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Methodologies for high-density domestic heat pump deployment in the UK

Nicola Lazenby^{a1}, Alex Hobley^b,

^aGovernment Department for Energy Security & Net Zero (DESNZ), 1 Victoria St, London, SW1H 0ET, UK

^bGovernment Department for Energy Security & Net Zero (DESNZ), 1 Victoria St, London, SW1H 0ET, UK

Abstract

The UK Government's Department for Business, Energy & Industrial Strategy (BEIS) has embarked on a 3-year innovation programme, 'Heat Pump Ready', part of its Net Zero Innovation Portfolio. This paper considers one of the programme's objectives to drive forward methodologies which support the high-density deployment of domestic heat pumps across urban and rural areas. Projects delivering against this objective have conducted feasibility studies which address both technical and consumer barriers to high-density heat pump deployment, bringing together key stakeholders in the journey to ensure a 'joined up' approach from the energy networks right through to installers and consumers. Emphasis is being placed on providing a cost-effective installation and on-going support package to consumers. The key findings from these feasibility studies, carried out by project teams across Great Britain, are presented in this paper alongside proposals for the trial of these methodologies in order to achieve high-density heat pump deployment within the project's specific locations.

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1. Introduction

By 2028, the UK aims to be installing 600,000 hydronic heat pumps per year [1], this is a considerable increase from the reported rate of 55,000 heat pumps installed in 2021 [2]. To achieve this deployment aim, as set out in the 'Heat and Buildings Strategy' [1], many factors must be considered including elements such as: achieving significant growth in the heat pump supply chain; affordability of heat pumps; the ability of the electricity network to accommodate an increase in electricity demand; and enabling the timely connection of heat pumps to the network.

The UK government have set out a package of measures to support the increase in heat pump deployment [3] which includes:

- Reducing the cost of heat pumps to consumers through zero-rate value added tax for the next 5 years on the installation of low carbon heating technologies
- Launching £450m Boiler Upgrade Scheme to provide consumers with up to £6,000 off the cost of a heat pump
- Expanding the UK's manufacturing capacity through a £30m Heat Pump Investment Accelerator
- Investing in heat pump innovation through a £60m Heat Pump Ready Programme, part of the Net Zero Innovation Portfolio [4], which aims to develop innovative methodologies for high density heat pump deployment, in addition to supporting the development of innovative tools and technologies to overcome barriers to heat pump deployment.

This paper sets out the development and delivery of the Heat Pump Ready Programme (HPR), considering the learnings from the programme to date.

¹ Corresponding author: Email address: Nicola.lazenby2@beis.gov.uk

2. Requirement for heat pump innovation

In the development stage of HPR, it was important to establish the bench-mark of current market and industry practice for heat pumps, in order to establish the areas for innovation. To determine this benchmark, an evidence review alongside stakeholder engagement was conducted. The programme design also drew upon the learning from the department's previous heat pump innovation programme, the Electrification of Heat Demonstration project.

2.1 Evidence review

A rapid evidence assessment (REA) of existing literature was carried out in order to establish the current benchmark for innovation [5]. This evidence review was carried out across 4 key areas:

1. Financial Innovations: What are the necessary financial innovations required to deliver a large-scale roll-out of heat pumps in the United Kingdom (UK)?
2. Low Voltage Grid Issues: What are the Low Voltage (LV) grid issues associated with a concentrated deployment of heat pumps and how can we mitigate these? What is the necessary size of a heat pump cluster to achieve appropriate grid impact learnings?
3. Roll-out Facilitation: What are the necessary innovations or learnings required to facilitate the large-scale roll-out of heat pumps? What tools or established processes of stakeholder coordination exist that could support the effective roll-out of heat pumps and are there examples of coordinated deployment?
4. Performance and Deployment: What are the technological improvements to the heat pump system and tools that could be developed to support any of the above aims - i.e. the large-scale deployment of heat pumps in the UK?

The REA found that significant benefit could be gained through innovation in the following areas:

- Design improvements - considering heat pumps as modular systems and how innovation could support the ease of design, installation, and optimization of low temperature systems. Design improvements could also support the ease of connection between heat pumps and other technologies such as heat storage.
- New ways of manufacturing - the use of computer modelling simulation tools to provide flexible, user-friendly interfaces to overcome inefficient designs, in addition to new methods of mass production such as 3D printing. These come with the opportunity to increase resilience in the UK supply chain.
- Installation – the use of ‘plug and play’ software and hardware.
- Monitoring, maintenance, and operation – the opportunity for improvements to the user interface and inclusion of internet of things data-gathering to support optimization, remote diagnostics, and predictive maintenance of heat pump systems. This presents the opportunity for an enhanced consumer experience, in addition to cost savings.

These areas were supported by recommendations for future innovation programs and research to consider:

- Trials which build on the scale of previous heat pump trials, utilizing up-to-date installation, commissioning, and operational practices.
- The performance gap between system design, installation and operational use of a heat pump and the role which different approaches to on-going monitoring and optimization can play in improving performance.
- Innovation ‘horizon scanning’ to seek out early-stage technology and tools which may be at lower technology readiness levels.
- Broader areas for innovation relating to the uptake and performance of heat pumps in areas such as noise and disruption.

2.2 Learnings from Electrification of Heat Demonstration Project

The Electrification of Heat Demonstration Project (EoH) [6] began in 2020, with the aim of demonstrating the feasibility of a large-scale roll-out of heat pumps in Great Britain. This project deployed 742 heat pumps in 3 different locations within the UK. Results from the EoH have produced the following 2 key findings:

1. All UK housing types are suitable for a heat pump [7] with no property or architecture, ranging from Victorian mid-terraces and pre-world war two semi-detached homes to 1960s blocks of flats, found to be unsuitable for a heat pump.
2. Heat pumps installed in the UK have been shown to be 3 times as efficient as gas boilers [8]. Measured real-world performance of heat pumps has shown a significant increase in performance through this

trial when compared to previous UK field trials. The study found that the heat pumps performed well even on the coldest observed days with only a relatively small reduction in performance.

EoH has demonstrated that heat pumps work in domestic properties from a technical perspective and data shows their efficiency. The Heat Pump Ready programme therefore looked to explore the tangential barriers associated with the increased uptake in heat pump deployment.

2.3 Stakeholder engagement event

To understand remaining innovation requirements for heat pumps, BEIS held a virtual stakeholder engagement session [9]. This event was attended by 342 representatives from across the sector. A total of 1,241 comments were received from participants with the key suggestions including:

- The use of smart controls to monitor heat pumps, improve consumer experience, and enable response to grid demands.
- The use of thermal storage to improve heat pump efficiency, consumer experience and enable demand reduction of electricity from heat pump users.
- Options for leasing heat pumps or heat charged as a service to a consumer.
- Green mortgage options which include heat pump and energy efficiency funding.
- The coordination of heat pumps by local authorities
- Heating engineers and installers are the most trusted to advise consumers on heat pumps
- The use of national media outlets, e.g. TV and radio, to raise the profile of heat pumps
- The use of clear and simple heat pump communication

3. Heat Pump Ready Programme

The funding opportunities available under HPR were launched in 2021 [10] with the aims of the programme being to:

- Reduce lifetime costs of domestic heat pumps
- Improve lifetime consumer experience of heat pumps
- Stimulate innovative research and solutions to address the impact of domestic heat pumps on the electricity system
- Develop and strengthen partnerships between the many players involved in the domestic heat pump sector
- Develop effective approaches and products to engage effectively on heat pump issues with homeowners and with other key players in the sector
- Establish an evidence base to enable effective design and development of future heat pump policy and regulation

The programme is split in line with its aims across 3 key objectives:

1. Innovative methodologies for high-density deployment: Recognizing the need for a shift from a very dispersed, consumer led approach in deployment to a coordinated, ‘street-by-street’ high-density deployment of heat pumps (Stream 1)
2. Support innovative tools and technologies to overcome barriers to high-density heat pump deployment (Stream 2) across key areas including [11]:
 - a. increasing the performance whilst reducing the cost of domestic heat pumps
 - b. minimizing home disruption whilst providing high quality installations
 - c. providing financial solutions for heat pumps
 - d. improving the consumer journey through their transition to heat pumps
 - e. creating a smart home energy system
3. Providing the opportunity for knowledge transfer and the dissemination of learnings across HPR projects and the broader heat pump sector (Stream 3).

This paper provides an overview of the Heat Pump Ready Programme (HPR) with a particular focus on objective 1 – the development of innovative methodologies developed which support high-density heat pump deployment within specific locations in Great Britain.

4. Scope for Innovative methodologies for high density deployment

In the development of the scope for the funding competition for project teams to carry out feasibility studies on innovative methodologies for coordinated, high-density deployment of heat pumps it was important to ensure the projects would add to the existing evidence based within this area. One of the greatest challenges

for heat pumps is increase their attractiveness to the able-to-pay, owner occupier and private landlord market – those who are responsible for the capital and on-going cost and maintenance of heat pumps installed within their homes. Coupled with this is understanding the impact on the electricity network of mass transition to heat pumps. This funding competition was divided into 2 Phases: Phase 1 developing feasibility studies for innovative methodologies for high-density heat pump deployment (6 months); and Phase 2 trialing these feasibility studies developed (24 months).

To ensure project developed methodologies which targets this demographic and scenario the following key elements of eligibility criteria [6] were applied to all applications:

1. Project costs must not exceed £200,000, as funding was being deployed through the mechanism of Small Business Research Initiative (SBRI) [12] with this funding being required to cover 100% of the total eligible costs of the project.
2. Projects must be up to 6 months in duration, ending 30th November 2022 to enable projects to apply their learnings to their Phase 2 application to trial the methodology they developed
3. Projects must be looking to achieve deployment of heat pumps in at least 25% of homes either on a low voltage network feeder, supplied from a secondary substation or supplied from a primary substation, during Phase 2, in order to be considered as achieving high-density deployment.
4. Funding for the cost of the heat pump, installation and on-going maintenance of the heat pump, in Phase 2, is capped in line with the Boiler Upgrade Scheme at £5,000 per air source heat pump and £6,000 per ground source heat pump.
5. Heat pumps are to be deployed, during Phase 2, in predominately on-gas grid, domestic, private existing homes, with a cap of 30% of trial buildings being eligible to be social housing, new build or non-domestic properties. Applicants could opt to include up to 15% of their trial homes as off-gas homes.
6. The technology eligible for deployment as limited to hydronic air source or ground source heat pumps, with only a maximum of 20% of the trial homes being eligible for hybrid or air-to-air heat pumps or other sources of direct electric heating. Shared ambient temperature ground loops were eligible, however high temperature ground loops and heat networks were not eligible for deployment.
7. All innovative methodologies for deployment were required to be replicable in other areas of the UK.
8. All technologies, tools and finance models deployed into consumers' homes must have already been trialed and be a commercial offering to the consumer.

5. Overview of Phase 1 projects

Following the assessment of applications, 11 projects were awarded Phase 1 funding to carry out a feasibility study into their innovative methodology for coordinated, high-density heat pump deployment [7]. The locations of project are shown below on Figure 1 with:

- Urban projects (shown in purple) based in Newcastle-upon-Tyne, Sunderland, Leeds, Oxford, Greenwich and Bristol.
- Urban with significant rural projects (shown in red) based in Perth & Kinross, Cherwell and Bridgend.
- Rural projects (shown in blue) based in Fenland and Teinbridge.



Figure 1: Map of Heat Pump Ready Stream 1, Phase 1 projects.

Across the project teams' feasibility studies there was a mix of projects focusing on the deployment of either air source heat pumps or shared ground loops. The number of heat pumps which project teams were looking to deploy in their locations ranged from 30 to 1000 heat pumps, with a mixture of financial offerings being considered such as upfront capital funding from the consumer, heat pump leasing and financial loans.

6. Findings of feasibility projects

Through the delivery of Phase 1 feasibility studies [13], project teams identified a range of challenges and opportunities to support coordinated, high-density heat pump deployment. This section will consider each of these in turn.

6.1. Coordination of stakeholders

To achieve high-density deployment within a given location, there is a strong requirement for the various actors supporting deployment in that location to come together. The actors which projects have identified as having a core role in deployment include:

- **Management entity:** across the projects, this role was carried out by a range of organisations. For the majority of projects, this role was carried out by engineering/project management consultancies [14-19] with energy suppliers [20-21] also taking on this role. For a small proportion of projects, a technology provider/coordinator took on this role [22-23] with one local authority [14]. For the local authority, they were supported by an engineering consultancy as part of their consortium to deliver the project management elements of their feasibility study. This role was responsible for bringing together the organizations necessary to deliver a coordinated methodology, developing the project communication plan alongside their approach to data sharing and governance.
- **Place based entity:** where a local authority was not fulfilling the management entity, the majority of projects included within their project team a local authority to provide support within depth knowledge of the local area.
- **Engagement coordinator:** most of the project teams had an organization specifically responsible for coordinating the consumer engagement within their location. This role typically delivered elements such as consumer surveys, developed marketing campaigns and conducted focus groups. For some projects, this role was carried out by an organization specializing in consumer engagement whilst others utilized local community groups to support this engagement.
- **Housing data modeler:** Some of the projects [15, 18-19, 21] included a specific role within their feasibility study project team for an organization responsible for utilizing available data on elements

such as housing architypes, social-economic data on occupants and energy data. How this data was utilized by the projects is discussed in Section 6.2.

- **Financing partner:** Developing an understanding of the consumer finance offer was a key element of the project's feasibility, which ultimately decided whether a project was confident to apply for Phase 2 of the programme to trial their methodology developed. The inclusion of a financing partner, as part of the feasibility studies was not necessarily required, however it was found to be very beneficial to have a member of the project team focused on developing the project's consumer financing offers [17-20, 24].
- **Technology provider:** Across the projects, there was a split between whether they chose a technology provider in advance of completing their feasibility study. 4 projects [15, 17, 21, 24] opted to include a member of the Kensa Group within their project team with the aim of deploying a shared ground loop (SGL) solution, in addition to the Oxford project, which was led by Samsung, aiming to deploy specifically Samsung air source heat pumps (ASHP). Choosing a technology provider upfront enabled the projects to focus their feasibility study on delivering that specific technology. Contrast to other projects who retained the ability to adapt their specific technology offers to the needs of the consumers depending largely on their house type and financial circumstances, demonstrating high levels of replicability for their innovative, coordinated methodology developed.
- **Distribution Network Operator (DNO):** Within the phase 1 project teams, there was limited representation of DNO's, with only a couple of projects formally including their DNO in the project team [17, 22]. It was found however through the feasibility studies that the role of the DNO was vital to deliver an innovative coordinated methodology for heat pump deployment. The key knowledge which was required from the DNO was an understanding of the network configuration and capacity within the areas the project teams were targeting, to understand whether network reinforcement would be required and to explore the opportunity for flexibility across the network to reduce peak demand. Early engagement with the local DNO provided the opportunity to develop a more in-depth feasibility study.

A key element throughout each of the feasibility studies was the understanding that a customer relationship management (CRM) platform which operated between the organizations within the project team was essential. The governance for the operation varied with approaches included a combined CRM platform across all project partners [18-19, 23], utilizing existing CRM platforms [20, 21] and the development of a cross organization 'data hub' architecture to support data sharing [15].

6.2. Technical appraisal of location and homes

Coordinating the deployment of heat pumps within a specific location unlocks the opportunity to optimize the process of technical appraisal of homes for their suitability of heat pumps. Many of the projects used a 'data led approach' to narrow down their location for high density deployment. Two projects which considered this in detail were Samsung's project in Oxford [16] and Buro Happold's project in Bristol [15]. This process included bringing together the following data (in compliance with data protection protocols):

- **Network data:** working within a specific location enables network capacity to be considered for all residents within that specific location, creating efficiencies in the network assessment process and coordinated sequencing of any grid reinforcement required. To access this data, projects established relationships with the relevant Distribution Network Operator within their location. For the Samsung project they combined this data with Oxford Brookes University's LEMAP tool to understand the load profile on the electricity network. Buro Happold utilized the DNO substation polygon areas and distribution substation capacity data available from National Grid to support their understanding.
- **Housing stock model:** Samsung drew upon the Energy Performance Certificate (EPC) dataset to feed into the analysis of the housing stock within the location they were targeting, with Buro Happold using data provided by Parity Projects, which also included energy data. Another project, E.On [17] working in Newcastle, took this analysis further by testing the feasibility of carrying out drone surveys across the location they were targeting, to develop a thorough understanding of the archetypes and features of the homes which would impact the heat pump system design.
- **Energy data:** For Samsung's project, work was led by the University of Oxford and Oxford Brookes University to develop analytical approaches which reveal the attributes, capabilities and priorities of the target communities. This project drew upon the Energy Demand Research Project

(EDRP) dataset and The Smart Energy Research Lab (SERL) dataset to enable demand profiling to be conducted for the homes within their focused location.

- Occupant data: For Samsung’s project, the ACORN classification and MOSAIC datasets were used to determine the defined socio-economic types for each of the homes within the location. This classification was used to identify common factors which explain the energy demand profile associated with the home and enable the project team to explore the demographic, socio-economic status and lifestyle of the consumer. Buro Happold utilized social housing data from Bristol City Council regarding council owned properties in addition to other social housing providers data.

This flow of data is presented in Figure 2 below, which shows how the collection of data feeds into decision making regarding the location for heat pump deployment. For most of the project teams, the decision was made to trial their methodology in a location which met the following criteria:

1. The properties have high levels of energy efficiency, requiring little to no additional fabric upgrades.
2. The majority of consumers being classified as able-to-pay, middle income residents, enabling access to a wide range of financial products such as loans or heat pump rental.
3. There is sufficient headroom on the electricity network within that location, or a Distribution Network Operator (DNO) on board with the project, supporting the required upgrades within that location.

Most projects focused on location whereby they had an existing relationship with an organization within the location; this was typically with a local authority or a community energy group.

Once this data was collected, project teams planned how it would flow through the consumer journey, to support the trial of their methodology. This data was identified to support the design and survey of the heat pump by:

- Enabling remote survey and triaging of the properties: Enabling an understanding of what would be required from a heat pump install to be developed prior to visiting the consumer. This data allows the project teams to make an informed choice as to where to target the high-density deployment of heat pumps.
- Streamlining in home surveys: Having an established data set of property details will enable the project team to reduce the number of visits to a property, but also allow for data about the property to be pre-populated into surveys so that data is checked and verified during the surveys rather than collected for the first time, leading to a reduction in errors and re-visits required.
- Supporting occupant surveys: Ensuring that consumers are not required to repeatedly provide their personal information, in addition to providing pre-populated information within their surveys for consumers to verify rather than specific, for example asking consumers to confirm they have cavity wall insulation, based on data drawn from their EPC, rather than having to select what type of insulation their home has.

Bringing together this data centrally was identified as being key for the project teams to support the development of their specific offer to the consumer, in Phase 2, with regards the size of heat pump they required, any energy efficiency or home upgrades required and consumer financing.

Through the understanding of the role of data throughout the consumer journey and how this data supports stakeholders throughout the journey, the project teams are able to develop a standardized process for data storage and transfer which could be replicated in other locations.

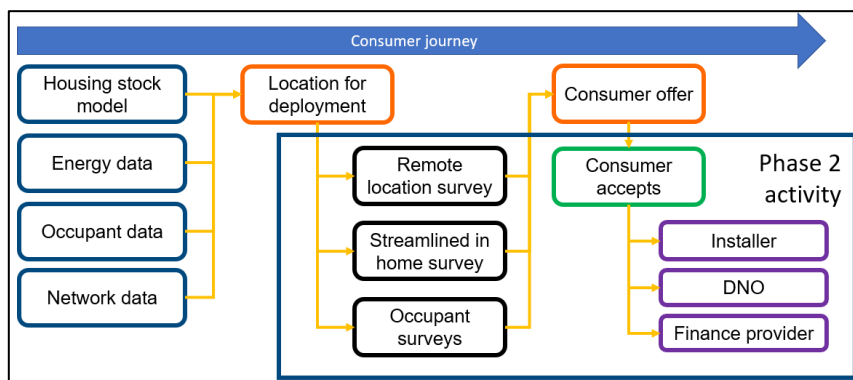


Figure 2: Diagram showing the flow of data identified in Phase 1 feasibility studies

Consumer journey and engagement

For each of the projects, a key emphasis of their feasibility study was placed on how to support the consumer throughout their heat pump journey. For each of the projects, a ‘consumer platform’ was proposed which brought together various elements of the innovative coordinated methodology. For projects with an existing consumer base, such as the energy suppliers [16, 20-21], the project teams looked to utilize their existing consumer platforms, adding to them the functionality to support their heat pump journey, including registering interest for a heat pump installation, find heat pump installers and providing post-installation guidance.

Each of the project teams conducted early consumer engagement within the location they were working. The early consumer engagement largely consisted of either focus groups, online surveys/expression of interests and/or face to face surveys either at the consumer’s home or at a community event. Where surveys were conducted, the project teams findings predominately aligned with findings from existing literature, with limited local variation regarding consumers’ perspectives or motivations. Surveys however, especially when conducted face to face, did provide the first ‘touch point’ with the consumer to open the conversation regarding the project and establish early trust in the project team and build momentum for the project.

Through location specific deployment, project teams were able to consider more bespoke engagement with their communities. Project teams identified the importance of local engagement to generate interest across the community, in addition to building momentum across residents. The findings of the consumer engagement are provided in each project’s feasibility reports [13].

7. Projects progressing to Phase 2

During Phase 1, projects were eligible to apply for funding under Phase 2 of the programme in order to proceed to trial the methodology developed as part of their Phase 1 feasibility study. Upon successful completion of Phase 1, 4 projects were awarded Phase 2 funding [18]:

1. Urban projects, one led by Samsung (project value £3,206,448) focusing on heat pump deployment in Rose hill, Oxford and another by Bristol City Council (project value £2,925,450.72) focusing on heat pump deployment in Westbury on Trym, Bristol.
2. Rural project being led by City Science (project value £1,815,391) focusing on heat pump deployment in Fenland, Cambridgeshire.
3. Urban with significant rural project led by City Science (project value £1,799,245) focusing on heat pump deployment in Cherwell, Oxfordshire.

Across three of the four Phase 2 applications, there was a significant decrease in ambition in comparison to their Phase 1 applications, this was primarily due to the ‘cost of living’ crisis which is ongoing in the UK. These project teams looked to minimize their delivery risk by reducing the scale of their deployment from the range of 500-700 heat pumps to 100-150 heat pumps, whilst still meeting the high-density eligibility criteria. They achieve this by reducing down from doing multiple areas of the electricity network to just limited elements. Bristol City Council were the only project to maintain their deployment ambition of approximately 200 from Phase 1 into Phase 2. From a project perspective, this reduced ambition will still provide the opportunity to trial the project innovative methodologies for coordination and gather the learnings required from the programme.

Through the trial of the projects’ innovative, coordinated methodologies for high-density heat pump deployment, some of the key overarching barriers and challenges being addressed include:

- Capital vs lifetime cost of heat pumps: projects are looking to demonstrate and present a detailed overview and understanding of lifetime costs of a heat pump to consumer. Through lifetime cost modelling project teams are including capital cost pay by the consumer and financing options, in addition to their projected operational cost of the heat pump and any income from electricity demand flexibility. Through trialing their methodologies, project teams will be able to establish exactly the cost associated with coordinated deployment of heat pump installations and the potential capital cost reduction available to consumers through this approach.
- Perceived disruption of homes: for the locations which the projects have selected, minimal home retrofits will be required, however some of the homes are likely to require radiator upgrades, for example. To demonstrate the level of distribution required, project teams are looking to set-up ‘open homes’ and ‘show homes’ to enable consumers to see and feel a heat pump installation in real-life.
- Limited installer capacity: project teams are taking a variety of approaches with regards to ensuring the installer capacity is in place for their deployment. The 3 approaches being trialed are: tendering for installers; including an installer provider on the project team; and including an installer training provider on the project team to develop a local installer hub and training programme.

- Requirement for network reinforcements: City Science’s Fenland project is aiming to deploy heat pumps in a constrained part of the electricity network. Here the project team are working closely with the DNO in the area to understand how to coordinate heat pump deployment alongside network reinforcements and the role of flexible demand profiles from the heat pumps. The other City Science project in Oxfordshire, and the Samsung project, whilst not working in a constrained part of the network, are using this project to demonstrate how to coordinate heat pump deployment (with DNO monitoring) in the area, to understand the network impact of deploying heat pumps at high density.
- Coherent consumer journey: All Phase 2 projects have a strong emphasis on providing a coherent consumer journey from a consumer’s initial expression of interest in a heat pump through to the operation, maintenance and getting the best performance from their heat pump once installed. All projects are establishing a ‘consumer portal’ through which consumers manage their heat pump journey, rather than having to navigate various websites and platforms of the various actors who play a role in their transition to heat pump adoption.

8. Conclusion

From the initial 6 month’s feasibility studies developed by the Heat Pump Ready, Stream 1 – Phase 1 projects, key learnings have already been provided:

- The support required for the future of heat pump deployment in terms of the actions which stakeholders can take to increase the uptake of heat pumps within their local areas.
- The role of data has been shown to be vital in unlocking the coordination of high-density heat pump deployment and supporting the consumer through their heat pump journey.
- The potential role of future policy regarding the role of DNO’s, flexibility in the energy network, developing installer capacity and engaging consumers.

The Heat Pump Ready, Stream 1 – Phase 2 projects will continue to provide vital learnings as they progress through their mobilisation stage into heat pump deployment.

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