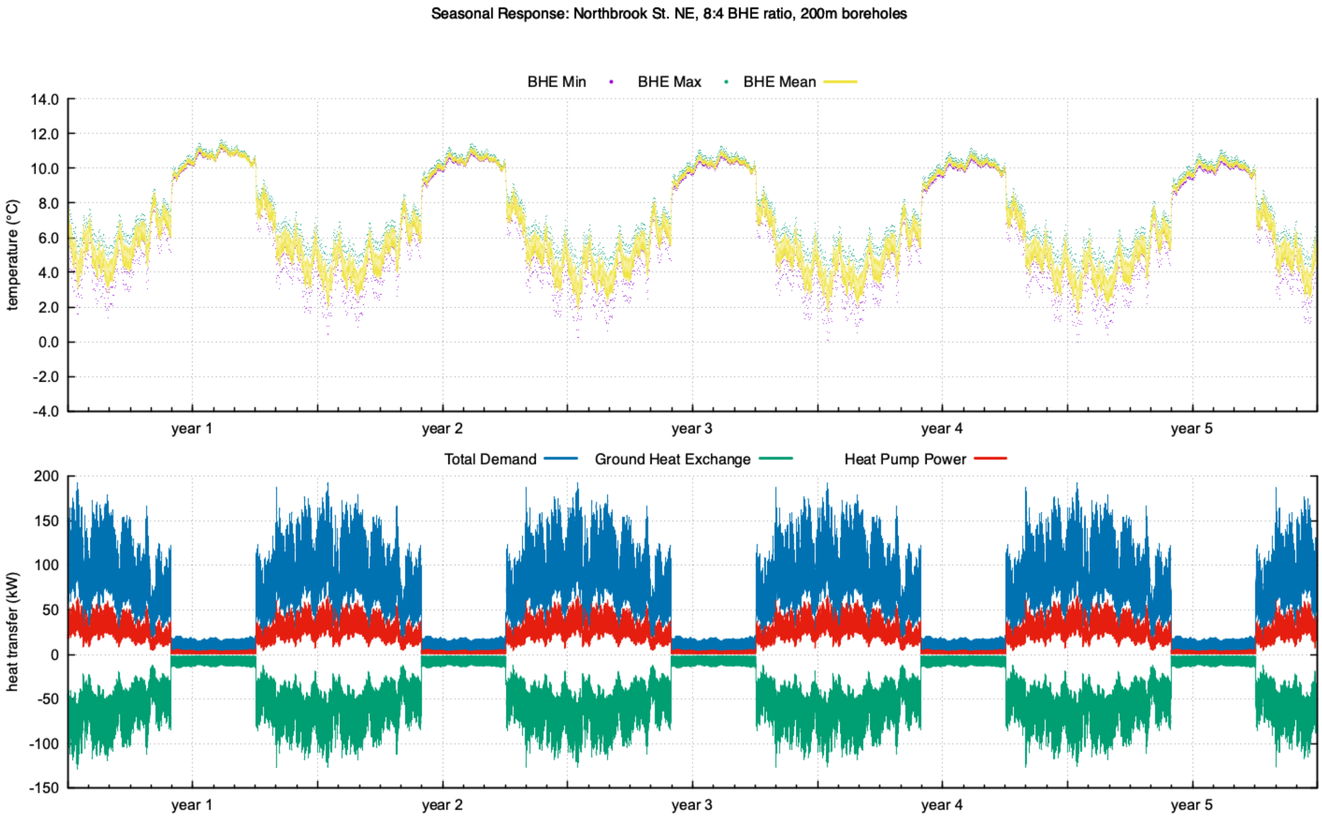

Figure** Error! Unknown switch argument. **- Simulated responses of the Northbrook St shared loop heat pump network

In order to provide data to evaluate the relationships between heat and power demand, the thermal simulation data has been analysed in terms of expected variance of demand (and hence power) over the season. These data reflect the non-linear relationship of heat demand to power due to the variation in heat pump characteristics with temperature noted above. The frequency of occurrence of heat demand is shown in the histogram (Figure Error! Unknown switch argument.). This variation in demand is shown along with the nominal thermal capacity of the heat pumps in the system (based on heat pumps with 6kW nominal capacity). This suggests that the peak demand experienced in this system is 72% of the maximum capacity of the installed heat pumps. This result suggests a good level of design risk but is very dependent on the peak heat losses of the properties vs the heat capacity of the heat pump selected.

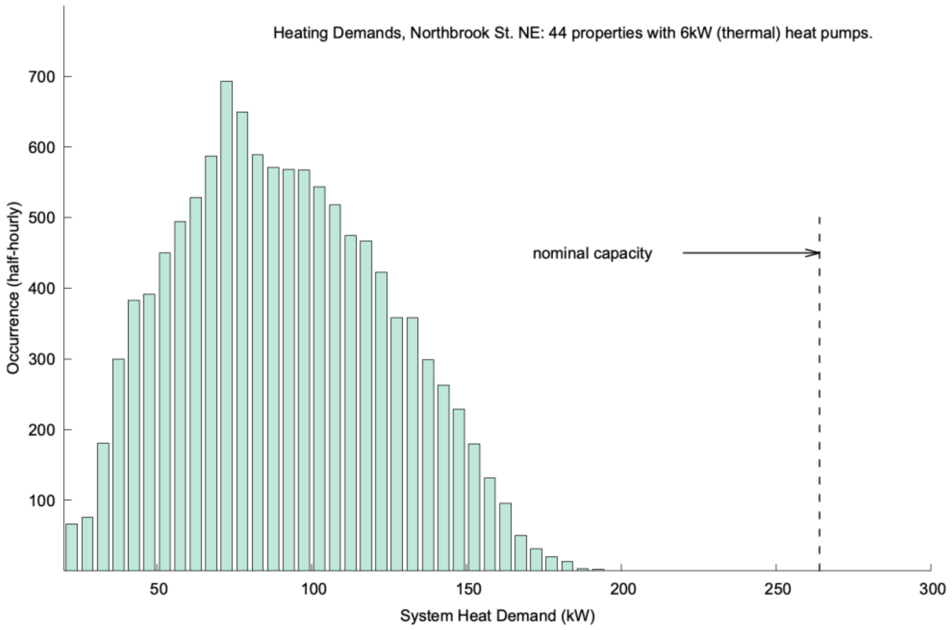

Figure** Error! Unknown switch argument. - **Frequency of system heat demand simulated for Northbrook St NE over a typical year

Variation in heat demand has been further related to variations in heat pump power (current draw) over the season in Figure Error! Unknown switch argument.. The frequency of heat pump current demand is shown relative to the typical current draw stated by the manufacturer of the heat pump and also the rated current. This data is based on the hourly heat demand rather than the instantaneous draw on the substation circuit during cyclic operation of the heat pumps. Higher frequency analysis and detailed consideration of heat pump controls along with further statistical analysis of heat pump trial data would be needed to address questions of the impact on circuit design and operating risk.

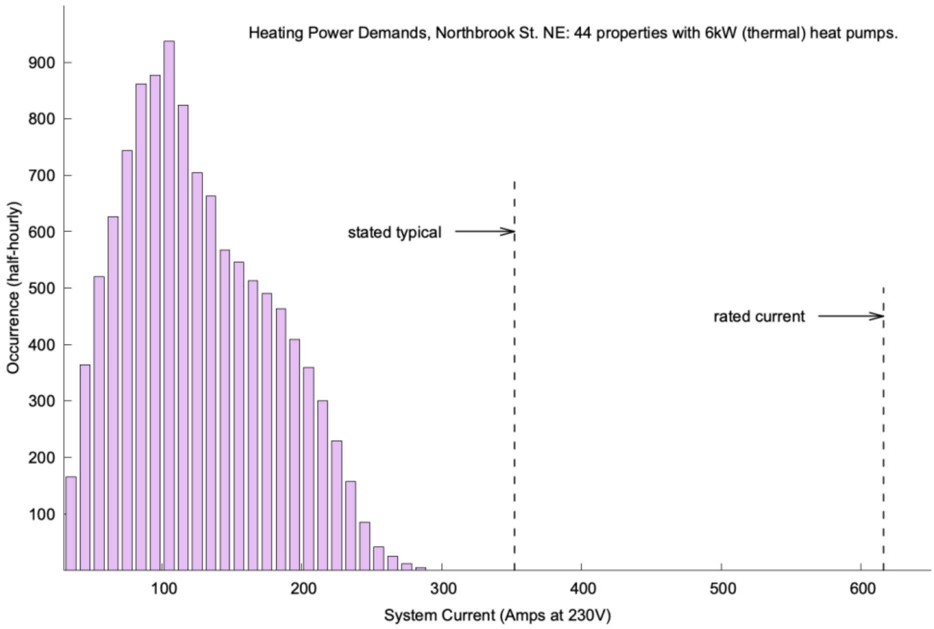

Figure** Error! Unknown switch argument. **- Frequency of simulated power demands for Northbrook St NE. over a typical year.

6.3. System Monitoring Plans

Technical data from geothermal heat pump systems has been collected by multiple partners in the project for a range of purposes. Data collection, storage, analysis and feedback can be used for a number of purposes, and these require different monitoring point and frequencies of collection. These requirements (summarised in Table 9) are over and above the room, system and possibly external temperature data and occupant programmer inputs required for routine operating and system control.

Table 9 – Summary of system monitoring

Metering/sensing objective	**Beneficiaries**	**Monitoring points required**	**Typical reporting intervals**
Occupant billing and operating information feedback. Fault detection.	Occupants and energy suppliers. System operators and funders (depending on business model).	Electrical energy consumption. Display of heat pump status/mode of operation. Heat metering depending on cost model.	Monthly metering data. Instant feedback of status/mode. Possible smart meter user feedback.
Heat pump deployment evaluation	System installation contractors, operators, funders and policy makers.	Electrical energy consumption, metering of heat delivered, system temperatures and status/mode.	1 – 5 minutely data reporting.
Engineering validation and technology development	System installation designers/contractors, researchers, operators, funders.	In addition: circulating pump operation/energy data, ground loop temperatures and flow data	1 – 5 minutely data reporting.

In the first stage of deployment the intention would be to provide monitoring points and data analysis for occupant information and billing along with further data collection for engineering validation. Data analysis for heat pump programme evaluation requires further penetration of data collection and management of occupant participation in order to support statistically meaningful evaluation of technology efficiency. This would provide data on shared loop operation over multiple seasons to allow validation of the design processes and also identification of further opportunities for optimisation of design and operational practices. The sensor and meter installation and data analysis standards adopted would be guided by a combination of DECC/BEIS heat pump trial technical findings[6] and current international best practice as reported by Annex 52 of the International Energy Agency (IEA) Heat Pump Programme.

Remote pressure monitoring of the shared ground array would also be undertaken by Kensa as part of the communal infrastructure operation, this would allow detection of leaks within the boreholes or shallow pipework and enable preventative maintenance. In the unlikely event that there is a failure within a borehole, heat could likely still be provided to properties as each shared ground array would comprise multiple boreholes, Kensa would then respond to rectify the fault within 90 days or less. In an emergency situation where there is a loss of heat from the shared array, Kensa would respond within 24hrs to provide backup heating, with DHW provision through the immersion heater in the DHW storage and otherwise complying with best practice consumer protection as discussed in Section 9.6.

6.4. Key findings

- The cost estimation assumption of a 2:1 property borehole ratio has been verified by detailed system simulation.
- The horizontal distribution pipe network plays a beneficial role in heat exchange and provides opportunities for summer recharge of heat.
- A seasonal efficiency of 3.17 was predicted for the proposed ‘shoebox’ heat pump when used in conjunction with an enhanced control package.
- Improved efficiencies should be possible where larger heat pumps can be accommodated.
- A significant diversity in demand on the power network was demonstrated in detailed studies but is sensitive to property peak heat demand and would need further analysis before general conclusions could be drawn.

[6] UCL Energy Institute/DECC (2017). Final Report on analysis of Heat Pump Data from the Renewable Heat Premium Payment (RHPP) scheme.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/606818/DECC_RHPP_161214_Final_Report_v1-13.pdf

7. WP5 (Funding & Business Model) – Methodology & Findings

This WP focused on developing a methodology to refine the customer package for the shared ground array heat pump system based on the current available funding and business model. The aim of the methodology was to offer a cost reduction for consumers: through the coordinated provision of heat pump deployment to a high-density of buildings in a single area.

7.1. Split ownership business model

Using an approach to install shared ground arrays financed as a new utility (similar to the gas or water networks) helps to reduce the biggest barrier in terms of required upfront capital cost from the end user and at the same time helps to deploy heat pumps at high density.

The shared ground array solution provides the opportunity to split the total system cost and ownership into two parts:

1. Heat infrastructure / shared ground array (including boreholes, pipes, manifolds), which extends to the outer wall of each dwelling.
2. The customer/end-user for the heat pump and the internal heat distribution system within the dwelling.

The "split ownership business model" arrangement mirrors ownership as with other utilities (gas, water, electricity etc). The heat infrastructure provider (Kensa Utilities Ltd) would fund, own & operate the shared ground array (including boreholes, pipes, manifolds), which extends to the outer wall of each dwelling connected to the shared ground array. The customer/end-user (homeowners) would own and be responsible for the heat pump and the internal distribution system within the dwelling.

In this model the heat infrastructure provider levies a monthly standing charge to each property to access the shared ground array for its heat supply, which covers all of the ambient heat supplied and all operation & maintenance (O&M), billing, overheads to operate & maintain the ground array. The standing charge is adjusted annually with inflation (up to a cap), with no other ways for the heat infrastructure provider to alter the standing charge. The standing charge would also be reduced if additional consumers connected to the shared infrastructure.

In an environment where central plant heat networks are exposed to commodity prices to run their systems and can therefore charge significantly increases to heat network rates, this model offers significant protection to consumers. The heat infrastructure provider could also offer a separate service & replacement package for the internal heat pumps (similar to boiler care).

The split ownership model reduces the upfront cost to the customer and also allows private investment capital to be utilised. Private sector investors could range from pension funds to strategic investors to high-street banks which moves the emphasis of funding the low carbon transition from government to the private sector. This could provide a suitable long-term return for investors with an interest in making sustainable investments. In the whole life cost analysis, a strategic investment fund was considered for the Leeds deployment.

7.2. Cost without grant and investment support

Initial estimates were made by Kensa to understand the full capital cost to the consumer when there is no grant support or private investment into the shared ground array or heat pumps.

These costs are estimated based on the current market price to install Kensa's Shoebox 6kW heat pump system for terraced properties and Evo 7kW system for semi-detached properties. A "Cost to Consumer Calculator" provided by BEIS was used for the calculation and Table Error! Unknown switch argument. shows the full capital cost to the consumer for two cases: 1) typical mid terraced property with solid walls and 2) typical semi-detached property with solid walls.

As part of WP2 activities, the impact of light fabric measures (combination of airtightness & loft insulation where applicable) and better heating control systems (including programmer, room thermostat, and TRVs) were considered for their benefit in reducing the required heating system capacity. For the cost analysis, only the applicable light fabric measures (airtightness, loft insulation) were considered based on a BEIS report[7] on electrification of domestic heating.

The cost is based on an assumed cluster size of 40 properties and assuming streets with 80% uptake. With this number of properties, diversity in heat demand can be assumed which reduces the peak load on the shared ground array system and therefore allows for reduced borehole depth and lower capital cost. Part of the capital cost is due to the typical cost of drilling boreholes for the shared array in public highways, this is more complex than siting them within the curtilage of properties but allows all properties on a street to benefit from ground source heating including those that have no available space for boreholes or poor access for drill rigs on their property. A summary of other technical cost reduction measures is given in Appendix 3 – Shared Ground Array Cost Reduction Measures.

With no funding support, the full capital cost to the consumer is ~£24k for a typical mid-terrace property and ~£33k for a typical semi-detached property (both with solid walls). These costs include the effect of the light fabric measures on reducing the system capacity.

As an additional comparison, the cost to the consumer for a compact semi-detached property which is assumed to be "heat pump ready" (i.e. no additional fabric measures or heat emitter replacement required) was also considered and the full capital cost would be ~£22k.

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[7] BEIS (2021). Cost-Optimal Domestic Electrification (CODE) Final Report. https://www.gov.uk/government/publications/cost-optimal-domestic-electrification-code

Table** Error! Unknown switch argument. - **Cost to Consumer: Full capital cost to consumer (with no funding support) for the shared ground array syste–. NB - the cost of the shared infrastructure is included in "other ancillary building services".

		Mid-terrace with solid walls (<=100m^2)	**Semi-detached with solid walls (>100m^2)**	**"Heat pump ready" semi-detached (<100m^2)**
Dwelling heat pump	Equipment	£3,308	£4,127	£3,308
	Installation	£1,650	£1,650	£1,650
Building fabric upgrade	Materials	£600	£800	N/A
	Installation	£400	£700	
Window upgrade	Materials			
	Installation			
DHW storage	Equipment	£1,000	£1,110	£1,000
	Installation	£624	£624	£624
Heat emitter upgrade	Equipment	£1,800	£1,800	N/A
	Installation	£1,720	£1,720	
Other ancillary building services	Materials	£11,318	£18,658	£13,581
	Installation	£1,370	£1,370	£1,380
Renewable energy generation	Materials			
	Installation			
Capping of gas supply		£550	£550	£550
Total cost to consumer		**£24,340**	**£33,109**	**£22,093**

7.3. Cost with current grant and investment support

HPR Phase 2 would have provided up to £6,000 of BEIS funding per GSHP install for the trial deployment and installation. The split ownership business model (as described in Section 7) could therefore reduce the upfront cost to the consumer by 70-80% via a combination of the HPR funding and private investment. The 'Cost to Consumer Calculator' was updated to include this additional funding and is shown in Table 11.

The proposed offer is based on providing a 6% internal return of return (IRR) over a 40-year term on the private investment. This high IRR demand on investment is expected to reduce as the shared ground array market grows.

The £6,000 grant from HPR provides approximately 18-25% of the total capital cost per property and the 'utility style' private investment equates to the 50-54%. This combination therefore leaves the end customer with approximately 25% of the full capital cost (as derived in Section 7.2) to pay.

This remaining capital cost could be paid via two principal options:

1. Directly by the customer (e.g. from savings)
2. In the form of a loan provided to the customer

Table 11- Cost to Consumer: Full capital cost to consumer with HPR grant and private investment for the shared ground array system

		Mid-terrace with solid walls (<=100m²)		Semi-detached with solid walls (>100m²)	
		Cost	Proportion of cost payable by consumer	Cost	Proportion of cost payable by consumer
Dwelling heat pump	Equipment	£3,308	0%	£4,127	0%
	Installation	£1,650	0%	£1,650	0%
Building fabric upgrade	Materials	£600	0%	£800	0%
	Installation	£400	0%	£700	0%
Window upgrade	Materials				
	Installation				
DHW storage	Equipment	£1,000	0%	£1,110	0%
	Installation	£624	100%	£624	80%
Heat emitter upgrade	Equipment	£1,800	100%	£1,800	100%
	Installation	£1,720	100%	£1,720	100%
Other ancillary building services	Materials	£11,318	0%	£18,658	0%
	Installation	£1,370	100%	£1,370	100%
Renewable energy generation	Materials				
	Installation				
Capping of gas supply		£550	100%	£550	100%
Total full cost to consumer		**£6,022**		**£6,951**	

The utility style private investment into the shared ground array system is expected to help engage and recruit more customers for heat pump deployment. Nesta studies[8] show 32% of people would be willing to pay £6k-£7k for a heat pump – although this study was for a scenario where a boiler needed imminent replacement. The consumer research carried out in WP3 found that around half of people are open to the idea of getting a heat pump, and most of these would be prepared to pay for the heat pump (if it cost £6,000) out of their own savings.

Figures from the UK government Boiler Upgrade Scheme[9] (BUS) state that the upfront cost of an ASHP is on average £13k. After the £5k BUS grant for ASHP installs, the average upfront cost to the consumer would be £8k and so it is apparent that proposed split ownership business model for the shared ground array would be cheaper for the end consumer.

The split ownership business model offer demonstrates the potential for high density roll out of heat pumps across the UK that can serve properties that would otherwise be unable to convert to heat pumps.

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[8] Nesta (Mar 2022). Estimating the willingness to pay for a heat pump. https://media.nesta.org.uk/documents/Estimating_the_willingness_to_pay_for_a_heat_pump_v1.pdf

[9] BEIS (Sep 2022). Boiler Upgrade Scheme statistics (September 2022). https://www.gov.uk/government/statistics/boiler-upgrade-scheme-statistics-september-2022

7.4. Ongoing annual operation & maintenance costs

Operation & maintenance costs of the heating system within the dwelling (payable by the end users) would include the following – these would vary based on the dwelling type and equipment installed:

1. Fuel cost (electricity) to run the heat pump.
2. Ongoing maintenance and repair costs of the heat pump
3. End of life replacement cost of equipment (heat pump and DHW storage)

Estimates for these costs are based on assumptions as provided in Table 12 for different heating systems. The service cost and frequency of the GSHP is based on Kensa product lifetimes, typical service cost and intervals are assumed for other technologies.

Table 12– cost per dwelling per year

System Assumptions	Individual GSHP	Shared Ground Array System	Gas Boiler	ASHP	Direct Electric
Expected Replacement Schedule (years)	25	25	10	15	20
Service cost (£)	£100	£100	£100	£100	£80
Service Frequency (years between services)	3	3	1	1	1
System Efficiency (%)	310*	310*	80**	240***	100

*Efficiency based on performance calculations for Leeds cluster from WP4 (Section 6)

**Boiler efficiency of 80% is assumed based on EPC data from target dwellings (lower than C rated are below 80%[10]). Over time, the boiler efficiency declines.

***Typical UK ASHP efficiency assumed[11]

Additional costs payable by the end user for the shared ground array system include:

4. Repayments for any deferred initial costs (e.g. if a loan is taken for the upfront cost)
5. Standing charge to cover connection to the shared ground array and O&M of the shared infrastructure – see additional detail below.

Standing charge

In shared ground array systems, customers have a contract with the heat infrastructure provider. After commissioning of the heat pumps, the heat infrastructure provider, (in this case Kensa Utilities Ltd) would require a standing charge. The cost of O&M of shared ground arrays are covered under the standing charge paid by the end user. There will not be any additional cost in terms of the O&M

[10] https://www.britishgas.co.uk/home-services/boilers-and-heating/guides/boiler-efficiency.html

[11] University College London (Feb 2020). Analysis work to refine fabric energy efficiency assumptions for use in developing the Sixth Carbon Budget. https://www.theccc.org.uk/publication/analysis-work-to-refine-fabric-energy-efficiency-assumptions-for-use-in-developing-the-sixth-carbon-budget-university-college-london/

of arrays from the end user. It will be the heat infrastructure provider's responsibility to ensure delivery of ambient heat needed to run each heat pump, and conduct repairs and O&M on the shared ground array as required to ensure its performance.

The standing charge also provides a return on investment for the private investors in the shared ground array, a 6% IRR has been assumed alongside annual increases in the Consumer Price Index (CPI) of 2.5% (both are clearly subject to the macro-economic environment). The capital cost of the infrastructure is spread across a 40-year term, linked to the property. Not only is the barrier of the upfront cost to the consumer reduced, the cost to the individual is also significantly lowered. Ground array infrastructure has an expected lifespan of ~100years, whilst owner-occupiers in the UK stay, on average, 16.5 years in a property[12]. By linking the capital cost to the property, rather than the individual, this cost is passed to the new occupant. On average, we would expect each service agreement to be financed by three households across its term. The agreement with the heat infrastructure provider owning & maintaining the ground array lasts for a minimum of 40 years, but will roll-over after this until end user choose to terminate it, ensuring continuity of supply & heat for as long as the consumer desires.

7.5. Overall cost analysis (Option 1 - customer upfront payment)

Whole life cost analysis is performed over 40 years (the infrastructure lasts 100 years) to understand the impact of capital and operational costs on the end user and is attached as Appendix 5. The analysis assumed an annual increase in CPI of 2.5%. Results are presented below for the two solid wall property types considered in Section 7.3, also using typical costs for alternative heating systems for comparison.

7.5.1. Case 1 - mid-terraced house with floor area ≤100m2

Table 13 and Figure 26 show a comparison of upfront costs, Table 14 and Figure 27 show the annual costs. The shared ground array heat pump solution has the lowest upfront cost to the consumer compared to other heat pump solutions and also keeps the running costs similar to a gas boiler, with the high efficiency of the system offsetting the difference in electricity vs. gas prices.

Table 13 – Comparison of upfront costs for typical mid-terraced property

	Individual GSHP	**Shared Ground Array System**	**Gas Boiler**	**ASHP**	**Direct Electric**
Capital cost of installation	£31,450	£24,340	£4,000	£13,000	£3,000
Grant Funding	£6,000	£6,000		£5,000	
Private Investment		£12,320			
Cost to Consumer	£25,450	£6,020	£4,000	£8,000	£3,000

[12] Barclays Bank (2018). Barclays Home Improvement Report. https://home.barclays/news/press-releases/2018/10/uk-homeowners-stay-put-for-nearly-two-decades--choosing-to-impro/

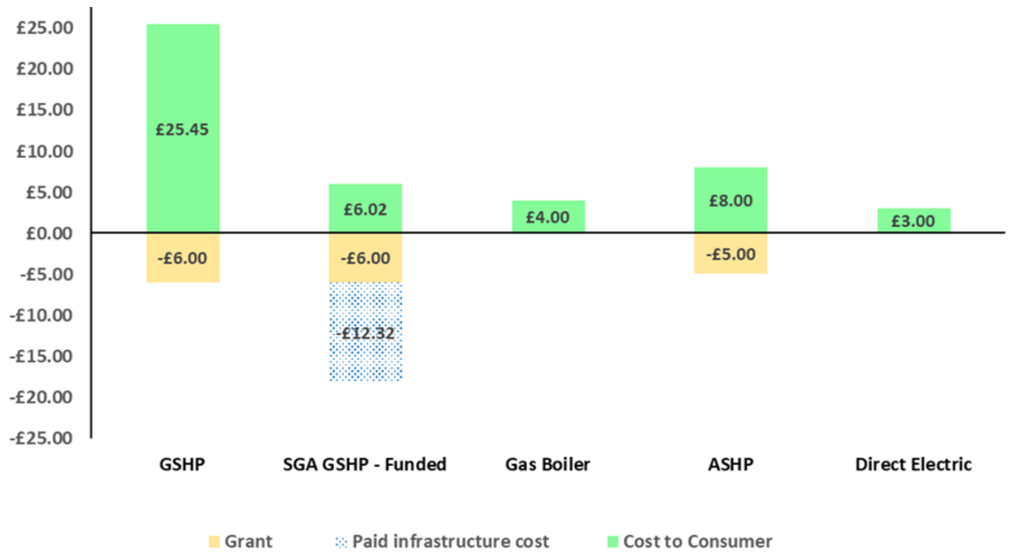

Figure 26 – Comparison of upfront costs for typical mid-terraced property (£k)

Table 14 – Comparison of annual costs for typical mid-terraced property

	Individual GSHP	**Shared Ground Array System**	**Gas Boiler**	**ASHP**	**Direct Electric**
Heat Demand (kWh)	13,500	13,500	17,000	13,500	13,500
CoP	3.1	3.1	0.8	2.4	1.0
Electricity Unit Rate (p/kWh)	34				
Gas Unit Rate (p/kWh)	10.3				
Total Fuel Cost	£1,481	£1,481	£2,189	£1,912	£4,590
Replacement & Maintenance	£114	£114	£786	£574	£216
Standing Charge	-	£753	£105	-	-

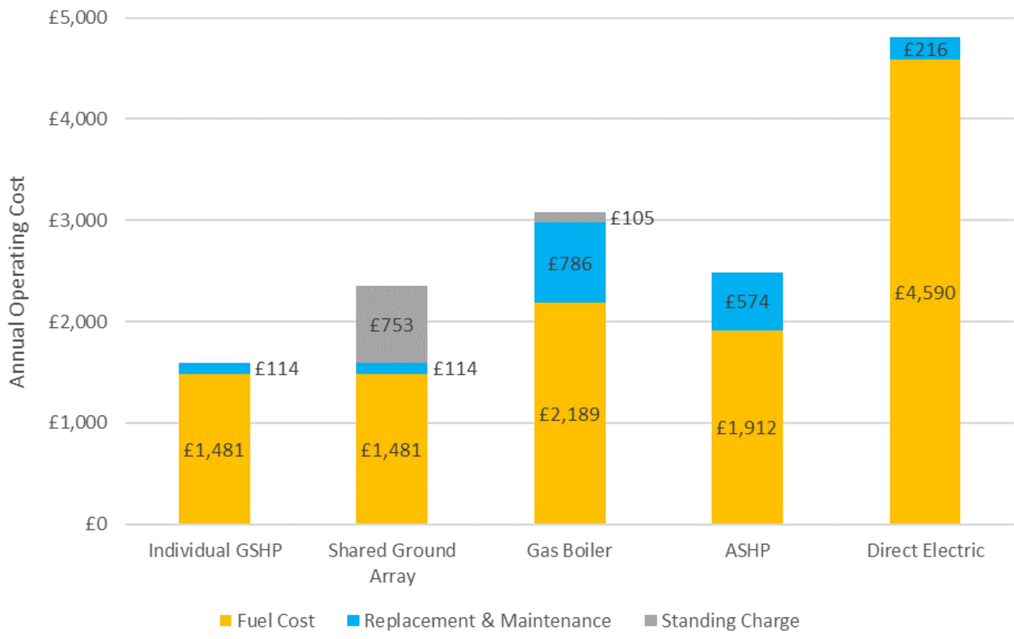

Figure 27 – Comparison of annual costs for typical mid-terraced property

7.5.2. Case 2 – semi-detached house with floor area >100m2

Table 15 and Figure 28 show a comparison of upfront costs, Table 16 and Figure 29 show the annual costs. For large semi-detached houses an ASHP system would be the most cost-effective low carbon heating solution with current prices as the shared ground array system requires significant additional capital investment which therefore necessitates a higher standing charge.

Table 15 – Comparison of upfront costs for typical semi-detached property

	Individual GSHP	**Shared Ground Array System**	**Gas Boiler**	**ASHP**	**Direct Electric**
Capital cost of installation	£44,250	£33,100	£4,000	£13,000	£4,000
Grant Funding	£6,000	£6,000		£5,000	
Private Investment		£20,160			
Cost to Consumer	£38,250	£6,950	£4,000	£8,000	£4,000

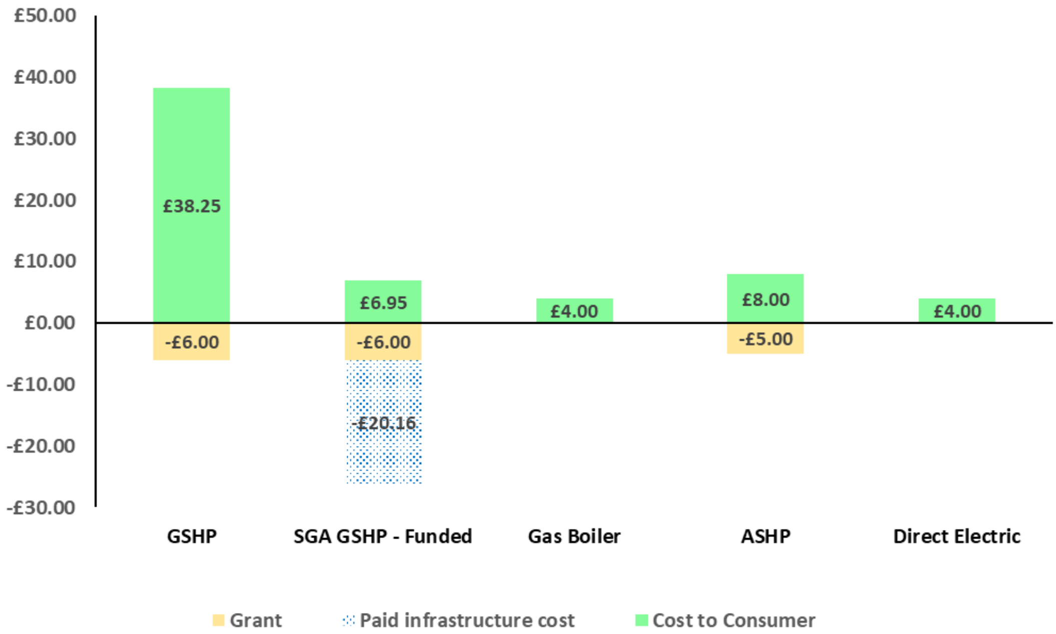

Figure 28 – Comparison of upfront costs for typical semi-detached property (£k)

Table 16 – Comparison of annual costs for typical semi-detached property

	Individual GSHP	**Shared Ground Array System**	**Gas Boiler**	**ASHP**	**Direct Electric**
Heat Demand (kWh)	17,000	17,000	22,000	17,000	22,000
CoP	3.5	3.5	0.8	2.4	1.0
Electricity Unit Rate (p/kWh)	34				
Gas Unit Rate (p/kWh)	10.3				
Total Fuel Cost	£1,651	£1,651	£2,833	£2,408	£5,780
Replacement & Maintenance	£140	£140	£786	£574	£216
Standing Charge	-	£1,212	£105	-	-

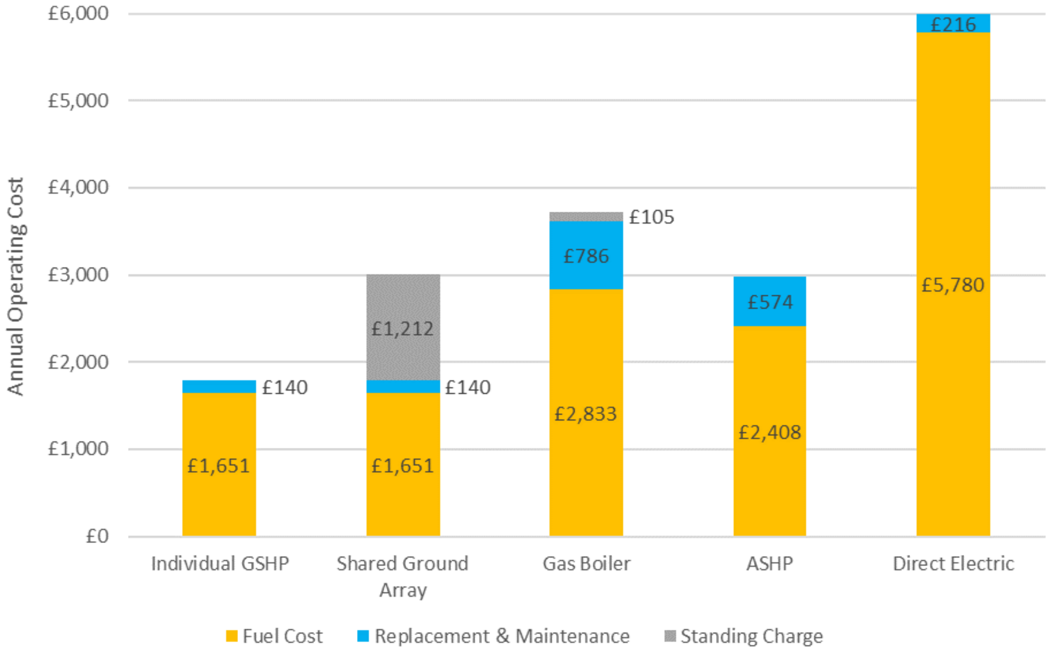

Figure 29 – Comparison of annual costs for typical semi-detached property

7.6. Overall cost analysis (Option 2 - customer loan)

A similar cost analysis to Section 7.5 is presented in Appendix 6, for the situation where a customer chooses to take a loan to cover the upfront cost of the shared ground array.

7.7. Cost to Consumers – Leeds Clusters

The capital and operational costs are detailed in earlier sections for typical properties that are part of a cluster deployment. A 'cost to consumer' calculator was provided by BEIS for the Phase 2 application and this was completed to show the breakdown of estimated total costs for the shortlisted clusters from WP2, using assumptions on the overall uptake discussed in Section 12 and based on the mid-terraced property in Section 7.5.1. These spreadsheets are included as Appendix 4 – Cost to Consumer Calculator (upfront contribution) for Option 1, where the customer makes an upfront contribution and as Appendix 5 – Cost to Consumer Calculator (no upfront contribution) for Option 2, where a loan is taken out.

For the 151 properties there would be a total capital cost of approximately £3,700,000, with £900,000 of BEIS HPR funding, £1,900,000 of private investment and £900,000 remaining cost paid by homeowners. It should be noted that these values are indicative of the potential project scale as considered for the HPR Phase 2 application, but do not account for estimates of consumer uptake based on findings from WP3.

7.8. Additional Business Model Considerations

For both property types assessed in Section 7.5, the standing charge payable by the consumer could be reduced if lower cost financing was available (e.g. obtaining co-investment from the local authority who can borrow at more favourable public sector rates, thereby creating a private-public partnership for decarbonisation). Additionally, the IRR required by investors may reduce in the future as the business model becomes more widespread, again reducing the standing charge required and further reducing the annual running cost of the shared ground array system compared to alternatives.

A recent study[13] by the World Wildlife Fund (WWF) discusses how Low Carbon Technologies (LCTs) can increase home equity value, with heat pumps increasing sales values by £5,000-8,000 and therefore potentially recovering the upfront cost of install for homeowners if/when the property is sold.

Further bill savings can be made by switching to a heat pump-specific or Time of Use (ToU) tariff, such as Octopus Agile. This will be beneficial to consumers as they can avoid consuming (and therefore paying) for electricity at times of peak prices and consume greater volumes when electricity prices are low. It will also benefit consumers who are unable or unwilling to flex their demand: for example, if enough demand is deferred from peak times, this will dampen wholesale price spikes, making electricity more affordable for all. The DHW storage in each property could be used to take some advantage of a ToU tariff by charging from a heat pump during off-peak hours (although this benefit would be proportional to the storage size available) as well as potentially shifting space heating times. Battery storage would be required to realise savings on a ToU tariff from load-shifting other non-heating electrical demands.

With the support from the HPR grant and private investment into the shared ground arrays, the shared ground array heat pump solution is an attractive heat decarbonisation solution in areas where alternatives such as air-source heat pumps are not viable due to practical issues such as space constraints, planning restrictions on unit locations and acceptable noise levels.

Data from the Parity Pathways software shows that terraced and semi-detached properties represent 84% of all properties in the three wards of Leeds that were investigated in this study, with 13,450 terraced properties in total. Figure 30 shows the split of different archetypes (in all three wards) and Figure 31 shows the distribution of EPC ratings within this group of properties.

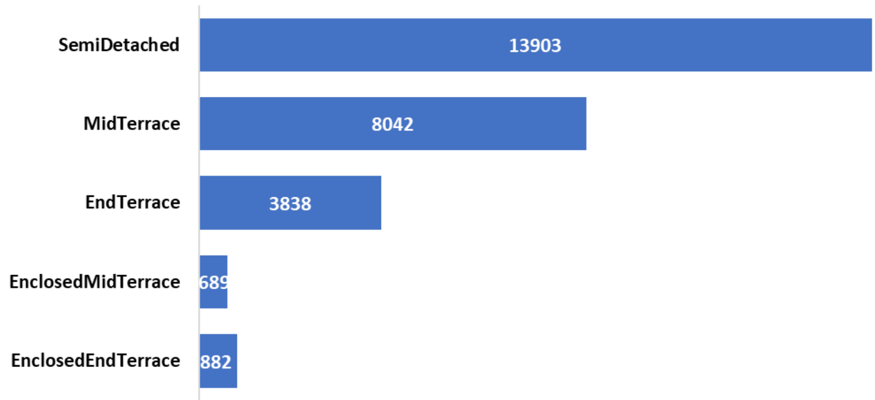

Figure 30 - Number of each archetype within Leeds wards (Roundhay, Chapel Allerton and Otley & Yeadon)

13 WWF (Aug 2022). Better Homes, Cooler Planet. https://www.wwf.org.uk/our-reports/better-homes-cooler-planet

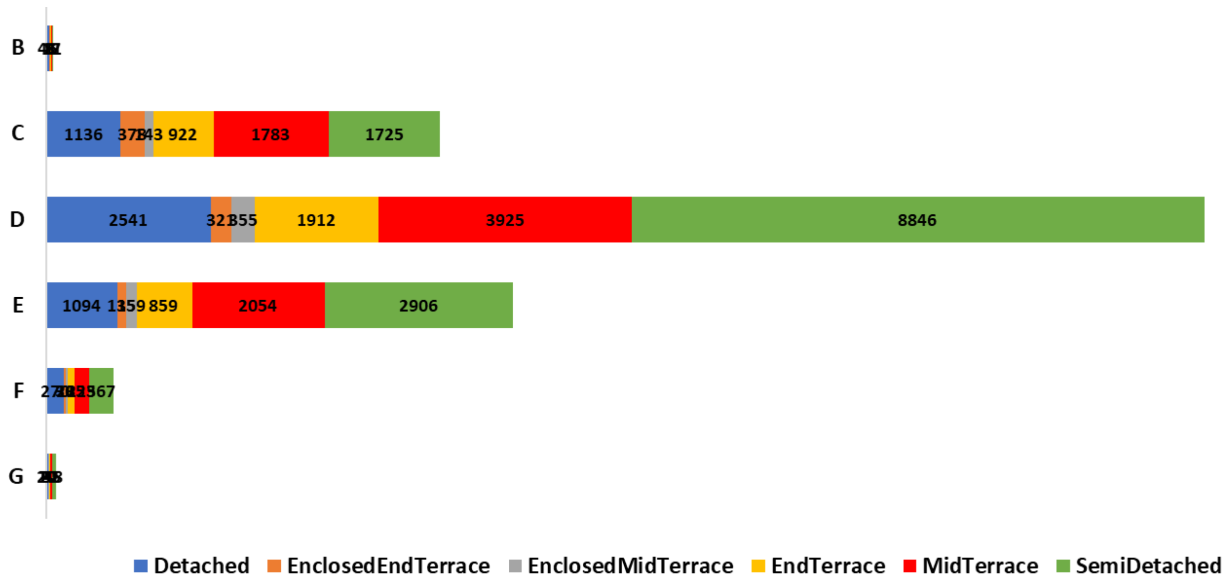

Figure 31- Distribution of EPC ratings across archetypes within the three Leeds wards

The Parity Pathways data also shows that 54% of the terraced properties in the area are of solid wall construction (see Figure 32). If solid walls are not insulated, the shared ground array system may be preferable for the delivery of higher heat loads in areas of high density solid wall properties.

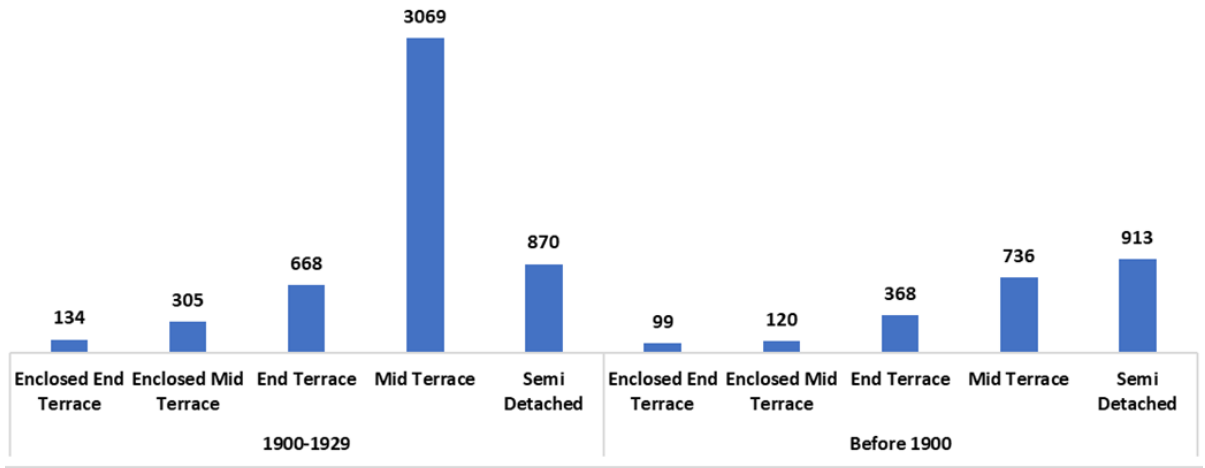

Figure 32 - Number of each archetype with solid walls, split by construction period

The mass electrification of heat with heat pumps will inevitably have an impact on the electricity grid. The Energy Networks Association (ENA) Connect & Notify approval identifies Kensa's Evo and Shoebox ground source heat pump ranges to be of low grid impact, enabling their installation without any prior approval requirement from local DNOs.

As shown in Section 6, the shared ground array system is expected to produce 3-3.5 units of heating averaged over the year per 1 unit of electricity and this efficiency is less affected by ambient air temperatures compared to ASHPs, also not requiring defrost cycles that contribute to reduced ASHP efficiency in colder weather.

In the short term, because the shared ground array solution requires less electricity to operate, this implies that it would be possible to install more heat pumps via shared ground arrays than ASHPs or direct electric heaters in an area where grid headroom is limited.

Whole life cost modelling has shown that lifetime value for money of the shared ground array is comparable to existing gas boilers and ASHP heating systems (see Appendix 5). However, and significantly, these cost saving estimates do not include any reflection of the extensive savings expected in the reduced requirement for generation capacity and upgrading of the electricity grid. Modelling hypothetical savings to potential future asset investment presents challenges and presenting these as savings to consumers is not straightforward.

A recent study[14] concluded that in the long term, high uptake of networked GSHPs (such as shared ground array solutions) could reduce peak electricity demand relative to a predominantly ASHP scenario and also reduce system costs for grid upgrades by nearly £40bn by 2050. Another study[15] also concluded significant savings with shared ground arrays (potentially a third less capacity requirement) compared to other electrical heating systems.

7.9. Key findings

The business model overcomes four key barriers to high density heat pump deployment:

- The high cost of ground source heat pumps, particularly the groundworks, by splitting responsibility for the upfront costs between the homeowner and a third party.
- The potential increased running costs compared to a gas boiler counterfactual.
- The lack of commercial investment opportunities in low carbon heating
- The coordination of individuals for a fundamentally street-by-street solution that's required to be able to deliver at the scale and pace required for net zero.

The roll out of the shared ground array system on a street-by-street basis could assist LCC in fulfilling their strong commitment to decarbonisation - WP5 shows that this is potentially the most cost-effective solution for terraced houses which are hard to treat and have limited alternative options for decarbonising heating. The split ownership business model could unlock substantial private investment into homes that would not otherwise be able to commit to low carbon heating systems in the given timescales and therefore offers a viable route to high density deployment of heat pumps in Leeds and across the UK.

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14 Aurora Energy Research (Oct 2021). Decarbonisation of Heat in Great Britain. https://auroraenergy.wpenginepowered.com/wp-content/uploads/2021/10/20211020-Aurora-Heat-Decarbonisation-Public-summary.pdf

15 regen (Mar 2021). A utility based approach for ground source heat pumps. https://www.regen.co.uk/wp-content/uploads/HeatPumpReport_Final_04PDF.pdf

8. WP6 (Supply Chain) – Methodology & Findings

This small element of WP6 focussed on providing a preliminary overview of the different supply chain elements required to deliver a shared ground array heat pump system serving multiple domestic properties, using the RHINOS project as the base case. Supply chain elements include physical equipment and materials, but also a range of activities essential to implement the project and achieve the project aims.

Both materials and activities are mapped and analysed in order to identify the constraints, opportunities and uncertainties in the supply chain, with a specific focus on where there is the opportunity from greater Small and Medium-sized Enterprise (SME) involvement and development.

This outline analysis is informed by interviews with five expert informants from the RHINOS project team representing different domains of expertise in the supply chain, as well as industry body data and previous research on low carbon construction supply chains in the UK. The commentary below therefore includes some RHINOS-specific points, and also points which are relevant to the potential wider, national deployment of high-density heat pumps using a shared ground source array. The expert informants brought insights from the whole implementation process, from design, through procurement, to installation and the customer experience. Interviews were carried out between July and September 2022.

8.1. Scope

The supply chain is scoped as all the commercial activities that are carried out in designing, installing, and operating a shared ground array heat pump system. These activities are separated into below ground– designing, building and connecting the ground source array- and above ground (including ‘in home’). Three activities are identified as important to successful project development (area-based consumer engagement and planning; DNO activity; ongoing data collection) but as they are not part of the commercial supply chain for the project, these activities are noted but remain outside the scope of analysis.

8.2. Mapping

Mapping of the supply chain is shown in Appendix 10 – Supply Chain Research. Each box is a separate supply chain element, which could be an activity/service or could be the supply of material/equipment. These boxes indicate elements which could be provided by separate and distinct organisations. The mapping is intended to illustrate the range of discrete supply change elements needed to deliver high heat pump density deployment, based on a shared ground loop heat source. The mapping is not intended imply that elements are, or should be, delivered by a separate organisation.

There are areas where vertical integration along the supply chain enables efficiency. For example: designing the ground source array, designing the individual home heating systems, and connecting the array to individual home heat pumps are three activities requiring common data in terms of heat demand and system efficiencies. Vertical integration so that these design and implementation are carried out by the same organisation can help with the efficiency of data transfer and be more efficient in dealing with issues that arise in implementation that require changes to design i.e. vertical integration helps with information feedback loops, learning and adaptation.

At the current early stage of supply chain development, vertical integration between the different parts of the Kensa Group also facilitates capacity building, with Kensa operating companies who provide direct support for new firms to come into the field and take on responsibility for parts of the supply chain delivery. However, if SME development is a particular interest, then identifying the smallest units of activity helps identify where there are SME entry points to this kind of work. This is why the supply chain mapping identifies the smallest discrete elements.

8.3. Headline findings

8.3.1. Potential Constraints

Drilling rigs. There are a relatively small number of drilling companies in the UK; the British Drilling Association is the trade body that supports extensive technical training and capacity building. The capital intensity of acquiring the drilling rigs (and associated ‘mud puppies’ for spoil disposal) puts a limit on the number of SMEs that choose to enter the sector. It is estimated that there are around 150 drilling rigs in the UK, which is sufficient, in theory to resource a significant increase in demand for new boreholes for ground arrays. There are sufficient drilling rigs to be able to implement the Leeds scheme explored in this study, although availability can be limited given the range of other infrastructure projects that might call on this kind of equipment so carefully scheduling is vital. However, beyond this Leeds scheme, it is worth noting that there are no drilling rigs in the UK that can drill to a depth greater than 300m, and the majority of UK-based drilling rigs are limited to drilling to depths of 200m or less. The potential for high density heat pump deployment in the UK will, necessarily, be in areas of high-density dwellings, where there is very limited land availability and, often, high property values. For those areas to be able to access geothermal heat supply, the UK ground array market will require drilling to greater depths, up to 500m.

Ground loop design. There are a relatively smaller number of design firms in this space at present (probably less than 15) although capacity would likely be increased if there was market demand. Training, technical competence and professional indemnity insurance are the barriers to new market entrants, rather than capital equipment.

Ground loop commissioning. There are insufficient Microgeneration Certification Scheme (MCS) accredited competent individuals to commission the volume of GSHP projects envisaged by the Heat & Buildings Strategy. Becoming registered with the MCS is an investment by individuals, although suppliers such as Kensa are facilitating a greater awareness in heating engineers of how they can extend their work into this expanding area.

Equipment supply. A range of factors might constrain equipment supply, particularly from UK suppliers. For the manifolds, there are a small handful of UK suppliers (2 – 5, estimated) and if they cannot meet demand then manifolds are imported from Scandinavia. Similarly, there are only two significant glycol suppliers in the UK. Such a small number of suppliers does not suggest that the supply chain is resilient. Obviously, many factors that affect the supply chain are not going to be within the UK’s control. A pump manufacturer dependent on importing raw materials from Ukraine has reported that it has eight million pumps on back order. Global issues are also limiting heat exchanger supply, with new heat exchanger orders being scheduled for delivery in April 2024.

8.3.2. Opportunities

UK heat pump manufacture. At the heart of the RHINOS project lies an innovative 'shoebox' heat pump design, designed, developed and manufactured wholly in the UK. Kensa are expanding their manufacturing capacity rapidly. Deploying this technology, at scale, offers significant opportunities in high value manufacturing jobs through two routes:

- Heat pump assembly – scaling up from current capacity producing around 3000 'shoebox' heat pumps at the moment, to a maximum of approx. 400 000 per annum (one third of the total number of heat pump installations indicated by the Heat & Buildings Strategy) would create over 2000 direct new jobs. Other related employment in design, civil engineering and in home installation are not considered in this estimate.
- The number of manufacturing jobs could be further amplified if the UK market scales up sufficiently to make the on-shoring of component manufacture viable. This covers items such as the heat exchangers used by Kensa that are currently only produced outside the UK. It is beyond the scope of this analysis to estimate the number of component manufacturing jobs needed to underpin the huge expansion of ground source heat pump deployment.

Local SME heating engineers and installers. There are a range of project activities which could be carried out by local heating/plumbing subcontractors and in some cases building up specific local knowledge would be very powerful in accelerating heat pump deployment. There are currently a small number of M&E contractors (the suggested number is four) in the UK building their capacity to undertake this kind of work, supported by equipment suppliers. A model where these larger regional or national M&E contractors have alliances with local pools of SME plumbing and heating firms is a major opportunity, although it will take policy support to realise. The activities where local SMEs could have a role are above ground / in-home: installation, commissioning (with appropriately certified supervision), monitoring and maintenance. The longer life and longer service intervals that are assumed for this type of Kensa heat pumps (see Section 7.4) suggests that maintenance requirements are minimal. However, provision of ongoing support if householders do have concerns and queries; monitoring of systems to identify those rare faults; and supporting customers to upgrade as technology improves further, are all areas where local plumbing/heating SMEs are well placed to deliver trusted, long-term services.

8.3.3. Uncertainties

Aftercare and maintenance. Connecting to the discussions about quality assurance systems in WP3, the scope of this kind of project to extend into aftercare and maintenance is not yet clear. There are clear customer benefits from ongoing support, but who does this, and whether the homeowner is willing, or able, to select a support package, needs discussion. The anticipated lower frequency services (see Section 7.4) and low levels of call out in the small number of systems installed thus far, allow an assumption that in-home maintenance requirements will be very low. Telemetry enables monitoring and early intervention to keep the ground array operating effectively. Because of the limited scope at present for standalone commercial services in maintenance and aftercare, an effective, competitive market for such services is a long way in the future.

Home energy demand reduction through fabric measures. Work, and equipment, associated with reducing energy demand through fabric measures such as improving insulation or airtightness are shown with a dotted line around them in Appendix 3 – Shared Ground Array Cost Reduction Measures, Figure 1. It is not clear whether these activities will fit with the commercial model being tested. Section 7.2 above includes costs for light retrofit measures and Section 7.8 indicates that the depth of retrofit works, and who pays for it, is a consideration in the business models that could support high density deployment using a shared ground source array.

There is a case that some demand reduction measures may be close to cost-neutral across the whole project because the reduction in heat demand may reduce the capital cost of the shared ground loop. However, the potential reduced capital cost of the shared ground loop is a benefit to the heat company installing or operating the shared asset, while the increased initial capital cost in reducing demand in individual homes through retrofit is likely to be paid for by individual homeowners. Thus, cost neutrality across the whole system is not cost neutral for the different commercial actors in that system. In analogous projects to date, such works were carried out in advance of the household design and funded separately from the heat pump installation.

Further energy demand reduction measures would reduce customer fuel bills and might increase the likelihood of households signing up. However, in simple cost-benefit terms, bespoke demand reduction measures rapidly become more expensive, in skilled labour if not in materials. A question to be resolved is whether the value in reducing energy demand and therefore carbon emissions, as well as the comfort of the home, makes some retrofit measures desirable even if they do not deliver simple payback.

9. WP6 (Consumer Journey & Quality Assurance) – Methodology & Findings

9.1. Introduction

This section reviews the processes and standards that cover the engagement, design, installation, and aftercare stages of both the main Kensa model and the addition of retrofit measures as part of the customer offer. It considers how these processes could be integrated, accounting for the customer journey (Section 5.7), supply chain (Section 8), Quality Assurance (QA) (Section 9.5), and Consumer Protection (CP) (Section 9.6).

9.2. Scope

We analysed Kensa's well-established model for deployment of its shared ground arrays, along with their existing experience of incorporating retrofit measures into the process.

We then considered alternative approaches to the customer offer, incorporating the proposed energy efficiency measures in addition to the Kensa system. This involved:

- researching customer journey development from the retrofit sector, bringing in national best practice;
- analysis of relevant QA standards and CP approaches;
- a review of LCC's existing experience across both heat network deployment and area-based retrofit; and learnings from parallel projects that partners within the consortium are involved in, namely the West Yorkshire Better Homes Hub and Leeds Retrofit Accelerator.

A high-level structure has been developed to both compare and combine best practice elements from different projects, and to identify the role of the supply chain at each step of the customer journey.

9.3. Methodology

Activity	Notes
Gathering existing HPR project QA and CP guidance	Reviewing and extracting existing guidance and thinking on QA and CP from HPR workshop, helping to ensure initial alignment with the goals of the project.
Mapping high level Kensa business model and process	Mapping out initial assumptions based on high-level Kensa business model and process map and its relationship to the supply chain, consumer protection, and the overall HPR model development.
Research into QA environment and approach to CP for the Kensa system and retrofit works including MCS and PAS2035 accreditations	Gathering publicly available data on MCS and PAS2035, reviewing to establish their respective QA and CP processes. This activity set out best practice and accredited approaches and their baseline processes against which we could carry out a compare and contrast exercise of Kensa's and others' processes.

Business process framework development	Developing a framework for the customer journey from the delivery, QA, and CP perspective, based on the information gathered to inform a compare and contrast exercise.
Gathering detailed info from Kensa	Gathering and reviewing detailed business model, process, and QA and CP information from Kensa including projects that incorporate retrofit measures, to ensure a solid foundation of understanding for the analysis.
Mapping data gathered into framework	Mapping the more detailed data and information supplied by Kensa on their business process, QA, and CP into the established framework, and refining the framework as necessary.
Review of framework and mapping	Review and discussion of framework and mapping to establish gaps in the understanding of Kensa's process, and the integration of retrofit measures, and identifying other models to include in compare and contrast exercise.
Establish additional list of models including retrofit-based models	Establishing list of additional models to research and contact to provide additional evidence around QA and CP.
Queries on QA and CP processes	Drafting and sending out queries to Kensa and other organisations/models to ask for more detail on their respective QA and CP processes.
Integrate WP6 supply chain work	Integrate work from University of Leeds on supply chain mapping to ensure alignment with the stages.
Interviews with key models re QA and CP	Conduct interviews to gain more detail on specific QA and CP models incl. MCS, Irish OSS, various LCC projects, and Retrofit Works.
Update mapping based on interviews	Update the framework and mapping based on the additional detail gathered from interviews.
Update mapping based on resources	Update the mapping based on additional detail from resources shared as a result of interviews.
Confirm Kensa process aligns with QA and CP best practice	Carry out a compare and contrast exercise to confirm the Kensa process aligns with the identified and mapped QA and CP processes.
Mapping document	Finalising this mapping as a key output to be included in the report.
Finalising outputs and write up	Finalising the outputs to be included in the final report and writing up all relevant sections.

9.4. Mapping

Kensa confirmed that their installations are certified under the relevant QA regimes:

- Microgeneration Certification Scheme (MCS): An accreditation body which certifies, quality assures and provides CP for low-carbon energy technologies and contractors.
- PAS2035: A specification enforced by TrustMark which provides a framework for the application of whole house retrofit energy efficiency measures and provides best practices for their implementation.

Our research included a mapping of these QA frameworks and alternative models that deliver heat pump systems and in some cases energy efficiency measures. This mapping was informed by desk research and a set of interviews with representatives from key models and frameworks to understand more about their processes with a focus on QA and CP approaches.

A high-level framework was developed from a synthesis of an initial HPR workshop output focusing on QA, the potential areas of analysis which could be explored, and the initial analysis of the models. This framework includes the following stages: engagement, assessment, design, installation, commissioning, handover, and consumer protection.

Kensa's model for delivery of shared ground array Ground Source Heat Pumps (GHSPs), and the QA frameworks of PAS2035 and MCS were mapped into this framework, as well as several examples of alternative models including LCC's work on heat pumps in tower blocks and their Leeds PIPES heat network.

This mapping of frameworks is shown Appendix 8 – Quality Assurance QA Process Mapping.

Mapping out the gathered information into a set of detailed process maps allowed for the identification of common stages and steps across the models and frameworks, as well as potential gaps within their processes relating to QA and CP. A more direct compare and contrast exercise was then undertaken to establish the alignment of Kensa's existing process with MCS and PAS2035.

This compare and contrast mapping is shown in Appendix 9 – Compare & Contrast of Kensa's process with QA frameworks.

9.5. Findings – Quality Assurance

Headline findings around QA have been drawn out from the detailed compare and contrast exercise shown above. The key reference documents for this are from MCS[16,17] which provide a significant amount of detail on QA.

[16] MCS (2022). The MCS Specification for Ground Source Closed-loop Drilling. https://mcscertified.com/wp-content/uploads/2022/02/The-MCS-Specification-for-Ground-Source-Closed-loop-Drilling-1.0.pdf

[17] MCS (2021). The Heat Pump Standard (Design). https://mcscertified.com/wp-content/uploads/2021/12/MIS-3005-D-Heat-Pump-Design-Issue-1.0.pdf

This section should be read in correspondence to the above mapping, which illustrates Kensa's process for shared ground loop array GHSPs and a parallel process for fabric measures, both aligned to the respective QA regimes of MCS and PAS2035.

Overall, our findings suggest that both the Kensa process for the installation of their technology and energy efficiency measures are well aligned with these QA regimes. This is verified by their successful accreditation through these schemes.

9.5.1. Kensa's process compared with QA models

Assessment

At the assessment stage, Kensa's process is well-aligned with both MCS and PAS2035. Carrying out a detailed home survey including heat loss calculations maps to both the MCS home survey step which asks for detailed measurements and photographs of existing systems. For fabric measures, this step would require additional detail to be recorded to feed into a whole house assessment, aligning well with PAS2035 which asks for a whole dwelling assessment and report. This whole house approach is welcome in the context of LCC's commitment to reducing energy demand as part of the pathway to decarbonising the housing stock.

As MCS requires space heating design to inform heat pump sizing and components, Kensa carries out detailed heat loss calculations to meet these criteria and as a key aspect of their assessment and design. These calculations feed into the scheduling of radiators, again an MCS-aligned step which asks for these schedules to be informed by both calculations and photographs.

The final step within the assessment stage is the geological study for the boreholes that will be drilled and installed as part of the ground array. The MCS specification dictates that this step must be carried out to validate the design, locating and delivery of the boreholes, taking the form of a detailed site survey including an assessment of geology, unexploded ordnance (UXO) risks, and any other potential hazards. Kensa appears to be well-aligned with this requirement.

Design

As part of the design stage, Kensa carry out a detailed design process for the installation of boreholes, GSHPs, and their hydraulic systems. MCS asks for installers of these components, in particular boreholes, to have a membership of the Ground Source Heat Pump Association (GHSPA) to ensure the design validation of these installations, and as Kensa are MCS-certified, our assumption is that they meet these criteria.

A detailed design is undertaken for a whole house/phased retrofit to inform the selection and installation of fabric measures, with a plan delivered to the customer. This step aligns with PAS2035, which requires a retrofit design to be produced by a Retrofit Designer (RD) and reviewed by a Retrofit Coordinator (RC). For in-home survey work, Kensa follow the PAS2035 guidance and pathways and have a dedicated RC within their team. Following this, a scope of works and projected costs for the installation are developed, including for fabric measures, and financial options and a financial plan are developed. Similarly, the contract or scope of works step is aligned to MCS, as is the requirement for installers to receive design and costs before contracts are signed and work is commenced.

Critical to the geological survey is the UXO risk assessment which ensures it is safe to commence borehole drilling, reinforced by MCS guidelines around design validation. Both accreditations refer to the need for risk assessments to inform installation pathways.

At this point of the design stage, the Kensa Contracting Design Team checks records of buried assets. Installer teams are aware of any risks and trained to check for issues on site as they proceed with the works. Trenching and depths are specified as part of design, and on site would be a site manager to ensure everything installed as per the design.

Kensa also complete a full topographical survey of the site, again aligned to MCS's guidelines around achieving design validation for the installation through a detailed site survey.

Installation

In the installation phase, Kensa drills and installs the required boreholes, which should be aligned with MCS's requirement for installer compliance with the GSHPA Vertical Borehole Standard. These installations are tested through a Thermal Response Test (TRT), as is required by the MCS specification which sets the standard for the installation, grouting and testing of closed loops.

The waste generated by borehole drilling must be managed and disposed of in accordance with MCS guidance and current legislation, again Kensa's step covering the disposal of liquid and solid waste suggests that this is aligned.

MCS certifies the whole Kensa system, accounting for the design and installation of the ground array and the internal measures including the distribution system.

Fabric measures are likely to be installed in in appropriate sequencing with the internal and external measures for the ground array and GSHP, and for this process to be PAS2035 compliant these measures need to be installed by PAS2035-certified installers to the specific standards.

Post-completion

After installation has been completed, there are further critical steps for MCS and PAS2035 accreditation. MCS provides more detail on this step which would consist of an installer test and the commissioning of the installations, and the delivery of a Claim of Conformance.

MCS dictates that installers carry out tests and commission the installations, and Kensa meet this through the inclusion of a Building Regulations certification of heat pump installation and Part P certification of electrics.

Critical to post-completion is commissioning for technological measures, with both MCS and PAS2035 requiring testing, commissioning and sign-off, including the supply of the records to the customer.

During the post-completion phase begins Kensa's one-year defects liability and QA period for the ground array. This liability should be communicated in the handover documentation – including an offer of maintenance and replacement services – as stipulated by MCS guidance.

Handover

Across both technology and fabric measures, a handover and supply of an information pack to customers are critical to ensuring they understand their new system. In line with both MCS and PAS2035, Kensa supplies an end-user literature and handover pack. For full compliance, this pack must include detailed information on Claims of Conformance, PAS2035 compliance, guarantees and warranties.

To assist with customer understanding of the information pack and handover of systems and controls, Kensa ensures a Tenant Liaison Officer (TLO) is on hand to answer any post-works questions. MCS requires documentation to be explained to the customer, and PAS2035 dictates that a Retrofit Coordinator (RC) is on-hand to give general advice on or shortly after the handover. In the case of an area-based approach, a TLO should be present by default, otherwise the project manager would fill this role when dealing with owner occupiers.

Additionally, Kensa supplies a video which provides customers with an overview of their new system and how it should be operated, providing a supplementary, interactive form of a user manual.

Kensa's contact details are left with the customer for post-installation recourse, which feeds into the CP approach explored in Section 9.6. This step is well-aligned with MCS, which specifies that contact details be supplied for ongoing reporting and monitoring.

The majority of issues are from installer errors which fall under the 2-year extended workmanship warranty. Heat pump failure rates are low due to the quality control process at the manufacturing stage. Data on faults is recorded by Kensa but at this stage has not been compiled into a dataset.

9.5.2. Alternative models and Quality Assurance (QA)

Leeds City Council projects

LCC's existing experience with the delivery of technology and fabric measures provides a useful basis for informing the development of a QA regime. Their process for both the Leeds PIPES and tower blocks work follows a comparable structure of stages with the inclusion of engagement as a key means of kicking off the work. This engagement stage allows residents to understand the offer and what the installation process will look like, as well as meet the QA-certified contractor who will deliver the work.

The assessment and design stages of these models map to the established MCS QA framework, following the home visit, assessment, and design methodology. The QA approach appears to be light touch overall, with responsibility largely sitting with Vital Energi or Cenergist, the appropriately accredited private sector organisations responsible for delivery of Leeds PIPES and tower blocks respectively.

At the post-completion stage, both models ensure QA through a confirmation of the standard of workmanship, delivered by attendance from a Leeds City Council representative along with the contractor. This workmanship standard carries through into the CP regime, which is explored in more detail in Section 9.6. As with Kensa and the MCS approach, LCC supply a handover pack to residents which includes a commissioning certificate and a walkthrough of the controls. This handover is supported by an officer on-hand to answer questions. In both models, a post-works satisfaction survey is also completed as part of the QA regime and ongoing scheme improvement.

LCC have also been successful in securing government Local Authority Delivery (LADS) and SHDF funding, requiring PAS2035 certification which is managed successfully by their managing agent Equans.

LCC therefore have direct experience of this type of project and their QA processes are aligned should they play an active role in a future model. They can gain confidence in any case from Kensa's QA approach.

Irish one-stop-shops

The Irish Government and Sustainable Energy Authority of Ireland (SEAI)'s one-stop-shop (OSS) sets out a model[18] for those developing schemes under the framework. This applies to organisations that are appointed to administer and deliver the €8bn National Retrofitting Scheme which provides grants of up to €6,500 for heat pump systems.

As with LCC's work, the process starts with engagement, taking complementary approaches of targeted marketing and community-based social marketing (CBSM). The OSS must have a documented customer care procedure, incorporating elements of CBSM, the provision of information, awareness and training events, and the promotion of energy services to prospective customers. This approach is well-aligned with Kensa's and LCC's own engagement processes which builds in aspects of CBSM and the provision of advice and information.

The Irish OSS uses ISO (the International Organisation for Standardization) standard 9001 for its quality management system (QMS), and standard 10005 as a guideline for establishing, reviewing, accepting, applying, and revising quality plans for homes. The application of this international standard ensures that the model's assessment and design stages are quality assured.

Through the installation stage, the Irish model also quality assures these steps through the implementation of contractor assessments and standards, technical standards and specifications for the installation of measures. As with the development of plans, contractors are assessed through the ISO 10005 standard, and QA is upheld with the SEAI Quality Assurance and Disciplinary Procedures for Contractors guidance document[19]. The Domestic Technical Standards and Specifications[20] document supports contractors in the quality-assured delivery of measures.

A Registered Electrical Contractor (REC) Is required to supervise and sign off on the electrical installation of heat pumps, a post-works Building Energy Rating (BER) is carried out, and quality and specification compliance forms are completed. These measures ensure QA of works once completed.

Our analysis demonstrates alignment with both MCS and PAS2035 and our initial discussions with organisations exploring the model for application in the UK suggested that the approach represents a pragmatic and practical regime, placing appropriate levels of trust in the larger contractors to manage work and the supply chain in a cost-effective way.

There are live discussions across the sector in the UK about establishing a standard that takes the sound principles of PAS2035 and allows flexibility in how they are applied in different circumstances. This Irish model which has been developed over 10 years, is worth further investigation.

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[18] SEAI (2022). One Stop Shop Operational and Quality Requirements Guide. https://www.seai.ie/register-with-seai/one-stop-shop/One_Stop_Shop_Operational_and_Quality_Requirements%5b1%5d.pdf

[19] (SEAI) (2022) Quality Assurance and Disciplinary Procedures for Contractors. https://www.seai.ie/publications/Better-Energy-Homes-QADP.pdf

[20] SEAI (2020). Domestic Technical Standards and Specifications. https://www.seai.ie/publications/Domestic-Technical-Standards-and-Specifications.pdf

9.5.3. Conclusions on Quality Assurance

Kensa's installation of their heating systems and any energy efficiency measures are accredited through, and demonstrably aligned to the key respective MCS and PAS2035 QA regimes.

LCC can gain confidence from this in any form of future involvement in this type of project and have experience of working with contractors under these QA regimes also, including with the use of Kensa technology.

Importantly there are complementary approaches between LCC and Kensa in engagement within area-based schemes with opportunities to enhance Community Based Social Marketing (Section 9.5.2).

PAS2035 accreditation is Kensa's default approach to delivering energy efficiency measures and is often a requirement of government funded schemes. The whole house approach is welcome even when simple measures like those proposed in the project as it allows 'no regrets' approaches and can encourage further investment from homeowners.

Discussions in the sector and examples from elsewhere suggests that projects such as these could be managed effectively with a more flexible application of the principles PAS2035.

Kensa's successful approach in its existing market can be developed further by incorporating LCC's engagement experience and emerging best practice from the energy efficiency sector to support both a combined offering and the delivery of the offer beyond fuel poverty and social housing schemes.

9.6. Findings – Consumer Protection

9.6.1. Consumer protection environment

The Changeworks framework

A 'collective approach' to CP would allow for a comprehensive customer journey where customers understand the measures being installed, the decisions they are making, the process of installation, and support and recourse for issues before, during and after the completion of works.

Changeworks has published research[21] into energy efficiency and CP, setting out the ideal approach split into the following stages and related elements:

Pre-contractual:

- Standardised advice package
- Clear referral network
- Verification of installer memberships
- Verification of installer inspection rates
- Independent audit of installer information provision
- Pre-contractual survey

[21] Changeworks (2020). Consumer protection in the domestic energy efficiency and renewable retrofit market. https://www.changeworks.org.uk/sites/default/files/CAS_Consumer%20protection_Final%20report.pdf

- Update of MCS energy performance models
- Detail of required ongoing maintenance and likely costs
- Upload of contract and survey to centralised data warehouse

Contractual:

- Photographs at pre-installation and installation stages
- Increased number of independent QA inspections

Post-contractual:

- A standardised package of support
- A measure-specific process map
- Referral network to enable a more seamless process
- Access to a data warehouse to support redress
- Capacity for referral and escalation of redress
- Regulation around complaint response and resolution
- Independent audits of regulation adherence
- Consumer awareness of due diligence to prevent ‘phoenixing’
- Monitoring of complaints via data warehouse

Legislation

The existing energy efficiency CP landscape focuses on the provision of legislation, certification, guarantees, and warranty schemes. The Consumer Rights Act 2015[22] provides a framework which consolidates consumer rights, making the law clearer and easier for consumers to understand, helping to build consumer-business confidence. These measures aim to provide CP and recourse for installation mistakes, technical issues, failures, and more.

Certification

Several QA frameworks which have been mapped and analysed as part of this research, including MCS offer an approach to ensuring CP, and technical standards for both installers and products. MCS standards are largely referential, providing references to existing standards, specifications, and consumer codes. The certification currently includes an audit of a business’s processes rather than any works.

An example of these consumer codes is the Renewable Energy Consumer Code (RECC), which sets out CP standards for businesses selling or leasing renewable energy generation systems to domestic consumers. MCS certificates for solar PV, battery storage and wind installations now include RECC membership, a measure primarily aimed at increasing consumer awareness.

Warranties, insurance and guarantees

At a basic level, the existing landscape for CP includes the provision of warranties, insurance, and guarantees for both installers and products. Research into QA in the energy efficiency market

[22]UK Government. (2015). Consumer Rights Act 2015. https://www.legislation.gov.uk/ukpga/2015/15/contents/enacted

commissioned by Citizens Advice[23] found that the landscape is highly convoluted, with multiple schemes, organisations, remits, and standards creating complications for both CP and QA.

The research https://www.citizensadvice.org.uk/Global/CitizensAdvice/Energy/Pye Tait - Research into quality assurance in energy efficiency - web.pdf finds that the broad range of existing QA mechanisms – which include quality marks, codes of practice, consumer codes, operating standards, guarantees, warranties and insurance – are undermined by loopholes and a lack of consumer understanding leading to diminished CP.

This research has informed our analysis of both QA and CP within the Kensa process and for the ideal regime.

Insurance-backed guarantees (IBG)

An IBG provides consumers with protection if an installer has ceased trading and can therefore no longer honour their written guarantee. This type of insurance policy covers the original installer guarantee, allowing for a claim to be made under its original terms.

IBGs are already applied to the home improvement sector, with several providers already in operation. The Home Insulation and Energy Systems Quality Assured Contractors Scheme (HIES) is a CP organisation covering the installation of renewable energy and energy efficiency products and offers an IBG both via its installer membership, and direct to consumers.

Building IBGs into the customer journey and offer would help to provide consumers with an additional layer of protection and confidence in the process and installation long-term.

Accreditation bodies

There is currently no formal CP or recourse built into the offering from existing accreditation bodies. If customer commissions the installation of heating or fabric measures without the support of an OSS or scheme, there is little they can do when something goes wrong. Accredited installers can be reported for poor-quality work, and may be sanctioned accordingly, but the customer is left with no recourse to with that installer unless they take legal action.

The Ideal CP landscape might therefore work alongside the existing accreditation bodies such as MCS and PAS2035 (managed by TrustMark) to provide customers with built-in CP whereby recourse can be sought through established processes.

Kensa's consumer protection approach

Kensa provide a 12-month workmanship warranty on their installation, which aligns with the MCS stipulation for workmanship guarantees and warranties.

Alongside this is the provision of a warranty on the heat pump unit and parts, which lasts either five years from the date of commissioning or five and a half years from the date of manufacturer, whichever is shorter. Kensa's guarantee includes protection if installers become insolvent or cease trading. There is no protection if Kensa become insolvent or cease trading which would generally require some form of Insurance Backed Guarantee (IBG). Regardless of Kensa's financial stability which hasn't been considered, this can be a key element of trust for homeowners.

[23] Citizens Advice (2015. Research into quality assurance in energy efficiency and low carbon schemes in the domestic market. https://www.citizensadvice.org.uk/Global/CitizensAdvice/Energy/Pye%20Tait%20-%20Research%20into%20quality%20assurance%20in%20energy%20efficiency%20-%20web.pdf

In Kensa's model, the customer owns the heat pump they receive, and this can be serviced or replaced by Kensa if required due to operational issues or failure. These heat pumps are protected by a two-year heat pump CP agreement, as stipulated by MCS. Kensa or an alternative Special Purpose Vehicle owns the shared ground array installation and charges an ongoing service fee. MCS then require for this to be added to their Installations Database (MID).

The ongoing service fee will be subject to effective running of the shared ground array and so there remains a commercial and contractual commitment to maintenance. There doesn't appear to be any direct protection from Kensa or the SPV ceasing to trade.

During the handover stage, contact details are left with the customer for post-installation recourse, providing a known point of contact in support of CP.

The energy efficiency measures, include manufacturers warranties and 2-year workmanship guarantees. Customer satisfaction and monitoring are carried out and these steps are consistent with both MCS and PAS2035, which calls for monitoring that includes a customer satisfaction questionnaire.

Registration of Kensa's ground array installation with the Heat Trust provides an additional layer of CP. This scheme includes provision for protection around billing, payments, faults and interruptions, and complaints procedures via the Energy Ombudsman.

9.6.2. Alternative models and Consumer Protection

Leeds City Council projects

As part of their work on tower blocks and Leeds PIPES, Leeds City Council have included a 12-month manufacturer guarantee to their CP approach. This means that within the first year of the installation's use, there is recourse for users who experience issues or failures with their technology via the manufacturer.

In parallel, Leeds offers a 12-month recourse through the council's Housing Asset Management database, as managed by Housing Leeds, a critical department involved in the engagement, delivery and CP stages of these schemes. Leeds City Council Building Services then takes on responsibility for ongoing issues and recourse for the installations after this initial 12-month period has lapsed.

Discussions with manufactures and distributors suggests that the market will determine what duration of warranties are acceptable and that for ASHP this could to be 5-10 years. It is reasonable to think that equivalent warranties should exist for GSHP.

Irish one-stop-shops

The Irish OSS model similarly has provisions for the response and resolution of customer issues around the works completed, with a detailed customer care and aftercare policy set out to provide QA throughout the whole process, with an emphasis on the CP stage. Customer issues are logged in a customer feedback log and addressed as per the defined guidelines. The SEAI Customer Care Centre supports this by assisting the Irish OSS models with providing quality customer service.

As with Kensa's process and the QA frameworks analysed, the post-monitoring stage for the Irish OSS model provides customers with a detailed handover pack which feeds directly into supporting ongoing CP. This pack includes a copy of the REC installation certificate, and a manufacturer, system supplier and/or contractor guarantee. This ensures customers have CP in the form of verified paperwork that allows them to proceed with recourse should any issues arise.

Any re-works required because of customer recourse are carried out in consideration of the ISO 10005 standard, helping to deliver consistency across the assessments, designs, plans, installations, and potential re-works delivered within the Irish OSS model.

This form of clear, national standard can provide significant confidence for homeowners and remove a layer of complexity in decision making.

9.6.3. Conclusions on Consumer Protection

We have reviewed a number of relevant Consumer Protection frameworks and approaches including MCS and PAS2035. The Kensa approach which is also registered with the Heat Trust compares favourably to these including:

- A 12-month workmanship guarantee on installation of the system.
- This guarantee includes protection if installers become insolvent or cease trading.
- Manufacturers warranties and 2-year workmanship guarantees on any energy efficiency measures.
- A warranty on the heat pump and parts lasting the shorter of 5 years from installation and 5.5 years from manufacture.
- A specific 2-year heat pump consumer protection agreement to support ongoing consumer protection beyond warranties and guarantees.

High levels of consumer support before, during, and after installation. The ongoing service fee will be subject to effective running of the shared ground array and so there remains a commercial and contractual commitment to maintenance.

There is no apparent protection from either Kensa or the SPV becoming insolvent or ceasing to trade. Regardless of the associated risk, this may factor in the decision making for some homeowners. Insurance Backed Guarantees could be used to address this but come with additional costs for the model.

As found in WP5, a heat infrastructure provider could also offer a separate service & replacement package for the internal heat pumps (similar to boiler care), providing an additional layer of consumer protection within the approach.

10. Summary of Work Package Findings

This section summarises the key findings from each WP and categorises those that are positive and challenging with regards to high density deployment of the shared ground array system within Leeds and more broadly.

Positive Findings:

- WP2 – a methodology for filtering and visualisation of properties was developed, with several viable clusters of properties identified for the deployment of the shared ground array system in Leeds, that would meet the BEIS, electrical network and shared ground array criteria.
- WP2 – work with Northern Powergrid showed that based on current data, the shared ground array system and small per-dwelling heat pumps allow for 'high density' deployment on secondary substations with little or no reinforcement required, and with strategies identified for improved monitoring in the deployment phase.
- WP2 – Interactive SAP modelling using Parity software of properties under alternative retrofit scenarios provided evidence for expected energy cost savings and identified light, medium and deep retrofit options with compelling visualisation and customisation of scenarios available.
- WP3 – People were interested in ways in which they could contribute to tackling climate change and would be willing to consider changing to a new form of domestic heating.
- WP4 – The shared ground array design for the target areas and economic analysis has been verified in detailed simulation studies. This has identified some sensitivities to borehole design, heat pump and control selection. There are modest opportunities for optimisation.
- WP5 - Shared ground arrays with individual heat pumps and the split ownership/street by street business model are potentially the most cost-effective decarbonisation solution for terraced houses which are hard to treat and are highly space constrained.
- WP5 – The business model has the potential to unlock substantial private investment the domestic heating sector, moving the emphasis of funding the low carbon transition to a public-private partnership investment. The model provides lower lifetime costs for users, a suitable long-term return for investors and significantly reduces carbon emissions.
- WP6 – Kensa has an established supply chain and their approach to Quality Assurance is accredited by MCS for installation of its heating systems and to the PAS2035 standard for energy efficiency measures. LCC has experience of working with contractors within these QA regimes and has complementary approaches to Kensa's homeowner engagement. Kensa's Consumer Protection compares favourably to industry standards.

Challenging findings:

- WP2 – whilst the shift to assessing high density at the secondary substation rather than LV feeder level adds some flexibility on homes that can be included, there remain risks associated with poor data on LV feeders, meaning that current data may not reflect the number that require reinforcement, and which could therefore affect deployment timescales
- WP3 – Research showed that there are likely to be significant barriers to achieving sufficient consumer uptake. These primarily centred around cost, with research data showing that the

expected energy cost savings were not sufficient for the consumers to consider paying for a heat pump, retrofit measures, and a standing charge to cover the ground array. Participants did not believe they were getting a good deal.

- WP3 & WP4 – The lack of significant energy bill savings from the heat pump install alone is due, fundamentally, to the fact that the ratio of retail electricity:gas prices in the UK is close to the expected Seasonal Performance Factor (SPF) of compact ground-source heat pump systems (in the context of the RHINOS project in small terraced homes where flow temperatures are assumed to be as high as 55°C). This therefore places a reliance on retrofit measures and a reduction in heat demand to achieve cost savings for the consumer. Greater bill savings were suggested with higher efficiency heat pump models, but their physical size may prevent their application in small, terraced properties.
- Additional measures, such as deeper retrofit, solar PV and battery storage were considered as means to reduce net energy demand and therefore bills, however the upfront capital cost is significant, and the works were judged to be complex to schedule (in terms of potential funding and physical installation) alongside the shared ground array and heat pump installations.
- WP4 – whilst there is modest scope to optimise the design of the shared ground array, there is unlikely to be scope for significant savings in the capital cost of this infrastructure during more detailed design stages.
- WP5 showed that with the high installation cost per property, a consumer contribution was still required to close the gap after consideration of private finance and BEIS funding. This could be achieved either via a cash contribution or through a low/zero interest loan and variations on these arrangements were key inputs to the WP3 research. The business model allowed for light retrofit measures to be included alongside the heat pump installation, providing only a modest expected reduction in gross heat demand.
- WP2 & WP5 – the use of lighter retrofit measures in the business model combined with EPC data at a building level means that there is some uncertainty as to the expected true heat demand reduction possible in each home, due to assumptions made in the modelling of retrofit effectiveness and requiring more detailed survey data.
- WP6 – Supply chain constraints exist in the sector and could present a barrier to rapidly scaling the model. A national standard for both flexible approaches to QA in different circumstances and exemplar Consumer Protection could provide benefits for both the supply chain and homeowners. This could include protection against installers and manufactures becoming insolvent and ceasing to trade through some form of Insurance Backed Guarantees (IBGs) or a national scheme.

11. Methodology for Coordinating High-Density Heat Pump Deployment

The UK's Net Zero Strategy recognises the need for a whole-systems approach to delivering net zero. This approach can optimise the connections between sectors like housing, power, and heat, tackle the complex and overlapping barriers within and across these sectors, and work with all stakeholders to build capacity so that they can play an active role.

This RHINOS project and the innovative work of the consortium partners offers a practical example of how collaborative working holds the key to a whole-systems approach, requiring coordination, and combining the knowledge, skills, and resources necessary for complex project development and delivery.

Optimising connections between sectors

This project considered neighbourhood selection, housing stock analysis, demand reduction measures, heating system design, grid local network capacity, and behaviour change. These approaches can support and be supported by future Local Area Energy Planning (LAEP) in Leeds by taking a more holistic approach to energy scenario planning across heat, power, and transport. LCC is interested in exploring their role in LAEP, building on their work with heat networks. It has had discussions with multiple stakeholders including West Yorkshire Combined Authority, Northern Powergrid, and LAEP providers. Like most Local Authorities it lacks the resource to actively pursue this active role without dedicated funding.

Tackling complex and overlapping barriers

Low levels of deployment for both heat pumps and enabling energy efficiency measures are a result of a well-documented, complex system of market failures and barriers. At the heart of the system that includes technical, supply, demand, finance and policy challenges, is a lack of a compelling offer for homeowners. These barriers are interconnected and therefore compound each other (see Figure 33).

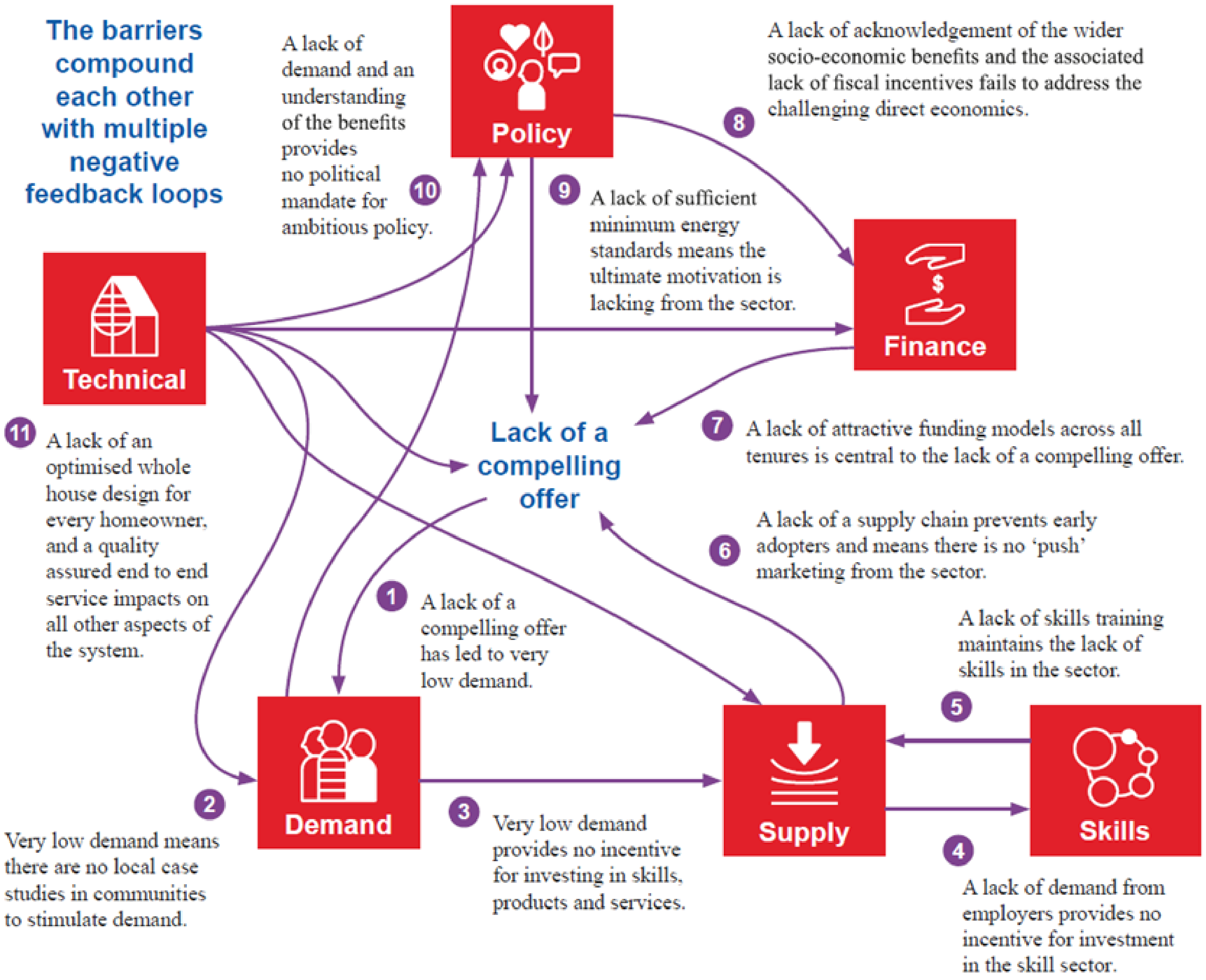

Figure 33 - The system of barriers to decarbonising our homes (Otley Energy)

The broad expertise of the consortium across these elements of the system has been able to analyse these barriers and start to demonstrate what it will take to stimulate the market in a coordinated way. By addressing more than one of the barriers simultaneously we can overcome the negative feedback loops and build momentum in the market.

In summary we need to establish:

- the target heat demand across our housing stock to deliver net zero, comfortable homes, and affordable, secure energy taking into account the need for future investment in the grid;
- the most cost-effective interventions to deliver this level of heat demand and how the value proposition can move away from direct financial considerations alone, to more aspirational elements of home improvement and quality of life;
- delivery models for these interventions that provide trust, protection, and minimise the complexity and hassle for homeowners;
- finance mechanisms that are affordable and attractive for homeowners in the context of the wider value proposition;

- a clear pipeline of work for the supply chain and skills sector to justify investment and support to build capacity at the rate required;
- clear, ambitious, and long-term policy to support the above elements and provide additional fiscal and regulatory stimulus to the market.

There are areas of policy specific to heat pump deployment that emerged as clear challenges in this project. Firstly the UK history of cheap gas and poor insulation means policy can't easily change the gas:electricity price ratio without exacerbating the current cost of living crisis. This places a direct limit on how compelling the heat pump offer can be in comparison to gas boilers. Secondly, all stakeholders need to be able to trust stable, long term government policy. The history of short-term programmes creates uncertainty and therefore investment risk for both homeowners and the supply chain. The sector needs long term policy and investment to drive both demand and supply.

The consortium can see clear routes forward for developing each of these elements, building on existing experience and collaboration in the sector such as the soon to be launched National Retrofit Hub.

Working with stakeholders

The consortium included local government, two university teams with multiple specialisms, manufacturing and installation capability, technical consultants, data providers, a DNO, a finance institution, and a community energy company. All had an essential role to play including:

- understanding national and local government and policy
- access to relevant data and data management and analysis
- local knowledge of the community and engagement
- technical system and network design, quality assured delivery, and supply chain management
- heating systems and energy efficiency measures
- finance and business models

Whilst barriers remain to the development of a compelling offer for high density deployment of heat pumps, the combination of specialist knowledge across the consortium and collaboration across work packages has brought both an understanding and solutions to these challenges and their connections closer.

The role of the Local Authority as convener is key. LCC also has experience of direct involvement in deployment of heat networks, shared systems and area-based energy efficiency schemes. They have ambitions to do more but like all Local Authorities lack the capacity for this kind of project development in terms of knowledge, skills, and critically resource. The funding in this HPR programme is a valuable contribution to this capacity building, laying foundations for LCC and the consortium to take the broader understanding of the challenge, working across traditional silos to develop joined-up solutions.

The innovation and knowledge sharing across this project and the Better Homes Leeds project involving LCC, multiple members of this consortium, and the Prime Minister's Business Council has added value to both projects. The Better Homes Leeds project is developing a Local Authority led delivery and finance model for area-based retrofit in able-to-pay neighbourhoods and is aiming to deliver a pilot in the chosen area for this HPR area, Chapel Allerton, in 2023.

The Better Homes Leeds project addresses the question of being 'heat pump ready' from the other direction, by promoting the significant benefits of energy efficiency and preparing the housing stock for future deployment of low carbon heating systems.

One of the key innovations in the project is the shift of emphasis away from focusing only on technical and economic considerations toward a focus on the homeowner. In common with the Better Homes Leeds project, the work of LBU has attempted to push business model development more towards user-centred approaches.

This must be a critical approach across the net zero agenda, designing programmes from a deep understanding of our communities' attitudes and priorities. Area-based schemes and therefore hyper-local approaches to engagement, building on the trusted relationship and community networks of Local Authorities can accelerate engagement and deliver economies of scale. This is the existing experience of both LCC and Kensa within their respective fuel poverty and social housing schemes and how these benefits translate to the rest of the market will be tested through the Better Homes Leeds project.

There is clear desire from LCC to play a direct role in this kind of project and the Better Homes Leeds project and they require continued support to develop models by overcoming their capacity gaps, having access to development capital and de-risking decision making.

Whilst the RHINOS project did not apply for Phase 2 given the challenges in the business model, the coordinated methodology would benefit from further development to maintain momentum.

The current barriers to deployment are expected to diminish over time, but require a combination of government policy, cost reductions, and consumer awareness/experience of heat pumps and energy efficiency measures. It is therefore important that we continue to work on *how* the innovation and development of these coordinated methodologies, business and finance models, stakeholder engagement, and market making can overcome the barriers discussed above and support and respond to the potentially large changes in policy that will be necessary.

12. Approach for Mobilisation and Deployment

This section describes some of the processes and methods considered during the feasibility study to be applied as part of heat pump deployment, with further development across the full range of stakeholders and installation stages to take place in HPR Phase 2.

12.1. Home survey methods

The innovative survey & customer engagement methodology is set up to identify & recruit 80% pockets in each of the 4 areas, leading to 151 heat pumps at 25% density in each of the 4 areas.

Current survey and sales techniques for private household retrofit for heat pumps has a high per-property sales cost, largely from house-by-house targeting and high dropout rates after in-home surveys.

Proposed methodology turns this process on its head through community-led, time-limited and highly targeted deployment. Messaging will be focussed on a community call-to-arms with fast action required. The customer journey will begin with area-wide engagement. This is critical to ensure general interest, warming up and driving community-based discussion. The engagement activities will be designed specifically to tackle the need to find and recruit homeowners and to assess their homes for suitability as quickly as possible.

To support this process, additional educational and awareness raising events will need to be conducted online as well as at locations in the community. Weekly ‘drop in’ online event with collaborators will be available on ‘Teams’ to discuss issues with any homeowners that log in to the event.

Interested households (from community events, leaflet drops, conversations with neighbours, online marketing etc) register their interest in an online portal. Customers will be offered a 1 to 1 home suitability screening call where they can discuss their specific property. Where the property is suitable, they will be offered a home heat pump survey to estimate the size required and what cost-effective energy efficiency measures may be needed. From this, streets/clusters within each of the 4 areas will be identified where there will be high sign-up. Underpinning the engagement work will be a dedicated office situated centrally to the target areas where customers can meet team members face to face and gain further insights into the programme.

From Kensa’s experience running the *Heat the Streets* project, this is highly likely to yield clustered interest caused by the similar life stage, level of disposable income and ethos of neighbours, as well as neighbour-to-neighbour discussions. In the case of Heat the Streets, 80%+ clusters were already identified through just this registration of interest, which gives strong evidence that an initial area-wide engagement approach should yield similar outcomes, assuming a similar finance package is available.

The engagement team will also identify those particularly interested to help volunteer by visiting their neighbours to encourage uptake. Engagement process will make clear to neighbours that their own costs go down if they get their neighbours to sign up. Prior to conducting surveys, to further narrow the clusters and to minimise the number of surveys required, energy champion from engagement team with local volunteer will visit and introduce the project to the homes in such clusters who haven’t registered interest. This aims to increase the proportion of homes interested & registered on the portal within a target cluster.

Two stages in home survey will be planned. Within the identified target clusters, the suitable homes in the cluster will be called for a PAS2035 retrofit coordinator first survey. Floor plan, measurements, building information, insulation information and heat loss calculations will be undertaken, allowing to revert after the visit with a targeted quote and draft contract. Kensa Utilities will supply these, with the energy champion delivering & explaining (via phone call/email), thus maintaining a trusted point of contact throughout the engagement.

The secondary survey by an installer will discuss, together with the householder, the layout of pipes, radiators, heat pump and insulation. Once the customer has a full understanding of the installation and had time to review the contract, they can make the decision to proceed or not. A 14¬day cooling off period follows contract signing, to aid consumer protection.

This highly targeted approach minimises the number of surveys. It is conservatively estimated that there would be a ~50% drop out after the first survey, and 20% drop out after the second survey. The number is higher after visit 1 as then the costs to consumer become targeted & specific, which is what most people need to make their decision. For 151 homes, this means 380 initial surveys are required (see Table 17). This saves significant time and money compared to a business-as-usual (BAU) approach, where dwellings are not pre-filtered / focussed by cluster.

Table 17 – Assumed survey numbers and signup rates

Leeds Cluster	Number of homes to survey at 1st stage	Number of homes to survey at 2nd stage (assuming 50% continue)	Final number of homes (assuming 80% signup after 2nd survey)
Pasture Terrace	130	65	52
Northbrook Street	83	42	33
Orchard Street	120	60	48
Bridge Avenue	47	24	18
Total	380	191	151

12.2. Quality Assurance Method Statement

Works will be delivered through Kensa's existing service delivery processes which are aligned and accredited through the key QA frameworks for the sector MCS and PAS2035, covering their heating systems and energy efficiency measures respectively.

Kensa's QA-accredited methodologies provide clear stages and steps for delivering a quality-assured customer journey. At this stage, we are not proposing changes to their process from a QA perspective, but see that there would be value in implementing additional measures around CP.

Our analysis has shown that Kensa's process is well-aligned to existing QA schemes. The QA approach going forwards should therefore follow the stages, steps, and underlying key principles identified, as captured in detail in Section 9.5 .

Some enabling work will be needed to deliver an effective, fully detailed, and finalised QA regime for the Kensa process and HPR programme which aligns with the customer journey and CP environment. Activities to support this might include:

- Ensuring Kensa's ongoing alignment and compliance with sectoral QA frameworks
- Developing a comprehensive CP package including IBGs
- Working with accreditation bodies to create provision for customer recourse.

13. Long Term Sustainability

13.1. Business model sustainability

The business model for the RHINOS Leeds project aims to overcome five key barriers to high density heat pump deployment:

- The high cost of ground source heat pumps, particularly the groundworks by splitting the upfront costs between in-home works and groundworks
- The potential increased running costs compared to a gas boiler counterfactual
- The degree of infrastructure required for high density heat pumps, especially for GSHPs: by carrying out works on a street-by-street scale and taking advantage of demand diversity the extent of infrastructure required is far less than for an equivalent number of individual GSHP systems
- The lack of commercial investment opportunities in low carbon heating: by making the enabling infrastructure an investment opportunity, the low carbon heating transition becomes of commercial interest, attracting low-cost finance from pension funds
- The coordination of individuals for a fundamentally street-by-street solution that's required to be able to deliver at the scale and pace required for net zero. Relying on everyone to organise their own surveys, designs, installs etc would hamper the pace of deployment.

The methodology put forward in the project requires a number of roles to achieve the aims of high-density heat pump deployment. The costs to fulfil each role may be to recoup the costs via sales (i.e., all costs are recouped via the consumer offer) or the service of the organisation(s) may be contracted by an entity such as a local authority with the aim of reducing emissions from domestic heating. The coordination of stakeholders and roles to successfully implement the methodology would require further development during the first deployment (such as would have occurred during HPR Phase 2 or explored in supplementary work). It should be noted that the shared ground array solution always requires a coordinated approach due to the interconnection of multiple properties and the shared infrastructure. In the longer term the methodology would likely be driven and owned by the shared ground array developer and/or relevant local authority as the most invested/engaged partners, with links to industry, private investment and regional stakeholders. Local authority ownership or involvement in the overarching coordinator role is likely to be required but would again be developed further as part of the first deployment or supplementary work.

13.2. Commercial offering to consumers

The commercial offering through the split ownership model effectively tackles three aspects of cost:

- The shared ground array infrastructure cost which feeds ambient heat into the heat pumps (i.e. all outside the property)
- The cost of insulation upgrades which enable a larger running cost saving to the resident
- The cost of the heat pump and its installation

Future shared ground array infrastructure cost: Given that ground-source heat pumps are generally more expensive than alternative low-carbon heating solutions upfront, but much cheaper to run, the solution to facilitate uptake is to spread upfront costs into longer-term running costs, thereby reducing barriers. Given the shared ground array is estimated to last 100+ years, funding needs to come from long-term, patient investors (i.e. not households) such as pension funds, strategic investors and high-street banks keen to fund a CPI-linked green infrastructure asset.

Future cost of insulation upgrades: The cost of insulation is also a long-lasting benefit, often beyond the tenure of households, so therefore is also included as a Kensa Utilities funded asset. Both of these are paid back through monthly standing charges over a 40-year period. This means residents pay for just their use of the infrastructure for the time they're there, lowering the overall costs to them. This already reduces costs upfront by a significant margin, leaving just the heat pump & install costs.

Future cost of the heat pump and its installation: This is covered from three sources: [1] The BUS grant amount; [2] additional targeted funding where applicable (e.g. ECO for lower-income homes); [3] home-owner contributions. This home-owner contribution is either an upfront lump sum or paid back over time as a loan.

Compared to a ~£25k cost someone may see for an individual ground-source heat pump install, the innovative coordinated methodology and business model employed through Leeds RHINOS allows for a commercial offer where just ~£6,000 is residual for customers to cover upfront. This offer compares very favourably to alternative low-carbon heating solutions, as demonstrated in Section 7.

Future cost of in-home survey & design, private investment & organisations responsible: There are a number of savings that industry expects to deliver for future rollouts:

- Attracting investment from private organisations, largely financial institutions, who are expressing ongoing interest in funding the green infrastructure assets (ground arrays) deployed through shared ground array heat pump solutions at large. This will reduce the cost of finance from the current modelled 6% down to 3-4%, from discussions Kensa has had with some of the UK's largest pension funds.
- Trained installer bases requiring less upfront support and having more confidence in pricing jobs (as opposed to adding a risk premium given the uncertainty of what's required in a home, an observation Kensa has made in the field).
- Economies of scale on heat pump manufacturing costs, with British manufacturers scaling up to serve a larger market.
- Time of Use Tariffs to become more common designed especially for heat pumps, not taken into account at the moment due to the current energy crisis.
- Wider public awareness and comfort with heat pumps, lowering sales & marketing costs required to receive sign-up.
- Innovative solutions for conducting surveys more cheaply (e.g., 3D in-home scanners from a phone/tablet)

These cost reductions are expected to create significant headroom for the cost to consumer to absorb some of the costs which are currently covered by BEIS funding in the RHINOS project:

- Surveys & in-home design
- Marketing & customer engagement
- Coordinating parties in improving consumer recruitment

Instead of the cost to consumers absorbing this, there's a high likelihood that local authorities going forward will take a larger role in the coordination & uptake of regional heat decarbonisation approaches. Given Zoning Coordinator powers being granted through the Energy Bill, and their net zero by 2030 targets, Leeds Council and others already understand that meeting decarbonisation targets will require investment from the Council. It may be that the coordination and some of the consumer recruitment could be led by the Council themselves, collaborating with local community energy organisations with the option to bring in external parties to support on aspects or stages of the project.

The challenge however remains that the counterfactual ~85% of UK households compare against is gas, where gas is relatively cheap vs electricity compared to other countries (10.3p/kWh gas vs 34p/kWh electricity in the UK, compared to 23c/kWh gas vs 30c/kWh electricity in the Netherlands), and levies/taxes are on electricity but not on gas.

We're confident that we have put together the best possible & deliverable heat pump solution for terraced streets, which is the most common housing type in the UK. Industry will deliver cost reductions through it, but for widespread adoption beyond public funding, it will require several policy levers, many of which are being discussed WP5 finding section.

13.3. Replicability of methodology to other locations

The innovative methodology developed in the Leeds RHINOS project has been designed expressly to be replicable across most of the UK's urban and semi-urban regions, targeting one of the most common house types: terraced solid brick homes. Indeed, within a suitable cluster of homes, the shared ground array infrastructure in a lot of ways acts as a utility network to replace the gas network, with a network feeding input energy to individual in-home white boxes (in this case heat pumps, not gas boilers). With the gas network covering ~85% of UK homes, this is the reach, which is supported by studies[24] into the applicability of the technology. Therefore, replicability is at the core of this project.

The conditions present for the methodology here in Leeds are:

1. **Suitable housing types for shared ground array infrastructure heat pumps**: primarily terraced streets and blocks of flats where there is potentially limited space for alternative low carbon heating technologies.
2. **Council interest in supporting the decarbonisation of heating in communities**: Leeds City Council (like two thirds of English councils) has a carbon neutral target date of 2030.

[24] regen (Mar 2021). A utility based approach for ground source heat pumps. https://www.regen.co.uk/wp-content/uploads/HeatPumpReport_Final_04PDF.pdf

3. **Installer base available for upskilling & training**: Plumbers, gas engineers and heat pump engineers present to go through training program to install shared ground array ground-source heat pumps.
4. **Limited consumer awareness of heat pumps**: Our surveys show limited awareness of heat pumps and how they work, and what the benefits are, requiring the detailed consumer engagement approach in a community-led way to build trust in the process.
5. **Grid integration coordination**: Coordination needed with the local DNO to ensure grid capacity and/or upgrades are available in target areas.
6. **The need for solution coordination**: Coordination is needed in identifying the best solution for different areas of the city to avoid conflicts or duplication in new infrastructure (e.g. heat networks, grid reinforcement and hydrogen) and facilitating scaled, street by street deployment.

These conditions are present across the majority of urban and semi-urban areas of the UK, accounting for 75% or 19.2 million UK households:

1. **Replicability of: suitable housing types for shared ground array solution**

Terraced housing is the most common UK housing type present, accounting for 6.9m houses. In addition, there are 6.1m flats, together accounting for ~50% of the UK's housing stock. Kensa has deployed in 1000s of tower block flats already (Enfield, Croydon, Gentoo etc) with a similar methodology of shared ground arrays. Given BEIS' Electrification of Heat trial focussed more on detached and semi-detached houses, this methodology offers a blueprint to tackle the other major housing types. With expected cost declines & demonstration of the model here in Leeds, shared ground array solution can also expect to cover many of the UK's 6.2m semi-detached houses. Altogether here 75% of the UK's homes are likely very suitable for this innovative methodology.

The focus in Leeds has been on EPC D & E homes (which make up 43% and 18% of England and Wales homes respectively), given that some simple & cost-effective insulation measures can help achieve savings below that of the gas boiler counterfactual. These are also perceived to be 'hard to decarbonise' homes. However, the methodology works just as well for any EPC, where insulation upgrades may not be done.

2. **Replicability of: council interest in supporting the decarbonisation of heating in communities**

80% of English local authorities have a climate action plan and two thirds of councils are aiming to be carbon neutral by 2030[25]. In many cases heat from buildings is the largest source of emissions to tackle and a methodology that requires them to aid coordination but drives in purely private investment to deliver it is likely very attractive for them.

3. **Replicability of: installer base available for upskilling & training**

Plumbers, gas engineers and heat pump engineers present across the country, many seeking upskilling to transition from gas onto heat pumps.

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[25] https://www.local.gov.uk/delivering-local-net-zero

4. **Replicability of: limited consumer awareness of heat pumps**

Nationwide surveys show limited awareness of heat pumps is present across the country, and indeed the surveys conducted by the Energy Systems Trust as part of Heat Pump Ready Stream 1 show a low willingness to transition away from gas across all Heat Pump Ready regions. In order to make the UK 'heat pump ready', awareness is required. The innovative methodology starts with awareness and education through fun, community-led workshops and activities. It targets schools to encourage family discussions on it. It targets neighbourhoods to encourage neighbour discussions. This all helps demystify heat pumps and make it a group transition, whilst making clear the benefits of lower carbon, energy security, cooling, pathway to significantly lower prices, home value uplift etc. We believe this approach is replicable and necessary anywhere in the country.

5. **Replicability of: grid integration coordination**

Coordination needed with the local DNO to ensure grid capacity and/or upgrades required to ensure heat pumps can be delivered in the area is present across the country, with all DNOs dealing with the dual challenges of EV and heat pump uptake. Our methodology of area-by-area rollout facilitates their planning of upgrades and makes this process easier, and unlikely that DNOs will delay rollout, which may occur if uptake is done sporadically in regions.

6. **Replicability of: the need for solution coordination**

The same argument of not setting up multiple infrastructures to serve different heating solutions is valid across the country and is reflected in the Government's approach to zoning, where certain zones are specified for one solution to be deployed.

13.4. Heat pumps expected to be deployed by 2028 by utilising the methodology

As noted in Section 13.3 the methodology for high density heat pump deployment presented in this report is replicable across a wide proportion of UK housing stock and the shared ground array/heat pump system would therefore also be similar to what has been assessed as part of Leeds RHINOS. Key stakeholders involved in the RHINOS project such as companies with the ability to model housing stock performance, local authorities, the DNO and the shared ground array supplier/installer could also be involved in other UK locations to replicate the key steps. The core offer to the consumer, assuming the same national policies are in place, would likely remain similar in terms of the average cost as this is largely driven by capital outlay which would not be expected to show a significant regional difference. However, stakeholders in some locations may be better suited to take advantage of the recommendations outlined in Section 14 that could provide efficiencies, such as combining street works with other utilities.

In terms of the number that could be deployed by 2028 using this innovative methodology, we start top-down. The Government's target is 600,000 heat pumps deployed by 2028 (including newbuild heat pumps). The CCC's Balanced Pathway assumes 624,000 retrofit heat pumps required (excluding newbuild) in achieving net zero. This is therefore the starting point. We've outlined that 75% of the UK housing stock is suitable, and near-term the most suitable segment for the methodology includes 50% of the UK housing stock (terraced housing & flats), and therefore our estimate is that 312,000 heat pumps can be deployed by 2028 (in total) using this innovative methodology, with likely a greater share of the UK housing stock addressable by this methodology after this date. This is naturally a significant step up from the current proposed target through Heat Pump Ready, but it highlights the significant scale deployment that will be required over the coming few years, where we'll need to exploit tipping points in a similar fashion as to electric vehicles. Table 18 shows how this number of heat pumps would be distributed if deployed proportionally across the 10 largest UK cities.

Table 18 - Number of heat pumps by area

City	Total number of households[26]	Number of heat pumps installed by 2028 (assuming 8% homes suitable)
London	1,586,350	120,665
Birmingham	448,570	34,120
Leeds	357,750	27,212
Glasgow	328,229	24,967
Sheffield	252,500	19,206
Edinburgh	239,364	18,207
Manchester	234,290	17,821
Liverpool	232,100	17,665
Bradford	219,140	16,669
Bristol	203,490	15,478
Total		**312,000**

Taking a more conservative approach, we assume each of these areas would wait to see Phase 2B stage gates completed before being 100% confident in replicating the methodology in their locality. We envisage that future will follow a similar 'stage gate' approach, starting with a few hundred homes in the first instance before ramping up to 10,000+. In order to be on track for their net zero goals by 2030, councils cannot afford to go any slower. The outcome from this 'wait and see' approach in replicating the innovative methodology is that 110,000 heat pumps are deployed by 2028, see Table 19.

Table 19 – Number of heat pumps by area, conservative rollout

City	Total number of households	Number of heat pumps installed by 2028	Proportion of housing stock decarbonised
London	1,586,350	11,000	1%
Birmingham	448,570	11,000	2%
Leeds	357,750	11,000	3%
Glasgow	328,229	11,000	3%
Sheffield	252,500	11,000	4%
Edinburgh	239,364	11,000	5%
Manchester	234,290	11,000	5%
Liverpool	232,100	11,000	5%
Bradford	219,140	11,000	5%
Bristol	203,490	11,000	5%
Total		**110,000**	

[26]*Table CTSOP3.0 - https://www.gov.uk/government/statistics/council-tax-stock-of-properties-2020*

The methodology naturally applies to many more than the UK's top 10 cities, just used above for illustration. As previously mentioned, with 50% of the UK's 26m housing stock very suited to this innovative methodology (and 75% total suited to it), the limitation on the numbers deployed is really down to some of the accelerants described previously.

14. Future Innovation & Recommendations

14.1. Process & Technology Innovations

This section lists some areas for innovation or further consideration that were identified during the feasibility study, which would be beneficial to the RHINOS methodology of high-density heat pump deployment as well as more generally. Some of these areas would have been within scope to develop and test during HPR Phase 2, whilst others would require dedicated resource or additional time to develop.

<table>
<tr><th>Area for innovation</th><th>Potential collaborators for development</th></tr>
<tr><td>1 – DNO assessment of some LCTs in demand modelling remains conservative and potentially limits deployment due to the assumed maximum demand, e.g. with battery storage where credit is not taken for the time-dependence of the peak load.</td><td>Further work with DNOs and equipment suppliers is required to reduce conservatism in the modelling and in connection applications.</td></tr>
<tr><td>2 – Wider adoption of load shifting approaches/technologies could reduce need for grid reinforcement, through a combination of behaviour change, battery storage, thermal storage and heat pump modulation. There are however limited benefits to the homeowner currently of doing so and a high cost of hardware.</td><td rowspan="3">Further work with DNOs and energy suppliers to better incentivise load shifting and demand reduction for consumers.

Potential for DNO or other public body to fund installation of these costly controls/measures in homes as a lower cost and socially valuable alternative to grid reinforcement, in conjunction with the consumer offer for the shared ground array.</td></tr>
<tr><td>3 – Time of Use tariffs potentially offer cost reduction for residents, although stability of these tariffs is an issue in predicting longer term savings and requires load-shifting potential to avoid import at peak times. Savings may be limited if there is only thermal storage available as small power & appliances would continue to run during peak times.</td></tr>
<tr><td>4 – Fabric improvements reduce heat demand and therefore load on the local electrical network for homes with heat pumps or other electrified heating. This could reduce the need for grid reinforcement and also improves the comfort of the home.</td></tr>
<tr><td>5 – To overcome the lack of knowledge and uncertainty around the technology, fully fund a ‘demonstrator’ install of the shared ground array and home energy efficiency measures within a cluster. This would allow future potential consumers to see the technology working in-situ and speak to owner/occupiers who have real world experience with the system in their area or home type, thereby increasing uptake and enthusiasm.</td><td rowspan="2">Further work with government or local authority as sufficient funding would be required to incentivise/overcome financial barriers to adoption identified in this study.</td></tr>
<tr><td>6 – Setting up ‘test homes’ that could be occupied on a short-term basis by consumers to try the technology without further commitment and increase familiarity</td></tr>
<tr><td>7 – Incorporating residents in targeted areas into early design stages of ‘their’ shared ground array system and heat pump installs via collaborative,</td><td>Could be facilitated by shared ground array</td></tr>
</table>

Area for innovation	Potential collaborators for development
specific workshops to influence/shape the consumer offer (although noting that there are limits to the flexibility) to increase familiarity and buy in to the system	developer (e.g. Kensa Utilities) and utilising contacts from local organisations
8 – As identified in WP3, develop a customer journey and delivery model that builds on LCCs position of trust and connections within communities to support a hyper-local, community based social marketing strategy.	Collaboration between resident groups, local authority and trusted organisations as identified in WP3 research to increase awareness.
9 – Adapt resident engagement schemes to centre around crisis management, as consumers are only likely to consider a heat pump when their gas boiler is close to the end of its life.	
10 – Given the survey finding that most people don't think about boiler replacement until they have to, a key question to be studied is "What has to happen to change that behaviour?" With reference to the COM-B behaviour model, what has to happen so that homeowners have the capability, opportunity and motivation to learn about heat pumps before they need to? Cars provide a case study where owners are often aware of replacement options before a replacement vehicle is required and behaviour/attitude change in this area should be investigated further.	
11 – Although not within the scope of the RHINOS project, there is significant potential for alternative financing arrangements that may improve the consumer offer or uptake, such as property linked finance, green mortgages and other products that are being considered in the private finance sector. These could make significant progress towards homes being 'heat pump ready' in the future and may improve the offer sufficiently to increase demand in certain circumstances.	Further work in private sector to provide consumer confidence in alternative finance arrangements and with shared ground array developer to incorporate into consumer offer.
12 – Further standardising designs and equipment for shared ground arrays, as well as bulk ordering of key components to reduce upfront costs (particularly relevant when deploying at high density)	Further work with shared ground array developer and supply chain
13 – Install shared ground array infrastructure in conjunction with electrical network replacement/reinforcement works (or other utilities), to minimise resident disruption and to share (significant) costs of work on public highways	Closer collaboration between local authority, shared ground array developer and DNO to identify scheduling opportunities

14.2. Recommendations

General recommendations for high density heat pump deployment, following learning from the RHINOS project, include:

- A reduction in gross heat demand or provision of other LCTs is currently critical to providing attractive energy bill savings and therefore increasing uptake amongst residents. It is recommended to incorporate a 'whole house' holistic retrofit approach from the start rather than focussing on heat pump deployment only, so that the associated costs and additional works can be planned for.
- Coordination of heat pump installation, retrofit measures and other LCTs should be prioritised so as to minimise disruption to residents (due to the potential negative impact on uptake from protracted or stop/start works).
- Engaging residents at the earliest possible stage of design to address concerns, develop interest and maximise uptake.
- Backing of trusted and longstanding local organisation is recommended (e.g. local authority)
- Consider targeted support and incentives to encourage the transition of existing, local SME heating engineers to support GSHP install.
- Use of a housing stock database and visual mapping is recommended to enable efficient iteration of filters during selection and to easily share with other stakeholders.
- Use of software to cross-reference potential retrofit measures with available funding sources (such as IRT Surveys' DREam platform) to maximise the interventions that can be made to each property (although noting that the use of some funding streams may preclude others or introduce scheduling constraints to an overall retrofit program). This could assist in developing a more compelling offer for homeowners through reduction of energy demand and greater operational cost savings.

- As part of discussions regarding the HPR Phase 2 application, closer integration of the DNO into the RHINOS project team was discussed (i.e. as a formal member of the consortium) in order to mitigate future issues with data sharing and seeking to 'reserve' a proportion of staff time specifically for the HPR project. However, there are limitations on how closely the DNO can be integrated into a project, as they must (under the Ofgem regulatory framework) balance the level of their involvement in specific projects with impartiality and technology agnosticism stipulated in their licence requirements. DNO income is also regulated and so they cannot generally be paid for staff time from external funding sources.
- Nevertheless, early engagement with the DNO is crucial to understand the data available, format and how it can be linked to other datasets. Protocols for data sharing should be discussed at the inception stage so that agreements can be put in place as early as possible. The RHINOS project proposal included a letter of support from Northern Powergrid and a level of senior engagement and buy in is recommended.

- Similar electrical network criteria to those developed in WP2 should be agreed with the DNO (likely to vary between DNOs and the type of heat pump being proposed) to reduce the risk of future connection applications being rejected or suffering long delays due to reinforcement requirements.

- Where possible, a single point of contact at the DNO should be identified for the project to ensure consistency in data requests and with sufficient technical knowledge to identify issues or potential improvements in the methodology.
- Requesting additional metering (or prioritisation of existing programmes) on relevant LV feeders as early as possible is recommended so that high quality data is available at the design stage, also providing post-installation demand data to verify assumptions made.
- Where available, incorporating area-specific future energy demand scenarios developed by the DNO to account for future rollout of EV charging, electrified heating and their effect on local grid reinforcement plans.

Policy recommendations

- Rebalancing the relative prices of electricity and gas to allow renewable energy to be delivered more cheaply and aid the economic case for heat pumps vs. gas (as is done with fuel duty for diesel vs. electricity for EVs).
- Heat pump zoning policy: Mandating a connection to heat network or the use of heat pumps in specific areas will provide longer term confidence for the sector and will bring investment and real cost declines from longer-term Government signals of certainty.
- Finalising a date for banning gas boiler replacements in existing homes and potentially introducing a gas boiler scrappage scheme to encourage en masse replacement in areas where heat networks are feasible.
- Confirming the Future Homes Standard would aid confidence in the sector and see many UK-based manufacturers scale up production, reducing costs through economies of scale.
- Providing finance with 0% interest to networked GSHP developers until a threshold of heat supply is reached.
- Low-cost financing of the groundworks by local authorities or central government. Local authorities could co-invest, who are able to loan from the Treasury at much lower cost public sector rates. BEIS could also significantly support and accelerate this by making UKIB loans easier & more accessible to shared ground array infrastructure.
- Competition offering capital support for existing drilling firms to invest in new deep drill equipment, together with skills transfer from existing skill bases (e.g. Norway).
- Grant aided training and accreditation schemes that work with the grain of CPD for construction, to increase the number of MCS-accredited and PAS2035-literate installers.
- New regulation or incentives to allow natural gas utility companies to invest in infrastructure and have a role as suppliers of heat given the loss of revenue that would be caused by larger roll out of electrified heating and homes disconnecting from gas. Pilot schemes are being carried out in other countries and could be replicated in the UK.

15. Conclusion

Significant collaboration took place throughout the feasibility study between all project partners and other stakeholders, with a number of positive findings coming from the work packages with respect to high density heat pump deployment in Leeds using the shared ground array system. Despite delays during the project that affected the intended feedback loop of data and findings between work packages, the aims of the feasibility study listed in Section 2 were met.

The findings of the feasibility study will be of value in several areas of LCC's future work on retrofit and decarbonisation of housing, building upon the area selection work with a wider project around retrofit zoning. This will produce a map of the city indicating appropriate retrofit and decarbonisation approaches in different neighbourhoods, taking into account factors such as housing stock characteristics, infrastructure capacity, tenure, household income and other demographic factors.

The financial model elements will feed into planned work with third parties to develop retrofit finance products for the wider able to pay market and the customer research and consumer journey findings will inform LCC's work to develop a 'one stop shop' for retrofit in Leeds, with a particular focus on the able to pay market. The feasibility study has provided valuable insights into the specific barriers around heat pumps (complementing other studies such as the Energy System Catapult electrification of heat project). It has also provided a greater understanding on the factors that motivate a household to invest in retrofitting their own property and what sort of financial models are most likely to gain traction with consumers.

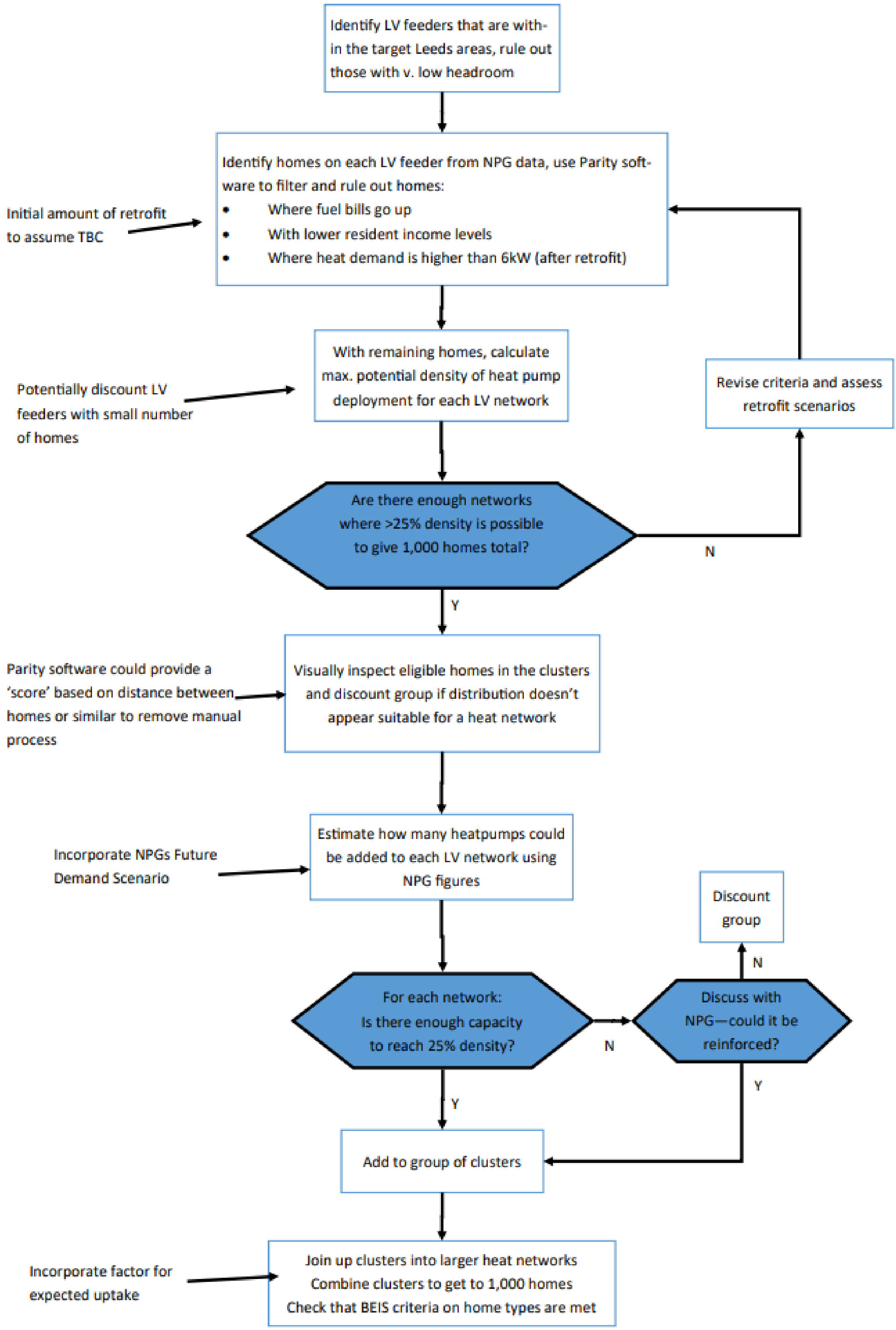
HPR Phase 2 Application

Data and conclusions from the feasibility study were not fully developed at the point of application for Phase 2, partly due to delays in commencement of the project and in obtaining sufficient data to progress WP2. Whilst this limited confidence in committing to the Phase 2 application, the main factor in the consortium's decision not to apply was due to the challenging findings that had become clear from the feasibility study work up to this point. These findings meant that the consortium could not provide sufficient confidence that a successful trial deployment could be achieved in Phase 2B in Leeds; they are detailed in this report but some of the key findings that influenced this decision were:

- Low expected uptake of the consumer offer, primarily due to the overall costs that residents are required to pay against relatively low projected cost savings. This is compounded by the current economic climate and also by other systemic factors such as the unfavourable ratio in gas vs. electricity prices. For consumers who are willing to spend money, fabric measures or other LCTs will often be more cost effective than heat pumps.
- Additional incremental hurdles to uptake identified from consumer research, such as limited appetite to replacing existing gas boilers that are not otherwise due for replacement.
- Limited scope for significant changes to the business model that would be achievable during Phase 2A to reduce capital or operating costs for the consumer, given the timescales and funding limitations of HPR Phase 2 as well as the wider policy background.
- Impact of this low expected uptake on the viability of the shared ground array solution in a given location (due to the physical density requirement) and also of meeting the BEIS high density criterion on the local electrical network.

The consortium felt that there was significant beneficial further work that could have been carried out as part of Phase 2A to develop the customer offer and a more robust methodology, through further consumer research, development of additional retrofit measures and funding streams as well as looking to incorporate innovative processes and approaches highlighted during the feasibility study. However, Phase 2 of HPR was clearly focussed on the mobilisation and physical deployment of heat pumps rather than as an extended feasibility study and this also contributed to the decision not to apply.

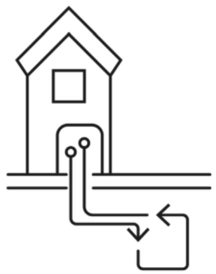
Appendix 1 – Property Selection Flowchart

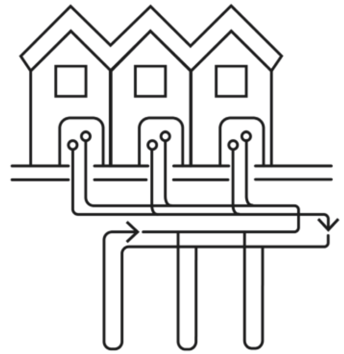


Appendix 2 – Focus Group Infographic

WOULD YOU SWAP YOUR GAS BOILER FOR A NEIGHBOURHOOD HEAT PUMP?

What is a heat pump? → **What if a neighbourhood heat pump scheme were an option in Leeds?**





Interested in making the switch?

- Comfort?
- Energy efficiency?
- Energy security?
- Reduction in CO_2 emissions?
- Save money in future?

Find out more

Sign up

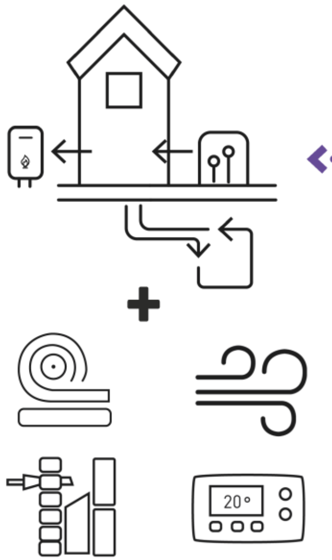
Then what?

- Pipes installed in the street

- Gas boiler removed
- Home energy efficiency improvements
- Heat pump installed and connected

- Standing charge includes maintenance
- 5 year warranty on heat pump
- Heat pump serviced every three years

- 20-25 year lifespan for heat pump
- £2k to replace



PAYING FOR IT

	Option 1: Pay upfront	Option 2 a: Surcharge	Option 2 b: Surcharge
Payment options	Pay upfront for heat pump equipment	Zero up front payment	Small upfront payment
Upfront payment	£6,000-£10,000 (out of savings or a short term loan)	£0	£3,000
Bill surcharge (pays for the heat pump equipment)	£0	£50 per month	£40 per month
Bill standing charge (pays for the ground array)	£50 per month	£50 per month	£50 per month
Total per month	£50 If a loan is taken out, the repayments would be separate and at agreed interest rate	£100	£90

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Appendix 3 – Shared Ground Array Cost Reduction Measures

Upfront cost reduction for consumers with heat pump size optimization

The feasibility study considered the impact of light fabric measures (combination on airtightness, loft insulation and cavity wall filling where applicable and better heating control system includes programmer, Room thermostat, and TRV) on reducing the required heating system capacity. Fabric measure for the dwelling type were selected based on the CODE Report.

Size of the HP mainly depends on the heat loss coefficient (HLP, $W/K/m^2$) of a dwelling. Heat loss coefficient basically indicate how much energy (W) a building would require for every unit change in temperature between the outside and indoor temperature. HLP of a dwelling is highly influenced by the building fabrics and so the better the insulation level of building fabrics (Wall, Floor, Roof and Windows), lower the heat loss coefficient and so smaller size of HP required.

The light fabric measures provided to install lower capacity HPs, helping to reduce the cost of the HP and borehole drilling. Borehole drilling costs are less due to reduced borehole depth requirements due to reduced heat demands. It was estimated that the borehole drilling cost per property could be reduced from £11,000 for a typical 9kW HP system to ~ £5,500 for a 6kW HP system for mid-terrace properties.

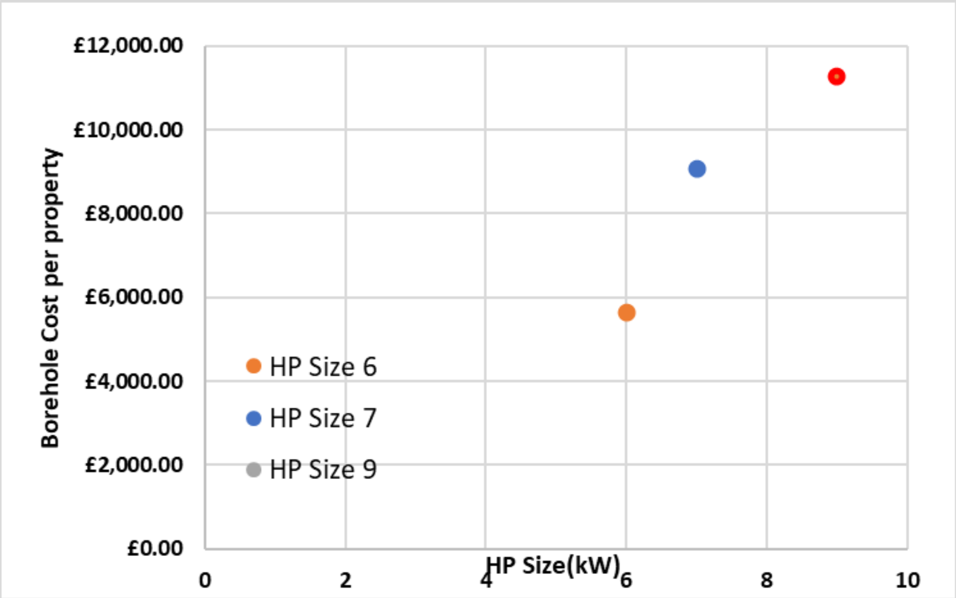


Figure 1 - Change in borehole cost per property with change in HP size

Upfront cost reduction for consumers with Diversity factors

Due to the scale of shared ground array, in the design of shared ground array (SGA) HP solution, a diversity factor can be applied to reduce the total peak heat demand and associated peak electricity demand for a cluster of homes, helping to reduce the total borehole depth required. Based on research and experience, diversity factors were used to calculate heat demand at any point in a shared ground array network. It was found that for 40 homes clustered on an array, diversity factors could bring saving of 21%.

Upfront cost reduction for consumers by targeting 80% uptake

A minimum cluster size of 40 properties were found to be needed to offer better economical solution to the end customer. High uptake scenario is considered in the cost analysis. In a cluster size of 40, 80% HP uptake is restricted to lower the trenching cost per household. As the cost of trenching is shared between more houses, 80% uptake in an area lowers the cost per household. If, for example, a street had 40% HP sign up, the same trenching would need to be laid across the street but the cost divided between half the number of households compared to the 80% uptake case. With trenching costs for a mid-terrace home at ~£5,000 per household at 80% uptake, we see a ~£4.300 saving compared to a 40% uptake case. The pre-installation of utility scale underground infrastructure also allows consumers to easily and inexpensively change to GSHPs when they're ready. This is a significant solution for reaching high density HP deployment.

Upfront cost reduction for consumers by bulk purchasing & upfront planning

In this project, we expect to reduce unit costs of heat pumps and installation by 10% / per property. This model is replicable for 'group purchasing', where neighbours get together to convert to HPs as a group. Upfront planning allows a more cost-effective use of installers in an area, reducing installation costs and allowing reductions in equipment costs through bulk purchase.

Appendix 4 – Cost to Consumer Calculator (upfront contribution)

[see link Appendix 4 Cost to Consumer Calculator LeedsRHINOs Upfront]

Appendix 5 – Cost to Consumer Calculator (no upfront contribution)

[see link Appendix 5 Cost to Consumer calculator LeedsRHINOs NoUpfront]

Appendix 6 – Overall cost analysis (Option 2 - customer loan)

In this option, the upfront cost is paid for through a consumer loan (loan for home upgrade). Whilst there is zero upfront cost to the consumer, the annual running cost will increase compared to Option 1 (direct payment), with the difference depending on the loan term and interest rate. Several examples of sample bank loans possible in 'zero upfront cost offer" and the effect it has on overall costs would be clarified to the customers.

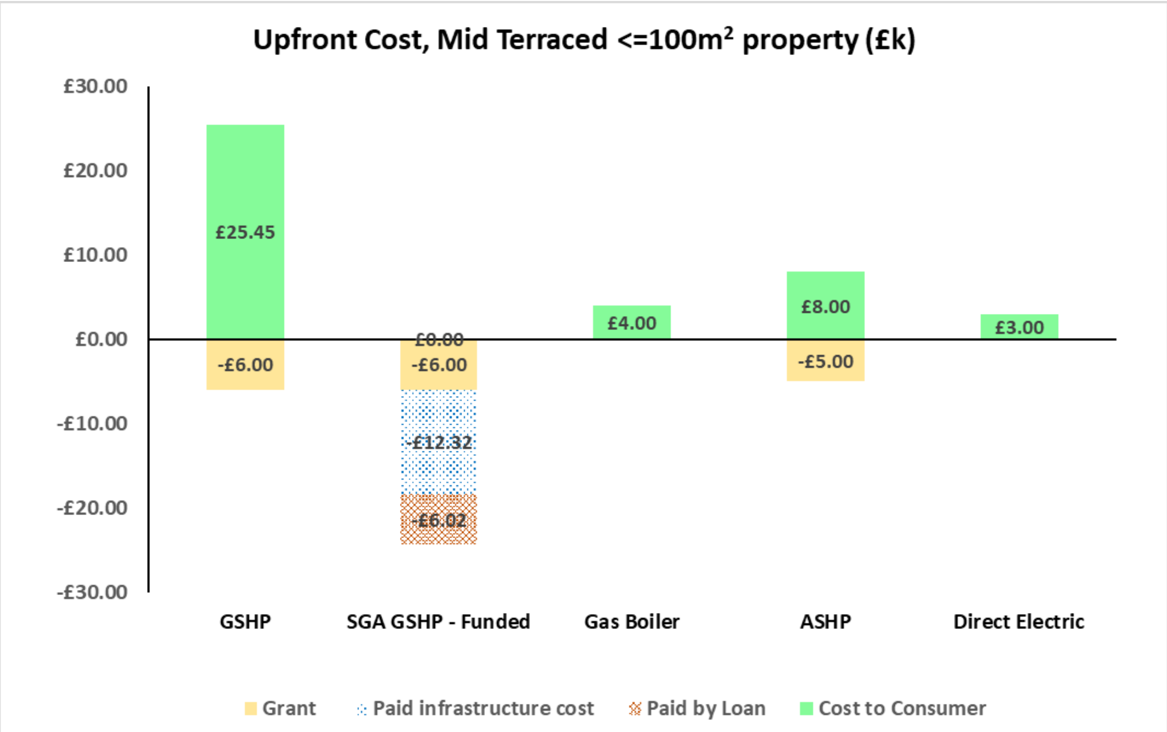
Assuming a 5-year loan term at 3.29% interest, annual finance repayments for initial costs is expected to be £1308 for mid-terraced (Case 1) and £1510 for large semi-detached properties (Case 2) for the five years which increases the overall operational cost for the first 5 years. The BEIS Cost to Consumer calculator is included for this case as Appendix 5 – Cost to Consumer Calculator (no upfront contribution).

After 5 years when the loan is paid back, annual operational costs would be equal to those of Option 1. Figure below shows the capital and year one operational cost to consumer for mid terraced and large semi-detached property for funding option 2.

Case 1 – Mid-terraced house with floor area <=100m^2

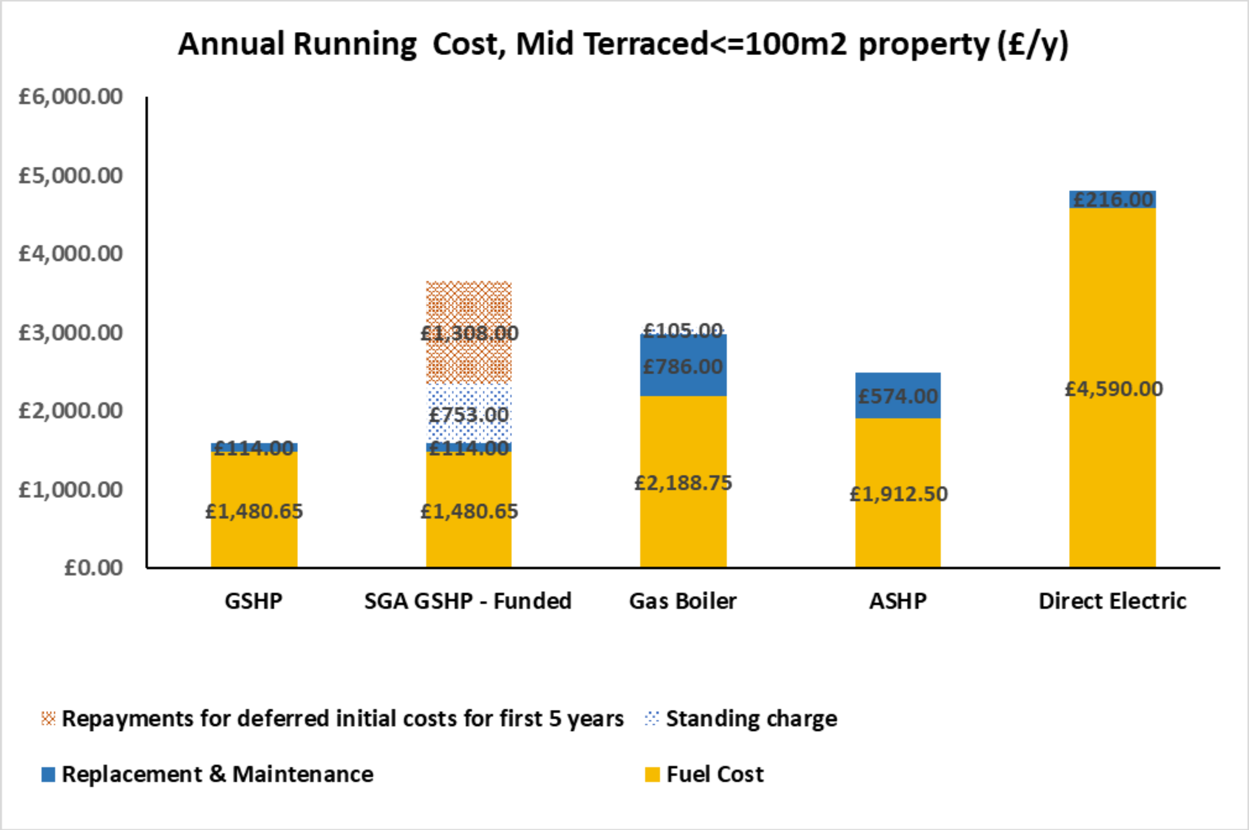
Upfront Capital Cost

	GSHP	SGA GSHP - Funded	Gas Boiler	ASHP	Direct Electric
Capital cost of initial installation (£k)	£31.45	£24.34	£4.00	£13.00	£3.00
Grant (£k)	-£6.00	-£6.00		-£5.00	
Paid infrastructure cost (£k)		-£12.32			
Paid by Loan(£k)		-£6.02			
Cost to Consumer(£k)	£25.45	£0.00	£4.00	£8.00	£3.00



Annual Operational cost

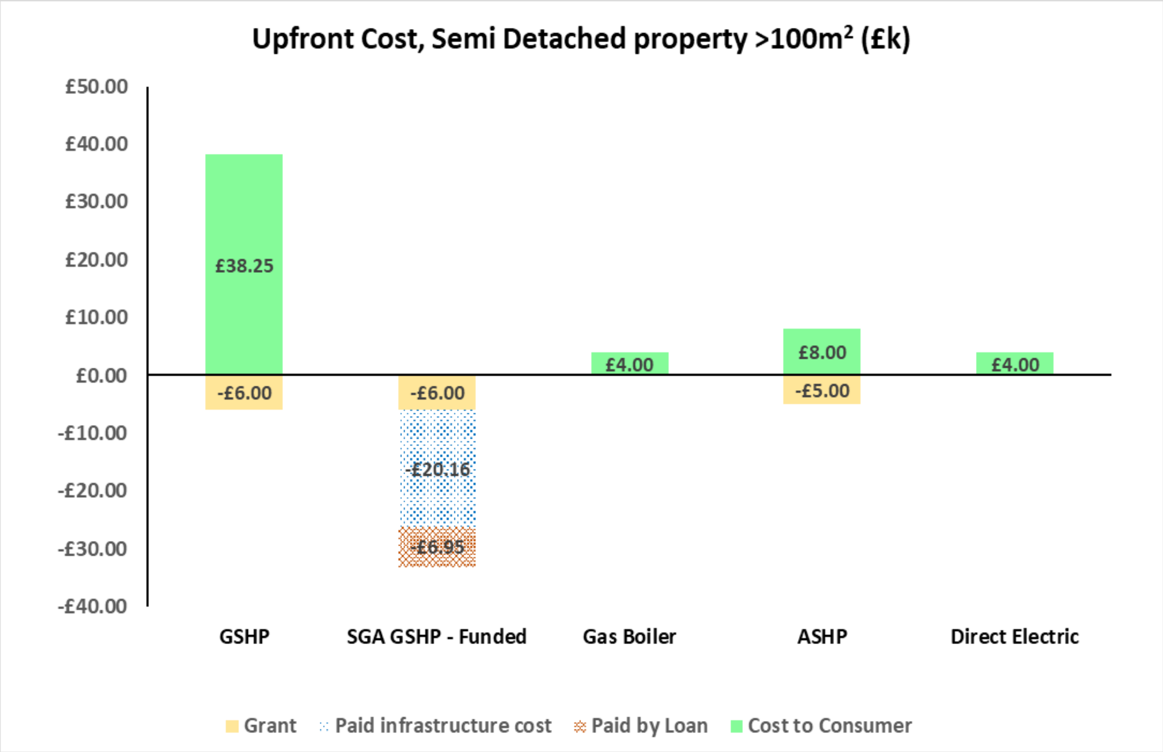
	GSHP	SGA GSHP - Funded	Gas Boiler	ASHP	Direct Electric
Demand (kWh)	13500	13500	17000	13500	13500
COP	3.1	3.1	80	2.4	1
Fuel Cost (Electricity);p/kWh	34	34	34	34	34
Fuel Cost (gas);p/kWh	10.3	10.3	10.3	10.3	10.3
Fuel Cost (£)	£1,480.65	£1,480.65	£2,188.75	£1,912.50	£4,590.00
Replacement & Maintenance (£)	£114.00	£114.00	£786.00	£574.00	£216.00
Standing charge(£)		£753.00	£105.00		
Repayments for deferred initial costs for first 5 years		£1,310.00			



Case 2 - Large semi-detached house with floor area >100m^2

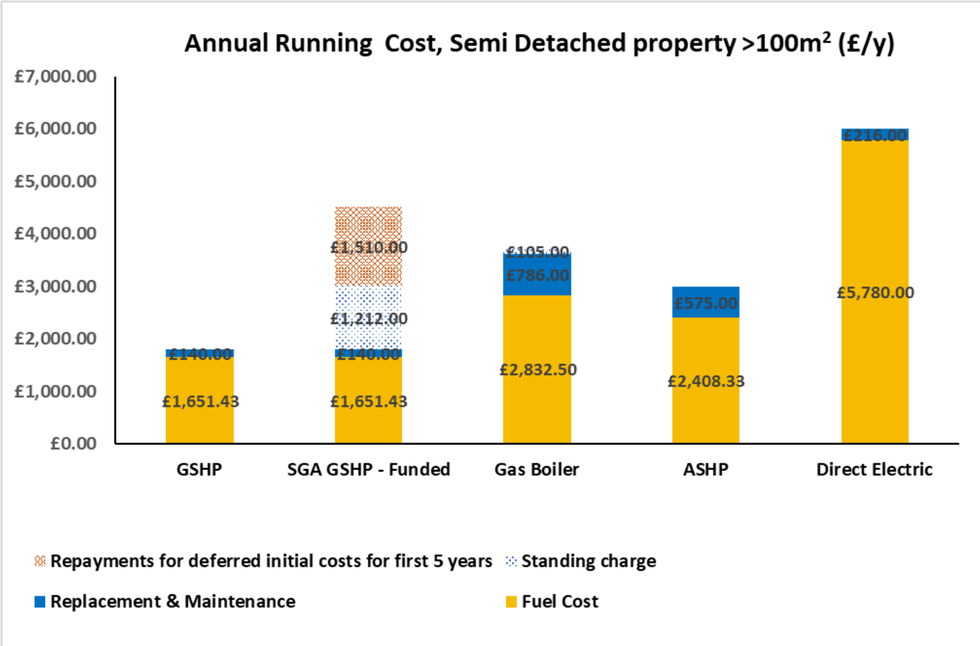
Upfront Capital Cost

	GSHP	SGA GSHP - Funded	Gas Boiler	ASHP	Direct Electric
Capital cost of initial installation (£k)	£44.25	£33.11	£4.00	£13.00	£4.00
Grant (£k)	-£6.00	-£6.00		-£5.00	
Paid infrastructure cost (£k)		-£20.16			
Paid by Loan(£k)		-£6.95			
Cost to Consumer(£k)	£38.25	£0.00	£4.00	£8.00	£4.00



Annual Operational cost

	GSHP	SGA GSHP - Funded	Gas Boiler	ASHP	Direct Electric
Demand (kWh)	17000	17000	22000	17000	22000
COP	3.5	3.5	80	2.4	1
Fuel Cost (Electricity);p/kWh	34	34	34	34	34
Fuel Cost (gas);p/kWh	10.3	10.3	10.3	10.3	10.3
Fuel Cost (£)	£1,651.43	£1,651.43	£2,832.50	£2,408.33	£5,780.00
Replacement & Maintenance (£)	£140.00	£140.00	£786.00	£575.00	£216.00
Standing charge (£)		£1,212.00	£105.00		
Repayments for deferred initial costs for first 5 years (£)		£1,510.00			



The table below shows the absolute and relative increase in annual repayment costs at different interest rates for both archetypes – zero interest 'green loans' would reduce repayments by more than £100 per year, making heat pump adoption via this funding option more competitive.

Table 20 – Repayment costs for typical properties at a range of interest rates

	Annual repayment			
Loan interest rate	0%	3.29%	5%	7%
Case 1 - mid-terrace property (£6,022 loan)	£1,204	£1,308	£1,364	£1,431
Case 2 - semi-detached property (£6,951 loan)	£1,390	£1,510	£1,574	£1,652
Increase relative to 0% loan	-	+9%	+13%	+19%

Appendix 7 – Customer Journey Proposal Process Map

[see link Appendix 7 Customer journey proposal process map]

Appendix 8 – Quality Assurance QA Process Mapping

[see link Appendix 8 Quality assurance QA process mapping]

Appendix 9 – Compare & Contrast of Kensa’s process with QA frameworks

[see link Appendix 9 Detailed compare and contrast of Kensas process with QA frameworks]

Appendix 10 – Supply Chain Research

Figure 1 attempts to put all the activities and equipment required for RHINOS deployment into a single diagram. Table 1 lists these elements and adds some explanation of the elements' attributes.

Activities (SA and SB) are placed indicatively on a timeline running from left to right, to show an approximate order. The mapping diagram is not intended to suggest a project plan or Gantt chart. The timeline is not equivalent for the above ground and below ground parts of the figure i.e. it is not assumed that SA3 is done before, say, SB4. Similarly, activities above or below ground may run concurrently rather than in the simple non-overlapping series that the map might suggest. Equipment and materials (E) are not placed in timeline order but are broadly separated between the equipment for the ground array in the left hand column and the equipment for the in-home heating system in the right hand column.

Table 1 – List of supply chain elements identified in RHINOS proposal

Ref no.	Item or activity	Notes clarifying scope
Equipment		
E1	Ground loops / grout	
E2	Manifolds	Connecting ground loops to pipes that go above ground.
E3	Glycol	
E4	Pumps and associated plant	
E5	Heat pumps and associated plant	Kensa product. Associated plant Includes Insulation for pipework, although this could also be put alongside E6.
E6	Water cylinders	
E7	Radiators and associated supplies	
E8	Control systems, smart thermostats etc	System is deliberately designed to use widely available control systems.
E9	Energy efficiency materials	e.g. External or internal wall insulation. Airtightness usually requires labour rather than materials.
Services above ground		
SA1	Recruitment (of households)	Technically informed, but customer benefit led.
SA2	In home Surveys	Requires technical skills and adaptability; building surveyor skillset

Ref no.	Item or activity	Notes clarifying scope
SA3	In home Design	The design task is iterative with any fabric or energy efficiency works that are undertaken.
SA4	In home co-ordinator	For retrofit and heating system installation – the first point of contact for householders. For ease of presentation, Figure 1 shows this as a discrete activity but in fact it could, and arguably should, run throughout the whole above-ground process.
SA5	Fabric changes	Fabric measures and other energy demand reductions increasing insulation and airtightness can be carried out by general construction firms, appropriately competent, or direct labour organisations.
SA6	Heating system installation	And removal of old system elements e.g. radiators
SA7	Heat pump installation (includes water cylinder)	Together with SA6 and SA8-9, this activity typically takes 3 – 5 days.
SA8	System assessment	A Quality Control 'gateway', requiring certified professional assessments against public standards: MCS, and potentially PAS2035
SA9:	Commission	
SA10	Monitoring and aftercare	
SA11	Maintenance and upgrade	
Services below ground		
SB1	Survey	
SB2	Ground loop design	
SB3	Dig – vertical	Depth of borehole will dictate choice of contractor.
SB4	Spoil disposal	Usually combined with SB3
SB5	Dig – horizontal	These activities are standard for utility contractor firms i.e. laying and fusion welding pipework.
SB6	Connect (manifolds)	
SB7	Ground loop commissioning	Must be MCS registered to commission the GSHP array.
SB8	Monitoring / aftercare	
SB9	Maintenance and upgrade	

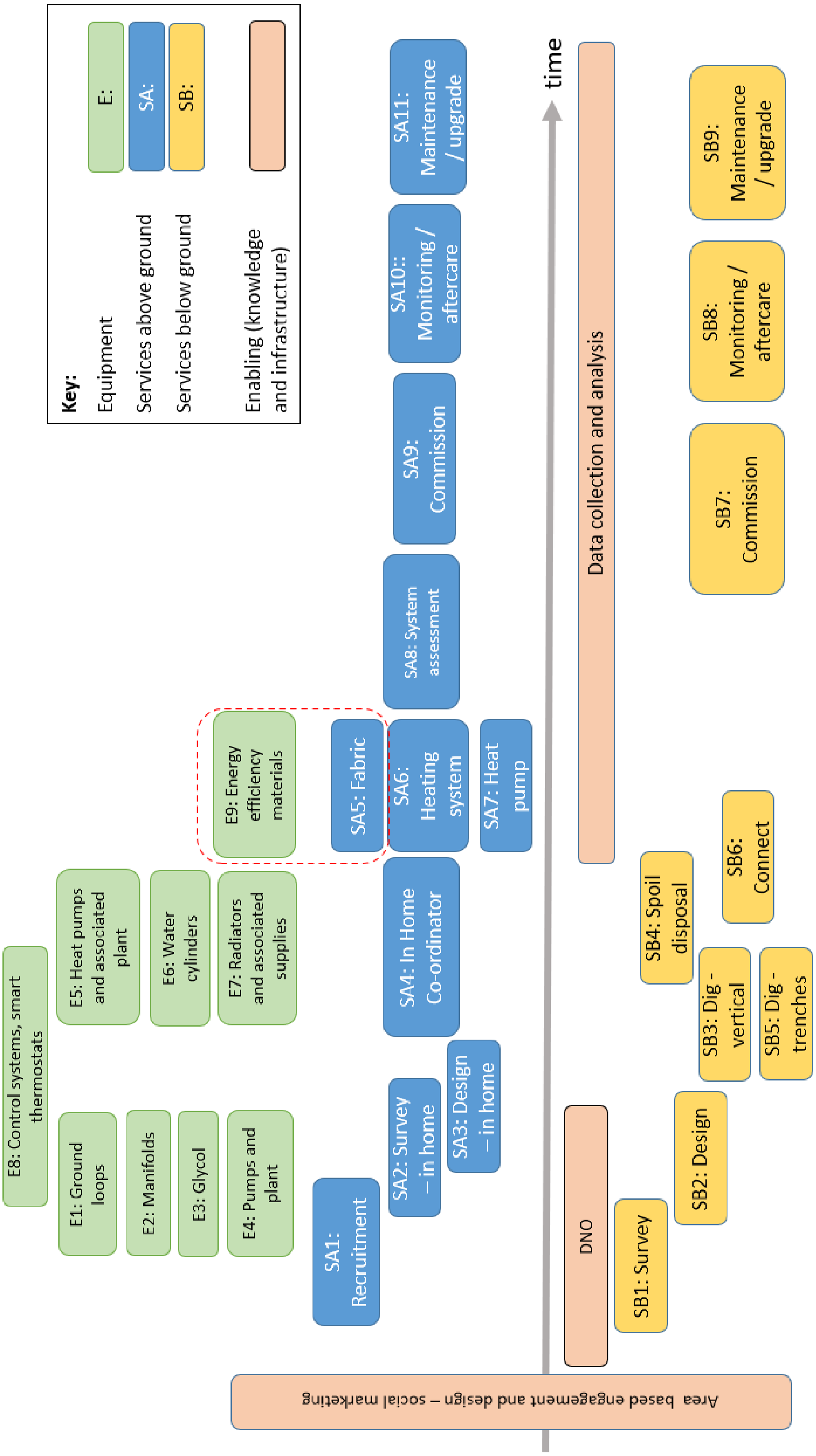


Figure 1 – Supply Chain Map