BURO HAPPOLD

HPR Bridgend

Feasibility Study

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Glossary

Term	Definition
ASHP	Air Source Heat Pump
CapEx	Capital Expense
DNO	Distribution Network Operator
HP	Heat Pump
HPR Bridgend	Heat Pump Ready Bridgend – This feasibility study
GSHP	Ground Source Heat Pump
GSHP+SGA	Ground Source Heat Pumps with a Shared Ground Array
LAEP	Local Area Energy Plan
NGED	National Grid, the Distribution Network Operator
SBRI	Small Business Research Initiative
SGA	Shared Ground Array
SPV	Special Purpose Vehicle
WPD	Western Power Distribution, now known as National Grid, Distribution Network Operator

1 Executive Summary

The United Kingdom is transitioning to a low-carbon economy, and one aspect of this is to decarbonise heating for buildings. Heat pumps are a mature low-carbon heating technology that can be used to reduce carbon emissions; however, they are not yet as common as gas-fired boilers.

The purpose of this feasibility study is to explore collaborative methods of working to identify the potential for high-density heat pump deployment in private homes.

This study, Heat Pump Ready (HPR) Bridgend, is one of 11 feasibility studies funded by BEIS, the Department for Business, Energy, and Industrial strategy, through the Heat Pump Ready Programme[1].

The only Phase 1 project to be deployed in South Wales, the project was well received and sponsored by Bridgend County Borough Council (BCBC) as a much-needed look at interventions and innovative solutions to address a region where there are a number of communities at risk of fuel poverty under the transition of heat decarbonisation. The feasibility study was prepared by a collaborative group led by Buro Happold with significant input from Challoch Energy, NuVision Energy Wales, and Kensa Consulting. There was also strong collaboration with the Distribution Network Operator (DNO), National Grid (NGED). NGED was formerly known as Western Power Distribution (WPD).

HPR Bridgend Study Description Summary

- Location: In Bridgend County
- Population: In areas which are urban with significant rural, below 10,000 persons, which can include the fringes of large settlements (small town)
- Density: High-density heat pump deployment of 25% or greater on a Low Voltage network
- Grid: On a Low Voltage Network
- Building ownership: Focus on private homes, which are on the gas network
- Technology: Ground Source Heat Pumps with Shared Ground Array and Air Source Heat Pumps
- Customer Journey: Improved joined-up journey to having a heat pump installed
- Business model: Established business model
- Innovation: Collaborative method of working, including the following: reducing barriers to heat pump deployment through improved stakeholder engagement, District Network support, Council support, screening of areas suitable for heat pumps, and expertise in heat pump technology and deployment
- Scale: 150 homes identified as suitable for heat pumps

[1] Gov.UK, 2022. Heat Pump Ready Programme, Stream 1. URL: Heat Pump Ready Programme: apply for Stream 1 opportunities - GOV.UK (www.gov.uk) Accessed 29/11/2022.

Challenges

The highest challenge to high-density heat pump deployment projects is stakeholder uptake. For an HPR project to achieve high-density heat pump deployment, it is required to secure 25% or more customer uptake of heat pumps in an area on the Low Voltage network.

To date, high-density deployment of heat pumps has not happened organically due to contextual barriers. The current market mechanism is reactive, relying on consumers to directly interact on an individual basis with the supply chain. Feedback from community engagement during the feasibility study has been that the potential for decarbonisation using heat pumps is not well understood, yet there is a strong aspiration for community members to do their bit and decarbonise.

The approach and resulting benefits

The Bridgend Heat Pump Ready Project Phase 1 study has developed a methodology based on proven technologies and targeted planning and consumer and community engagement which addresses these challenges. In contrast to the normal subsidised offering from the Government targeted at only individual homes, the methodology includes for heat as a service using community heating solutions.

The benefits of this are considerable. Many communities in the South Wales region do not have the option of procuring individual heat pumps. Affordability is an issue. Installing heat pumps (even with subsidy) is expensive and often efficiency measures are also required to ensure the system works. Many properties in the region are terraced house communities with space constraints prohibiting the installation of Air Source Heat Pumps (ASHPs) in particular.

The only option without intervention for these communities, if they were to decarbonise, would be to move to direct electric boilers which would prove extremely expensive to run forcing more members of these communities into fuel poverty.

A community heating approach removes these barriers providing lower cost shared heating between homes supported by innovative finance packages to pay for necessary efficiency measures. Targeted community engagement with the right information overcomes barriers of uncertainty by clearly explaining the benefits and options and bringing community members together collectively to provide assurance.

Another key benefit derived from this approach is the significantly reduced electrical load on the local electricity network. The coefficient of performance (CoP) is significantly better and more resilient during cold spells than ASHPs and typically these systems will use a third of the energy of the counterfactual of electric boilers. In the future, through smart integration, further benefits could be provided to the DNO through flexibility as these systems typically deploy far more thermal storage (hot water) into homes via either hot water tanks or thermal batteries.

The technology used combines ground source heat pumps with ambient loops, deployed in clusters of homes. The finance package includes a loan arrangement incorporated as part of the standing charge to pay for efficiency measures and a standing charge element to recover the heat infrastructure costs, typically over a 30-year period. This thereby effectively 'socialises' the cost for the community rather than the upfront costs otherwise needed under current mechanisms.

It should be noted that Phase 1 also recognised that the required density for shared community heating is not always possible and so the alternative of ASHPs is also offered to certain categories of homeowner. However, the other service elements remain i.e., targeting of heat pump ready consumers and supporting information to inform decisions. This is in conjunction with building local supply chain relations to ensure quality of delivery.

Initial findings from Phase 1 demonstrated strong community interest in the offer provided. The techno-economic assessment demonstrated clear cost advantages to consumers by taking up the solution if communities are to come off fossil fuels. The use of digital planning techniques ensured communities and homes were quickly identified that would not otherwise have been selected by the supply chain for deployment. That in conjunction with working with granular DNO data ensures deployment can happen quickly, accelerating deployment of low carbon technologies.

Challenges to be focussed on going forward are to develop an approach to property surveys that delivers the necessary building performance data required to optimise efficiency measured and heat system sizing in homes. There were also constraints on the granularity of DNO data and the use of EPC data in some areas which would be addressed through data agreements with the DNO and use of other tool sets as well as incorporating actual survey information.

2 Introduction

2.1 Heat Pump Ready (HPR) Programme

The Department for Business Energy and Industrial Strategy (BEIS) is running the Heat Pump Ready (HPR) programme. HPR is targeting innovative, coordinated methodologies for high-density heat pump deployment. By way of the HPR Programme, BEIS funded 11 feasibility studies – this being one of them. The Heat Pump Ready programme is run as a Small Business Research Initiative (SBRI) competition. Stream 1 of this programme – feasibility studies – focussed on solutions for high-density heat pump deployment in areas with majority 'able-to-pay', owner-occupied homes, with aims for an improved consumer journey, a cost reduction for consumers, and an opportunity to understand electricity network impacts.

2.2 Structure of this Report

This feasibility study, HPR Bridgend, is structured as follows:

- Section 1. **Executive Summary**. Overview of the report, key findings, and conclusions.
- Section 2. **Introduction.** Information about this HPR Bridgend feasibility study and description of the organisations which collaborated to produce this report.
- Section 3. **Aims, Expected Outcomes & Objectives**. The aims, expected outcomes and objectives of this HPR Bridgend feasibility study.
- Section 4. **Description of Work Packages**. Description of how the delivery of the feasibility study was structured, outlining the work packages, key activities, and deliverables.
- Section 6. **Methodology for Feasibility Study**. Description of how the work packages were carried out, including description of the analysis performed for the feasibility study.
- Section 6.5. **Findings from work packages**. Findings from the work packages.
- Section 7.6. **Recommended Methodology for Coordinating High-Density Heat Pump Deployment.** Key stakeholders proposed for the coordinated methodology, their roles and responsibilities, and interactions between stakeholders.
- Section 9. **Areas for Innovation**. Areas for innovation around customer engagement, installer engagement, energy planning and digital data platform, and electricity network considerations.
- Section 10. **Approach for Mobilisation Deployment following Recommended Methodology**. Number of heat pumps that could be deployed in Bridgend County using this approach, number of customers to engage, survey methods, quality assurance, installer engagement, DNO engagement, and challenges the methodology overcomes.
- Section11. **Costs to Consumers**. Costs to the consumer delivered through innovative coordinated high-density deployment.
- Section 12. **Long Term Sustainability**. How the business model presented in this feasibility study could be maintained beyond the life of a Heat Pump Ready project.

- Section 13. **Recommendations**. Summary of recommendations to stakeholders in other locations who may be looking to deploy heat pumps at high density.
- Section 14. **Conclusion**. Key point determined during the feasibility study indicating that the proposed approach to coordinated high-density deployment could be possible in Bridgend County.

2.3 Strategic Focus for Heat Pump Uptake – Space-Constrained Homes

The HPR Bridgend feasibility study integrates the process of Local Area Energy Planning (LAEP), community engagement, deployment of community heating options and involves strategically targeting communities for heat pump solutions.

In Bridgend County, there are many highly space-constrained properties, which have limited options in terms of low carbon technologies. Many terraced homes use the entire property including garden space for the home and extensions, allowing little to no outdoor space for ASHPs. A key example is the rows of terraced houses in the South Wales Valleys, although there are many similar communities around the UK. In fact, there are nearly 10 million terraced homes in the UK, of which a high proportion could have this problem. Choices available to consumers to decarbonise their household heating are limited in these highly space-constrained homes. In some cases, decarbonising heating would mean direct electric heating only, as ASHPs cannot be installed due to space and noise constraints.

For space-constrained properties, Ground Source Heat Pumps (GSHPs) with a Shared Ground Array (SGA) may be suitable. A Shared Ground array is a shared, closed ground-source loop with vertical boreholes.

Nevertheless, there are areas within Bridgend County that are also suitable for ASHP, and so both GSHP+SGA and ASHPs are included in this feasibility study.

2.4 Location - Bridgend County South Wales

The HPR Bridgend study area is Bridgend County, Wales. This study focused on areas highlighted in the Local Area Energy Plan (LAEP) as being suitable for the electrification of heat (Figure 2-1).

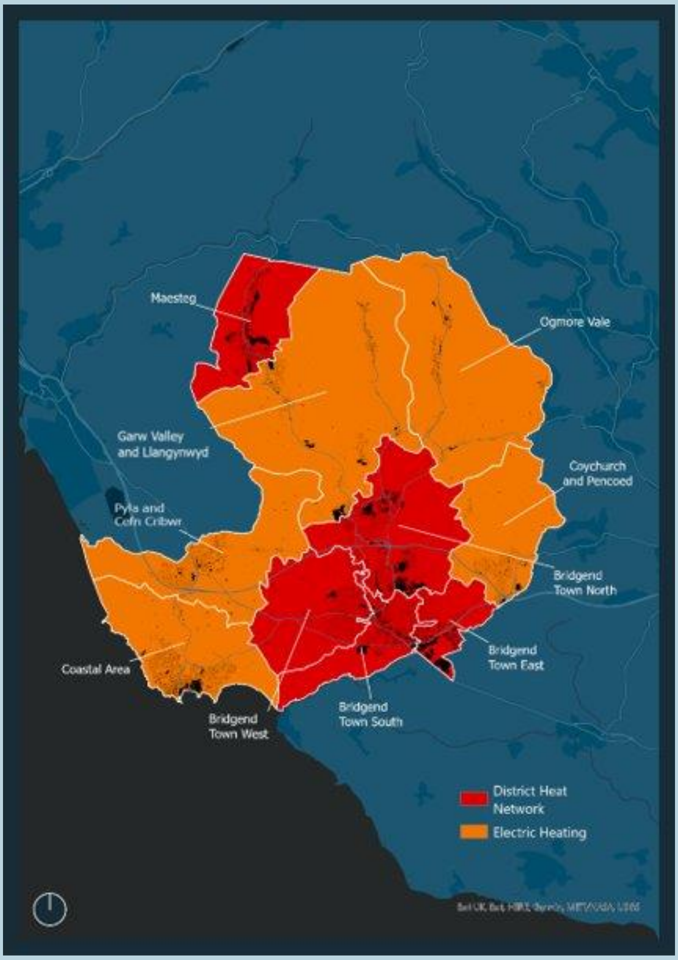


Figure 2-1 Bridgend LAEP[2] – Heating zones highlighted for electric heating

[2] BCBC LAEP. Bridgend County Borough Council, Local Area Energy Plan. August 2021

Areas where homes are identified as potentially suitable for heat pumps are in North Cornelly, Nottage, and Ogmore Vale. (Figure 2-2).

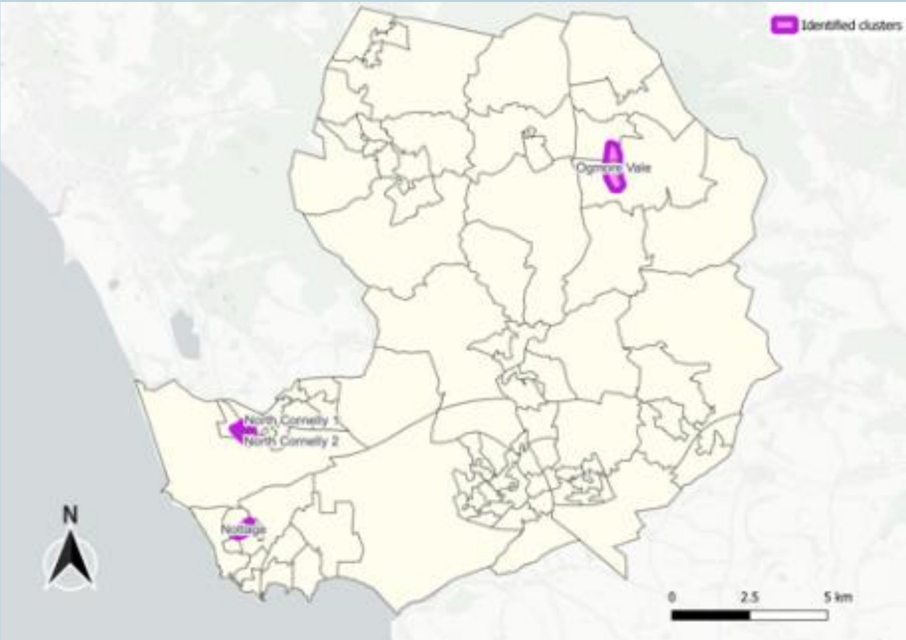


Figure 2-2 Study Areas – North Cornelly, Nottage, Ogmore Vale

2.5 Scale

This feasibility study targeted 150 homes for the deployment of heat pumps. Of the 150 homes, 126 were identified as suitable for GSHP + SGA, and 30 suitable for ASHP.

As part of the Stream 1, Phase 1 feasibility study application to BEIS, the team selected the following categories under which to apply for support from BEIS:

- **Local Definition**: BEIS Category 3, defined by BEIS as “Urban with Significant Rural”. This includes small towns and more rural areas, generally of 10,000 or fewer people in terms of population.
- **The High-Density Deployment Requirement**: Category A: At least 25% of the domestic buildings on at least one low-voltage network within the chosen Local Area Unit (LAU) Level 1 deployment locality.

Requirements of the HPR programme also include the following:

- **Private homes:** The focus on private residences, with a minimum of 70% heat pumps to non-social housing,
- **On-gas network:** A minimum 85% heat pump deployment to on-gas homes.

2.6 Organisations Involved in the HPR Bridgend Feasibility Study

A collaborative working group of organisations was organised to deliver the feasibility study. For ease of contracting arrangements, Buro Happold acted as the lead organisation, contracted by BEIS to deliver the work, and Kensa Consulting, Challoch Energy, and NuVision acted as subcontractors.

The HPR Bridgend team was selected to provide expertise in the following areas:

- **Digital spatial infrastructure planning.** Using the latest in digital planning techniques combing multiple data sets and spatial planning; Buro Happold screened whole areas of the region evaluating archetypes, DNO data and community data to target heat pump ready communities for targeting of community engagement. The same tool set can then be used to evaluate and undertake initial designs of heat systems as well as appraise opportunities for integration with renewables. The process involves building data mapping evaluation, collating information on building archetypes, energy performance, electricity grid capacity, and stakeholder interest in heat pumps. A visual interface is used to easily interpret the information and map areas by grading them on viability for heat pump ready deployment.
- **Heat pump technology and finance considerations.** Kensa Contracting is a specialist in GSHP + SGA solutions. Kensa has a working low-carbon heat offering with heat pumps and provided technical insights into optimising heat pump size to allow more units into clusters of houses that might otherwise be constrained in terms of network capacity. Within the Kensa Group, there is also Kensa Utilities, and members of this team provided input into the project. Kensa Utilities carries out home surveys for heat pump suitability, and designs and instals GSHP + SGA heating systems. Kensa Utilities also and has access to existing financial mechanisms GSHP + SGA. One of the benefits of including Kensa, a technology collaborator from the outset of the study, was that Kensa could advise on the financing mechanisms that already exist which could be considered for highly space-constrained properties where GSHP + SGA is a suitable low-carbon technology for heating.
- **Community Engagement**. NuVision has a track record of working in Bridgend in engagement – NuVision brings expertise in community, supply chain, and government engagement to promote customer uptake. NuVision led the customer engagement process as well as supply chain engagement and local government engagement.
- **Electricity network considerations**. Challoch Energy has strong experience working in Bridgend and brought in elements of Network constraint and opportunity considerations, working with the local district network operator, National Grid (NGED).

The study was crucially supported by Bridgend County Borough Council and National Grid (NGED).

3 Aims, Expected Outcomes & Objectives

HPR Bridgend aims, expected outcomes, and objectives are presented in this section of the report.

Aims

The aim of the HPR Bridgend study is to explore collaborative working methods for high-density heat pump deployment to homes, and to share recommendations.

Objectives

The HPR Bridgend feasibility study objectives are as follows:

- Identify and target heat pump ready communities which would benefit from community heat and integrated offerings for low carbon heat that will give them accessibility not otherwise available to them.
- Understand the community and build a strong interest in heat pumps by leveraging existing strong community focal points, engaging with organisations representing the diversity of residents in the area, demonstrating the benefits of home retrofit.
- Ensure households have a good experience – choosing a heat pump must be an attractive and viable solution for householders - they need to better understand their property, their system must be designed to a high quality, they must have easy access to support, and it must be a smooth process. The project could achieve this by understanding householder needs and using this as a basis for developing the offer.
- Provide a heat pump solution for space-constrained homes. For homes which are too space constrained for Air Source Heat Pumps, Ground Source Heat Pumps with Shared Ground Arrays can be considered. This feasibility study presents the GSHP and SGA approach as a real opportunity for these homes.
- Address barriers around affordability looking at innovative finance offerings to enable financially challenged communities to participate and transition without being stranded.
- Generate a cohort of skilled local installers by identifying those installers with a keen interest in quality heat pump design and making them ambassadors and using a variety of training methods.
- Minimising the impact of heat pumps on the electricity network through better heat pump sizing and flexible system design thus also accelerating deployment where otherwise it would not be possible.

Expected Outcomes

Expected outcomes of the study are:

- A developed and innovative methodology that tackles the challenges of decarbonising heat in communities in South Wales that would not otherwise be able to easily transition.
- Initial testing of engagement approaches with real communities to determine acceptance and potential for uptake.
- Supply chain engagement and support for deployable solutions under the new approach.
- Identification of real communities for targeting.
- Delivery of a feasibility study on high-density heat pumps for private homes in Bridgend County that summarises the methodology underpinned by a viable business model for deployment in subsequent stages.

4 Description of Work Packages

To produce the feasibility study, the following work packages were carried out:

- WP1. Energy planning and mapping – Buro Happold
- WP2. Customer heat package – Kensa Contracting
- WP3. Electricity Network – Challoch Energy
- WP4. Engagement – NuVision
- WP5. Project management and coordination – Buro Happold

4.1 WP1. Energy Planning and Mapping

Buro Happold led Work Package 1 on energy planning for identifying heat pump ready clusters. The key purpose of the work package was to develop an approach using the latest in digital planning techniques to select and target communities that would be heat pump ready. The process involves integrating and overlaying building data including building archetypes and their energy performance, in conjunction with electricity grid capacity, and stakeholder interest in heat pumps. Houses identified as suitable for heat pumps were located on single streets in groups (or as 'clusters') to achieve 25% or greater heat pump uptake on a Low Voltage feeder. The heat density calculation determines viability for shared heating and the level of interventions that may be required to make properties ready. Clusters were categorised for shared heating and separately for individual heat pump solutions depending on archetypes and density.

Work Package 1 is broken down into the following components:

- 1.1 Information collection and review was carried out to collect datasets for validation and manipulation, which formed the basis of mapping and visualisation work. The output of this work package was a Request for Information tracker, which listed the information requested and received.
- 1.2 Energy baseline appraisal involved the characterisation of the baseline case. The output of this work package was a technical note, presenting baseline case GIS maps. This baseline appraisal was a characterisation of the areas at the Lower Layer Super Output Area (LSOA) level, as part of an energy baseline appraisal.
- 1.3 Analysis involved the analysis of scenario modelling. The output of this work package was a note presenting screenshots of scenario case graphics and GIS maps. The analysis included detail at address level. It was carried out to Identify suitable clusters of homes on an LV feeder or street, for high-density HP deployment (25% or more homes on an LV feeder in a cluster.
- 1.4 Maps and Visualisations involved drawing the study information together in a set of visualisations, for the baseline case and the scenario case. The output of this work package was a technical note presenting screenshots and GIS maps.

4.2 WP2. Customer Heat Package

Work Package 2 is broken down into the following components:

- 2.1 Technology Suitability Assessment: To identify the suitable HP system for the high-density deployment of HPs for a given location, technology suitability assessment was planned. For the assessment a Weighted Decision Matrix analysis approach was adopted. This gave the basis to assign different technology to different area and different dwelling type.
- 2.2 Technology Optimisation: To address the biggest constraint to the deployment of heat pump systems in today's energy market as "customer affordability", various options to technology optimisation were reviewed. The study looked at how system size optimisation would influence to make the customer offer more attractive when compared to fossil fuel-based gas boiler heating system (which is unfair to compare though).
- 2.3 Business model (Techno-economic model): Techno-economic analysis were performed to estimate the Capital & Operational cost associated with the selected technology for a typical dwelling type and potential CO_2 emission reduction from selected technology. And based on the outcome of the whole life of the heat pump solution, a specific heat pump solution was recommended for different dwelling types.
- 2.4 Value added: The benefits of mass deployment from technical, commercial to consumer engagement were identified.

4.3 WP3. Electricity Network

Challoch undertook the work to fully understand the electricity network in the chosen area. Understanding of the network enabled us to identify the areas with spare capacity on the network which are then more suitable for heat pump installations, with minimum impact or need for reinforcement.

Work Package 3 is broken down into the following components:

- 3.1 Network Constraints: To identify network capacities across the region as well as the network infrastructure type. This fed into the technology assessment methodology with approach to constraints and enabled identification of individual substations and estimation of capacities.
- 3.2 Network Opportunities: Looked at DNO support for clusters and drew upon learnings from the local DNO (WPD) Equinox Project. It covered potential for increasing network capacity in the focus areas, reducing investment required for grid reinforcement leading to a reduced heat price as well as shared learnings from the WPD Policy Group on network connections, sizing and auditing as well as looking at transformer size increases.
- 3.3 Flexibility offering: Investigated the potential of using flexibility services to adjust supply and demand to achieve energy balance as well as flexibility in choosing electricity suppliers.
- 3.4 Innovative agreement: Identified innovative approaches to the evolving nature of the electricity consumption habits of consumers. Work covered the existing offers for specific heat pump tariffs from suppliers in addition to alternative market structures such as Local Energy Markets or clubs.

4.4 WP4. Engagement

Work Package 4 is broken down into the following components:

- 4.1 Intelligent survey was required as an efficient means of gaining insights into as many homes as possible in support of the rapid deployment of heat pumps in the area.
- 4.2 Community Engagement was essential to identify the best opportunities for the trial and to inform our decision making including our strategy for taking the trial forward.
- 4.3 Supply Chain Engagement was needed to establish the capacity of the supply chain to respond to the challenge of delivering the trial.
- 4.4 Government Engagement locally was required to help increase customer confidence in the project and to facilitate networking between key stakeholders such as the social housing sector and Further Education Colleges.
- 4.5 Capacity Building - Community was required to educate homeowners of the benefits of heat pumps and to help them make an informed decision in converting their home to this technology.
- 4.5 Capacity Building – Supply Chain was required to begin the journey of upskilling the heat pump workforce within South Wales.

4.5 WP5. Project Management and Coordination

Buro Happold carried out Work Package 5 on project management and coordination. The purpose of the work package was to provide a way for the groups to work collaboratively, towards the common goals of producing the feasibility study, and exploring ways of working to target high-density heat pump deployment for homes.

Work Package 5 is broken down into the following components:

- 5.1 Project management. As the project leader, Buro Happold worked with the overall group to agree the feasibility milestones and programme.
- 5.2 Advisory group. Bridgend County Borough Council, National Grid, and BEIS provided input into the project. This was initially envisaged as a group that would meet as an advisory group, and during the project, the advisory group members decided to participate by joining the weekly project calls with the project team, and to communicate by email and video conference (rather than separate calls).
- 5.3 Special Purpose Vehicle (SPV). The project team debated how to deliver a high-density heat pump project and agreed that a useful approach would be to form an SPV to carry out this role. A number of discussions were held regarding what form an SPV could take to allow high collaboration.
- 5.4 Draft Report and 5.5. Final Report. A feasibility study was produced as the final deliverable for the HPR Bridgend study.
- 5.6 Recommended innovative coordinated methodology for high-density heat pump deployment. The overall group decided to apply for Phase 2, to progress to heat pump deployment in the HPR Programme. However, the application was not one of those selected to progress.

- 5.7 Stream 3 Participation. As the lead organisation, Buro Happold participated in the knowledge sharing events in Stream 3. Information and lessons learned were shared back with the overall team.
- NZIP KPIs. Key performance indicators for the HPR Bridgend study were provided to BEIS at the beginning and end of the feasibility study.

5 WP2. Customer Heat Package

5.1 Work Package Description Summary

A summary table of the work packages with descriptions and outputs is presented in Table 5—1 . Please note that all deliverables or outputs are incorporated into the body of this feasibility report in the methodology (Section 6) and findings (Section 6.5) sections.

Table 5—1 HPR Bridgend Feasibility Study Work Packages

WP	Title	Description	Deliverables/Outputs
	Phase 1	**Feasibility. Project Lead: Buro Happold**	
	WP1	**Energy Planning and Mapping. Lead: Buro Happold**	
1.1	Information review and collation	Collection of all datasets for validation and manipulation to feed into the maps and visualisations Data collection and review of local information, not limited to: • Low Carbon Communities existing community group in Bridgend, organisation for implementation of Phase 2 trials • Local Area Energy Plan	Request for Information (RFI) tracker, listing information requested and information received
1.2	Energy baseline appraisal	Characterisation of the baseline case Assess the energy baseline in the focus areas in terms of: • Energy datasets • Demographics – affluence and fuel poverty • Building stock data – archetypes, fabric performance, heat demand, energy performance • Level of community engagement – existing involvement in Low Carbon Communities • Electricity grid capacity, information from NGED • Future grid infrastructure capacity, information from NGED • Opportunity to reduce network capacity, by avoiding oversizing heating equipment, and incorporating diversity in clusters of homes and heating systems • Renewable energy at homes • Future developments, information from Local Development Plans and planning applications	Baseline - Technical note, presenting screenshots of different baseline case graphics and GIS maps
1.3	Analysis	Analysis of scenario modelling Methodology to identify areas suited to heat pump installation, or other low-carbon technology: • Ready. Energy efficient homes with good insulation, ready now • Retrofit. Homes needing energy efficiency measures to reduce heat demand, ready soon • Other. Homes likely to require extensive retrofits, or which have too many constraints for this round, ready later	Scenario - Technical note, presenting screenshots of scenario case graphics and GIS maps
1.4	Maps and Visualisations	Visualisations to appraise community area, focus on HP suitability: • Maps identifying the three categories: Ready, retrofit, and other • Table summarising findings, allowing focus for Phase 2 trial on target areas	Report - Maps and visualisations with descriptions, for the baseline case and the scenario case

WP	Title	Description	Deliverables/Outputs
	WP2	**Customer Heat Package. Lead: Kensa**	
2.1	Technology Suitability Assessment	Methodology to identify most suitable heating system, given constraints • Multi Criteria Assessment of technology suitability on heat pumps and alternatives (e.g., ASHP, GSHP, clusters with shared loop, other) • Identify suitable heat systems, optimising for local grid availability for connections, including a distributed heat solution with individual heat pumps, community heat clusters using a shared loop and heat pumps, and other low carbon technologies where heat pumps are not suitable	Heat system suitability assessment methodology - Technical note
2.2	Technology Optimisation	Methodology to set technology approach making customer package financially feasible, optimising heat system size: • Identify opportunities to avoid oversizing of heating equipment, saving on capital costs, improving energy performance, reducing utility bills • Optimise capacity, size heat equipment for realistic loads	Technology optimisation - Technical note
2.3	Business model (Techno-economic model)	Business model to engage consumers • Make heat affordable by driving to a lower price for heat • Reduce heat tariff by working with an innovative supplier • Consider short and long-term costs to consumers • Integration of grants – government and other • Integration with retrofits	Techno-economic model - Technical note, presenting items considered in the TEM
2.4	Value added	Add value, from perspective of government • Less direct subsidy required as incentives for heat pumps, through energy efficiency measures and energy planning	Value added - Technical note
	WP3	**Electricity Network. Lead: Challoch**	
3.1	Network Constraints	Feed into technology assessment methodology, with approach to constraints • Network capacity • Network infrastructure type	Network constraints considerations - Technical note
3.2	Network Opportunities	DNO network support for clusters. • Potentially increase network capacity in focus areas • Reduce investment required in grid reinforcement, leading to reduced heat price • Shared learning from DNO Policy group on network connections, sizing, and auditing • Consider with DNO policy group: transformer sizes increasing from 0.5MVA to 1.5MVA	Network opportunities - Technical note
3.3	Flexibility offering	• Flexibility in choosing electricity supplier • Ability to adjust supply and demand to achieve energy balance - Draw on learning from DNO's Equinox project	Flexibility offering - Technical note
3.4	Market Structures	• Innovative supplier, dynamic tariffs • Consider Local Energy Market or Community Energy	Innovative agreement - Technical note
	WP4	**Engagement. Lead: NuVision Energy Wales**	
4.1	Intelligent survey	Develop methodology for intelligent survey to assess buildings for heat pump-readiness. Building categorisation methodology to link to tool for planning buildings • Building archetype and energy performance • Ownership • Existing use of renewables • Potential for on-site renewables (e.g., roof orientation) • Potential for retrofit upgrade to reduce heat demand • Potential for wet heating system upgrade	Intelligent survey - Technical note

WP	Title	Description	Deliverables/Outputs
4.2	Community Engagement	Community engagement through Low Carbon Communities • Focus groups to build knowledge of heat requirements Information and media to engage customers	Community Engagement - technical note. Includes material such as meeting minutes, communications to community
4.3	Supply Chain Engagement	Supply chain readiness, through Low Carbo Communities • Collate information on existing manufacturers, suppliers, installers • Material / pamphlet to engage supply chain Engage supply chain members	Supply chain engagement - technical note. Includes material such as communications to supply chain
4.4	Government Engagement	Engagement at UK, Wales, and Council levels, through Low Carbon Communities	Government engagement - technical note. Includes material such as communications to government contacts
4.5	Capacity Building - Community	Training and skills strengthening, link to Low Carbon Communities, for community members • Share case studies of early installations	Communication material on topics such as case studies from early heat pump installations
4.5	Capacity Building – Supply Chain	Training and skills strengthening, link to Low Carbon Communities, for supply chain members • Collate information on training available in BCBC, Voluntary quality standards, Voluntary customer heat guarantees • Gap assessment of skills and training • Signposting to existing training available • Forum for technical peer information sharing • Share case studies from the early pilots	Communication material to supply chain members
	WP5	**Management. Lead: Buro Happold**	
5.1	Project management	Coordination of work packages and programme • Project Leader with subcontracted partners (Buro Happold, Kensa, NuVision, Challoch)	Project progress – monthly slide deck .pdf (August, September, October, November)
5.2	Advisory group	Advisory group provides specialist input to the project • District Network Operator, National Grid (formerly Western Power Distribution) • Bridgend County Borough Council (BCBC) • BEIS	Description of communications held (these may be by calls, meetings, videoconferences, etc), topics addressed, points agreed and any actions.
5.3	Special Purpose Vehicle	Approach planned for a Special Purpose Vehicle to become a Legal Entity • Special Purpose Vehicle to deliver the project in Phase 2	SPV technical note
5.4	Draft Report	Draft for review	Draft report
5.5	Final Report	Deliver final feasibility study report	Final report
5.6	Recommended innovative coordinated methodology for high-density heat pump deployment	Application for Phase 2, for heat pump deployment	Application
5.7	Stream 3 Participation	Participate in Stream 3 dissemination and knowledge sharing events	Stream 3 meeting notes
	NZIP KPIs	NZIP KPI reporting at phase 1 project start, and at end of feasibility study	Complete reporting templates for the required collection stage for submission to the project Monitoring Officer

6 Methodology for Feasibility Study

6.1 WP1. Energy Planning and Mapping. Buro Happold

Heat Pump Ready (HPR) Bridgend study produced not only a proposed solution for high-density heat pump deployment but has developed a narrative behind how the solution was determined. It has captured innovative ways of working and collaboration, and documented the approach taken.

One of the components of the overall strategy is a planned approach to identifying clusters of homes for high-density heat pump deployment in areas characterised as urban with significant rural, and a visualisation of these areas. As part of this feasibility study, the visualisations are presented as maps.

6.1.1 WP1.1 Information Collection and Review

Work package 1.1, Information Collection and Review, was carried out to collect datasets for validation and manipulation, which formed the basis of mapping and visualisation work. The output of this work package was a Request for Information tracker, which listed the information requested and received.

Approach to data collection and review

A methodology was established, based on the data available (which was predominantly open access), to assess suitable areas within the Bridgend area for high-density heat pump deployment in domestic properties. Being based on open access data the approach is broadly replicable across England and Wales (Northern Ireland and Scotland have different data availability), without the need for data acquisition or extensive data sharing agreements to be put in place.

Error! Reference source not found. illustrates the overall process flow for the energy planning and mapping stage of the methodology, carried out by Buro Happold.

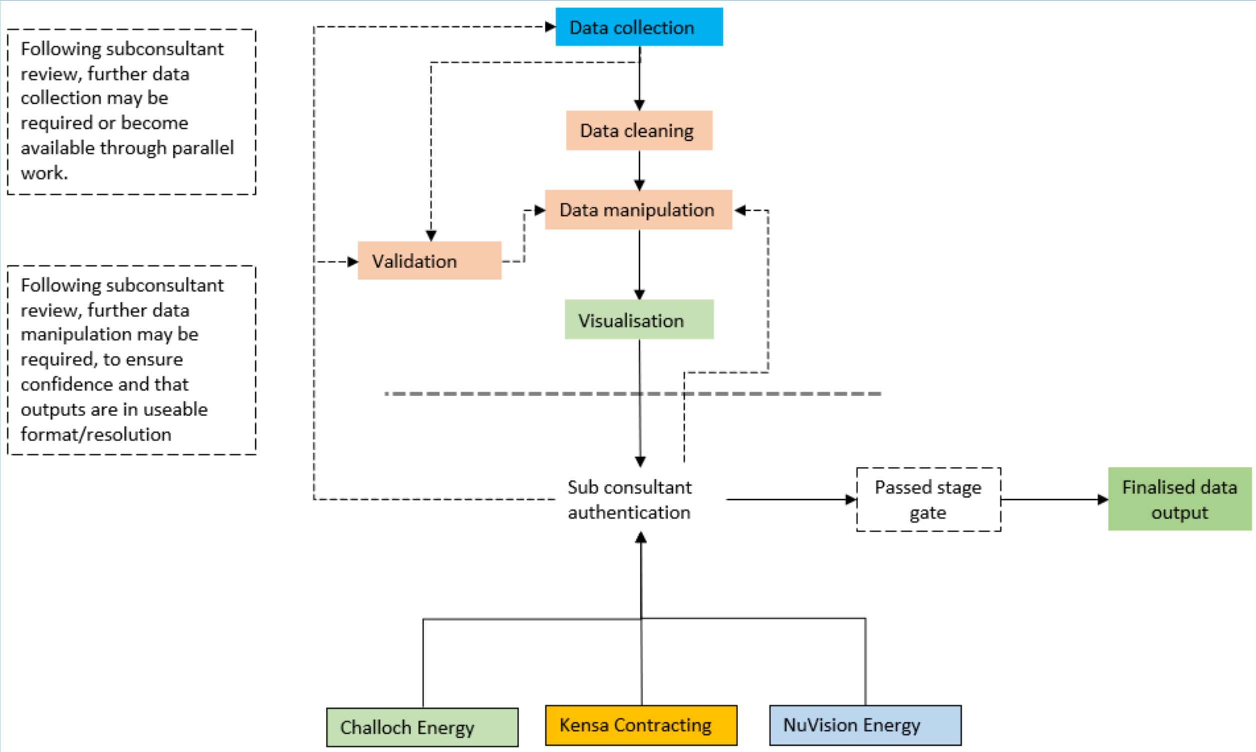


Figure 6-1 Energy planning and mapping workflow

Being based on open-source data, multiple sources were used, with some manipulation required to make the data fulfil the requirements of assessing heat pump readiness. An iterative approach to validation was undertaken to give confidence that the data manipulation wasn't creating inaccuracies in the data. Key validation techniques include aggregation of data to large areas which enables comparison to alternative dataset, and local insights from project partners.

As Figure 6-1 illustrates the manipulated data was visually represented and passed through a data validation stage gate where the other project sub consultants authenticated the data. If the data was not validated by the specialist subconsultants as being suitable for further analysis, it did not pass through this stage gate. Upon failing the data validation stage gate, other datasets were considered to improve the model or further manipulation was carried out. Finalised data outputs were carried forward for further analysis.

Data

Much of the data requested in the RFI process was not provided/ available. Therefore, open-source public data was used as an alternative. The data received and used for the project is displayed in Table 6—1.

Table 6—1 Breakdown of data sets received for this project

Data Theme	Data Set	Description	Source	Data Link (if applicable)
Building Characteristics	Unique Property Reference Number (UPRN)	Unique identifier for addressable locations. The UPRN is fundamental to data matching and data analysis	OS survey	https://www.ordnancesurvey.co.uk/business-government/products/open-uprn
	Local Area Energy Plan (LAEP) data	Bridgend County LAEP data – information transferred was very limited	Energy Saving Catapult (ESC)	Received from Bridgend County Council
	Energy Performance Certificate (EPC) data	Building Energy Performance Data, including SAP score, age band, primary fuel type	Department of Levelling Up, Housing & Communities website	https://epc.opendatacommunities.org/domestic/search
	BEIS experimental postcode gas data	Gas consumption data at the postcode level used for heat demand correction calculations	Department for Business, Energy & Industrial Strategy	https://www.gov.uk/government/statistics/postcode-level-gas-statistics-2020-experimental
	BEIS experimental postcode electrical data	Electricity consumption data at the postcode level used	Department for Business, Energy & Industrial Strategy	https://www.gov.uk/government/statistics/postcode-level-electricity-statistics-2020-experimental
Electricity Grid	Electricity grid data, substation level	Distribution network operator (DNO) information – substation sizes and location	National Grid (NGED)	Substation information file: https://connecteddata.nationalgrid.co.uk/dataset/distribution-substations Substation distribution polygons: https://connecteddata.nationalgrid.co.uk/dataset/spatial-datasets
	Electricity grid data, Low Voltage (LV) level layouts	Distribution network operator (DNO) information – LV feeder locations	Western Power Distribution	Received via Challoch Energy engaging with National Grid

Data Theme	Data Set	Description	Source	Data Link (if applicable)
Socio-economic	Electrical infrastructure and assets in the study area	Shapefiles representing the local area electrical structure down to the HV level	Western Power Distribution	https://www.nationalgrid.com/electricity-transmission/network-and-infrastructure/network-route-maps
	LSOA data	Various data sets aggregated to LSOA level provided by UK government website	UK Government	Various data sets available from various government departments: Gas consumption https://www.gov.uk/government/statistics/lower-and-middle-super-output-areas-gas-consumption Indices of deprivation https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019 Fuel poverty https://www.gov.uk/government/statistics/sub-regional-fuel-poverty-data-2021
	Index of deprivation (Overall, Housing, Income)	Index of deprivation data for Wales	Welsh Government	http://lle.gov.wales/catalogue?t=1&lang=en
Stakeholder Engagement	Intelligent survey	Surveys completed by customers, sharing information about their home to allow a better understanding of energy performance and opportunities and constraints for heat pump installation	Survey designed by Buro Happold and Stakeholder Contact by NuVision	N/A

Building Characteristics	**Unique Property Reference Number (UPRN)**	**Unique identifier for addressable locations. The UPRN is fundamental to data matching and data analysis**	**OS survey**	**https://www.ordnancesurvey.co.uk/business-government/products/open-uprn**
	Local Area Energy Plan (LAEP) data	Bridgend County LAEP data – information transferred was very limited	Energy Saving Catapult (ESC)	Received from Bridgend County Council
	Energy Performance Certificate (EPC) data	Building Energy Performance Data, including SAP score, age band, primary fuel type	Department of Levelling Up, Housing & Communities website	https://epc.opendatacommunities.org/domestic/search
	BEIS experimental postcode gas data	Gas consumption data at the postcode level used for heat demand correction calculations	Department for Business, Energy & Industrial Strategy	https://www.gov.uk/government/statistics/postcode-level-gas-statistics-2020-experimental
	BEIS experimental postcode electrical data	Electricity consumption data at the postcode level used	Department for Business, Energy & Industrial Strategy	https://www.gov.uk/government/statistics/postcode-level-electricity-statistics-2020-experimental
Electricity Grid	Electricity grid data, substation level	Distribution network operator (DNO) information – substation sizes and location	National Grid (NGED)	Substation information file: https://connecteddata.nationalgrid.co.uk/dataset/distribution-substations Substation distribution polygons: https://connecteddata.nationalgrid.co.uk/dataset/spatial-datasets
	Electricity grid data, Low Voltage (LV) level layouts	Distribution network operator (DNO) information – LV feeder locations	Western Power Distribution	Received via Challoch Energy engaging with National Grid
Socio-economic	Electrical infrastructure and assets in	Shapefiles representing the local area electrical	Western Power Distribution	https://www.nationalgrid.com/electricity-transmission/network-and-infrastructure/network-route-maps

	the study area	structure down to the HV level		
	LSOA data	Various data sets aggregated to LSOA level provided by UK government website	UK Government	Various data sets available from various government departments: Gas consumption https://www.gov.uk/government/statistics/lower-and-middle-super-output-areas-gas-consumption Indices of deprivation https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019 Fuel poverty https://www.gov.uk/government/statistics/sub-regional-fuel-poverty-data-2021
	Index of deprivation (Overall, Housing, Income)	Index of deprivation data for Wales	Welsh Government	http://lle.gov.wales/catalogue?t=1&lang=en
Stakeholder Engagement	Intelligent survey	Surveys completed by customers, sharing information about their home to allow a better understanding of energy performance and opportunities and constraints for heat pump installation	Survey designed by Buro Happold and Stakeholder Contact by NuVision	N/A

Data that was requested that was not received is detailed in Table 6—2.

Table 6—2 Data sets not received for project

Data Theme	Data set	Description	Source
Building Characteristics	OS Mastermap	Spatial data set displaying key information for the project such as property boundaries, roads and other key data.	OS / Bridgend County Borough Council
	OS Address Base Plus	Data set to link key properties	OS / Bridgend County Borough Council
	Domestic building characteristics from Bridgend LAEP	Domestic data set containing key information for housing stock e.g., energy demand	Energy Systems Catapult / Bridgend County Borough Council

Data Theme	Data set	Description	Source
		building fabric, heating technology etc.	
	Home Analytics data for relevant data zones	Domestic data set containing key information for housing stock e.g., energy demand building fabric, heating technology etc.	Energy Saving Trust
Land	Local Authority Land Ownership	Used to assess council owned land for shared loop GSHP Borehole drilling.	Bridgend County Borough Council
Electricity Grid / DNO	Information about which properties within the area are connected to which LV feeders and service cables. Electrical capacity of LV feeders	Information regarding the number of homes connected to each LV feeder. Used to assess available capacity and link the Home Analytics data to respective feeder.	Wester Power Distribution / National Grid

The DNO data although absent did have spatial information which could be used as a proxy. This included CAD layouts of LV conductors, although these did not include a direct count or capacity of connected properties spatial analysis could enable some insight to be gained regarding number of connections. The complexities of electricity network layout could result in some errors from this proxy method. These issues were compounded by projection issues with the CAD data, meaning it did not precisely align with streets and properties. However, the focus on a secondary substation level for the majority of the analysis helps to mitigate the impact of these.

At the project inception it was inferred that data from the LAEP carried out by Energy Systems Catapult would be made available to assist with the analysis. Whilst some data was made available, early on in the project timeframe, it did not relate to the property-level information, which is integral to the analysis. As an alternative the use of Home Analytics was considered, however, it was confirmed that data procurement could not be undertaken at this stage unless specified at inception. In either case both the LAEP outputs and Home Analytics would require an OS data sharing agreement to be in place, as they both rely on Master Map and Address Base Plus.

Despite multiple requests to Bridgend Council an OS contractor licence was not put in place. This is likely somewhat due to the nature of the contract, which was not with Bridgend Council, meaning granting a data sharing agreement can be complex. In any case the lack of these data was disappointing, as it is a request Buro Happold have made on numerous occasions for similar mapping activities in local authorities across the UK and not encountered this issue. The lack of this OS data not only limits the access to more detailed models but also Buro Happold's in-house stock modelling. The OS data highlighted in Table 6—2 are key for identifying domestic property typology, its absence and reliance on open access information impacts the precision and confidence in the stock model which was used for this analysis. However, it does mean an approach was created that can be used across England and Wales using only open access data.

In the absence of LAEP and Home Analytics property data EPC information was relied upon for detailed building stock information. It is important to note EPC data coverage is not complete and requires interpolation to infill the missing data. Relying on open access OS data for this infilling process meant it could only be based on very few parameters, this reduces accuracy at the individual building level and can create issues with data capture. However, these issues were somewhat mitigated through use of the BEIS experimental gas and electricity postcode data. This meant at a cluster level that confidence was relatively high, as the BEIS information could be used to validate and adjust the stock model as required.

Building Characteristics

Data collected from open data sources related to building characteristics and energy performance enabled the dominant building archetypes for each LSOA area in Bridgend County to be established, as part of WP1.2, Energy Baseline Appraisal. This process was carried out for key building parameters such as, construction age band, built form, primary fuel type and energy efficiency (based on EPC rating). In addition, socioeconomic factors at LSOA level were also considered, for example, levels of housing and income deprivation. This data was obtained readily from Government data sets as outlined in Table 6—2 . This added further context to the wider Bridgend area. This analysis aligned with the outputs of the LAEP, justifying the selection of the four towns. The process also generated a detailed building level dataset for use in the following stage of the HPR analysis.

Energy Performance Certificate (EPC) data for Bridgend was downloaded from the Department of Levelling Up, Housing & Communities website[3]. This data was cleaned and manipulated to establish key characteristics for domestic properties within the area. These characteristics were extracted from the raw EPC data and extrapolated and then aggregated to Lower Layer Super Output Area (LSOA) level. The extrapolation was required as not all domestic buildings have an EPC. It is important to note that certain information is reported nationally at LSOA level. This includes number of houses, which was key for extrapolation, and energy consumption – which helped informed the validation process.

The EPC data required extensive cleaning to remove duplicated and incomplete or invalid data. Key information such as address, postcode, EPC rating, EPC score, primary energy consumption (kWh/m^2), total floor area (m^2), built form, property type, construction age band, main fuel type and main heating technology was extracted. It is important to note some of this information is related to building location as well as technical elements.

[3] https://epc.opendatacommunities.org/

Electricity Grid

High-density heat pump deployment can add strain to the electrical infrastructure in the immediate vicinity as well as upstream assets. An assessment of the electrical infrastructure was carried out for the four identified towns. Secondary substation (11kV to LV) data was obtained from the Distribution Network Operator (DNO). This data included the max electrical demand on the substation and its total capacity, enabling an estimation of headroom. The secondary substation data was readily compatible with GIS, enabling them to be mapped with a relatively high degree of precision. GIS shapefiles of polygons that represented the area coverage of different secondary substations was also provided by the DNO, however, concerns were raised over the level of accuracy these provide for assigning different domestic properties to individual substations. Greater engagement with the DNO would be required to break down the secondary substation data to greater detail and validate the assignment of properties to specific secondary substations.

The DNO in collaboration with Challoch Energy was also able to provide low voltage (LV) feeder layout CAD files for the identified towns. This was utilised as a visual check regarding which properties were linked to which secondary substation. Although the LV feeder layouts were transferable into GIS (Figure 6-2), the transfer process meant that the layouts were not as accurate as possible.

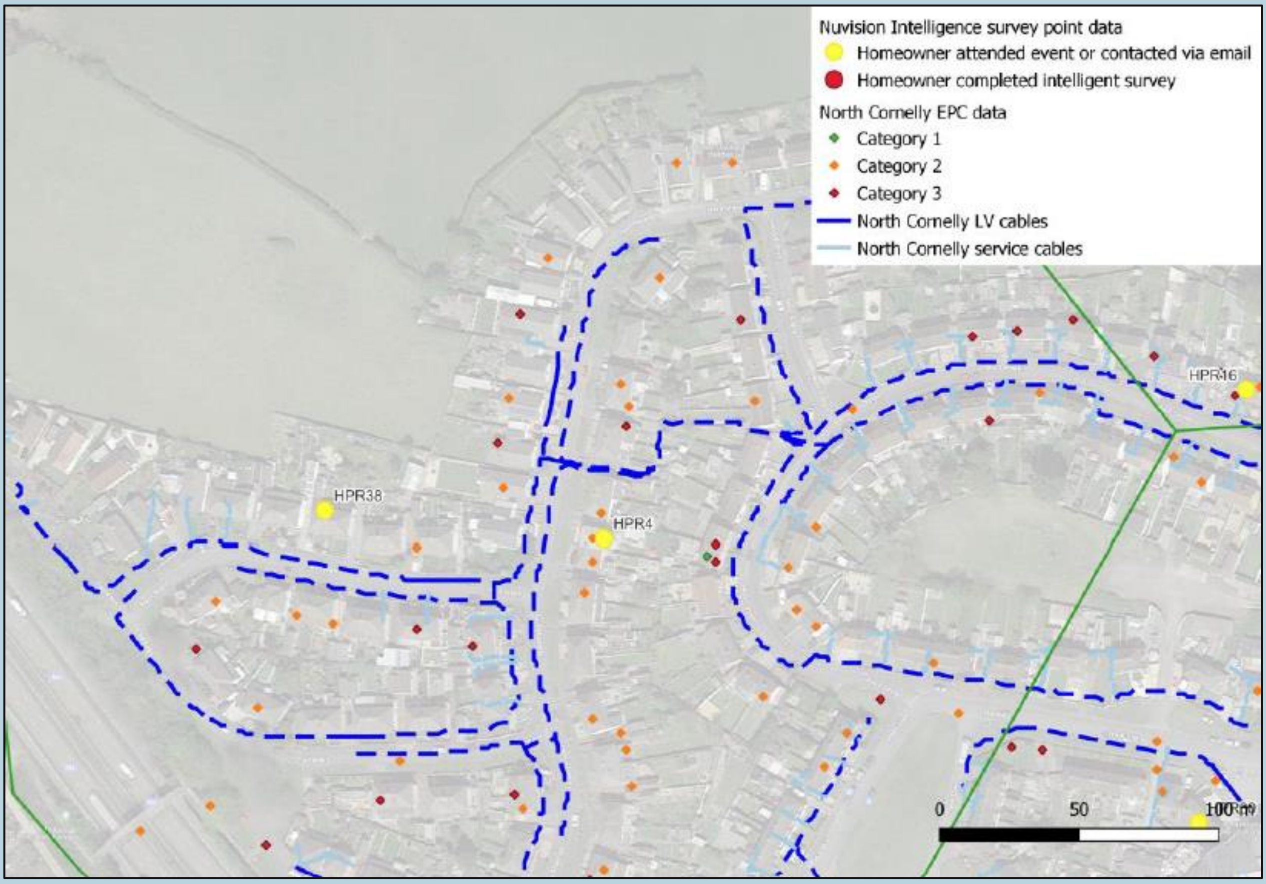


Figure 6-2 Example of LV feeder layout in North Cornelly

Socioeconomics

A high-level analysis of the broader socioeconomic context was carried out on the wider Bridgend area, using LSOA and MSOA data sets outlined in Table 6—1. This included identification of relative levels of fuel poverty and broader levels of deprivation. The method used was a quantitative analysis of these factors for the areas that the different potential clusters fall within. To aid this, the data was integrated into GIS, enabling spatial comparisons of the quantified factors (see section 7.1.2 for outputs).

This was to add context to the four towns identified for this study. Population density and demographic information was used to gain an understanding of the socioeconomic characteristics within this area. Population density, housing deprivation and income deprivation indices data was available from the appropriate government data bases.

Stakeholder Engagement

Local community engagement was a key innovative step in this project. Buro Happold assisted in constructing an 'intelligent survey' to gauge community interest in the heat pump installation. NuVision were able to use this survey to establish interest and provide key insights into building stock and occupancy behaviour within the area. This fed into the cluster identification process, alongside the wider socioeconomic analysis.

6.1.2 WP1.2 Energy Baseline Appraisal (Characterisation Maps)

Work Package 1.2, Energy Baseline Appraisal, involved the characterisation of the baseline case. The output of this work package was a technical note, presenting baseline case GIS maps.

The appraisal process involved the creation of characterisation maps of Bridgend County to allow the user(s) to explore areas that may be viable for heat pump deployment and appraise ease of deployment in that locality, at the Lower Layer Super Output (LSOA) level. The area characterisation maps were created using the readily available government LSOA data sets (Table 6—1). As mentioned, the EPC data was manipulated and aggregated to LSOA level. This was used for the creation of the area characterisation maps.

The area characterisation maps from this feasibility study presented the following metrics:

- Gas map – areas on the gas network
- Population density – number of people per square kilometre
- Demographic information – housing deprivation index, income deprivation index
- Dwelling type by concentration – semidetached, detached, terraced homes, flats
- Building energy efficiency – average energy performance score (SAP)
- Heating type by concentration – natural gas boilers, heat pumps, LPG, oil, electric, coal, communal and biomass systems
- Property age – Pre 1930s, 1930-1975, 1976-1995, 1996-present
- DNO network capacity – electricity forecasted consumption, substation headroom

The described maps are displayed in section 7.1.2. The characterisation maps developed for this project, and the raw numbers behind them, complement the insights from Bridgend County's LAEP. An example of the LAEP outputs these were compared to is provided in Figure 6-3.

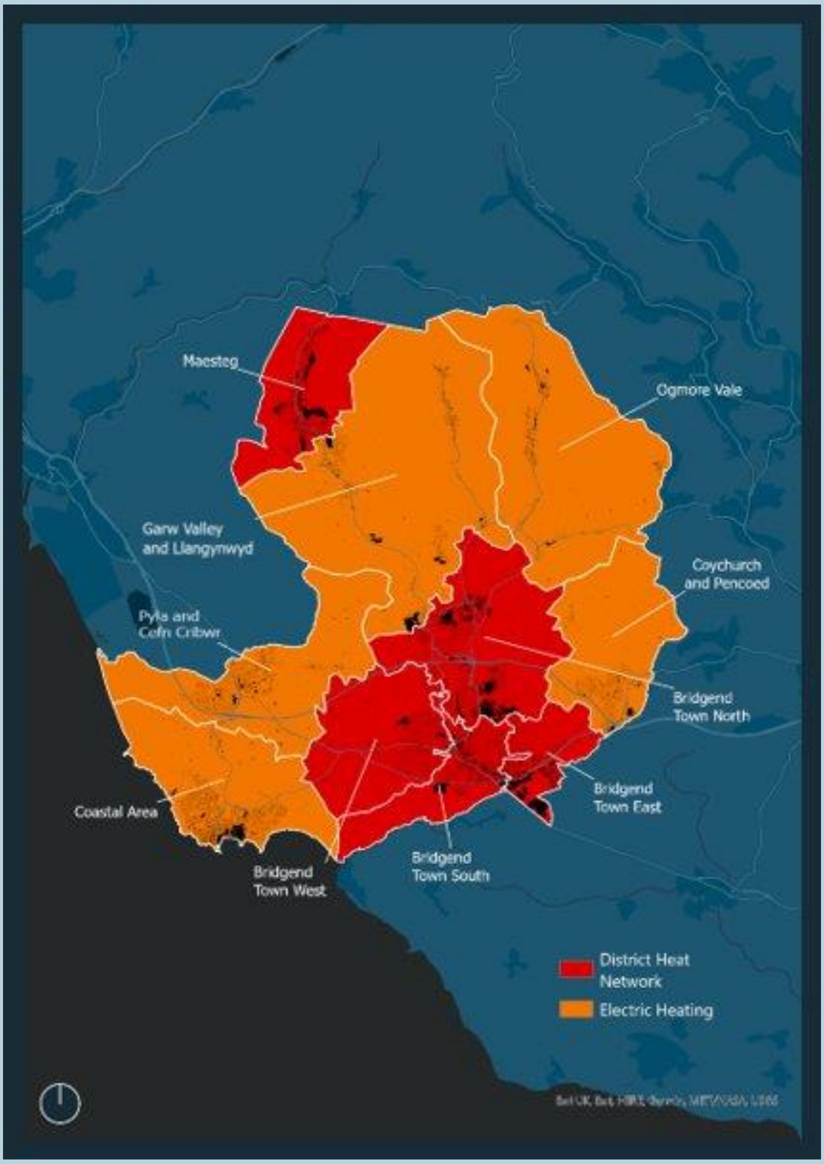


Figure 6-3 Bridgend LAEP[4] – Heating zones, without hydrogen

The focus of the analysis in this study is based around the electric heating areas identified in Figure 6-3.

[4] BCBC LAEP. Bridgend County Borough Council, Local Area Energy Plan. August 2021

6.1.3 WP1.3 Analysis

Work Package 1.3, Analysis, involved the analysis of scenario modelling. The output of this work package was a note presenting screenshots of scenario case graphics and GIS maps. These graphics are displayed in the findings section 6.1.4.

Following the characterisation of Bridgend County, the focus areas were considered to identify suitable clusters of homes for high-density deployment of heat pumps.

The Bridgend Local Area Energy Action Plan (LAEP) identified areas for electrification of heating: Coastal Area, Ogmore Vale as priority areas, followed by Pyla and Cefn Cribwr.

For this feasibility study, focus areas were identified which built on the LAEP areas for electrification, as well as the BEIS criteria – defined at the outset of the project. These are listed in Table 6—3, the focus areas are the towns within the wider LAEP defined areas.

Table 6—3 Focused study areas

LAEP defined areas	Towns/settlements
Coastal Area	Nottage, Porthcawl - Newton and Danygraig
Ogmore Vale	Ogmore Vale
North Cornelly	North Cornelly

These settlements fulfilled BEIS criteria, defined at the start of the project. Other settlements were screened out by a filtering approach aligning to the BEIS requirements. This approach considered the following parameters:

- Urban with significant Rural. Below 10,000 persons, including the fringes of large settlements (small town)
- On-gas network. Minimum 85% HP deployment to on-gas homes
- Property tenure. Private owned. Minimum of 70% heat pumps to non-social housing
- Network capacity (must be sufficient headroom for operations)

Non-gas properties were filtered out from further analysis in line with the project guidance provided by BEIS. Public owned domestic properties were also removed to maximise uptake in private tenure properties, which was another key KPI. The purpose of the extracted EPC data was to enable a categorisation of the identified properties in the study areas. The categorisation criteria are displayed in Table 6—2. This categorisation of properties would be taken forward into Table 6—4.

Table 6—4 EPC data categorisation criteria

Categorisation	Heating system	EPC score	Wall insulation general description	Roof insulation general description	Floor insulation general description	Glazing type general description
Category 1 – Heat pump ready	Wet heating system (Heat emitters may need upgrading due to changes in flow temperatures)	A-B	Cavity wall – general insulation	Loft insulation in place	Solid floor- general insulation	Double glazing
Category 2 – Light retrofit requirement	Wet heating system (Heat emitters may need upgrading due to changes in flow temperatures)	C-D	Cavity wall, sandstone or limestone – filled insulation	Loft insulation in place	Solid floor - no insulation	Double glazing
Category 3 – Deep retrofit	Wet heating system (Heat emitters may need upgrading due to changes in flow temperatures)	EPC score less than D	Various wall types- partial / no insulation	No roof insulation	Solid floor - no insulation	Double glazing

The categorised properties were added to a GIS model for further spatial analysis with Unique Property Reference Number (UPRN) data points serving as a visual check that the correct EPC data points were assigned the correct locations.

The headroom for each secondary substation was mapped to the appropriate distribution polygons. This methodology enabled a high-level electrical capacity analysis to be carried out. locations with large headroom were established, with these locations being suitable for cluster identification. The distribution polygons allowed spatial zoning and filtering of the EPC data until suitable cluster boundaries had been identified. Examples of this are provided in section 7.1.2.

A key component of sizing the heat pump technologies was establishing a representative peak space heat demand (kW) per home. A benchmarking methodology was applied using an industry standard BSRIA rule of thumb[5] benchmark (60W/m^2) which was corrected using BSRIA annual demand benchmarks (18MWh/home) and median BEIS experimental gas postcode data. The median experimental data reflected both weather corrections, occupancy behaviour and building fabric performance. This ensured the benchmarked peak demands were representative of the individual housing stock. The BEIS experimental data was also used to form representative annual demands (MWh/year) for each property.

Innovative collaboration between stakeholders enabled an in-depth analysis of the reviewed data sets. NuVision were able to identify postcodes with high levels of community engagement. A spatial analysis was carried out using a combination of the NuVision data and the secondary substation headroom data. This process identified suitable secondary substations that would outline potential clusters. Figure 6-4 displays this process. It should be noted some homes did not meet the criteria of being rural urban (populations over 10,000) and therefore were not taken forward for cluster identification.

[5] BSRIA, Rules of Thumb, Guidelines for building services, 5th ed., 2011.

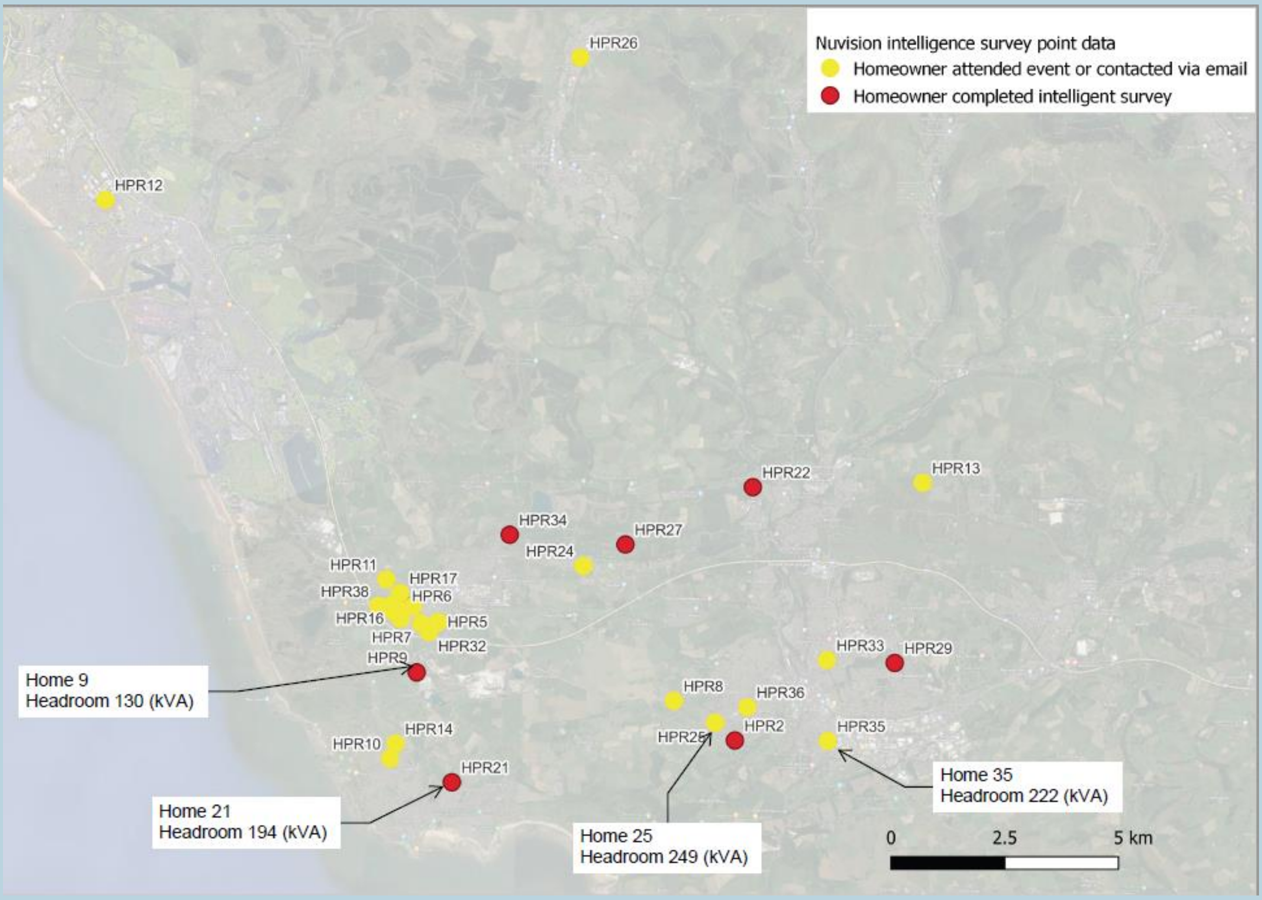


Figure 6-4 NuVision community engagement results with headroom

Based on community engagement and technical factors (available headroom) four clusters were identified across North Cornelly (North Cornelly 1 and 2), Nottage and Ogmore Vale (Figure 6-5). Some properties within the clusters were located in areas that appeared to have little or no headroom available at the secondary substation. However, discussions with Challoch Energy and other key stakeholders identified it would still be possible to install heat pumps in these areas if more detailed electrical infrastructure data was available at phase 2. Red-Amber-Green (RAG) Colour coding is used on the maps for households, with “Green” being heat pump ready, “Amber” requiring light energy efficiency retrofit and “Red” deep retrofit.

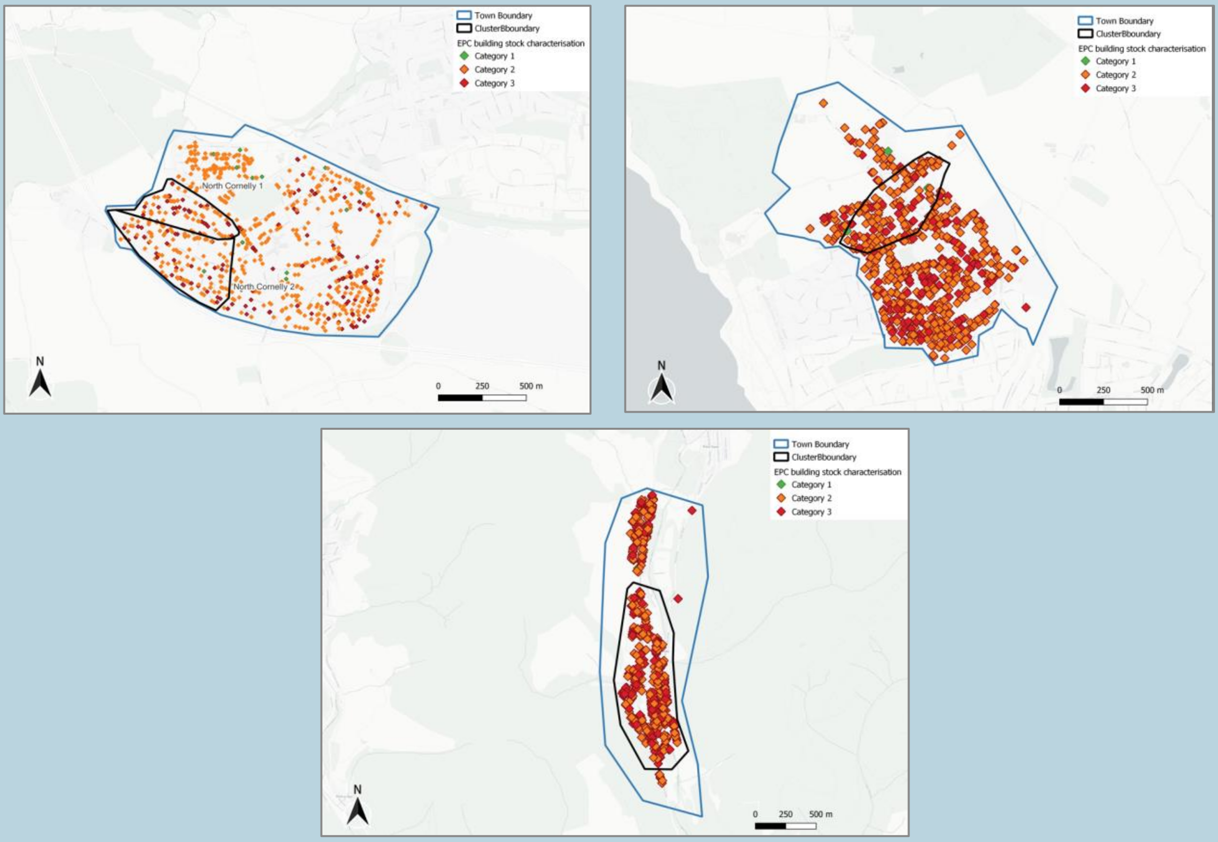


Figure 6-5 Identified clusters

Following the cluster identification, an interpolation process was used to gauge how many properties that met the study criteria were not captured within the EPC data set. This process was used scale the data to the capture the missing dwellings with the correct typologies. This interpolated data set was used to assign each property to one of twelve archetypes assigned by BEIS (Table 6—5).

Table 6—5 Archetype categories

Small flat	Ground-floor flat	Mid-floor flat	Top-floor flat	Bungalow	Mid terrace with cavity walls	Mid terrace with solid walls	Compact semi detached	End terrace with cavity walls	Semi-detached with solid walls	Detached with cavity walls	Detached with solid walls

Collaboration with Kensa Contracting was a key component of the archetype analysis methodology. As a result of the spatial analysis carried out by Buro Happold, Kensa were able to assess the distribution of archetypes within each cluster. North Cornelly 1 had a narrow distribution of archetypes as did Ogmore Vale, which were compact semi-detached and terraced homes. This indicated potential for a shared loop ground array system due to the dense nature of the housing stock. Although Nottage and North Cornelly 2 did not display a similar trend there was still potential for an ASHP or shared loop system. Annual heating demands were calculated for each cluster. From this analysis the bulk archetype in each cluster was targeted due to strong commonality indicating that similar retrofit packages could be used. This data directly fed into section 6.2.

6.1.4 WP1.4 Maps and Visualisations

Work Package 1.4, Maps and Visualisations, involved drawing the study information together in a set of visualisations, for the baseline case and the scenario case. The output of this work package was a technical note presenting screenshots and GIS maps.

Maps displaying key results from the spatial analysis were produced using GIS software. Results from the EPC building stock analysis and the electrical capacity assessment were visual represented through this method. This method in particular was key for assessing which areas had headroom available at the secondary substation. Additionally, the clusters were able to be emphasised and distinguished from the rest of the study towns, for example North Cornelly which contained two clusters within one site.

GIS maps were used for the analysis of the building stock and archetypes. This allowed correlations and trends between the data sets to be established.

6.2 WP2. Customer Heat Package

The methodology behind the development of customer offer for a typical dwelling type in the area is discussed below. Work package 2 focused on developing a methodology to refine the customer heat package for the three different kinds of heat pump system, namely ASHP, GSHP and Shared Ground Array (SGA) heat pump solutions based on the current available funding and business models.

6.2.1 WP2.1 Technology Suitability Assessment

Technologies Considered

The heat pump technologies considered for suitability, for the study area in Bridgend County, included:

- Ground Source Heat Pump (GSHP, stand-alone)
- Ground Source Heat Pump and Shared Ground Array (GSHP+SGA)
- Air Source Heat Pump (ASHP)
- Direct electric heating

Technology Suitability Considerations

To identify the suitable heat pump system for the high-density deployment of heat pumps for a given location, a Weighted Decision Matrix analysis approach has been adopted. In this decision matrix approach, the key parameters influencing the high-density deployment has been categorised into four subcategories: Technical Parameters, Deliverability Parameters, Index of Multiple Deprivation parameters, and Natural features parameters of a region (Table 6—6).

- **Technical Parameter categories** included network capacity, heat pump capacity, and heating system efficiency. These were given the highest weighting in the decision matrix analysis as for mass deployment of heat pumps. The availability of grid capacity to allow the heat pump connection is key to allowing high-density heat pump deployment. The capacity required for the heat pump deployment is, in turn, related to the total heat pump capacity and efficiency.
- **Index of Multiple Deprivation parameters** were of second highest weightage and data were reviewed to target the early adopters in the community. The analysis of Index of Multiple Deprivation took the approach to keep the fuel bill lower or neutral i.e., heat pump fuel bill for a dwelling either lower or at least remains the same as heating the house using gas as a heating fuel.
- **Deliverability Parameters category** included the dataset that could affect the delivery of mass deployment of heat pumps in the area due to skill shortage or local supply chain issues to deliver the deployment of heat pumps. Skill shortage and local supply chain issues can make the deployment a) uneconomic b) logistically or technically troublesome or c) impose unacceptable impacts on the house owner or tenants or others. These deliverability parameters can be improved by providing local training and skills strengthening for supply chain members and bringing the regulatory changes to planning policies and so third highest weightage has been assigned to this category in the decision matrix analysis.
- **Natural features parameters of a region** were also taken into the consideration in the selection of most suitable heating system for a given location. The reason for this is that any heat pump extracts heat from the outdoor environment, and its long-term performance and associated maintenance cost is also driven by the natural features of the region. For example, ASHP performance and its maintenance is very much dependent on the outdoor air temperature and also on the natural features of the area like distance from the coast. Any property within 4 miles of the coast[6] is particularly vulnerable to corrosion from the salty air. Similarly, GSHP system performance is dependent on geological conditions[7] influencing the thermal conductivity of soil/ground, potential of artesian water and its long-term performance capacity. However, parameters relating to local geography and geology were given the least weighting in our decision matrix analysis as different type of heat pump system design, equipment choice and other remedial measures can be implemented to mitigate these impacts.

[6] https://www.thegreenage.co.uk/can-i-get-an-air-source-heat-pump-if-i-live-on-the-coast/
[7] https:// www.sciencedirect.com/science/article/pii/S0375650519301944

Table 6—6 Heat Pump Suitability Assessment Parameters

Parameters to consider	Technical/ Deliverability Criteria	Rank for mass deployment of HP
	Technical Parameters	
Grid capacity	Available Headroom in the electricity substation, Practical barriers to electricity network	9
Running cost	COP of the system during winter	8
HP cost	Size of HP	7
Index of Multiple Deprivation parameters		
Consumer Type	Type and age of building, Ownership of building, Education, Employment, Income	6
Expansion potential	Proximity to other low carbon project, Proximity to grid reinforcement location	5
	Deliverability Parameters	
Internal works	Disruption to homeowners	4
Energy efficiency level	Extent of refurbishment and timescale of proposed refurbishment/development	3
Planning policies	Land ownership restraints for the drilling of boreholes & External space requirement for ASHP	2
Natural features parameters of a region		
Weather/region	Climatic condition/Geological ground condition	1

6.2.2 WP2.2 Technology Optimisation

The feasibility study considered the impact of light fabric measures (combination on airtightness, loft insulation and cavity wall insulation where applicable and a better heating control system which includes programmer, room thermostat, and TRV) on reducing the required heating system capacity. Fabric measures for the dwelling type were selected based on the BEIS Cost Optimal Domestic Electrification (CODE)[8] Report.

Size of the heat pump mainly depends on the heat loss coefficient (HLP, W/K/m^2) of a dwelling. Heat loss coefficient indicates 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. Therefore, the better the insulation level of building fabrics (Wall, Floor, Roof, and Windows), the lower the heat loss coefficient and thus, the smaller size of heat pump is required.

The light fabric measures provided to install lower capacity heat pumps, helps reduce the cost of the heat pump 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 GSHP system to ~ £5,500 for a 6kW GSHP system for a mid-terraced properties (Figure 6-6).

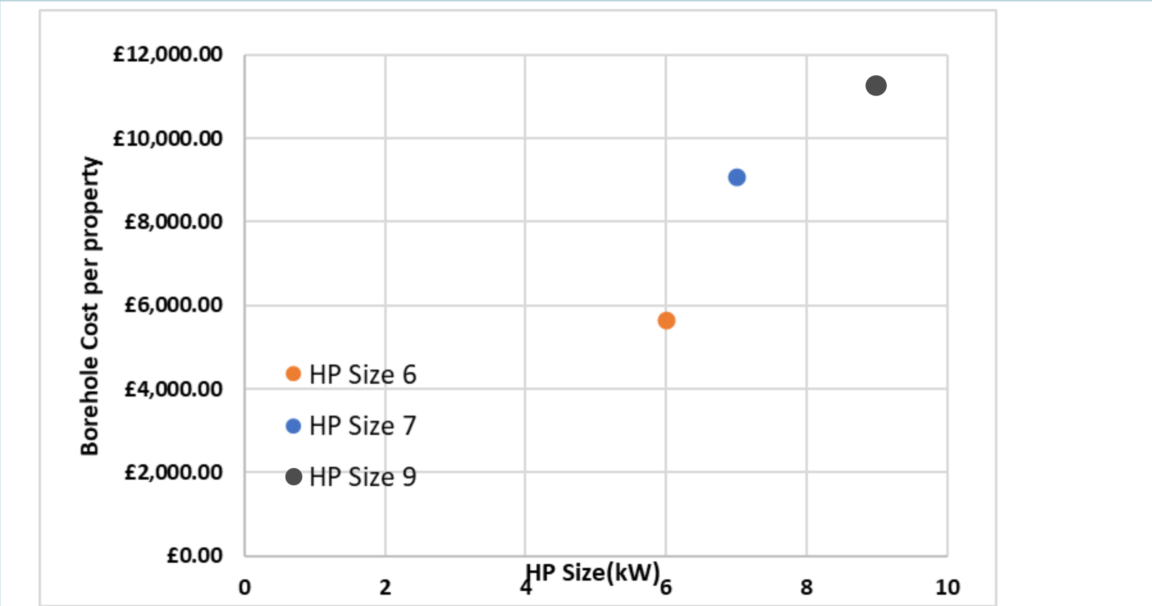


Figure 6-6 Change in borehole cost per property with change in HP size

[8] BEIS, CODE. Cost Optimal Domestic Electrification. BEIS, 2021. URL: Cost Optimal Domestic Electrification (CODE) - GOV.UK (www.gov.uk) Accessed 30/11/2022

6.2.3 WP2.3 Business Model (Techno-economic model)

A Techno-economic analysis was performed from the end user prospective. The model looked at the Capital & Operational cost associated with the three heat pump technologies (ASHP, GSHP, and GSHP+SGA) in the chosen location for the heat pump deployment, including potential CO_2 emission reduction.

The heat pump technologies considered for suitability, for the study area in Bridgend County, included:

- Ground Source Heat Pump (GSHP, stand-alone)
- Ground Source Heat Pump and Shared Ground Array (GSHP+SGA)
- Air Source Heat Pump (ASHP)
- Gas-fired boiler

Business Model Descriptions

For a shared ground array solution, "split ownership/street by street business model" approach was taken. This gives the opportunities 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 connected up to the shared ground array.
2. The customer/end-user for the heat pump and the internal distribution system from the dwelling up until the outer wall of the dwelling.

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

In return, the heat infrastructure provider charges a monthly standing charge to each property to access the shared ground array for their heat supply. The standing charge is paid monthly by each end-user, which covers all the ambient heat supplied and all 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 provider to alter the standing charge.

An approach to install shared ground arrays financed as a new utility, similar to the gas or water networks, helps to both reduce the biggest barrier in terms of required upfront capital cost from the end user and to deploy heat pumps at high-density. This model is tried and tested. It is being implemented by a number of organisations in the energy sector (e.g., Kensa Utilities Ltd[9], Scottish Power, Rendesco[10]).

[9] https://www.kensautilities.com/
[10] https://rendesco.com/grants-funding/ambient-heat-network/

Techno-Economic Analysis Methodology

Whole life cost analysis for all three heat pump systems were estimated for three typical dwellings in the Bridgend area.

- Solid wall mid-terraced houses with floor area less than 100m^2
- Cavity wall semi-detached houses with floor area less than 100m^2
- Cavity wall semi-detached houses with floor area greater than 100m^2

For details on the techno-economic analysis, see Appendix A.5: Lifetime Cost to Consumer for reference. Based on the outcomes of the techno-economic analysis, solutions for the selected area were chosen.

The model considers the effect on the "capital upfront cost to consumer" that is possible due to BEIS Grant funding and "Split ownership finance mechanics" that is available from Kensa Utilities Ltd under the Shared Ground Array Heat Pump system.

Solid wall mid-terraced houses with floor area less than 100m^2

Solid wall terraced houses are the predominant archetype in Ogmore Vale area. Due to due the high density of houses in the locality, ASHP and GSHP solution were not feasible to get installed, however due to split ownership model, the GSHP + SGA solution was feasible for mid-terraced houses. The reduced heat loss coefficient after the insulation measures in such dwellings and opportunity to design the system with diversity factor due to the scale of network, means the cost of a shared ground array reduces per property and overall the *Shared Ground Array Heat pump system makes the most cost-effective heating solution* for end user to decarbonise solid wall mid-terraced houses. This allows ground-source heating to be delivered in areas where alternatives such as air source heat pumps are not viable (due to outside space restrictions).

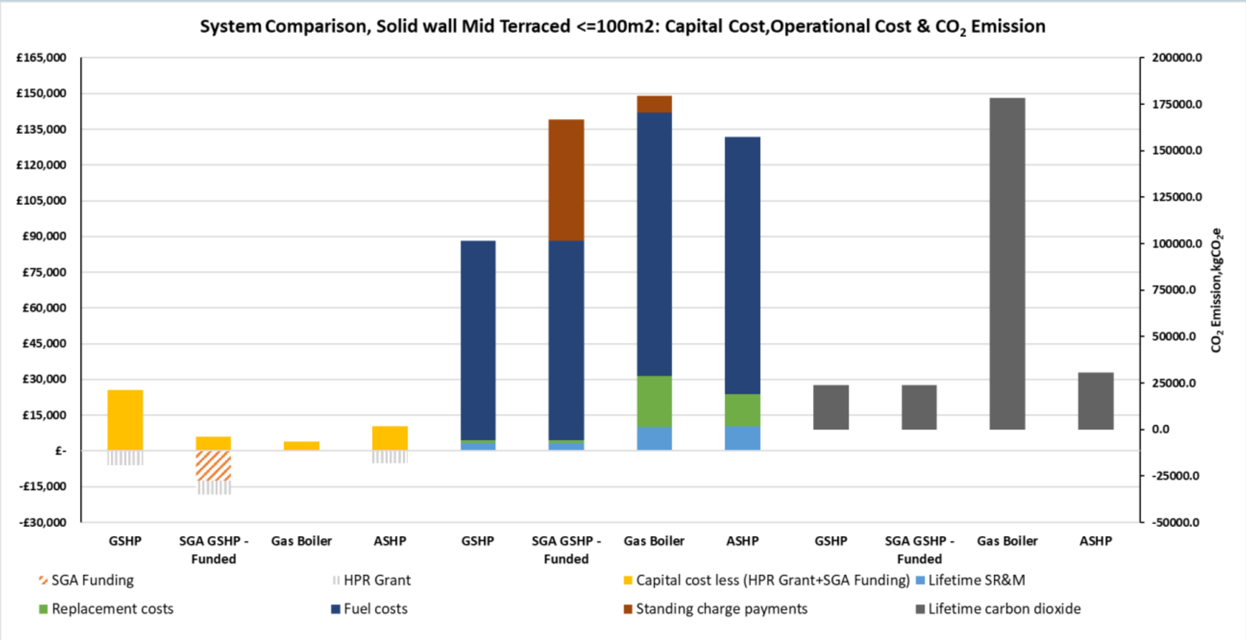


Figure 6-7 System comparison costs: solid wall mid-terraced house less than 100m^2

From the data in Figure 6-7 System comparison costs: solid wall mid-terraced house less than 100m²Figure 6-7 it is evident that the shared ground array heat infrastructure certainly helps to provide better and more cost-effective heating solution to the end user in longer run. Due to high Internal Rate of Return (IRR) demand on investment, the standing charge is high which is expected to reduce as the shared ground array market grows. Based on this SGA solution is defined for mid-terraced properties in the area.

Cavity wall semi-detached houses with floor area less than 100m²

For compact semi-detached houses with EPC rating C or above and where the fabric upgrade and internal plumbing to the house is not required, it is found that a shared ground array heat pump system could be the most cost-effective heating solution for end user to decarbonise the house; see Figure 6-8.

Due to high efficiency and low maintenance of an SGA system, its operational cost is similar to an air source heat pump system and gas heating system despite the fact that the SGA consumer could be paying a monthly standing charge. From the below graph it is evident that with capital investment from investors in the shared ground array heat infrastructure, a better and more cost-effective heating solution to the end user could be provided in the longer run. With the reduction in running costs leading to a higher IRR on investment, SGA solution could become even more attractive to compact semi-detached houses with EPC rating C.

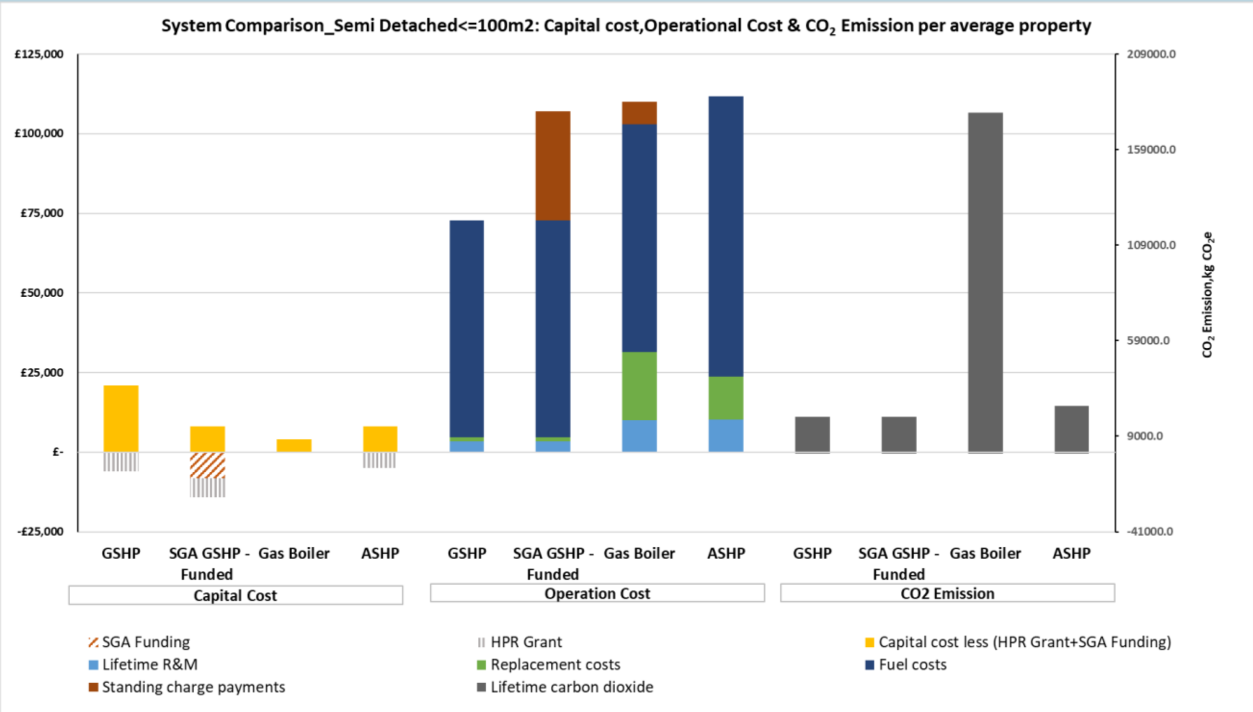


Figure 6-8 System comparison costs: cavity wall semi-detached house less than 100m²

Cavity wall semi-detached houses with floor area greater than $100m^2$

In case of larger semi-detached houses, it is found that an *ASHP system could be the most cost-effective heating solution* for end users to decarbonise the house in the current financial scenario if the consumer is unable to pay the upfront cost of the GSHP system. Otherwise, it is evident from Figure 6-9 that the GSHP system is the lowest operational cost heating system for large semi-detached houses.

Due to a high heat loss coefficient and high annual heat demand for larger semi-detached houses, the cost of shared ground arrays increases due to the need for more boreholes to be drilled and the cost of longer trenching. This increases the investment amount per property and, as a result, the annual standing charge for the end user increases which may require a lower rate of return on investment.

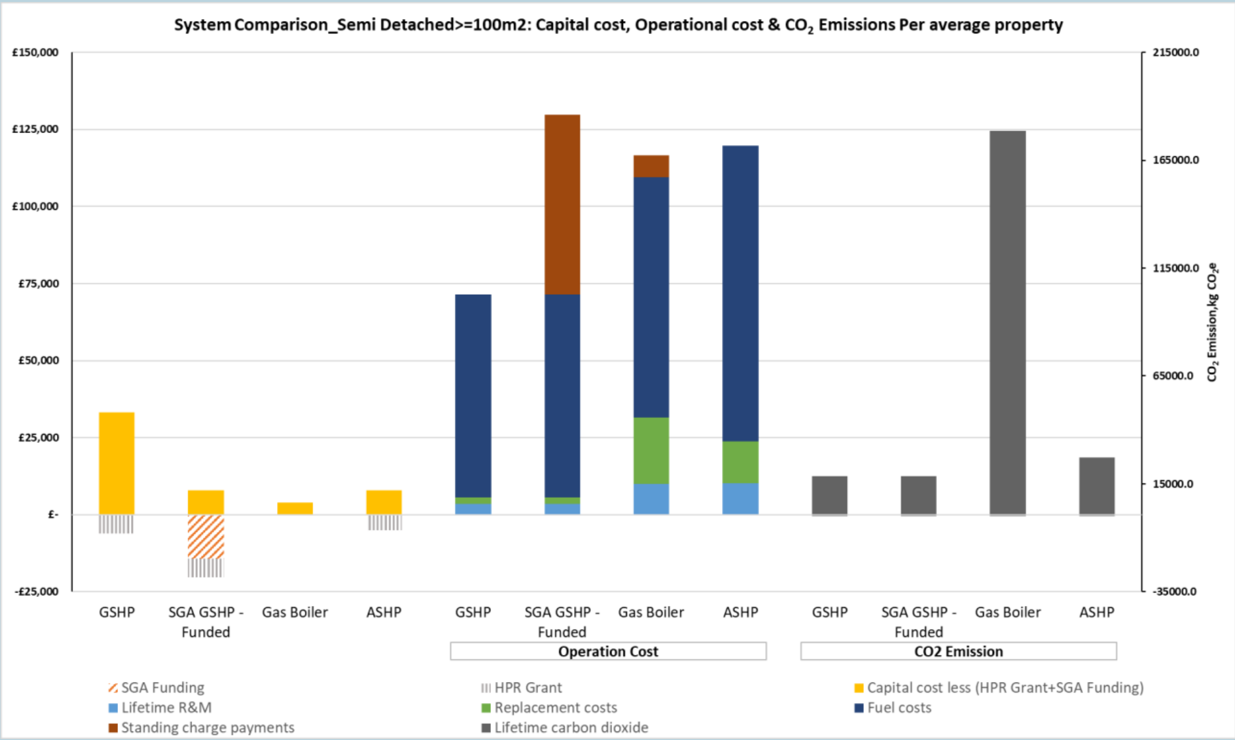


Figure 6-9 System comparison costs: cavity wall semi-detached house greater than $100m^2$

Currently, there is a high standing charge because of the requirement of a high rate of return on the investment (6%) to private investors. At this time this is the only available funding option. If the rate of return on investment were to fall in the future, the standing charge to the end user could be lower. One potential solution is around building a public-private partnership for such infrastructure.

6.2.4 WP2.4 Value added – GSHP + SGA

6.2.4.1 GSHP+SGA solution for high-density heat pump deployment

From the techno-economic analysis, it was clear that of all viable heating options, ground source heat pump is the cheapest to run[11], least hassle to maintain, least noise/visual impact, and allows for lowest-cost cooling. This was in line with an earlier published report from Regen 2021[12], & Aurora 2021[13]. The shared ground loop system takes advantage of ground source heat pump where, instead of having a ground loop designed for each dwelling, a shared pipe network outside the property feeds each dwelling level's heat pump with the ambient energy required to operate the heat pump. This is where this solution gives the added advantage to do the heat pump deployment at the area level rather than the individual house level (Appendix A.5: Lifetime Cost to Consumer).

Shared Ground Arrays utilise the scaled-up benefits of heat networks, can be used to connect multiple properties in an area, and are more efficient than standalone systems. The pre-installation of utility scale underground infrastructure allows consumers to switch from their current heating technology (e.g., gas-fired boilers) to heat pumps easily and inexpensively when they're ready. This is a significant solution for reaching high-density heat pump deployment (Figure 6-10).

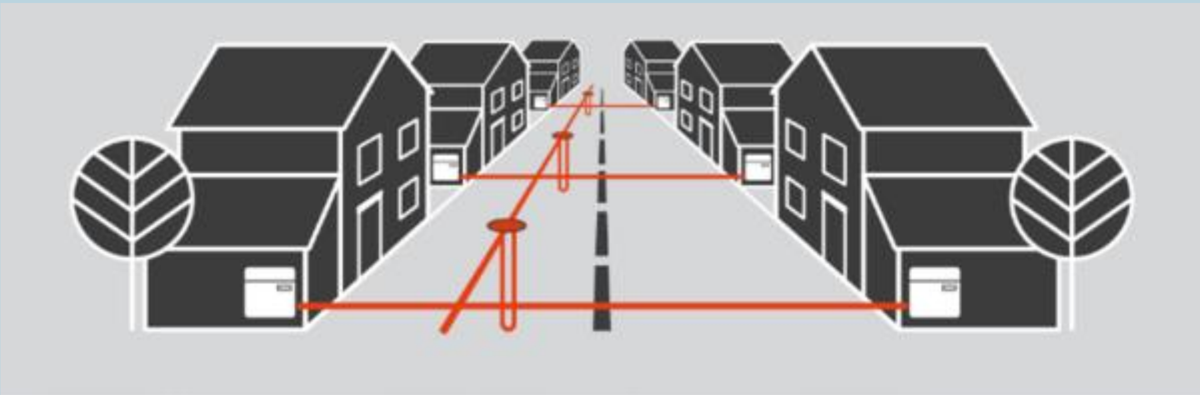


Figure 6-10 Ground Source Heat Pumps + Shared Ground Array

Benefits associated with Shared Ground Loop Arrays are:

- ***GSHP feature***: Provide more flexible energy system as it can be expanded with increase in demand.
- ***Higher annual efficiency***: Running cost benefit as GSHPs tend to have 300-500% efficiencies, as much of the heat is extracted from the ground and can be increased by flexibility and use of waste heat in shared arrays.
- ***Better performance in cold, humid conditions***: The UK can often see weather conditions that prove challenging for ASHPs, with high humidity around freezing point causing icing of evaporator coils, reducing output or efficiency. GSHPs are not directly impacted by air temperature or humidity.

[11] The ground source heat pump is cheapest to run for properties <100m^2, even including standing charge payment for shared ground array (SGA) costs (for properties >100m^2, the SGA costs more and so the standing charge under current financing terms, as described in the next section).
[12] https://www.regen.co.uk/wp-content/uploads/HeatPumpReport_Final_04PDF.pdf
[13] https://auroraenergy.wpenginepowered.com/wp-content/uploads/2021/10/20211020-Aurora-Heat-Decarbonisation-Public-summary.pdf

- ***Better fit for future flexibility***: Markets could reflect the value of flexibility to all aspects of the energy system, reducing peak demand and pressure on electricity networks.

A GSHP+SGA solution does however have higher upfront costs compared to other heat pump technologies, due to the cost associated with the ground array being located outside the property. To break the market barrier of the high upfront cost of ground-source heat pumps, and to provide better solutions for to end users, a split ownership business model was analysed for the selected area for the high-density deployment of a heat pump with a shared ground array heat pump system solution. (Appendix A.5: Lifetime Cost to Consumer).

6.2.4.2 Cost Reduction for Consumers with Split Ownership/Street by Street Business Model

An approach to install shared ground arrays financed as a new utility similar to the gas or water networks, helps to reduce the most significant barrier in terms of required upfront capital cost from the end user. This also provides a path to deploy HPs at high-density. For projects such as the study area, Kensa Utilities Ltd. could act as a contractor and infrastructure provider. Kensa Utilities could pay for, install and own the shared ground source heat pump network infrastructure, relieving responsibility from the homeowners.

This model not only reduces the upfront costs to the customer but also significantly leverages private investment capital. These investments range from pension funds to strategic investors to high-street banks. This moves the emphasis of funding the low carbon transition from government to the private sector in order to enable lower lifetime running costs for users, providing a suitable long-term return for investors and reducing carbon emissions.

In an environment where central plant heat networks are exposed to commodity prices to operate their systems and can therefore charge significant increases to heat network rates, this GSHP+SGA model offers protection to consumers. A heat infrastructure provider, such as Kensa Utilities, could provide a service and replacement package for the internal heat pumps (similar to boiler care).

Cost Reduction for Consumers with Diversity Factors

Due to the scale of the SGA, diversity factor could be applied during the design of the SGA heat pump solution in order to reduce the total peak heat demand associated peak electricity demand for a cluster of homes. Like with any network design, this would help reduce the total borehole depth required. CIBSE CP1: Heat networks: Code of Practice for the UK recommend considering the impact of diversity in demand for medium to large heating systems. The diversity factor at any point in the network can be defined as:

$$diversity\ factor = peak\ demand\ that\ occurs\ at\ this\ point\ in\ the\ heat\ network\ (kW) \\ /the\ sum\ of\ the\ peak\ demands\ at\ each\ customer\ supply\ point\ downstream\ (kW)$$

The design peak demand for each customer is normally the maximum demand that the heat network can supply, which is set at commissioning by limiting the maximum flow rate. This may be higher than the actual heat demand of the building as design margins are often built in. The Design Guide for Diversity Factors for Ambient Temperature Networks using the Zeroth Energy System also includes allowance for the fact that occupants vary their patterns of heat usage. As a result, the probability of a large proportion of occupants simultaneously using hot water at any one time decreases as the size of the network increases. Based on research and experience, Danish Standard DS 439 as well as Swedish DHA and CP1 Heat Networks: Code of Practice for the UK, 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%.

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 heat pumps 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. Although such reduction in total cost is not included in the techno-economic analysis, however it is anticipated that bulk purchasing should help to reduce the capital buying.

Cost Reduction for Consumers by Neighbour-to-Neighbour Encouragement for Uptake

By informing potential customers that it's more likely for their group to be selected and for them to see lower costs if their neighbours also sign up, individual cost of marketing and the drop-out rate post-survey could be reduced. This could lead to lower the overall costs of deployment. In the techno-economic analysis, 80% uptake is assumed with shared ground array solution.

Cost Saving to Upgrade the Electricity Grid and Generation Capacity

The mass electrification of heat with heat pumps could inevitably have an impact on the electricity grid; the ENA Connect & Notify approval identifies Kensa's Evo and Shoebox GSHP ranges to be of low grid impact, enabling their installation without any prior approval requirement from local DNOs.

Modelling has shown whole-life value for money, with costs for shared ground array comparable to existing gas boilers and ASHP heating system. However, and significantly, these cost saving estimates do not include any reflection of the extensive savings expected in the reduced requirement to upgrade the electricity grid, and generation capacity. Modelling hypothetical savings to potential future asset investment presents challenges and presenting these as savings to consumers is not straightforward.

A recent study by Aurora 2021: "Decarbonisation of Heat in Great Britain" concluded that in the long term, shared ground array solution would require the least electricity resource and would therefore require the least investment to prepare the electricity grid for high-density deployment of heat pumps. Nearly £40bn of savings to 2050 on grid upgrades and peak capacity is possible from moving towards shared ground array solutions. Regen 2021 studies also concluded there were significant savings with shared ground array (potentially a third less capacity requirement) compared to other electrical heating systems.

6.3 WP3. Electricity Network. Challoch Energy

High-density heat pump deployment can strain local electrical infrastructure, prompting an assessment of the electrical network for the identified areas[14]. Substation data were obtained from the DNO, including the maximum demand, total capacity, and thus the estimated headroom.

This information was combined with polygons representing the distribution coverage of each secondary substation. This helped identify which streets were served by which secondary substations and how much headroom was available on each. The results provided an initial assessment as to which of the areas considered could have the most suitable electrical infrastructure for heat pump deployment.

6.3.1 WP3.1 Network Constraints

To determine network constraints, the relevant substations and corresponding electrical networks were studied, identifying which ones have sufficient capacity for a minimum 25% uptake of heat pumps in connected homes.

Potential locations were provided by The BCBC Local Energy Action Plan (LEAP), which already identified the areas suitable for the electrification of heating: Coastal Area and Ogmore Vale, the towns and villages of Pencoed, South and North Cornelly, Pyle, and Maesteg, as shown below.

Figure 6-11 BCBC LAEP areas suitable for electrification of heating

Challoch proceeded to review the High Voltage (HV) network, identifying the Low Voltage (LV) substations (11kV to 415V typically) serving each area using information provided by NGED (National Grid Electricity Distribution, formerly WPD). The results were compiled into a database, along with pictures for each area. Porthcawl and Nottage were included within the coastal strip.

Following the initial selection of substations, the three villages situated above Ogmore Vale, Wyndham, Price Town, and Nant-Y-Moel were added to the list of potential locations.

[14] Western Power Distribution 2022 Low Carbon Heating Strategy p.38; chapters 7.4-7.6 https://www.nationalgrid.co.uk/downloads-view-reciteme/614534;

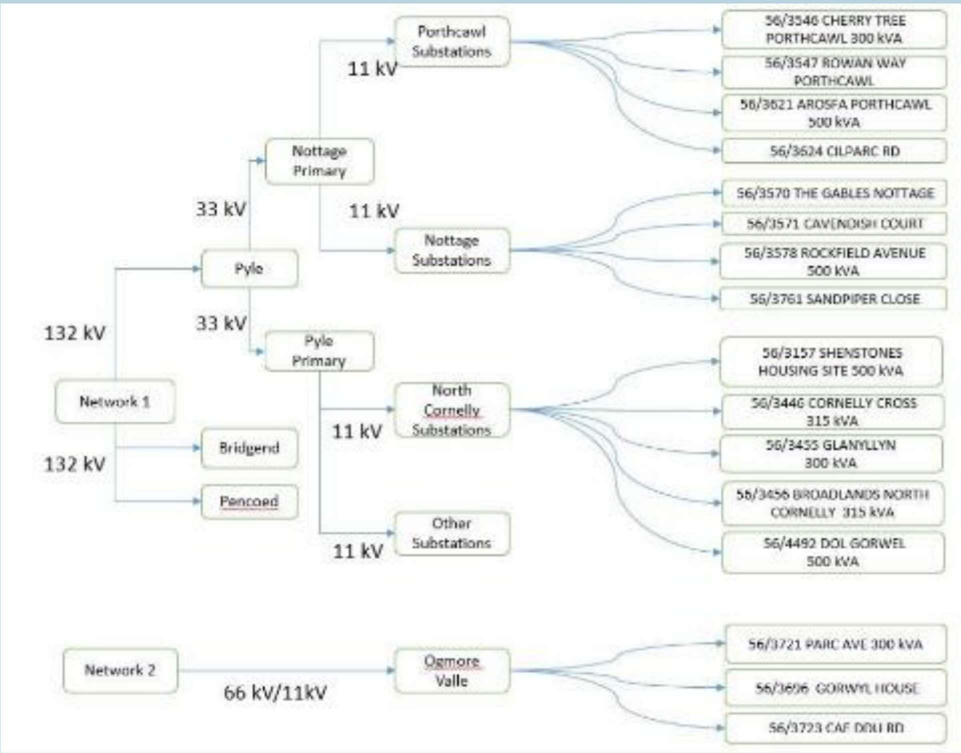
The consortium of partners narrowed the list of locations down to 4 areas: Porthcawl, Nottage, North Cornelly, and Ogmore Vale including the villages above Ogmore. These locations, highlighted in the LAEP report also represent a mix of housing types ranging from terraced houses predominant in Ogmore Vale to semi-detached and detached houses found in the other locations. Furthermore, they covered all levels of society including areas where fuel poverty is prevalent.

A list of potential substations was drafted for each location based on:

- Proximity to commerce – ideally substations should be in residential areas
- Proximity to schools – focus more on residential areas
- Density of housing

Figure 6-12 shows the network infrastructure related to these locations.

Figure 6-12 Network infrastructure



The substation network was obtained using the LineSearchBeforeUDig (LSBUD) tool[15], providing utility maps for specific areas. The maps obtained provide a view of NGED's medium and low voltage network (i.e., ≤11kV), showing substation connection.

In mid-July 2022, a request for information was made to Energy Systems Catapult (ESC) for data on NGED's network. This information helped identify the number of homes connected to the selected substation. ESC also provided an assessment of the capacity and load on the LV feeders.

While waiting for the ESC data, information from LSBUD was used to map out the network flow from each substation. This exercise proved complicated since certain substations are linked to one another to ensure security of supply should one be out of service. These links are often unmarked on WPD maps and difficult to identify.

The data from ESC provided:

- The number of houses on each substation
- The type of connection:
  - EV Home
  - Light Appliance
  - Heat (electricity)
  - Non-domestic
  - LV feeders connected to the substations and the number of houses on each feeder.

An initial review of the ESC data revealed a mismatch between the number of houses and non-domestic buildings per LV substation calculated by ESC and the number per the NGED maps. For example, data for substation 563723 in Ogmore Vale shows 241 houses and 193 non-domestic buildings connected to the substation, although there are 185 buildings directly connected to the 5 feeders. This difference suggests that the extra buildings are the result of looping, whereby more than one house is fed by one connection. As such, there are 185 buildings connected directly to the feeders, with an extra 249 likely to be connected via looping.

The ESC data was used to analyse the capacity of each feeder and its current load to determine what % of total capacity is presently used at feeder level. Both Low and High Voltage feeders were analysed. Note that this data was entirely modelled by ESC and consequently remains an estimate.

The load data for each of the feeders has been modelled and comes with a question mark over its accuracy in that in some cases it appears to exceed the NGED substation capacities.

[15] https://lsbud.co.uk/

6.3.2 WP3.2 Network Opportunities

This section assesses the challenges of integrating heat pumps and the opportunities for innovative network design and expansion. Here, the strategies and newly developed design procedures from distribution network operators' (DNO) for the design of LV networks to allow for the integration of heat pumps and other low carbon technologies (LCT) are analysed. The study focuses mainly on Northern PowerGrid's strategy, one of the first to emerge in the UK, setting the foundations for the policies and procedures of other DNOs.

6.3.2.1 Northern PowerGrid LV Network Design for Heat Pumps & Low Carbon Technologies

Electricity Distribution Network Operators (DNOs) are tasked with building and maintaining an effective electrical distribution network fit for the current, and above all, future electrical demand of the country.

The rise and adoption of low carbon technologies (LCTs) – EVs, solar PV, heat pumps (HPs), etc. – complicates this task as they affect the demand and strain placed on networks. Northern Powergrid's (NPG) Code of Practice for the Economic Development of the LV System[16] is a first attempt from a DNO regulating the incorporation of LCTs in LV network design, setting an important precedent other DNOs may choose to follow.

Unfortunately, their report overlooks the need for reinforcement of existing LV network assets, fails to address cases of multiple LCTs on one site, and makes erroneous assumptions regarding LCTs and their operation, resulting in a flawed LV network design procedure.

Absence of Network Reinforcement

Although Northern Powergrid's code of practice applies to system reinforcement and asset replacement works, it mainly consists of a procedure to evaluate demand requirements for new connections, and thus new LV networks. There is no procedure or policies for reinforcement work to be done on existing LV networks. This results in a crucial gap in the LV design process as it is mostly existing LV networks that are at risk from the increasing loads placed by LCTs. Effectively, the code outlines how network demand must be calculated based on the number of customers and LCTs, with specific calculations for different LCTs. Next, asset requirements such as transformer ratings and required cable sizes are laid out in relation to the estimated demand. This provides a clear procedure for how a new LV network may be designed based on new connections.

What is missing, however, is any link to the existing asset base. There is no procedure for DNO designers to re-calculate the capacity of existing network assets as demand changes with LCT installations. There are no capacity thresholds to indicate when network reinforcement is needed nor any procedure for how it should be done. The code does state, however, that when reinforcement is considered, it must be done using the updated procedure for demand calculation.

[16] Code of Practice for the Economic Development of the LV System https://www.northernpowergrid.com/sites/default/files/2022-05/4628.pdf

6.3.2.2 LV Network Demand Calculation

The approach used among DNOs to calculate LV network demand is the After Diversity Maximum Demand (ADMD)[17].

This calculates the demand of individual customers based on their assumed peak demand, how likely it is for their peak to coincide with other customers' peaks (known as the diversity factor), and how many customers they share the network with. The total network demand is then obtained by summating each individual customer's demand. The key parameters here are the assumed peak demand and the diversity factor. NPG updated these parameters for specific LCTs, developing separate ADMD calculations for EVs, heat pumps, and PV systems.

Issues With Key Assumptions for ADMD Parameters

Focusing specifically on heat pumps, erroneous assumptions are made with respect to the average HP size (in kW), its mode of operation, and the omission of temperature effects.

NPG's code of practice bases its ADMD on an average HP electrical demand of 3kW, less than the current average installed system. Interestingly, Northern Powergrid knows this as they state in their code that the average installed HP size is 3.6-3.9kW. System size is the most important assumption as it is directly proportional to HP demand. Basing ADMD on a 3kW system thus underestimates the demand from heat pumps.

Moreover, the DNO assumes heat pumps could be shut off at night and turned on in the morning, resulting in a morning peak due to a "cold start" phenomenon. This is based on current consumer habits; habits predicated on the capabilities of a typical gas boiler. Heat pumps, however, are not designed for this. To run effectively, they must be operated continuously. This is a technical limitation of heat pumps as it is difficult for them to rapidly close large temperature gaps such as those encountered on a cold morning. To bring a home up to temperature, the heat pump would be forced to run above its rated capacity. This leads to tremendous demand on the LV network while deteriorating the heat pump's longevity. The DNO thus risks oversizing the network for "cold starts" that may not occur.

Finally, the DNO completely omitted the effects of temperature on heat pump power demand. Yet, a heat pump's operational intensity is directly correlated to exterior temperature; the colder it is outside, the harder it must work. As such, ADMD peak demand cannot be based solely on system size, it must consider the coldest expected temperatures over the coming years. The current ADMD calculation makes no mention of temperature. The design engineer is not required to look at historical temperatures to estimate what the heat pump may encounter over its lifetime, and what the resulting demand may be. Neglecting a heat pump's dependence on temperature also compromises the estimated diversity factor. Effectively, while homes may lose heat to the outside at different rates, heat pumps in a specific region could still work harder/slower with as temperatures increase and decrease throughout the day. As such, the diversity factor is likely to be a lot closer to 1.

Failure to Account for Multiple LCTs

A major shortfall with this update, however, is NPG's failure to develop an ADMD calculation for customers with multiple LCTs. As such, the DNO has no means of estimating a client's demand if they have any combination of PV/EV charger/heat pumps or other. Considering customers often install more than one LCT in their homes, this severely undermines the updated code of practice. Moreover, the government's current ten-point plan calls for the electrification of heating via a mass roll out of heat pumps. Northern Powergrid could thus be unable to estimate their

[17] Development of New Network Design and Operation Practices by UK Power Networks, p.36 chapter 4.2.3 https://innovation.ukpowernetworks.co.uk/wp-content/uploads/2019/05/LCL-Learning-Report-D1-Development-of-new-network-design-and-operation-practices.pdf

network demand anywhere where homes with existing LCTs decide to add heat pumps, impeding the country's sustainability plans.

6.3.2.3 LCT Analysis from Other DNOs

As the impacts of LCTs on electrical networks increase, other DNOs across the UK produced their own reports on LCTs' effects and what procedures ought to be followed. This section provides a brief overview of these reports and their main conclusion, while comparing them with NPG's work. Specifically, reports from UK Power Networks, Electricity North West, and Northern Ireland Electricity Networks are considered.

UK Power Networks

In 2014 UK Power Networks produced a report entitled "Impact of Electric Vehicle and Heat Pump loads on network demand profiles". The report quantifies the effects of LCTs monitored in a trial, investigating the need for LV network reinforcement based these findings. As part of this work, the DNO also employed Element Energy to develop a bespoke LV network modelling tool capable of forecasting load growth from EV and heat pump uptake.

This work highlighted the operational realities of heat pumps and the significant impacts that arise on the LV network as the number of installations increases. Indeed, the load profile from the heat pumps monitored proved to be a lot flatter than what was expected, reflecting continuous operation. This contrasts greatly with the NPG's code of practice and proves that accurate estimates must assume continuous modes of operation instead of NPG's cyclical pattern. Moreover, UK Power Networks' modelling tool design procedure accounts specifically for environmental factors that affect heat pump performance. These include the housing type (terraced, detached, etc.), thermal insulation level, and average hot spells and cold spells in the area. This differs from NPG as it ties heat pump demand to environmental thermal factors, whereas NPG's ADMD method applies an assumed peak heat pump demand across customer groups, irrespective of environmental differences.

Finally, the study emphasized the impacts that clusters of heat pumps have on an electrical network and the need for increased DNO visibility and notification of heat pump installations. Effectively, it was observed that accumulations of heat pumps on a network may cause significant voltage distortions beyond acceptable limits. Furthermore, since DNOs are typically unaware of installations at the LV level (people do not call the DNO when they install a new appliance), there is a need to develop a notification procedure for the installation of heat pumps and other LCTs. This allows the DNO to actively monitor developments of the LV network and schedule reinforcements when/where necessary. This differs significantly from NPG's code of practice which has no provisions for an LV connections monitoring procedure and subsequent assessment of network reinforcement needs.

Electricity North West

In June 2022, Electricity North West released the second issue of its Electricity Policy Document 283 outlining the DNOs latest procedure for LV network design. This document is very similar to NPG's updated code of practice, providing methods for calculating and forecasting LV network demand.

Electricity North West uses the ADMD method and bases it on an average heat pump size. The difference, however, is that Electricity North West provides various possible heat pump sizes – ranging from 3 to 8kW – in efforts to obtain more accurate ADMD estimations. Still, this document also fails to account for temperature effects and the continuous operation of heat pumps.

That said, a key difference with and improvement on NPG's updated code of practice is that Electricity North West sets a hard threshold of 10% LCT penetration on a network, after which network reinforcement must be considered. As such, the DNO also implements a demand and voltage monitoring procedure, to assess the capacity of the LV network. Network reinforcement needs are then assessed, and work carried out following the latest design policies outlined in the document.

Northern Ireland Electricity Networks (NIE)

Unlike the DNO documents considered thus far, NIE's work is a consultation paper launched in June 2022 seeking industry and stakeholder advice on how to best improve LV network design for the widespread integration of LCTs. NIE currently uses the ADMD method to forecast/estimate demand on the LV network. The updated approach suggested in this consultation paper is based on NPG's Consumer Lead Network Revolution trial and the above updated code of practice analysed.

Effectively, similar to NPG's document, NIE proposes to increase the ADMD parameters used to estimate household demand. Consequently, the issues highlighted with NPG's approach exist in this consultation proposal. An improvement, however, is the addition of separate ADMD peak values for different house types and the emphasis placed on network reinforcement; two key weak points of NPG's work. Still, regarding network reinforcement, the current approach focuses on oversizing new network connections to reduce future reactive reinforcement. This leads to increased and possibly unnecessary upfront costs, as networks may not be sized appropriately. This approach is undesirable as the costs could be passed down to consumers who could bear the brunt of it. Ultimately, NIE's consultation process promotes increased collaboration amongst DNOs, essential for identifying a true set of best practices.

6.3.3 WP3.3 Flexibility Offering

This section addresses the potential to operate heat pumps in a manner that increases flexibility for the grid. The analysis is based on ongoing projects evaluating the potential for flexibility that heat pumps can deliver, namely the Equinox project. Also addressed is the tentative strategy put forth by NGED to increase heat pump uptake across its network. Key findings from both these works are provided.

6.3.3.1 Ongoing Projects Evaluating HP Flexibility Offerings for DNOs

There are several projects across the UK designed to explore the potential for heat pumps to offer flexibility services to DNOs and the LV grid. The goal is to test whether mass scheduling of heat pump operation provides significant load management benefits for DNOs to the extent that network reinforcement needs are minimal or eliminated altogether. Investigating this topic are two major projects deployed across the UK: the Equinox project and the National Grid (formerly WPD) Low Carbon Heating strategy. The following section provides a brief overview and key findings from these projects, demonstrating the expected and observed value from heat pumps and their potential for flexibility. A detailed description of both projects is given in the appendix.

Equinox Project

- Equinox could address the challenges DNOs face with the electrification of heat. It seeks to develop commercial arrangements to support technologies that unlock flexibility from residential low carbon heating, like heat pumps, while meeting the needs of all consumers.
- The project aims to deliver substantial network benefits through the deferral or avoidance of network reinforcement due to the predicted dramatic uptake of heat pumps.
- Equinox is developing three novel commercial methods that are designed to maximise participation in domestic DNO flexibility services.
    - **Save in advance:** the energy supplier, and in turn, the end-customer, receive an upfront flexibility payment in return for offering a fixed, minimum obligation of flexibility.
    - **Save as you go:** the energy supplier, and in turn the end-customer, are not committed to a fixed, minimum obligation but instead have more control over the flexibility they offer based on (near) real-time signals delivered in an automated way.
    - **Save in advance & boost as you go:** combine aspects of both upfront flexibility payments and dynamic price signals.
    - **Expected benefits**: significant financial, capacity, and carbon benefits; faster adoption of heat pumps; increased opportunity for value stacking, benefit for the National Grid ESO (system balancing cost reduction due to improved coordination with NGESO).

National Grid Low Carbon Heating Strategy

- For heat pumps to be able to realise their full potential for demand-response, UK building stock needs to be made more suitable for heat pumps (and their flexible operation) in that the buildings need to be brought up to the current level of insulation standards.
- The introduction of a simple heat store for the space heating would provide the ability to not run the HP at peak times introducing some flexibility into the existing housing market.
- With heat pumps offering low grade heat compared to gas fired central heating it means the building housing the heat pump needs to have an EPC rating of C or above.
- If the house is designed with an EPC of "A", the heat pump could not have to run 24/7 to maintain the heat in the home, and the size of the heat pump could be smaller than a house with a low EPC rating.

6.3.4 WP3.4 Market Structures

Innovative market structures and customer offers from electricity suppliers are needed to accommodate the evolving electricity consumption habits of consumers. These should reflect the new reality of high-volume consumption due to electrification, and the cheap nature of self-consumption from local energy assets.

This section explores the existing offers for specific heat pump tariffs from the suppliers to encourage a high level of penetration of heat pumps.

Good Energy's special tariff – Green Heat - could offer cheaper unit rates for homeowners with heat pumps, as well as reductions in rates during specific times of the day. This could help homeowners benefit at times when renewable output is high, or when there is lower demand on the electricity grid[18].

In December 2022 **Octopus Energy** launched a specific heat pump tariff, called Cosy Octopus. It offers a day rate, set at the standard Octopus Flexible rate; two cosy periods of cheap rates between 04:00 – 07:00 and 13:00 – 16:00 every day, (40% cheaper than the Octopus Flexible rate) and a peak rate between 16:00 – 19:00, 60% above the Octopus flexible rate[19].In March 2022 **OVO Energy** announced the trial of "type-of-use" heat pump tariff, Heat Pump Pro, which could allow heat pump owners to pay a lower rate for energy used to power their heat pumps. In the Heat Pump Pro tariff trial participants could get **5p/kWh off their standard rate** for electricity used to power their heat pump[20].

The current offers for special heat pump tariffs are either in trial stage or very recent, hence there is no feedback on the savings made through these tariffs.

Innovative market structures are discussed in detail below.

A white label is a structure where customers group together under a proprietary brand name – the white label. The brand then engages with suppliers, leveraging the large client base it represents to obtain bespoke and favourable electricity tariffs. This is particularly well suited for heat pump clusters as customers can leverage both their elevated client base and the significant electricity demand their heat pumps require.

It is envisaged white labels can serve to negotiate unique heat pump tariffs based on the customer's ability to operate their heat pump in the most efficient and effective manner for the power supplier and the electricity grid at large. Indeed, heat pumps are designed to run continuously as opposed to being switched on/off like a boiler. By operating this way, they consume less power overall throughout the day and help suppliers and the grid better manage their loads. The white label can thus capture the value of a large group of high demand consumers shifting their demand away from peak power demand periods and smoothing their overall power consumption habits. Currently, certain suppliers offer flexible tariffs specifically aimed at heat pump users, incentivising them to run the pump outside of peak periods[17]. Still, this tariff is targeted at individual consumers, not a collective.

Local energy markets (LEM) are, as the name suggests, a localised electricity market where electricity is generated and traded within a local community. Under this setup, power is generated and sold amongst residents at cost of generation, be it the levelized cost of energy. The community often owns the generation assets, and revenue is pumped into community programs and maintenance of the energy assets.

[18] https://www.goodenergy.co.uk/our-new-heat-pump-tariff-could-make-the-green-homes-grant-scheme-go-further-and-faster/
[19] https://octopus.energy/cosy/
[20] https://www.ovoenergy.com/blog/heat-pump-pro-trial

In the context of a heat pump cluster, a LEM can be built with the goal of satisfying heat pump demand using local renewable power such as household PV or a dedicated wind turbine for the community. The benefits of such a structure are twofold: firstly, members receive very favourable tariffs to power their heat pumps; secondly, feeding the heat pumps with dedicated local generation avoids strain being placed on the DNO's network and their supplier. Residents thus retain the relationship with their energy supplier but avoid drastically increasing their energy demand via heat pumps.

Energy Local Clubs (ELCs) are effectively a fusion of white labels and LEMs. The clubs function as a co-op whose members comprise local households and renewable energy generators. They operate under Energy Local's umbrella, the non-profit organisation that helps communities create and oversee ELCs.

By pooling residents and generators together, the co-op acts as a white label, leveraging its customer base to obtain bespoke tariffs with Energy Local's supplier. This setup also resembles a LEM as it allows locally generated power to remain within the community by selling it to ELC members at the LCOE.

An ELC can be used as an alternative to a LEM for smaller heat pump clusters that do not have the capacity of installing communal generation assets. Here, the cluster can invest in cheaper small-scale residential PV sized to match the consumption of the heat pumps. An ELC model can be established to work with a supplier and power the heat pump cluster with local generation at a favourable tariff. Alternatively, an ELC can created and used simply as a traditional white label to leverage Energy Local's experience and existing relationships with power suppliers. Here, the ELC would negotiate favourable tariffs for the consumption of ELC members just as a regular white label would.

Ultimately, an Energy Local Club offers a simple alternative to a LEM while combining the benefits of a white label. It is especially suited to smaller clusters within a community and not an entire community at large.

Whilst not the focus of the Heat Pump Ready programme, it is proposed in future stages of development that smart energy solutions can be integrated into the community heat offering to better exploit these emerging models including integration with local renewables schemes and flexibility measures to provide further cost reductions.

6.4 WP4. Engagement. NuVision Energy (Wales)

Our engagement methodology builds on the team's experience of engaging and building relationships with communities in the Bridgend area. Activities were focused on consumers, community leaders and the supply chain. In order to take advantage of the team's strong connections with BCBC, the activities were 'badged' under the Low Carbon Communities brand, a brand that we developed with BCBC on a previous projectand which has gained a track record of successful delivery and trust with residents. Our engagement activities are discussed in more detail in sections 6.4.1 to 6.4.6.

Figure 6-13 Low Carbon Communities brand

6.4.1 WP4.1 Intelligent Survey

One of the innovations to be trialled as part of the engagement activities was an online survey tool to gather data on homes. The intelligent survey is presented in Appendix A.2. All homeowners who attended the events plus those who had expressed an interest via email but could not attend in person (44 homeowners in total) were invited to complete the online 'Intelligent Survey' to understand how customers might move to a greener heating system in their homes. The Intelligent survey was made available online via a QR code and web link given to homeowners and hard copies provided for the event at the Cornelly Community Centre (See 6.4.2 for WP4.2). Results of the intelligent survey are discussed in the 'Findings' section.

6.4.2 WP4.2 Community Engagement

The team engaged with communities through Facebook campaigns, online surveys, leaflet drops and awareness raising events. This was followed up with email communications and home visits with those who had shown an interest in the Heat Pump Ready programme.

The initial direct approach to customer engagement was through a project leaflet drop delivered door-to-door.

Over a period of three days, leaflets were delivered to 1,500 homes in the target areas of North Cornelly and Nottage. Due to time constraints, the leaflets were designed and printed ahead of the target areas being finalised. It was therefore felt prudent to overestimate the number of leaflets required, and 2,000 copies were printed. The remaining 500 leaflets were therefore surplus to requirements and were recycled.

The leaflet design built on the BCBC Low Carbon Communities brand used on the South Cornelly Local Energy Market project and promoted the concept of an '*Affordable and Greener Heating for your Home'*. The Bridgend CBC logo was also used, demonstrating the Borough Council's commitment to the project. A copy of the leaflet is presented in Appendix A.1. The purpose of the leaflet was to:

- Raise awareness of heat pumps in the community.
- Explain to homeowners how the programme worked.
- Give an idea of what the benefits might be to homeowners.
- Direct homeowners to the event at the Cornelly Community Centre where they could learn more.

The **Facebook campaign** was launched with the objective of reaching as many homeowners as possible with a view to making them aware of the HPR Bridgend project and to invite them to the open days being held at the Cornelly Community Centre. As the team was focusing on the specific areas of North Cornelly, Porthcawl and Ogmore Vale, a relatively narrower geographic audience was targeted. Statistics from the Facebook campaign are presented in the findings section (Section 7.5.2).

Both the Leaflet and Facebook adverts contained links to the Intelligent Survey in the form of a QR code and web address. In addition, the Facebook advertisements contained a link to a short survey. The purpose of the short survey was to gauge interest and awareness of heat pumps from as many people as possible within the Bridgend target areas. Results of the survey are discussed in more detail in the 'Findings' section.

Two **Open days** were held at the Cornelly Community Centre with the aim of raising awareness of heat pumps and to build capacity within the targeted communities (Figure 6-14). Those who attended the open days and were keen to potentially sign up to the heat pump installation programme were invited to leave their contact details so that they could be kept in touch with the programme.

The open days were a good opportunity to meet local residents and to understand their needs and motivation for attending the events.

Figure 6-14 Open Days in North Cornelly Community Centre

Identifying HPR Bridgend 'Advocates'.

The events were attended by approximately 30 people (representing 17 homes). Those who attended the events and especially those who took the time complete the intelligent survey could prove to be good advocates of the programme and could 'champion' the initiative within their communities.

6.4.3 WP4.3 Supply Chain Engagement

The approach to supply chain engagement involved researching those companies within the industry that are involved in or could become involved in Heat Pump deployment. The exercise included contacting heat pump installer companies and mainly recording the plethora of smaller companies, mostly plumbers, who have moved into renewable technologies and now include heat pumps within their range of services. The categories of organisations encountered include:

- **Installers** - the established companies that offer both ground and/or air source heat pump installation.
- **Small companies** - offering heat pump services.
- **Heat pump suppliers** - who include product training and a have approved installers in the UK.
- **Heat pump suppliers** - with no training.
- **Training organisations**
- **Advice centres/organisations**

Please see results of the supply chain engagement in the findings section 7.5.3.

6.4.4 WP4.4 Government Engagement

Key to our engagement activities was the support provided by BCBC in the form of a number of officers and Councillors from respective wards attended the public open days held in the Cornelly Community Centre. The council also developed a project web page to promote the programme on the Council website in both English and Welsh which is a mandatory requirement from Welsh Government for all public domain information (Appendix A.3).

Three Councillors including the leader of the council were actively involved in the engagement activities and were pro-active in advertising the events via their Facebook and Twitter accounts.

6.4.5 WP4.5 Capacity Building – Community

Our experienced team members who are expert in heat pump supply, installation and ongoing maintenance support were available to provide face-to-face advice and guidance to homeowners who attended the events. These included:

- Community Engagement - NuVision Energy Wales (Dave Tucker, Rob Francis, and Matthew Tucker)
- Heat Pump Specialist – Kensa (Matt Zealley)
- Electricity grid considerations – Challoch Energy (Simon Minett).

Three home visits were made to support individuals with specific queries. Educational material was shared with those who enquired and our specialist heat pump partner, Kensa were able to demonstrate their heat pump technology through full size mock-up of a heat pump. Educational material was shared primarily from Kensa’s website resources. Link: https://www.kensaheatpumps.com/heat-pump-faqs/

6.4.6 WP4.6 Capacity Building - Supply Chain

Our specialist team members held meetings with Bridgend College to discuss their capacity to develop courses in support of heat pump deployment. The college is already embracing renewable technologies with practical training courses in heat pumps etc. and supporting these with a renovated house on the campus equipped with an air source heat pump, PVs and external wall insulation to demonstrate how a home can be decarbonised.

6.5 WP5. Management and Co-ordination Buro Happold

The purpose of the management and coordination work package is to facilitate the delivery of the feasibility study by a collaborative group. Project management is an integral part of every project, as is co-ordination where more than one organisation works together. The aspect of this work package that is especially for high-density heat pump deployment is encouraging new approaches by information sharing and knowledge sharing between groups, for the benefit of the overall study.

Over the course of the Feasibility Study, Buro Happold acted as the Project Leader (PL) and co-ordinator of the collaborative HPR Bridgend team.

6.5.1 WP5.1 Project Management

Approach to Project Management

Project management enabled a coordinated approach to arriving at a high-density heat pump feasibility study, where multiple organisations worked together. The spirit of the group was to work together as one team in cooperation. This involved:

- **Identifying a common goal.** At the project outset, agree the common goal, to allow everyone to have the same objective in mind.
- **Setting clear expectations.** Agree clear roles for each organisation, where each has a work package that connects to the overall project.
- **Agreeing milestones.** For each work package, agree milestones that fit with the overall study programme. Organisations are all accountable for their own milestone deliverables, and in a position to take the initiative to move their own aspect of the project forward.
- **Leveraging capabilities.** Tasks to be carried out by each organisation match their experience and capabilities. Plan for expertise from different fields to feed into the project, including energy planning, heat pump technology, electricity grid constraints and opportunities, and stakeholder engagement.
- **Checking-in regularly**. Agree frequency of project progress meetings and allow flexibility with emails and video conferences as needed.
- **Encouraging new approaches**. Encourage entire time to provide input to develop the study. Share knowledge and information within the collaborative group.
- **Developing strong relationships**. Reserve time at the beginnings of regular check-in meetings to get to know team members better.
- **Encouraging input from key stakeholders**. Engage with the local Council and the Distribution Network Operator to support the project and to share information. Make opportunities for these key stakeholders to join project meetings and to correspond by email and join videoconference calls.

Please see Section 7.6, Recommended methodology, for coordinating high-density heat pump deployment for a description of stakeholders suggested with roles and responsibilities for a heat pump deployment project.

6.5.2 WP5.2 Advisory Group

The approach for the advisory group was to invite key stakeholders to participate in the development of the high-density heat pump feasibility study, sharing information, and supporting the project. The two key stakeholders invited were the local council and the Distribution Network Operator.

6.5.3 WP5.3 Special Purpose Vehicle

During the application preparation for the Stream 1, Phase 1 feasibility study, the project collaborators discussed the approach to take for the Phase 2 deployment of heat pumps. The team noted that the BEIS guidance suggested that teams could potentially be requested to establish a legal entity to deploy the heat pumps during phase two. Taking inspiration from this, the collaboration group of Challoch Energy, NuVision Energy (Wales), Kensa Utilities, and Buro Happold decided to explore the option of forming a Special Purpose Vehicle (SPV) for Phase 2 heat pump deployment.

The approach taken included:

- Each group consulting internally on alignment with company strategy.
- Discussing the role of the collaborators as future shareholders of the SPV, as well as the potential structure of the SPV itself.
- Sketching the SPV's potential cashflows, considering how it could operate over the long term as a business.

6.5.4 Recommended Innovative Coordinated Methodology for High-Density Heat Pump Deployment

The collaborative approach taken to preparing this feasibility study and recommended approach.

Please see Section 6.5.1 on Project Management for more information on the collaborative ways of working within the team that produced this feasibility study.

6.5.5 WP5.4 Draft Report and WP5.5 Final Report

The approach to preparing the feasibility study was for each organisation to prepare the sections of the report relating to their work packages. The project leader prepared the front and ending matter for the report.

6.5.6 Stream 3 Participation

During the project, as Project Leader, Buro Happold attended the Stream 3 dissemination meetings and workshops. Following each workshop, Buro Happold shared summary meeting notes and a copy of the presentation slide deck from the Stream 3 organisers with the overall HPR Bridgend collaboration team.

7 Findings from Work Packages

7.1 WP1. Energy Planning and Mapping Buro Happold

This section summarises the findings from the data collection process outlined in section 6.1. The respective manipulated data is described in Table 7—1.

Table 7—1 Description of manipulated data sets from data collection process

Data	Collection process
Area characterisation data	LSOA and EPC data collected from open-source government websites. The EPC data was aggregated to LSOA level to create the area characterisation maps
Manipulated EPC data	The cleaned and filtered EPC data was categorised depending on various parameters (see Table 6—4 for further details)
Substation headroom outline	Secondary substation capacity and coverage data was combined into singular shapefile format and added to GIS software. This was based on using unique substation codes to link the two datasets together.

The baseline summary of the outlined information, the analysis of this information, and the visualisation of these outputs and displayed and described throughout this section.

7.1.1 WP1.1 Information Collection and Review

The information which was available fell into three major groups:

- **Aggregated** – this information generally captures all domestic buildings but does not allow individual building assessment. Information was generally aggregated to either Lower Layer Super Output Area (LSOA) or Postcode level and available through national sources. Information of this type ranges from counts of property types, to social factors like fuel poverty, and to energy consumption and heating system types.
- **Precise** – this information is tied to precise objects such as buildings or specific substations. This information often had issues related to accuracy and/or completeness. This was in a large part due to much of the data requested not being provided, as well as underlying issues with data that are looking to be improved.
- **Local insight** – this was rarely tied to precise objects but rather gave useful insights to areas, a key example of this being plumbing in area not being suitable for heat pumps given the relative temperatures delivered by heat pumps compared to gas boilers. In some cases, information was tied to specific objects, such as owners who interested in participating further stages of the work.

In general, the information collection process was challenging, with multiple datasets identified and requested at the start of the project not being immediately available and therefore alternative approaches having to be developed for the purposes of Phase 1. Lessons learned are to set up clear data guidelines and make provision for the license arrangements in good time for subsequent stages to account for the ability of providers to respond. This is particularly critical when liaising with the DNO. For Phase 1 the project therefore relied upon open access data. Gaps in this data meant a bottom-up approach to baselining and analysis were not possible, with a hybrid model involving elements of top-down and bottom-up modelling being developed instead. This meant aggregated data was used to inform the top-down model, whilst ideally this would purely be used to review and validate the bottom-up model.

Whilst the precise building data directly provided was incomplete (i.e., EPC information) electricity DNO data did cover many network elements. However, there are some key information that was either missing or unavailable, these are discussed by key electricity infrastructure item types in the bullet point list below:

- 11 kV conductors – spatial location appeared accurate, lack of information regarding conductor headroom
- Secondary substation – spatial location appeared accurate, some information relating to load but no clear headroom rating. Headroom had to be calculated and this highlighted some potential errors in the loading data received
- LV routings – spatial location appeared inaccurate (in part this is likely due to the format data was provided in), no rating and no reference to the secondary substation/substations it is served by. This makes it challenging to accurately aggregate demands to assess against KPIs.
- Service conductors – has similar issues to LV, however, the short runs make spatial analysis a more accurate process to associate the service cable with the relevant LV conductor (if required)
- Meter/connection points – incomplete information provided which is hard to sperate out from other nodal data due to limited identifiers and no code to associate with a specific LV conductor or secondary substation.

Alongside the precise network data, a polygon GIS shapefile was provided. This breaks down the whole of Bridgend into the areas served by different secondary substations. As is to be expected given the complex and interconnected nature of electricity networks there are potential errors due to precision. A precise estimate on the accuracy cannot be provided as no alternative information was available (e.g., connection nodes with a reference ID), however, as this is a standardised data format provided by multiple DNOs it is likely that errors could be relatively small.

7.1.2 WP1.2 Energy Baseline Appraisal

The energy baseline appraisal is split into two key areas the first baselines the building and some contextual social information with the second examining the electricity network infrastructure.

7.1.2.1 Building/Social Information

Open access national datasets relating to key societal factors relating to building stock (available at LSOA resolution) were collected and used to provide context to the four study towns in the wider Bridgend area Figure 7-1 displays the levels of housing and income deprivation in Bridgend.

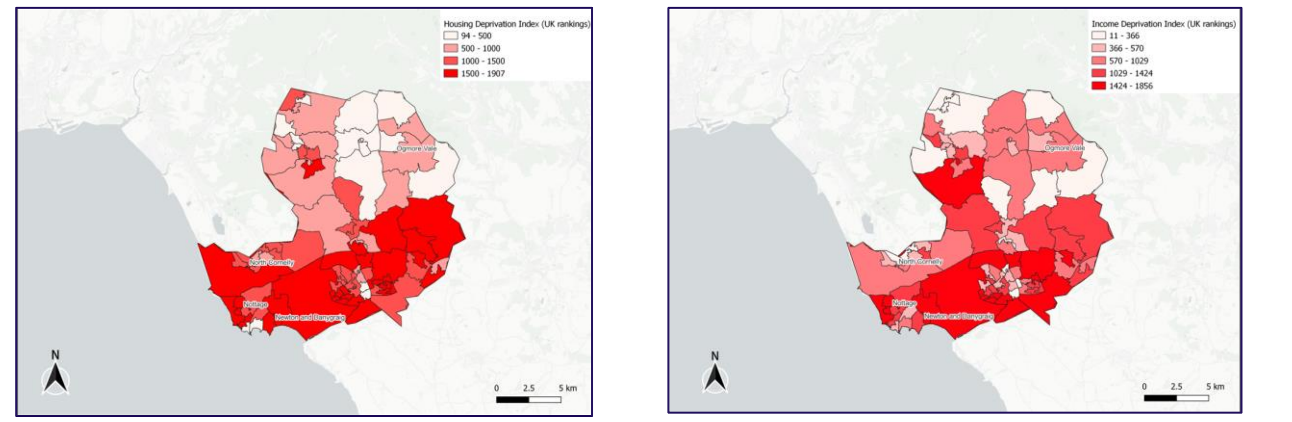


Figure 7-1 Housing and Income Deprivation Indices in Bridgend

The ranking is based on a scale of 1-1,909 with 1 indicating the most deprived area in the Wales.[21] All four towns could be considered as having high levels of housing and income deprivation in the context of the UK. In particular Ogmore Vale as it ranks within the top 500 most deprived areas in the UK for both income and housing stock quality. The high housing deprivation levels within the four towns initially indicated that some form of retrofit would likely be needed in the identified housing stock.

Figure 7-2 shows the population density for Bridgend. This characterisation map indicates that there is high population density in the Nottage, North Cornelly and Newton and Danycraig, compared to the wider Bridgend area. Typically, areas with higher population densities typically translates to greater variation in energy demand patterns and heating technology choices.

[21] Welsh Index of Multiple Deprivation, Stats Wales (2019), Available at : https://statswales.gov.wales/Catalogue/Community-Safety-and-Social-Inclusion/Welsh-Index-of-Multiple-Deprivation

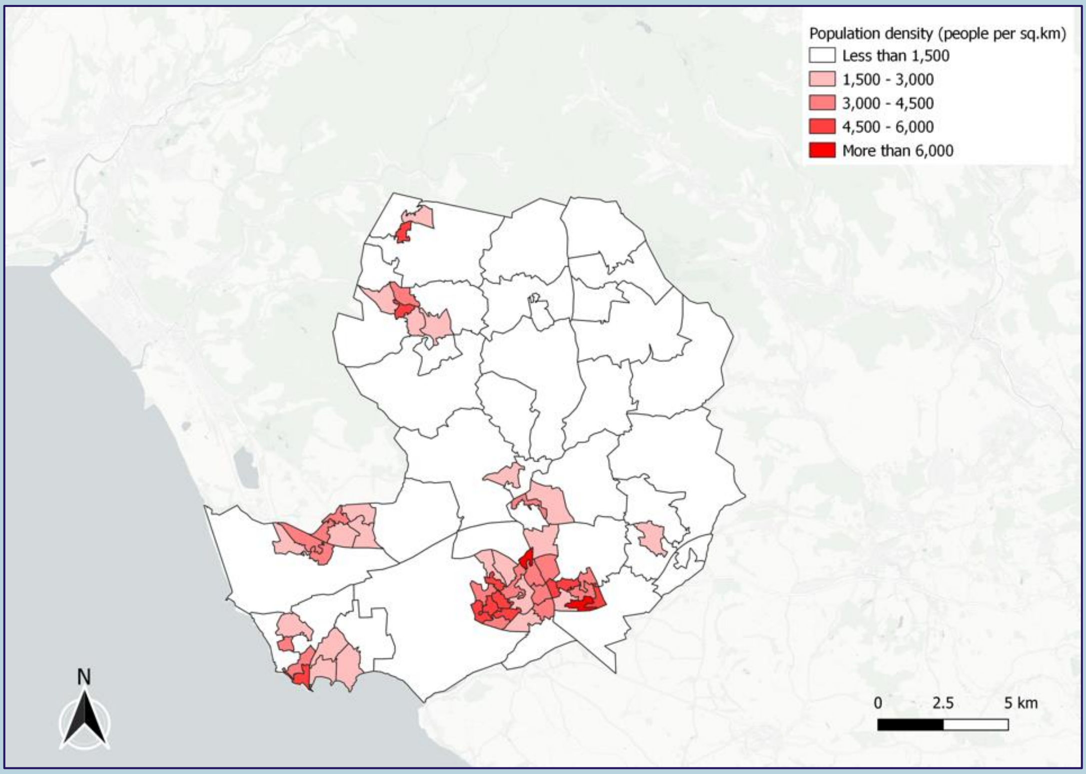


Figure 7-2 Bridgend population density (people per square kilometre)

Whilst this context is useful and highlights that there could be wider benefits from improving heating systems beyond decarbonisation, the main focus of the KPIs are high densities of dwellings suitable for heat pumps. EPCs were the main data source to allow for this detailed analysis. As EPCs are not available for all domestic properties the information had to be extrapolated from existing EPCs to cover those properties with no data. Key to this was establishing the number of dwellings for predefined geographic areas (using pre-aggregated datasets). Counts of key typologies/characteristics, generated from EPC data, were then made in GIS to these same predefined areas. A simple linear interpolation was used to scale up the EPC derived data to cover all the domestic properties.

Figure 7-3 indicates that North Cornelly, Nottage and Newton and Danycraig were primarily dominated by semi-detached and detached homes. Terraced homes were the primary build type in Ogmore Vale. There was a low concentration of flats in all of the four key areas.

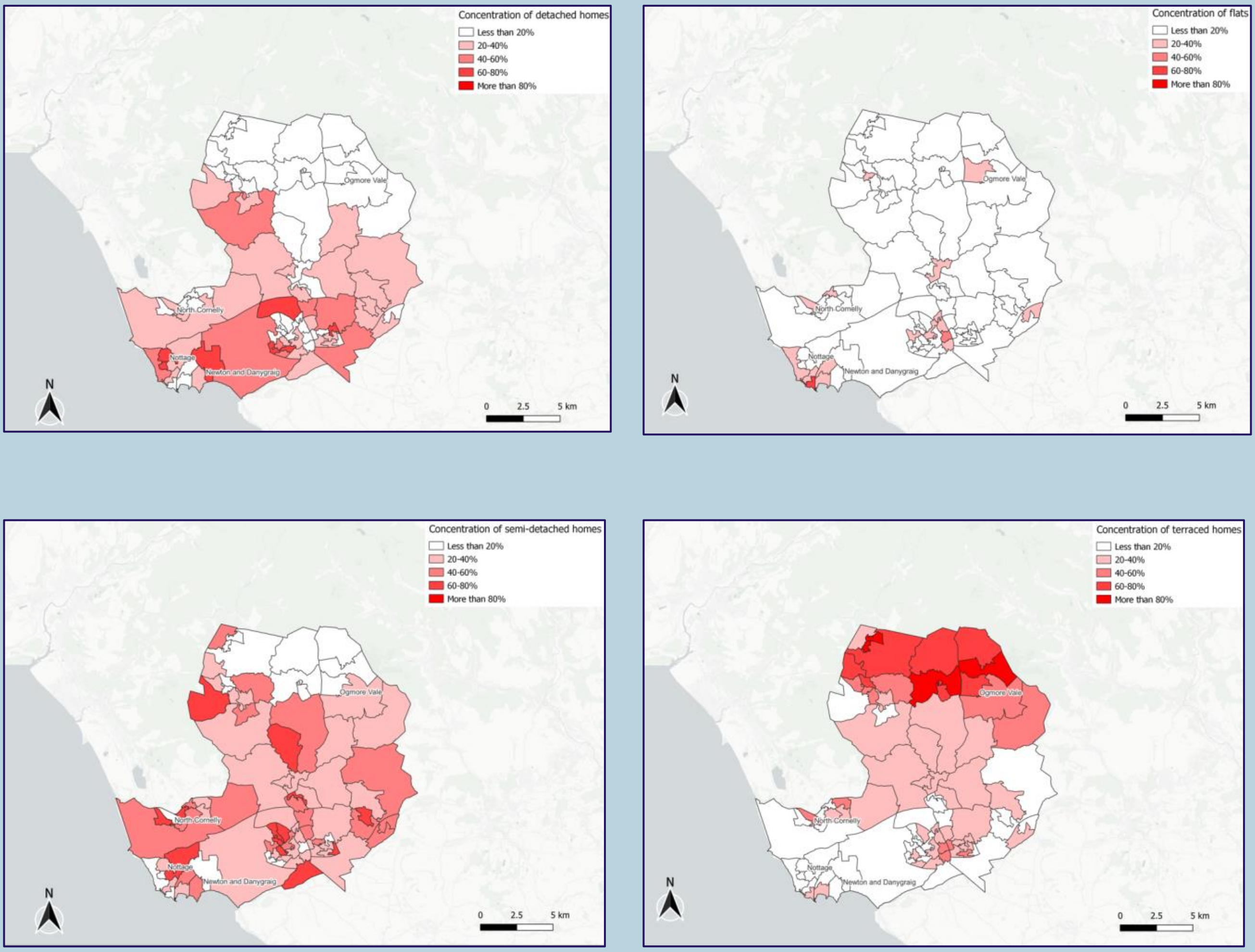


Figure 7-3 Housing type breakdown within Bridgend

As would be expected with the high levels of housing deprivation (Figure 7-1) the four study towns averaged a SAP score <65 (Figure 7-4). This indicates lower levels of housing energy efficiency.

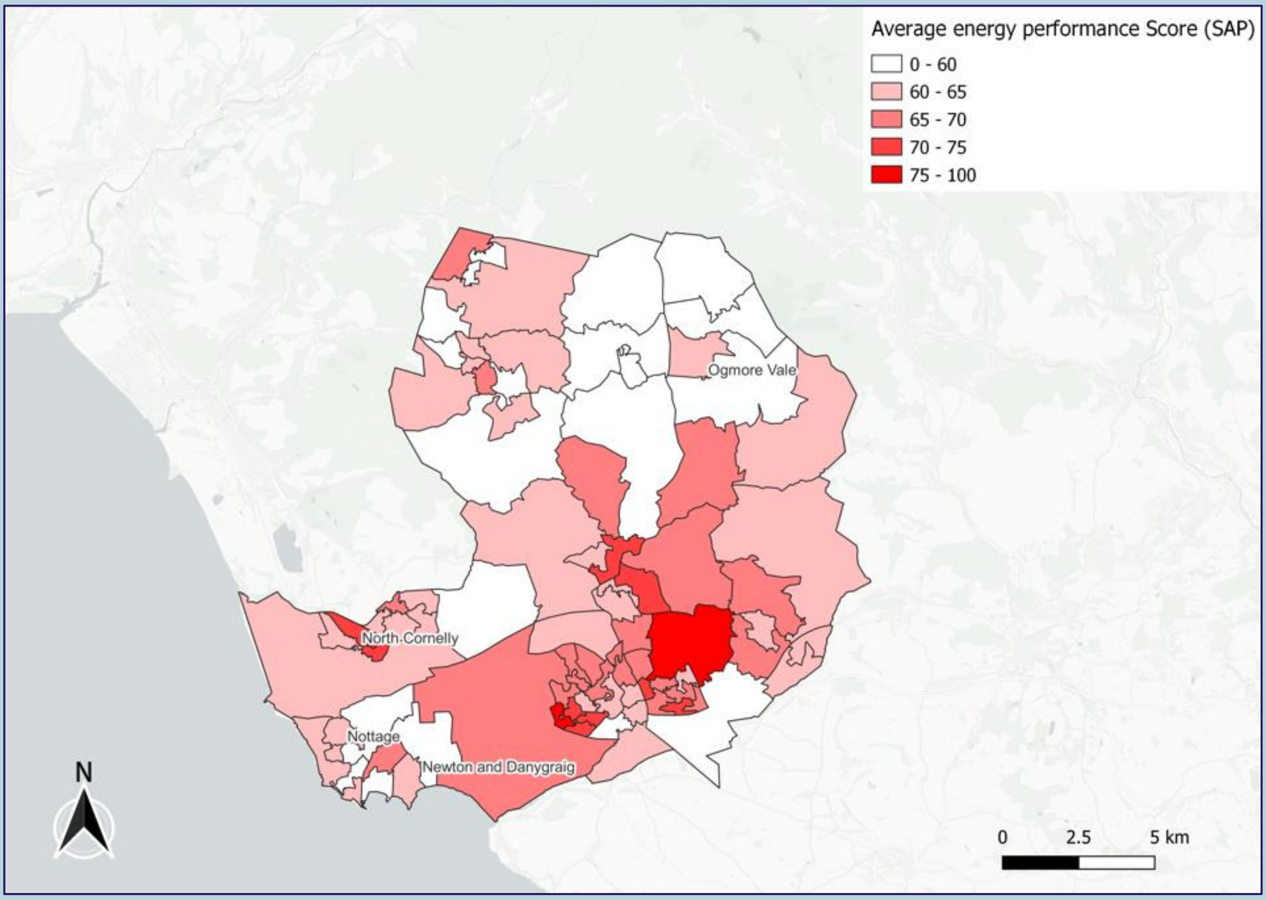


Figure 7-4 Average SAP score in Bridgend

The primary fuel type in Bridgend is natural gas (Figure 7-5). Approximately 2% of homes in the area use direct electric or heat pumps for their heating requirements. Both the breakdown of primary fuel types and the SAP scores indicate all of the four study areas would initially appear suitable for high-density heat pump deployment and are aligned with the project's KPIs.

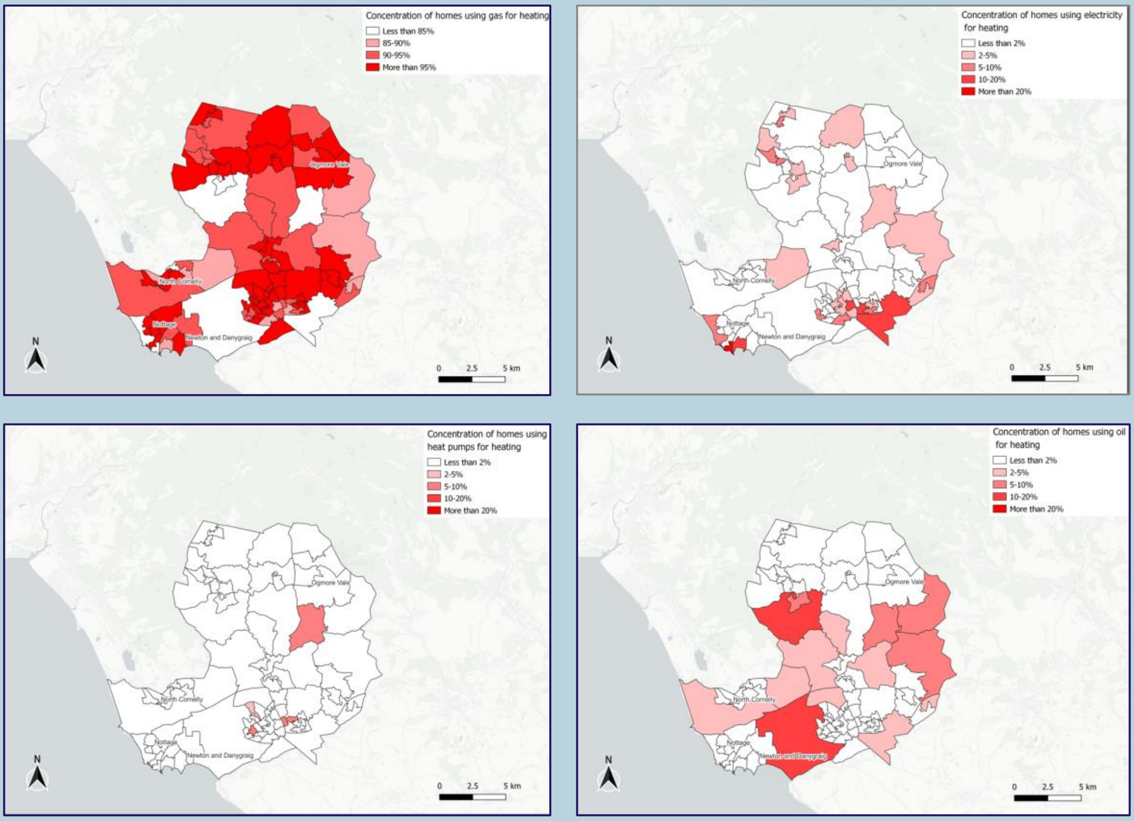


Figure 7-5 Breakdown of primary fuel types within Bridgend

The collected EPC data indicates the main construction band for North Cornelly, Nottage and Newton and Danycraig is between 1930 – 1975. However, for Ogmore Vale the dominant construction band is pre-1930s (Figure 7-6). However, the maps indicate that few dwellings in the Bridgend area could be considered “new builds”. New builds are typically seen as having more efficient building envelopes compared to older housing stock and are thus more likely to be suitable for heat pump adoption.

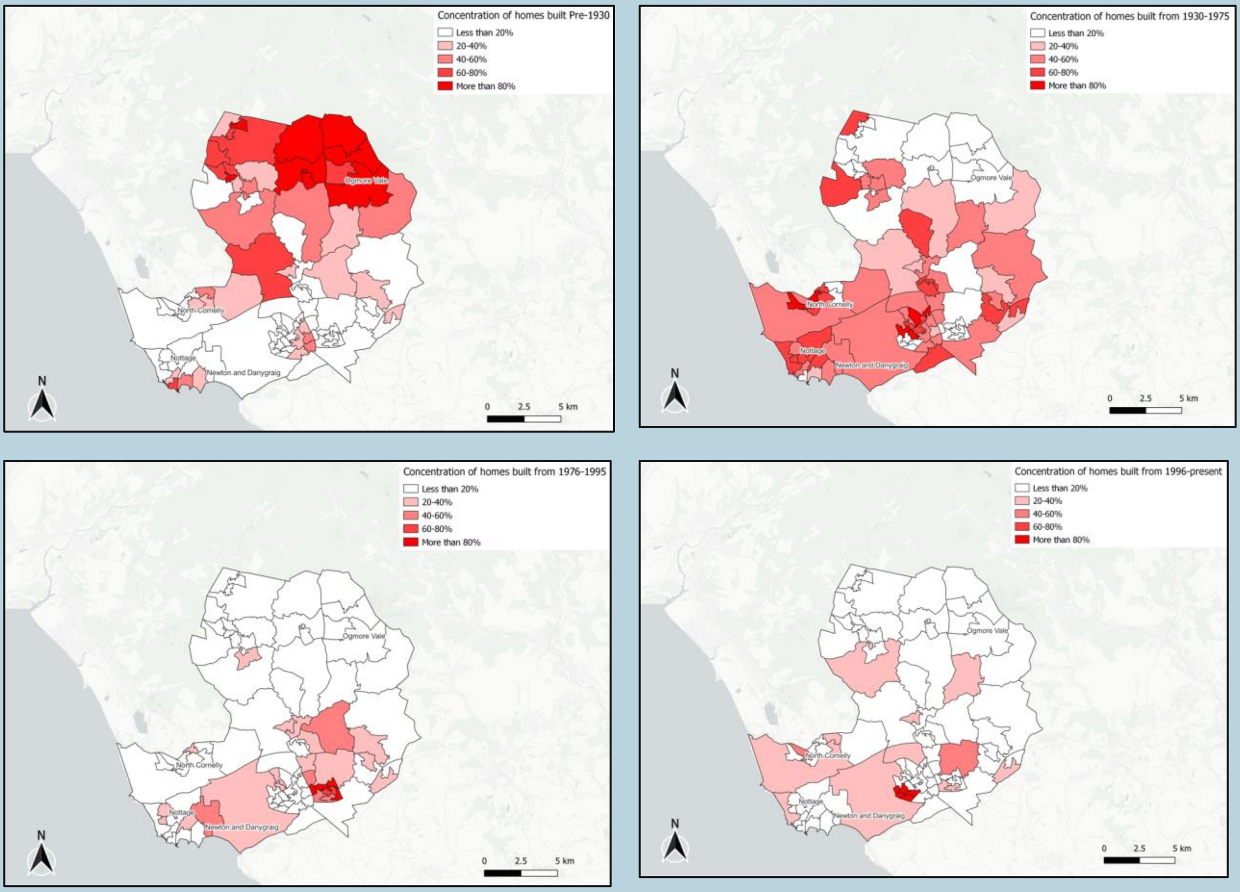


Figure 7-6 Distribution of domestic construction age bands within Bridgend

Figure 7-7 Categorised EPC data sets for the four study towns

Focus Areas

The baselining indicated that the selection of all four study towns for high-density domestic heat pump deployment was justified based on existing heating system type, wider societal benefits and having suitable build types. The fabric efficiency is in some instances challenging; however, this is relatively typical of other areas that fulfil the project KPIs (e.g., being settlements of a suitable population size).

The categorised EPC data was geolocated with the results displayed in Figure 7-7.

The majority of building stock within the four towns are category 2 and 3, indicating a high percentage of dwellings in the four towns has an EPC score of C or below. This indicates average to poor housing energy efficiency. This suggests some form of retrofit would be required to maximise heat pump performance. This aligns with the low average SAP score and the domestic age bands indicated by the area characterisation maps.

7.1.2.2 Electricity Infrastructure

When analysing the secondary substation headroom data, the results indicated a high occurrence of negative available capacity at the substation. This is unrealistic and indicates large inaccuracies in the data. It should be noted that Buro Happold have experienced similar inaccuracies when using similar datasets from other DNOs and other areas of National Grid's distribution network. These inaccuracies suggest the remaining substation headroom data may not truly be representative. For this project, where a negative headroom was calculated, the value was adjusted to zero. Ideally, improved DNO information would be available. More accurate readings of the headroom at each substation would improve the reliability of the modelling results, enabling greater precision when calculating the number of heat pumps that could be deployed in various locations. DNOs are improving the data available at this resolution, however, for confidence in the headroom availability a formal connection quotation would be required – which triggers the running of a full power flow model.

The graduated headroom per secondary substation is displayed in Figure 7-8. In the four study towns there are key areas that display both dense housing and a high electrical headroom. This information formed the basis of the cluster identification.

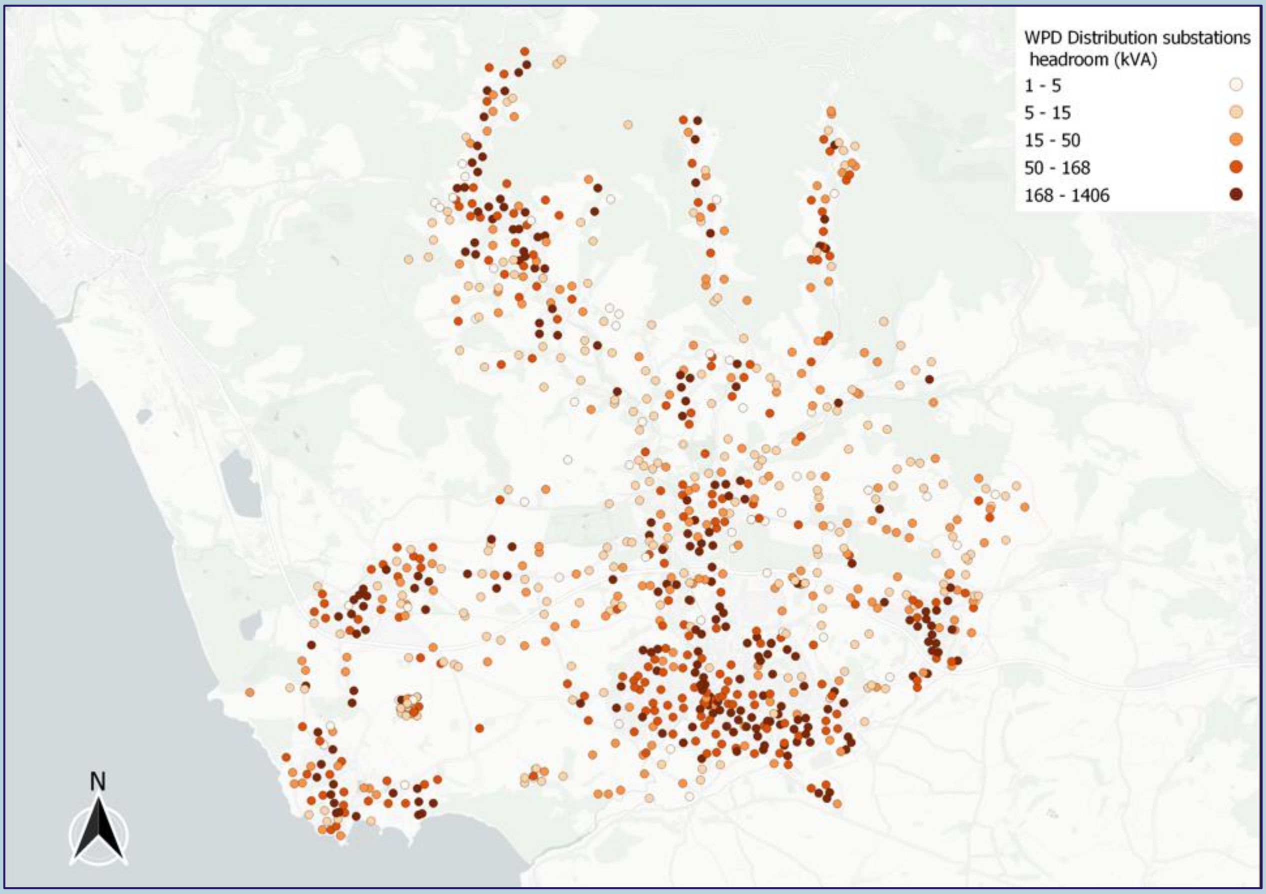


Figure 7-8 Headroom available per secondary substation

Figure 7-9 displays the distribution coverage per substation. Substations with zero or no values for headroom were classified as unknown or no headroom available. The high percentage of unknown or no headroom available polygons reflects potential inaccuracies in the data set. The available headroom for the secondary substations in each study town is displayed in Figure 7-10.

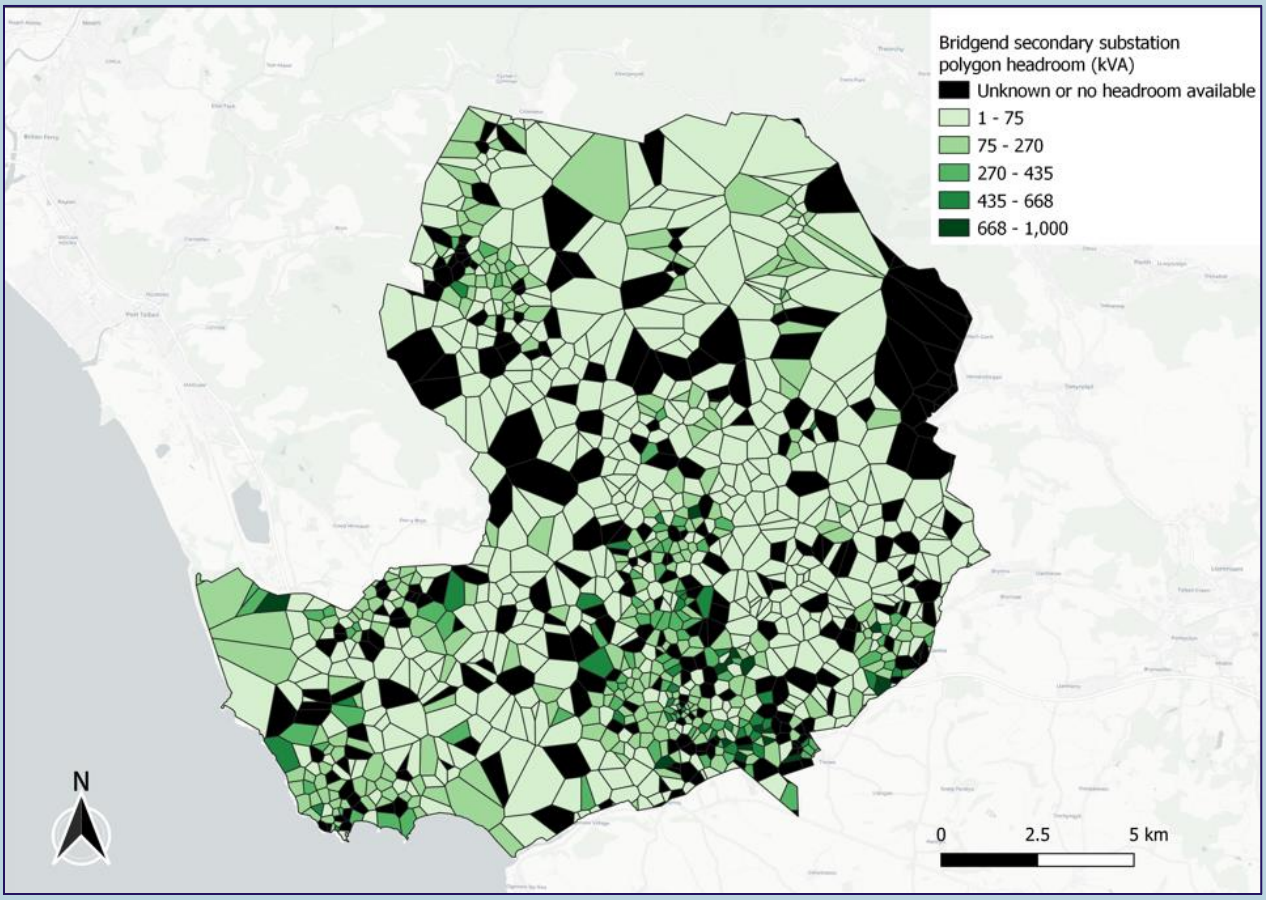


Figure 7-9 Distribution coverage per secondary substation with headroom across Bridgend

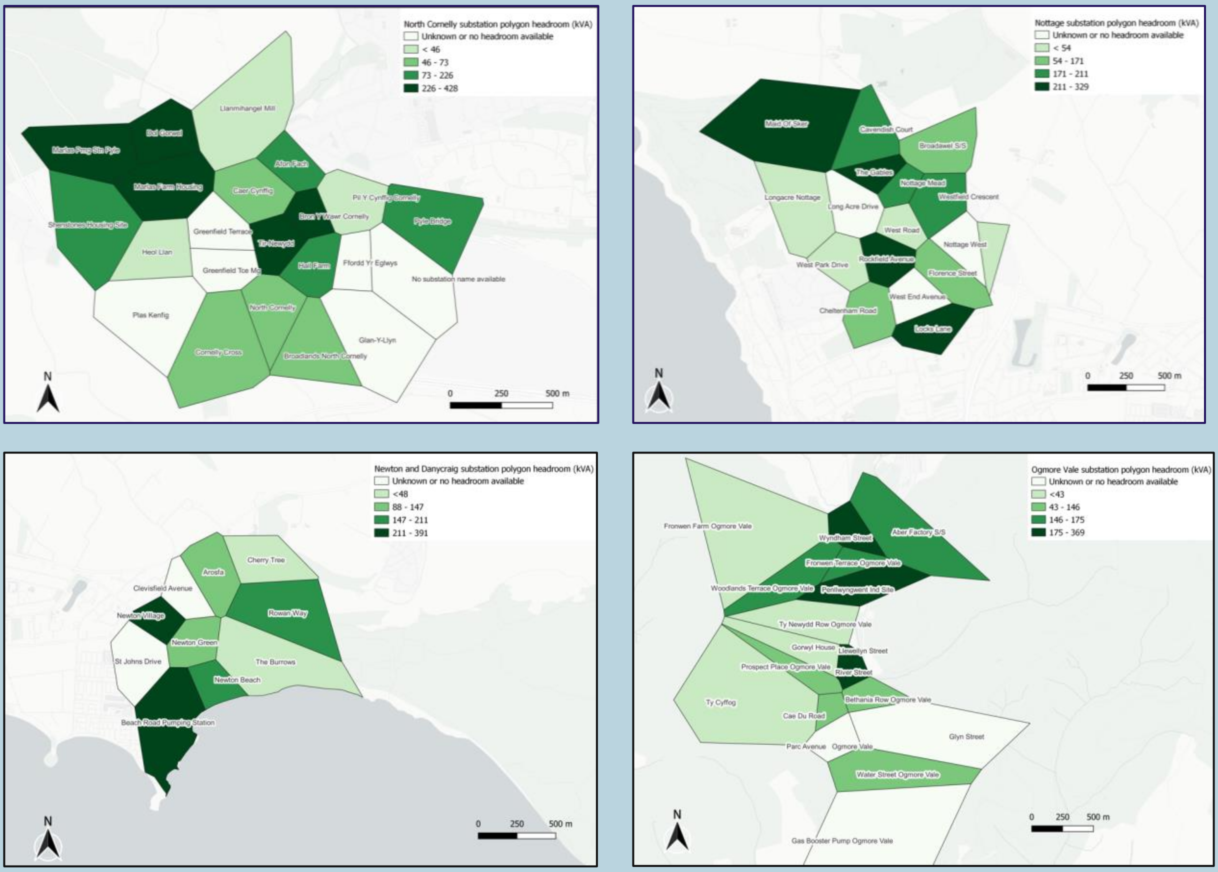


Figure 7-10 Headroom polygons for study towns

7.1.3 WP1.3 Analysis

The following figure displays the breakdown of archetypes present in the four clusters. Mid-terrace with solid walls is the most common archetype with compact semi-detached properties being the second most common. Although mid-terrace properties are primarily located within Ogmore Vale, the compact semi-detached homes are prevalent across all four clusters. The least common archetype was the various types of flats.

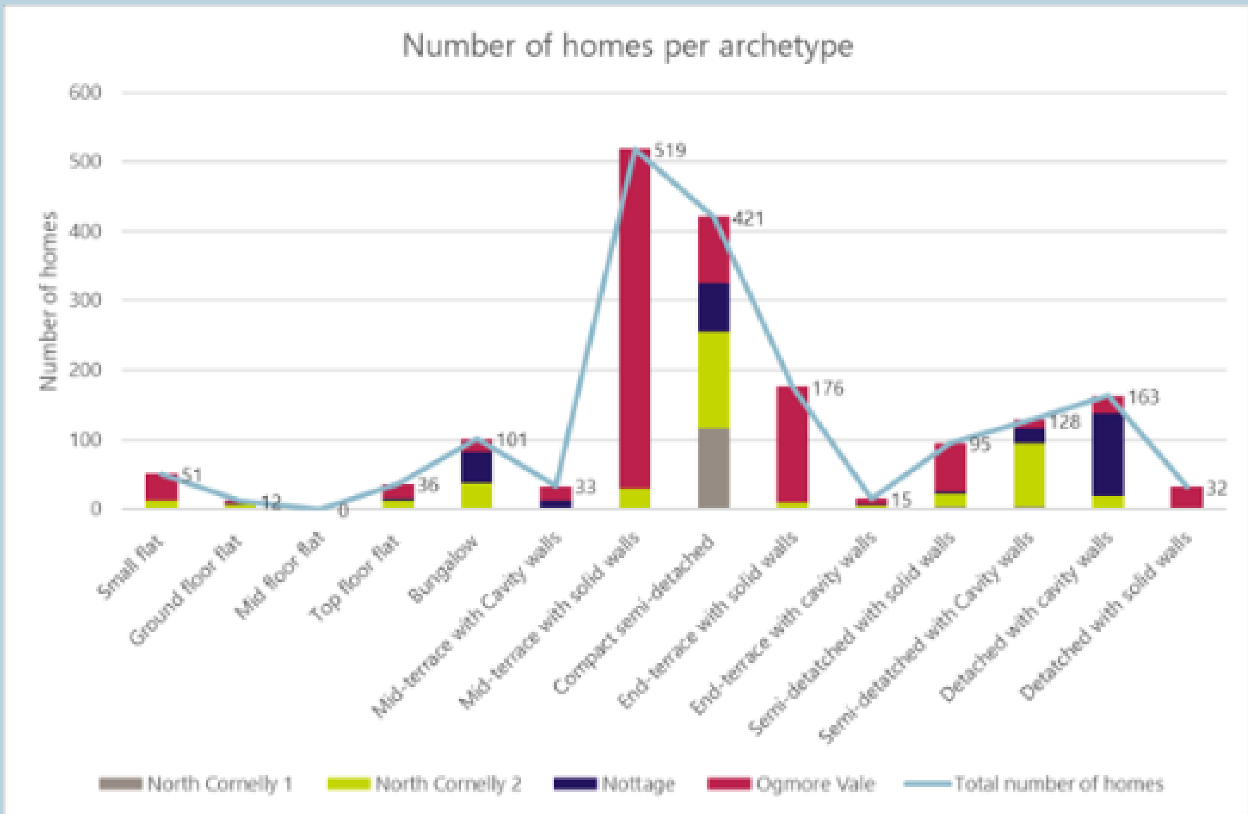


Figure 7-11 Breakdown of building archetypes within study area (graphic)

Ogmore Vale exhibited the highest heat demand per cluster due to the larger number of homes that were represented (Figure 7-12). North Cornelly 2 has the second highest number of homes, resulting in a greater heat demand than North Cornelly 1 and Nottage. The total heat demand per cluster does not provide meaningful insight about the characteristics of the housing stock in each cluster.

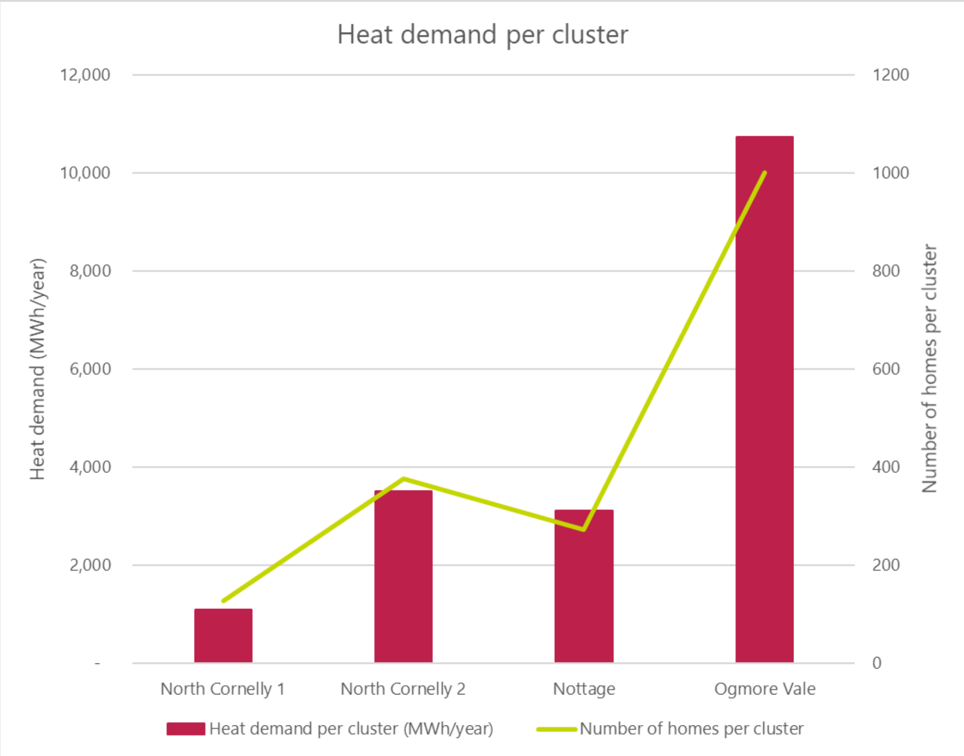


Figure 7-12 Heat demand (MWh/year) per cluster

Although it was expected that Ogmore Vale would have the highest mean annual and peak demand per home, Nottage displayed the highest values as seen in Table 7—2. This could be due to occupant numbers and behaviours in the dwellings. The size of the properties in Nottage were also indicated as being larger, due to more semi-detached properties existing in the area. However, Ogmore Vale displays a higher heat demand per m^2 value than Nottage. This indicates the properties in Ogmore Vale have a lower building envelope performance and less general energy efficiency measures installed. This suggests Ogmore Vale would benefit most from a retrofit approach in combination with the heat pump deployment.

Table 7—2 Heat demand breakdown per cluster

Cluster	Heat demand per cluster (MWh/year)	Average heat demand per household (MWh/year)	Average peak demand per household (kW)	Number of homes	Average dwelling size (GIA)(m^2)	Mean heat demand (kWh/m^2)
North Cornelly 1	1,104	8.6	2.3	130	80	106
North Cornelly 2	3,520	9.3	2.8	377	90	104
Nottage	3,112	11.3	4.1	274	104	109
Ogmore Vale	10,735	10.7	3.3	1,001	90	120

As compact semi-detached homes were prevalent across all four clusters they were taken forward for further analysis. In addition, due to Ogmore Vale consisting of primarily mid-terrace properties this archetype was also taken forward. A select number of properties would be surveyed in line with the community engagement element of this project. North Cornelly 2 and Ogmore Vale would be optimal for a shared loop system due to the dense nature of the housing. Decentralised ASHP systems could be considered for the targeted homes in North Cornelly 1 and Nottage as these homes are spaced further apart. This breakdown is displayed in Table 7—3.

Table 7—3 Archetype breakdown for further analysis

Cluster	Targeted Archetypes	No. Targeted Homes	Homes to survey	No. Homes to Survey	Homes sign-up 50%	GSHP + Shared Loop	ASHP
North Cornelly 1	Compact semi-detached and terraced	118	30%	35	18		18
North Cornelly 2	Compact semi-detached and terraced and similar	248	32%	79	40	40	
Nottage	Compact semi-detached and terraced	81	30%	24	12		12
Ogmore Vale	Compact semi-detached and terraced	615	28%	172	86	86	
	Total	1,062		311	156	126	30

7.1.4 WP1.4 Maps and Visualisations

The produced GIS maps were used to visually represent and spatially analyse the EPC data used for this project. Being able to overlay the substation headroom enabled suitable clusters to be identified. GIS mapping alongside the use of CAD software would be powerful tools for the Phase 2 analysis. Additionally, the data processed by GIS, to produce the relevant maps, could be linked to a digital twin for greater visual representation.

Table 7—3 Indicates the various scales used to visualise the data within this study. GIS maps were formed to assess the wider Bridgend area and relevant clusters. Once the clusters were identified, suitable graphics and illustrations were used to analyse the building characteristics in the area.

A key lesson learnt for replication of this study's methodology is that CAD software would be better suited for analysing electrical infrastructure at the LV level. Alternatively, the DNO would be required to supply LV layouts in GIS shapefile format. Shapefile format would allow greater integration with other workflows that are combined in GIS.

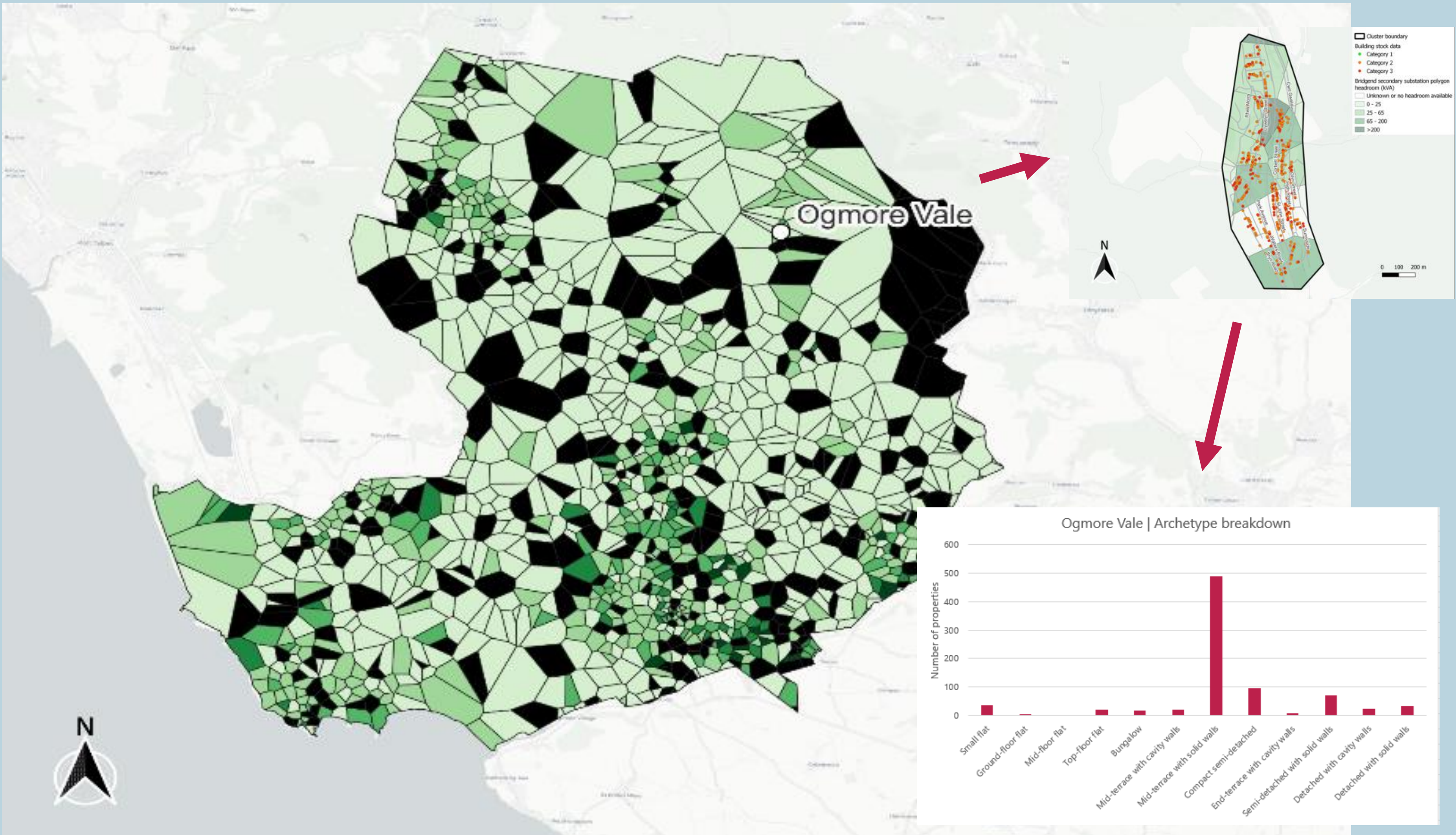


Figure 7-13 Visual representation of different data scale methodology

Using GIS software, OS survey street data was overlayed for each cluster. This was combined with the RAG categorisation of the EPC data. This process was used to identify streets with dense housing, which would have implications of the configuration of a shared loop system. Figure 7-14 displays the overlayed street data for each cluster.

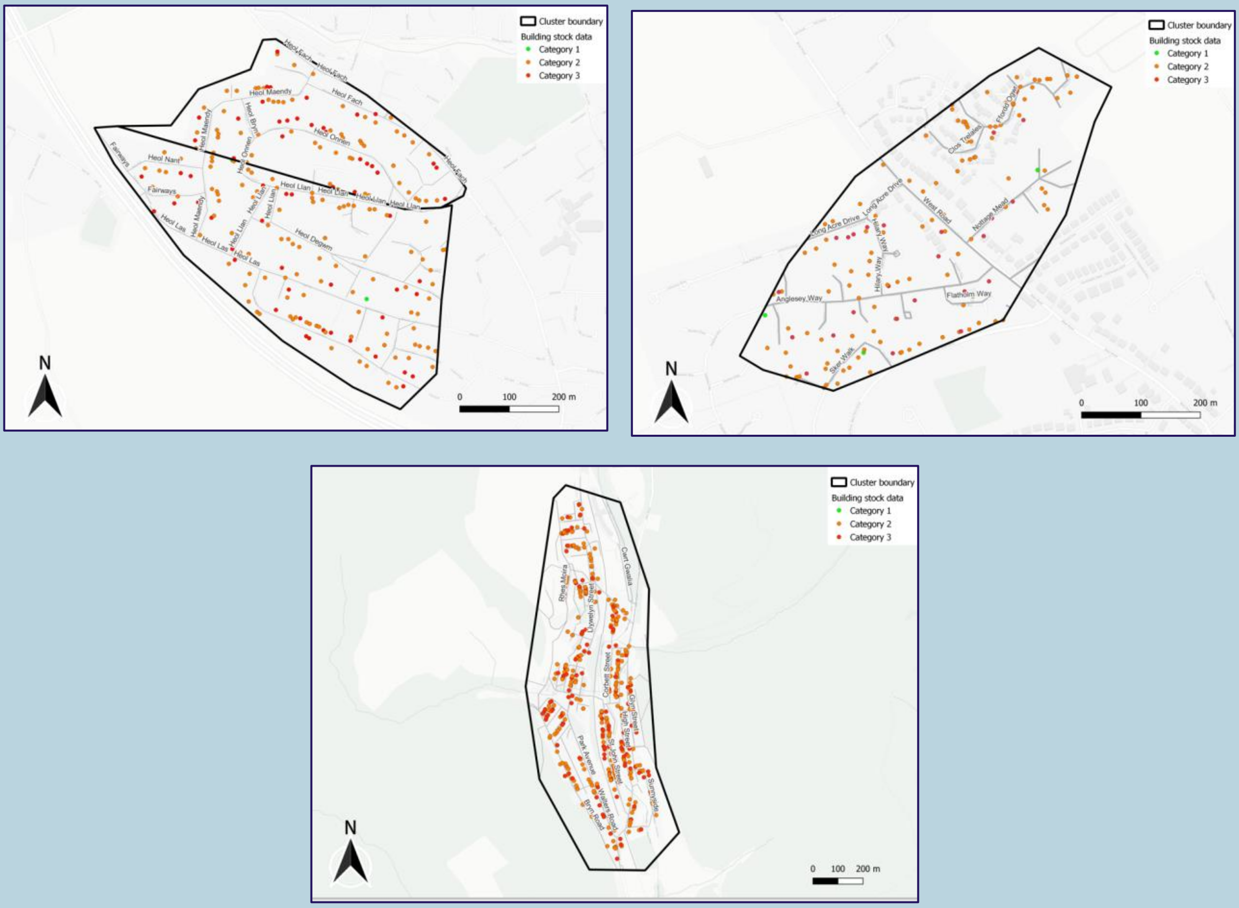


Figure 7-14 Cluster boundaries with street layouts added

The four clusters were identified using the methodology described in section 6.1.3. and the street layouts displayed in Figure 7-14, and Figure 7-15 shows the North Cornelly cluster with the categorised EPC data and headroom polygons overlayed. Although a portion of North Cornelly 2 is in an area where the headroom is unknown, further analysis of this particular section would be possible at Phase 2. A bottom-up approach towards the electrical assessment could be utilised for this particular region. Additionally, a more detailed breakdown of the electrical infrastructure data could be provided by the DNO.

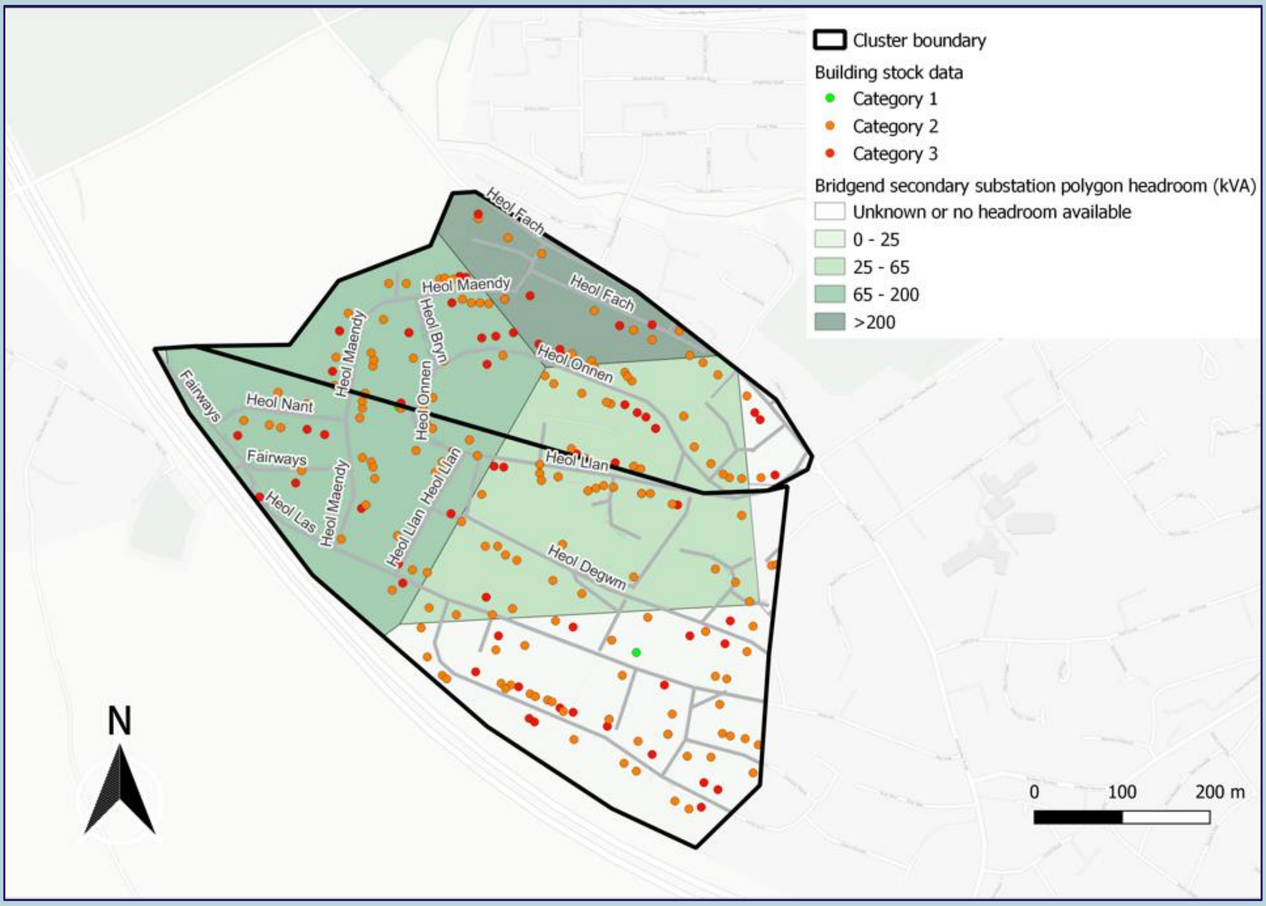


Figure 7-15 North Cornelly cluster visual analysis

Figure 7-16 Nottage cluster visual analysis shows the cluster identified in Nottage. As mentioned previously, this cluster is comprised of a majority of category 2 properties. The Nottage cluster has a greater number of properties than North Cornelly 1 but less than North Cornelly 2 and Ogmore Vale. Again, a section of the identified cluster resides in an area of unknown headroom capacity. This again suggests it is possible there are inaccuracies with the public access substation data and therefore greater collaboration with the DNO could be required in Phase 2.

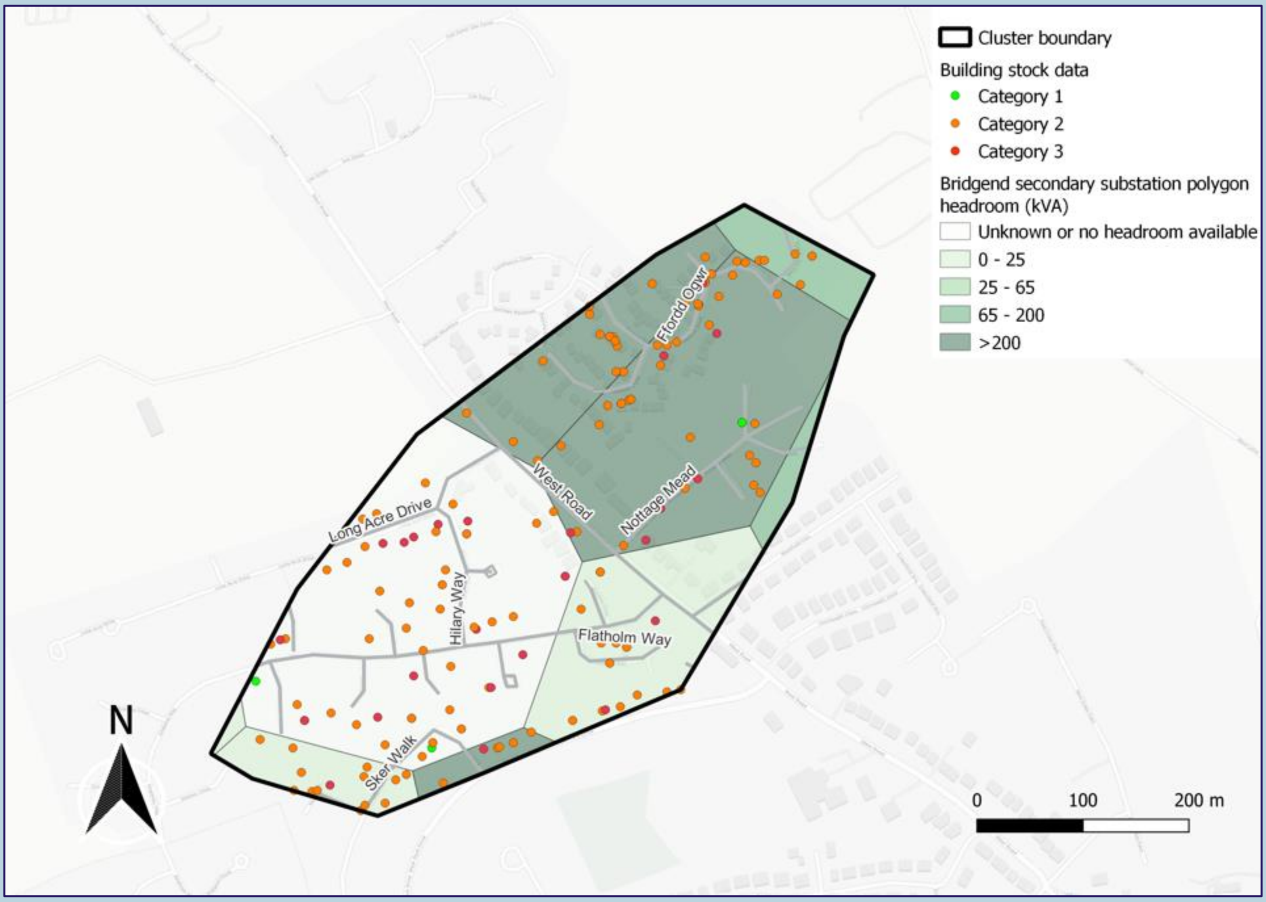


Figure 7-16 Nottage cluster visual analysis

The Ogmore Vale cluster contains the largest number of houses out of the four clusters. As indicated in Table 7—2 , the properties in Ogmore Vale have a high heat demand per internal floor area (kWh/m^2). Because of this it is anticipated more headroom would be needed per home than in other clusters. Ogmore covers more of the total town area than the other clusters, therefore a greater range of headroom polygons is covered in the defined cluster. This again illustrates the need for further electrical infrastructure analysis at Phase 2.

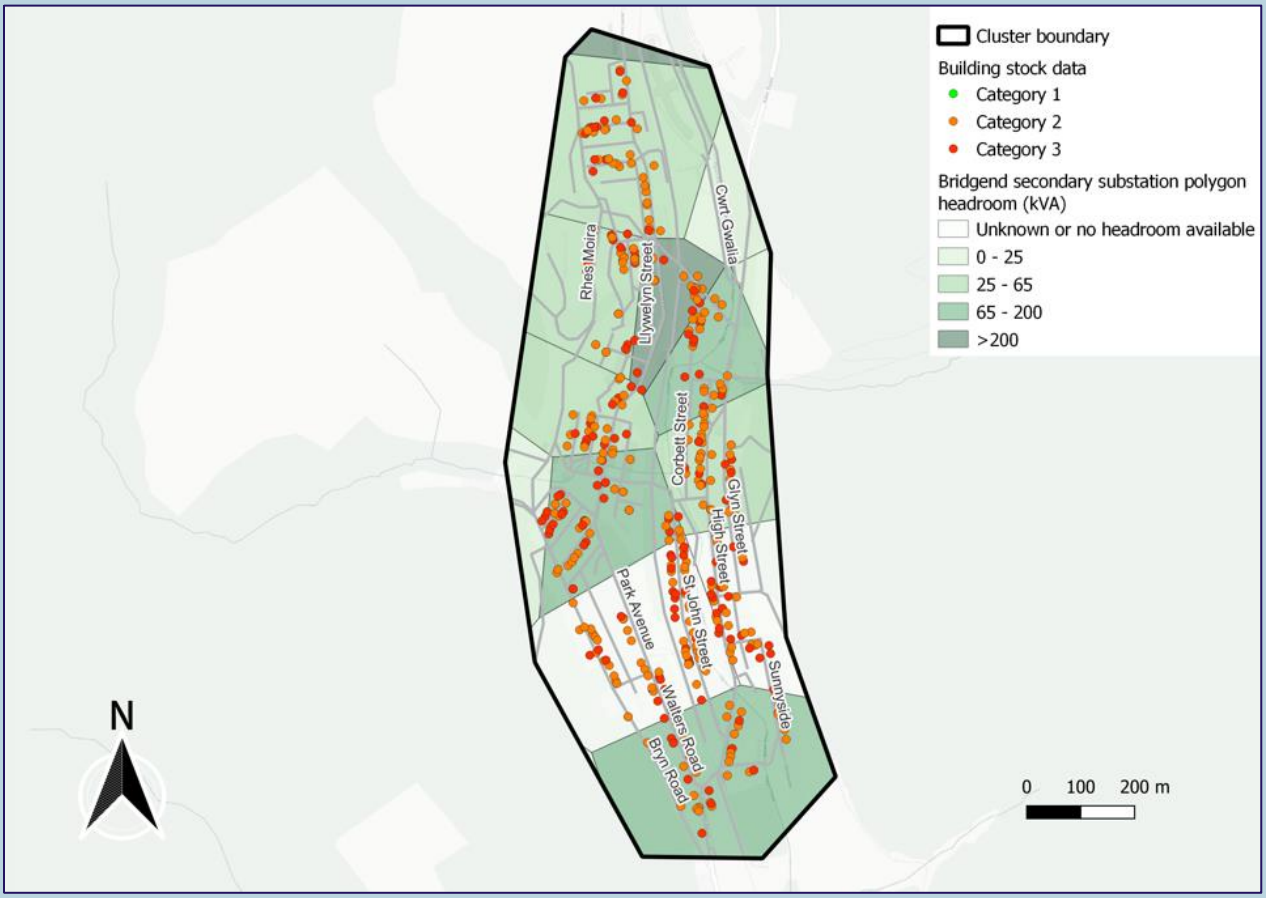


Figure 7-17 Ogmore Vale cluster visual analysis

7.1.5 WP1 Findings Summary

Using the outlined methodology, Buro Happold were able carry out an initial screening of the area, to determine suitable locations for further investigation into domestic heat pump uptake. The analysis starts at the local authority level, with investigations into local area characteristics. This informed site selection, before scaling down to the town level with an electrical capacity assessment. This informed areas for street level analysis, which was carried out to identify zones with potential for high-density heat pump deployment. Using this process household surveys were not required to identify target areas. However, household surveys provide key insight at later stages.

The energy baseline assessment indicated that it was likely there was available headroom in each of the clusters to withstand the increased strain on the electrical infrastructure. However, improved data quality would be required to support this assessment. Community engagement indicated there was interest into heat pump uptake within the selected cluster.

Nottage has the highest heat demand per household, due to the large properties within the area. Dwellings in the Ogmore Vale cluster have the highest heat demand per m^2 of internal floor area. This indicates that these properties would be able to reduce their heat demand through energy efficiency measures such as fabric retrofit. Reducing the heat demand in Ogmore Vale, and the other clusters, would have cost-saving implications in terms of low carbon technology sizing and electrical infrastructure capacity. Therefore, these findings should be carried forward and assessed further in Phase 2.

Manipulation and processing of the domestic point data enabled the most prevalent building archetypes to be established. It was concluded that compact semi-detached and terraced houses were most common across the four clusters. Ogmore Vale primary consisted of terraced properties whereas compact semi-detached houses were identified across all clusters. These trends align with established local area knowledge and feedback from the community engagement workflow, therefore supporting the accuracy of the methodology used. This suggests the established methodology could be replicated in other study areas.

Geolocating EPC and UPRN point data led to the conclusion that Ogmore Vale and North Cornelly 2 would be most suitable for a potential shared loop system due to the dense nature of the housing stock. Nottage and North Cornelly 1 potentially may be more suitable for an ASHP system, but a shared loop array could be feasible with further investigation.

The lack of data made available meant that the project relied entirely on open access data. This led to some innovative approaches in infilling and validation to create a baseline which was useable to carry out cluster level analysis. The methodology established in this feasibility study can thus be considered replicable across various other areas investigating high-density domestic heat pump deployment, without relying on complex and expensive modelling techniques (such as those in a LAEP) or the purchasing or signing of standard data sharing agreements (such as those required for OS Mastermap, OS Address Base Plus and Home Analytics).

The Energy Planning work package was able combine and feed into the various other workflows within this feasibility study. Dwelling location, building archetypes and levels of required retrofit was visually presented and fed into the Customer heat package assessment (Work Package 2). The overlaying of electrical headroom polygons was key to establishing appropriate clusters for high-density heat pump deployment and complimented the electricity network work package (Work Package 3). Key postcodes from the community engagement events (Work Package 4) were presented using GIS and were again a key parameter for cluster identification. The linking of various work packages using the described methodology and GIS visualisation added value both in terms of the screening process and data visualisation. However as discussed in section 13.2, improving the data quality would improve the outputs. Notably this includes data provision directly in control of the local authority; with the longer timeframes of Phase 2, issues with obtaining such datasets should be overcome.

7.1.6 Refined Methodology Based on Findings

This section provides a short summary of a suggested methodology for further work, which should use improved data to enhance the process and identify key clusters for heat pump uptake at secondary substation level. Once complete, a shortlisting process could be undertaken and, from this point, a manual manipulation of data to allow identification of clusters at LV feeder level. Interest in these clusters can then be communicated to WPD who will undertake in-house analysis to assess feeder suitability for uptake of heat pumps in at least 25% of houses. If a feeder passes, targeted stakeholder engagement will take place to try and achieve at least 25% sign up. A brief discussion of how this engagement process could be assisted by the technical team involved in Phase 1 is also provided.

7.1.6.1 Building Stock Characterisation

The first part of future analysis should be full characterisation of the domestic building stock in the focus areas identified in Phase 1.

Energy Savings Trust's Home Analytics dataset is proposed for this stage of the characterisation (alternatives such as Parity Projects exist but tend to require purchase for the whole local authority), as it provides fabric and demand data for all domestic properties, infilling where properties are missing. Home Analytics would be purchased for Phase 1 clusters as a minimum.

The cluster analysis from Phase 1 will be repeated using a similar methodology but with a complete domestic dataset.

As Home Analytics provides full domestic property coverage it allows for a bottom-up model of substation headroom (illustrated in Figure 7-18). This is useful as data confidence in the secondary substation headroom information is low, as using standard engineering equations there are many instances when very large negative headrooms are observed. It is therefore important to understand if certain areas are being artificially excluded due to poor data quality.

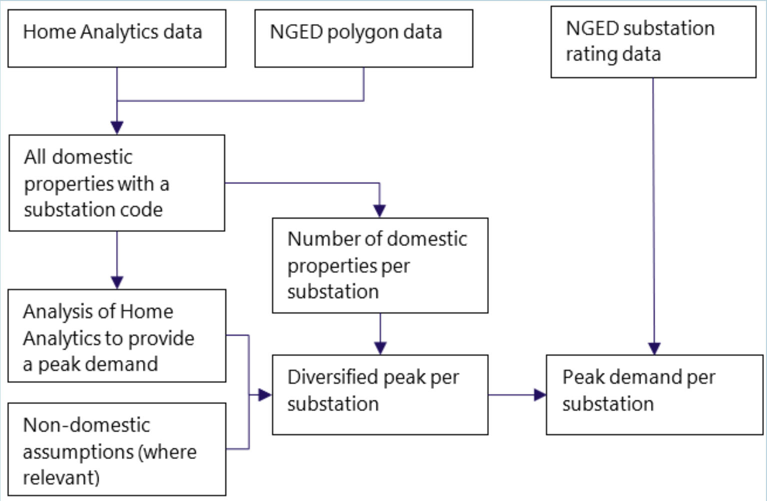


Figure 7-18 North Cornelly cluster visual analysis

This method will provide a useful validation of the NGED headroom data, to better assess available capacity for heat pumps.

7.1.6.2 Measured Data

The measured data from households could also be collected in future work. Based on Phase 1 insights 1950-1966 semi-detached properties are key typology capture within this being broadly representative of many of the initial clusters identified.

Measured data will help inform energy use for different properties, provide an indication of diversity of peak demands in the area, and inform the extent forcing factors impact demands in the local area (e.g., weather, time of day, day of week).

Houses who have already actively engaged with Phase 1 should be the priority for this free monitoring equipment and insights it will give. It is not vital that they are within a target cluster area, so long as the building is representative of those in a target cluster.

7.1.6.3 Network Information Strategy

NGED data is only available in a GIS format to secondary substation level. A further limitation is the polygons provided by NGED and used to establish which properties are served by which substation are of questionable accuracy, as highlighted by overlaying the NGED polygon data over images of the LV networks. These two factors mean in future stages manipulation of the base NGED data is required to better assess network readiness for heat pumps.

Digitising LV Data

The LV data was provided in CAD format for Phase 1. This can be entered into GIS but is inaccurate. Once the advanced cluster prioritisation has been completed, based on the property suitability analysis for heat pumps (that would be enabled by higher quality data in further work) and the bottom-up secondary substation headroom analysis, manipulation of the LV network will be undertaken for the priority clusters. This will likely require manual manipulation of feeder and service cables data to ensure each property connected in a priority cluster can be associated with either one or two secondary substations (depending on the network configuration).

Establishing Headroom

Once every property has an associated feeder the impact of different levels of heat pump penetration on the feeder can be assessed (informed by the demand modelling). Firstly, the current demand on the feeder should be assessed based on the Home Analytics information for each property, repeating the process in Figure 7-18 but at a feeder rather than secondary substation level. WPD will be engaged to help establish the capacities of different LV conductors (as this information is not currently available), if this information is not available a standard set of assumptions (based on the experience of whoever carries out this future work and input from NGED) could be applied and from this the current headroom can be calculated.

7.1.6.4 Demand Modelling

The change in electricity demand could be calculated based on the property information gathered through Home Analytics and any scaling based on insights from the in-situ measured data could also be applied. Also, any additional information gathered through meter information, or similar insights, should be incorporated. This can be added to the existing demand capacity, following standard diversity assumptions.

A key decision point at this stage will be if any improvements in fabric efficiency should be included in the heat pump modelling assumptions. The Home Analytics data allows a focus on certain parameters based on costs, e.g., cavity wall insulation may be considered a reasonable cost, whilst external wall insulation could be considered prohibitive. These improvements in fabric efficiency can then be fed back into the demand model.

7.1.6.5 Summary of Approach

A high-level summary of the approach suggested for further is provided in Figure 7-19.

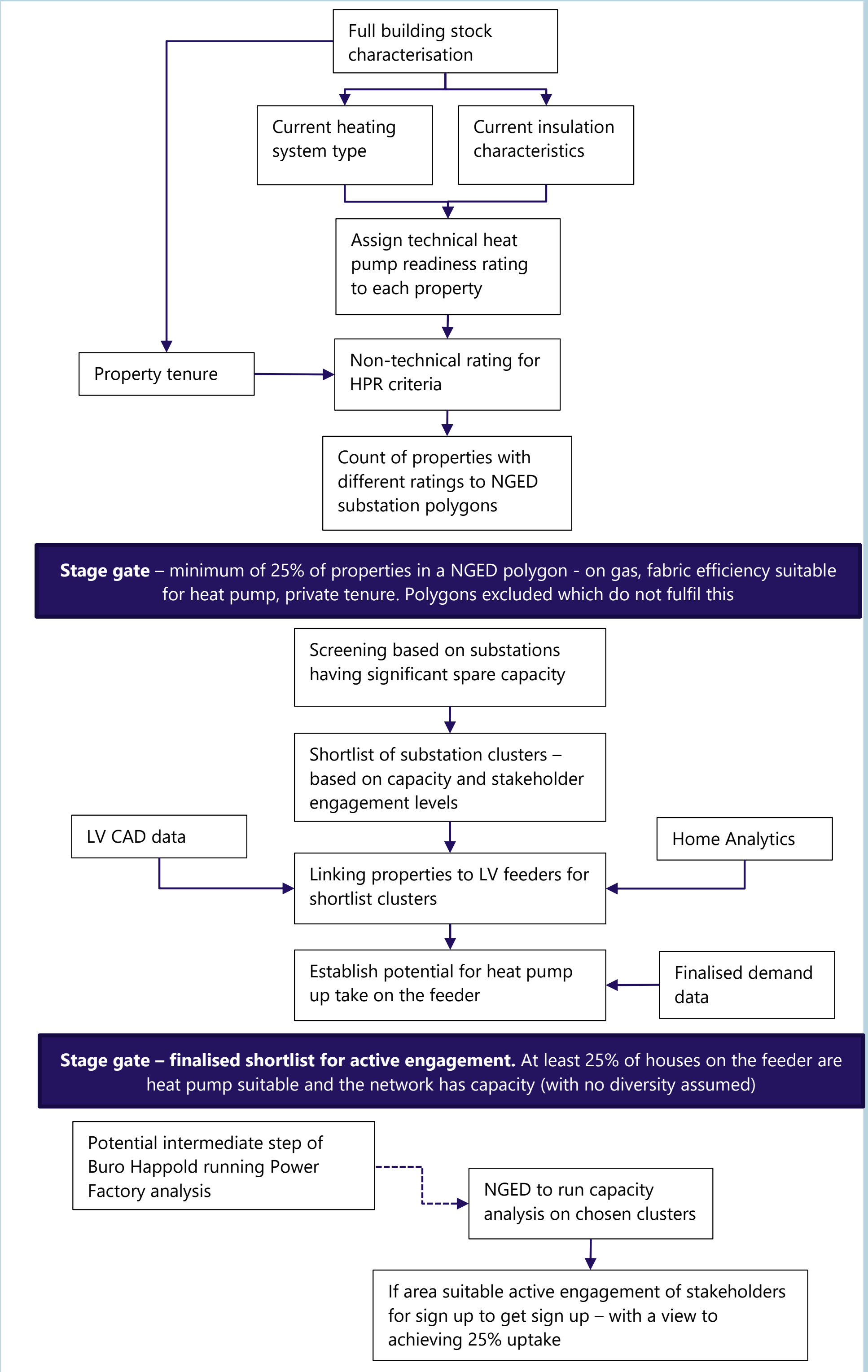


Figure 7-19 High level overview of suggested next steps

7.1.6.6 Engagement Process

Having an effective engagement process is integral to realising the next stages of the project. The community actively buying into the opportunity is a key enabler of this process.

One of the fundamental ways interest could be attracted is through the creation of a digital twin. This provides a clear visualisation of their community and can even show their own house and the benefits shifting to heat pumps will bring. An example of this is shown in Figure 7-20.

Figure 7-20 Example building dashboard for the digital twin for Communiheat – in this case showing the benefit of switching from oil to air source heat pumps

In the example above every household in the Communiheat area was given a unique login to the digital twin, allowing them to see detailed information about their own house. There was also a general level of login where information that is not GDPR sensitive is displayed. An example of the kind of information which could be displayed at this level is provided in Figure 7-21.

Figure 7-21 Example dashboard for the digital twin for Caerau (Bridgend) – providing information regarding a district heat network

As well as illustrating and allowing stakeholders to engage with the project the digital twin is also useful from a modelling perspective. Helping to visualise and analyse different energy system components and vectors in a dynamic manner.

It is proposed a digital twin for the target cluster areas could be created in future work. With wider non-detailed access being made available to the wider community.

This digital twin will sit alongside targeted doorstep engagement at the cluster level. There could be potential to show the digital twin platform during these in-person conversations, which is again seen as likely to aid engagement.

Ground Investigations

A more detailed assessment of the geographical and topographical conditions and indeed constraints could be undertaken in all study areas during a heat pump deployment project. One area of note is Ogmore Vale which is an old mining village in a steep-sided valley to the north of Bridgend. This village, which was built during the mining era, is comprised of mostly stone terraced housing accessed directly from the adjoining pavement; heat pump installation could be challenging due to availability of land for access by a borehole drilling rig. Detailed ground investigations are recommended to be carried out to investigate the effects of past extensive coal mining.

7.2 WP2. Customer Heat Package. Kensa Contracting

This section presents findings from Work Package 2 on the Customer Heat Package, by Kensa Contracting. Findings from the work package section are interrelated and are therefore presented as one coherent set of findings.

Please see the findings from the energy planning, engagement, and electricity network work packages for the more targeted selection of areas inside Bridgend County and the technologies considered suitable in the clusters of homes identified for potential high-density heat pump deployment.

7.3 Initial Estimates for Cost of HP to Customer

7.3.1 Cost without Grant and Investment Support

To evaluate the value for money of investment done by BEIS in the form of the HPR programme or potential investment support into ground array, an initial estimate was done to understand the full capital cost to consumer where grant support (like HPR) or third-party investment into a ground array are not available. These estimated costs are based on current market prices. As part of the HPR programme, BEIS provided a template calculator called the "Cost to Consumer Calculator" to be used across all feasibility studies. This helped present the cost of heat pumps for homes and was a tool used to base the calculation. Table 7—4 shows the full capital cost to consumer for mid-terraced with solid walls and semi-detached with solid walls with no grant support or any investment into ground array.

Full capital cost to the consumer is ~£24k for typical mid-terraced with solid walls including fabric measure cost and ~£28K for typical semi-detached with cavity walls properties after light fabric measures. Table 7—4 shows the cost breakdown, where the Shared Ground Array (SGA) costs are reflected under "other ancillary building costs", working within the category types available in the cost template provided. The SGA cost includes the shared ground loop and boreholes cost. Capital cost breakdown for GSHP & ASHP has been presented in the annex, "Lifetime cost to Consumer".

This project has focused on semi-detached houses which either have an EPC rating close to C or need very minimal fabric upgrade and internal pipework to bring to close to C or Low D.

Table 7—4 Cost to Consumer – Full capital cost to consumer without grant or ground array investment for Shared Ground Arrays HP solution[22]

		Mid-terrace with solid walls	Compact semi-detached	
Dwelling heat pump	Equipment	£3,308	£4,127	
	Installation	£1,650	£1,650	
Cost of heat pump equipment and installation				
Building fabric upgrade	Materials	£600	£0	
	Installation	£400	£0	
Costs related to building fabric upgrade work to improving thermal performance				
Window upgrade	Materials			
	Installation			
Costs related to window thermal upgrades				
DHW storage	Equipment	£1,000	£1,000	
	Installation	£624	£624	
Cost of upgrade to DHW storage required for efficiently utilising the heat pump.				
Heat emitter upgrade	Equipment	£1,800		
	Installation	£1,720		
Cost of upgrading radiators to efficiently utilise the heat pump				
Other ancillary building services related costs	Materials	£11,318	£18,758	
	Installation	£1,370	£1,380	
Cost of other building services related to the heat pump installation				
Associated renewable energy generation systems	Materials			
	Installation			
Cost of providing renewable energy generation with the heat pump installation				
Capping of gas supply		£550	£550	
Total full cost to consumer		**£24,340**	**£28,089**	

[22] Under ancillary building services subheading the given cost includes the cost of boreholes drillings and the cost of heat distribution system (trenching cost to connect boreholes to buildings, manifold, and expansion valves) as part of shared ground array (SGA) solution. The given cost is based on 80% uptake rate and borehole and trenching on public roads. Proposed funding mechanism is to spread these ancillary building upfront costs into longer-term running costs, thereby reducing barriers, given the shared ground array is estimated to last 100+ years. Semi-detached houses need more heat compared to terraced house which increased the borehole cost and the cost of trenching due to small garden and car park in front of the dwellings.

7.3.2 Cost with HPR Grant and Private Investment Support

The upfront cost to consumer is reduced significantly with the help of the HPR grant and, by extension, when private investment into Shared Ground Array is brought in by a company such as Kensa Utilities Ltd (Table 7—5). Under the "split ownership/street by street business model" arrangement, heat infrastructure provider (Kensa Utilities Ltd.) could fund, own & operate the shared ground array (including boreholes, pipes, manifolds), which extends to the outer wall of each dwelling connected up to the shared ground array. This leads to reducing the capital upfront cost to the consumer. The customer/end-user own and be responsible for the heat pump and the internal distribution system from the dwelling up until the outer wall of the dwelling.

Table 7—5 Cost to Consumer – Full capital cost to consumer with HPR grant and private investment for Shared Ground Array HP solution

		% Payable upfront by consumer for Semi-detached	Mid-terrace with solid walls	% Payable upfront by consumer for Semi-detached	Compact semi-detached	
Dwelling heat pump	Equipment	0%	£3,308	0%	£4,127	
	Installation	0%	£1,650	0%	£1,650	
Cost of heat pump equipment and installation						
Building fabric upgrade	Materials	0%	£600	0%	£0	
	Installation	0%	£400	0%	£0	
Costs related to building fabric upgrade work to improving thermal performance						
Window upgrade	Materials	100%		100%		
	Installation	100%		100%		
Costs related to window thermal upgrades						
DHW storage	Equipment	0%	£1,000	78%	£1,000	
	Installation	100%	£624	100%	£624	
Cost of upgrade to DHW storage required for efficiently utilising the heat pump.						
Heat emitter upgrade	Equipment	100%	£1,800	100%		
	Installation	100%	£1,720	100%		
Cost of upgrading radiators to efficiently utilise the heat pump						
Other ancillary building services related costs	Materials	0%	£11,318	24%	£18,758	
	Installation	100%	£1,370	100%	£1,380	
Cost of other building services related to the heat pump installation						
Associated renewable energy generation systems	Materials	100%		100%		
	Installation	100%		100%		
Cost of providing renewable energy generation with the heat pump installation						
Capping of gas supply		100%	£550	100%	£550	
		100%		100%		
Total upfront capital cost to consumer			**£6,022**		**£7,833**	

It is evident that the capital upfront cost to the consumer reduced to almost 72%-75% with the grant support and "Utility Style Private Investment" into the shared ground array heat pump solution which is expected to help engage and recruit more customers for heat pump deployment.

The £6000 grant from HPR approximately provides support ranging between 21% to 25% of the total capital cost per household. Utility style private investment into shared ground array infrastructure equates to the ~47%-51% of total capital cost.

The combination of the split ownership funding structure and grant requires the end customer to arrange the remaining 25-27%. Nesta studies[23] show 32% of people could be willing to pay £6k-£7k for a heat pump.

The Boiler Upgrade Scheme (BUS) figures state that the upfront cost is on average £13k[24] for ASHP, so £8k after BUS grant for ASHP and so it is apparent that proposed funding structure offer could be therefore the least expensive option to the end consumer for both building archetypes. There could potentially be opportunities for bulk purchasing of ASHPs, however, this was not considered as part of this feasibility study – the focus of this feasibility was on GSHP+SGA for space-constrained properties.

The impact from bulk purchasing and consumer engagement could lower the average cost of ASHP system. For SGA approach, a factor of 10% reduction in overall price is projected for bulk buying, however, to have the fair comparison in the cost analysis neither bulk buying nor consumer engagement factors were considered for any HP technologies.

This remaining upfront cost could be expected to be paid by either 1) Option 1: Directly by the customer as an upfront capital cost, or 2) Option 2: Alternatively, the required upfront cost could be paid in form of loan. In the presented business model, the loan would have to be arranged by consumer independently (e.g., a customer bank loan).

These offers demonstrate potential high-density roll out of heat pumps across the UK that can serve properties that would otherwise be unable to convert to heat pumps.

7.3.3 Ongoing Annual Operation & Maintenance Costs - All Applicable Regular Ongoing Costs on a Dwelling per year Basis (£/dwelling/year)

Overall, ongoing annual operation & maintenance costs to the consumer could include the below costs:

1. Fuel cost to run the heat pump at the end user side
2. Servicing, repair and maintenance cost of heat pump for the end user
3. Replacement cost of equipment (HP and DHW at the end of life of the product)
4. Standing charge to be paid by the end user in case of SGA HP heating system
5. Finance repayments for any deferred initial costs where upfront cost could be paid in form of loan

Depending on the upfront payment option chosen by consumer, ongoing annual operation & maintenance costs could be different for different dwelling types.

The estimation of ongoing annual operation and maintenance costs in the assessment are based on assumptions as provided in Table 7—6 for different heating systems. These estimates are based on Kensa's project experience.

[23] https://media.nesta.org.uk/documents/Estimating_the_couldingness_to_pay_for_a_heat_pump_v1.pdf
[24] https://www.gov.uk/government/statistics/boiler-upgrade-scheme-statistics-september-2022
• Boiler Efficiency: https://www.britishgas.co.uk/home-services/boilers-and-heating/guides/boiler-efficiency.html

Table 7—6 Ongoing operation and maintenance costs

System Assumptions	GSHP	GSHP - Funded	Gas Boiler	ASHP	Direct Electric
Expected Replacement Schedule (years)	25	25	10	12	20
Service cost (£)	-£100	-£100	-£100	-£100	-£100
Service Frequency (years between services)	3	3	1	1	1
System Efficiency	310	310	80	240	100

Due to the close proximity of the deployment site to the coast, expected life of ASHPs is assumed to be lower than the usual 15 years (including the case where ASHPs have a protective coating, as described below).

Heat pumps have a lower lifetime in coastal areas. This is due to the saline environment, which causes corrosion and gradually destroys equipment over time. Corrosion also causes an eventual decrease in capacity and consequent increase in energy consumption. Heat pumps positioned in coastal locations are more prone to corrosion than heat pumps located within dwellings. There are protective coatings that can be applied to the heat pump to avoid corrosion. These needs to be applied at the time of installation and may need touching up over the life of the unit. Due to a lack of data on the effectiveness of treatment, the conservative value for ASHPs has been assumed in the analysis.

A boiler efficiency of 80% is assumed due to the fact that, over time, boiler efficiency declines. As boilers near the end of their economic life they have relatively low efficiency[25].

Low efficiency of ASHPs is assumed. ASHPs are much more at risk of inefficiency in cold weather due to the exposed piping, especially when compared to the concealed ground source heat pumps. As a result, the ASHP could need to work extra hard in order to remove any ice that has formed in or outside of the system. It is important to note that ASHPs usually use an auxiliary heater in order to maintain their ability to create heat on cold days. So, while this allows the pump to continue working to heat the home, it is not a cost-effective option.

Typically, the defrosting cycle[26] takes place between ambient temperatures of approximately 10°C and 0°C. In the UK maritime climate where these reflect typical winter temperatures, it is therefore crucial that the efficiency of the defrost cycle is taken into consideration. The true efficiency of air source heat pumps can be difficult to ascertain. Their performance in test conditions is usually based on an inlet temperature of 7°C, which is not realistic, as the air temperature fluctuates.

[25] https://www.boilerguide.co.uk/articles/erp-boiler-efficiency-explained
[26] https://www.cibsejournal.com/cpd/modules/2010-02/

7.3.4 Summary of HP Cost Analysis Outcomes

With the support from the HPR grant and availability of 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 constraints that make standalone ASHPs an unsuitable solution for the following reasons:

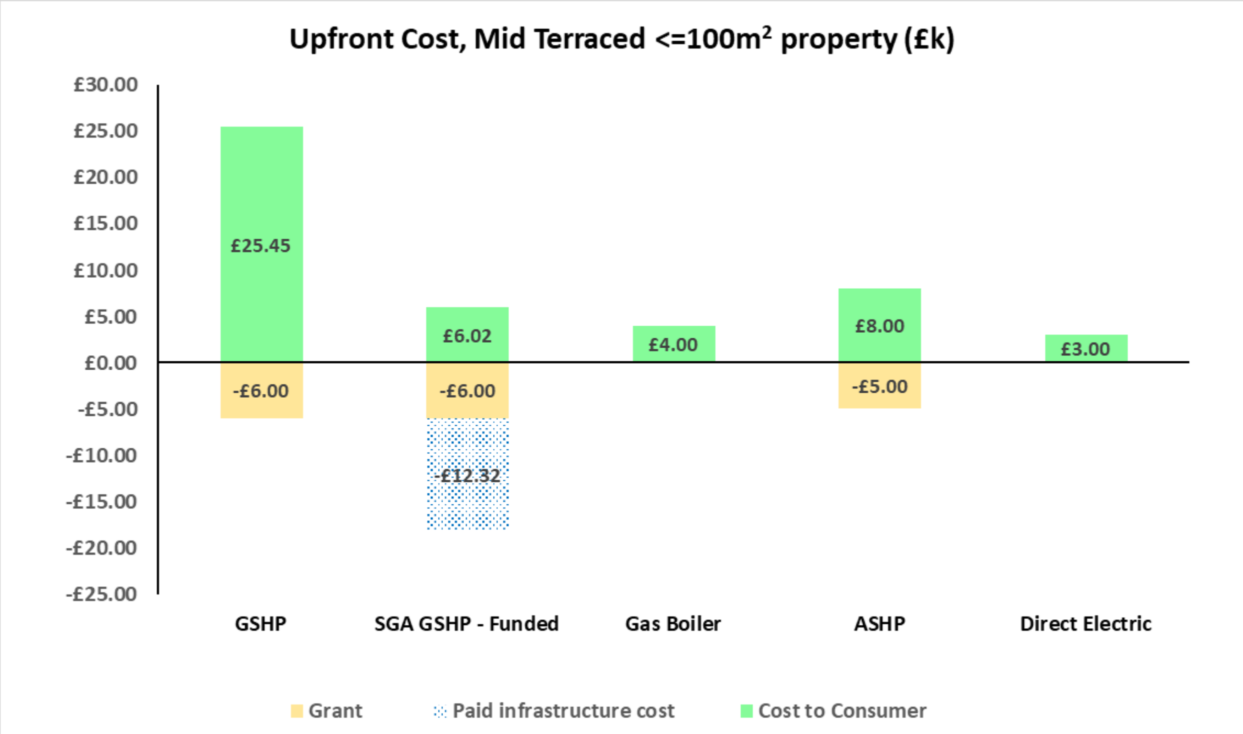
- Space constraints and aesthetics
- Noise generated by air source heat pumps, proportional to the size of the heat load
- The efficiency and capacity of the system and thus the thermal comfort is lowest on the coldest days
- Planning restrictions over unit location and acceptable noise levels
- Distance from the coast: Any property within 4 miles of the coast is particularly vulnerable to corrosion from the salty air which reduces the lifetime and increase the overall maintenance cost
- Ice formation on the outdoor unit occurs at temperatures between 0˚C – 5˚C and high humidity, which reduces the performance by up to 20% as defrost cycling occurs, dependent on the specific appliance. The UK often has cool, moist days leading to ASHPs to run defrost cycles. This not only reduces efficiency but has a considerable, sporadic, and highly significant impact on the grid – potentially exacerbated by additional direct electric heating being used to supplement such occasions.

7.3.4.1 Option 1: Customers Pay the Remaining Upfront Capital Cost

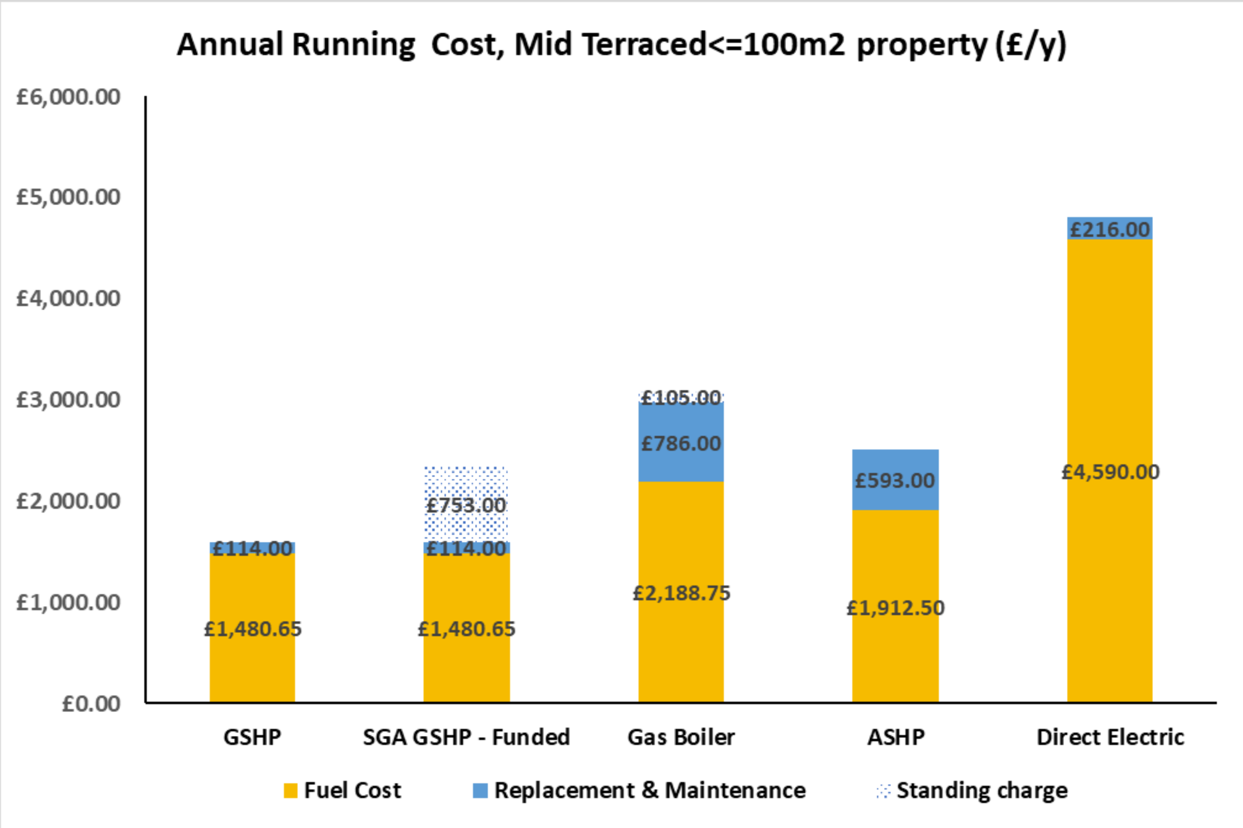
Cost analysis shows that a shared ground array heat pump solution has the lowest upfront cost to customer compared to other heat pump solutions and keeps the running cost similar to the gas boiler equivalent, because of its lower fuel bill due to highly efficient system and lower replacement and maintenance cost (Figure 7-22**Error! Reference source not found.**). Overall Shared Ground Array Heat pump system makes the most cost-effective heating solution for end users to decarbonise solid-wall mid-terraced houses. This allows ground-source heating to be established in areas where alternatives such as air-source heat pumps are not viable due to outside space restrictions.

	GSHP	SGA GSHP - Fundec	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			
Cost to Consumer(£k)	£25.45	£6.02	£4.00	£8.00	£3.00

Figure 7-22 Solid wall Mid-terraced houses with floor area less than 100m² Scenario



	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	£593.00	£216.00
Standing charge(£)		£753.00	£105.00		



Semi-detached houses with floor area of 100m² Scenario

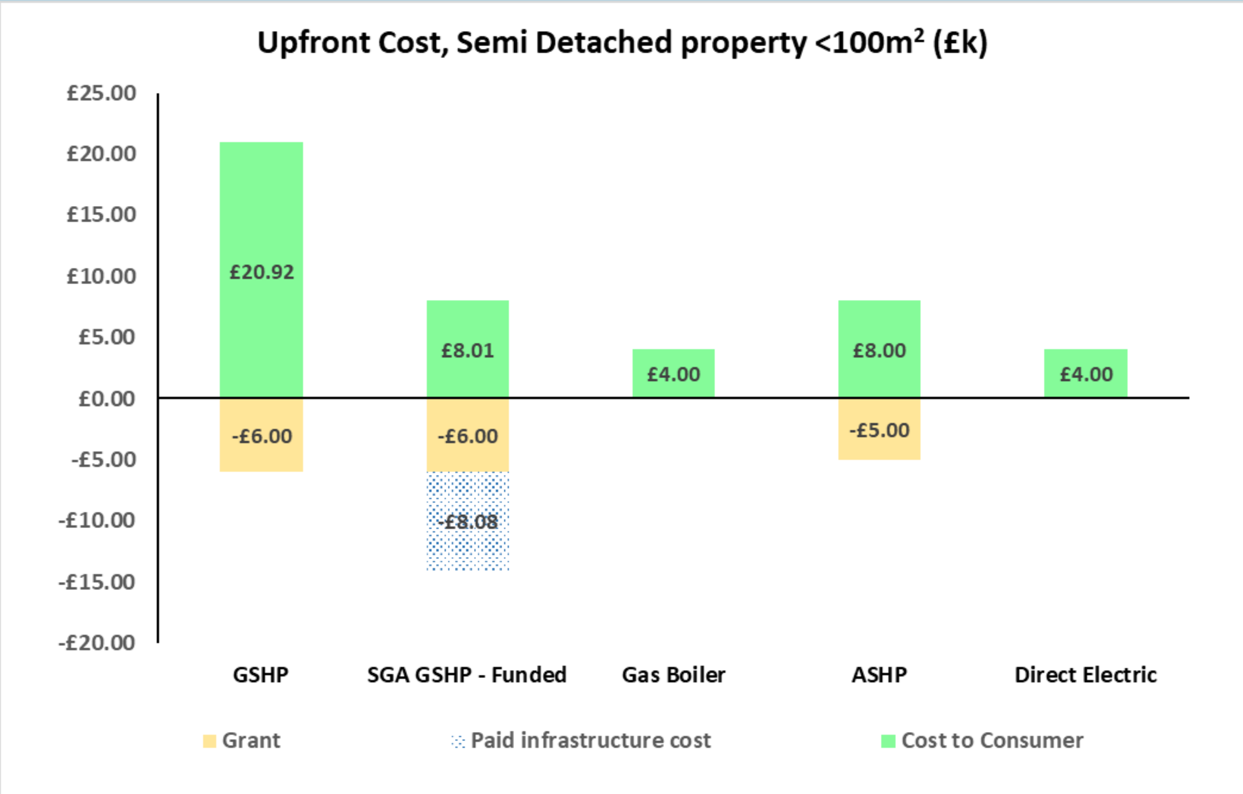
From the IMD dataset, it has been found that the socioeconomic conditions for semi-detached homeowners are better. For that reason, these properties are assumed to have a higher upfront cost to the customer compared to mid-terraced properties.

Due to the high heat loss coefficient and annual heat demand for semi-detached houses, shared ground array costs increase due to a greater number of boreholes drilling and longer trenching cost which increase the investment amount per property and so the annual standing charge for the end user increases.

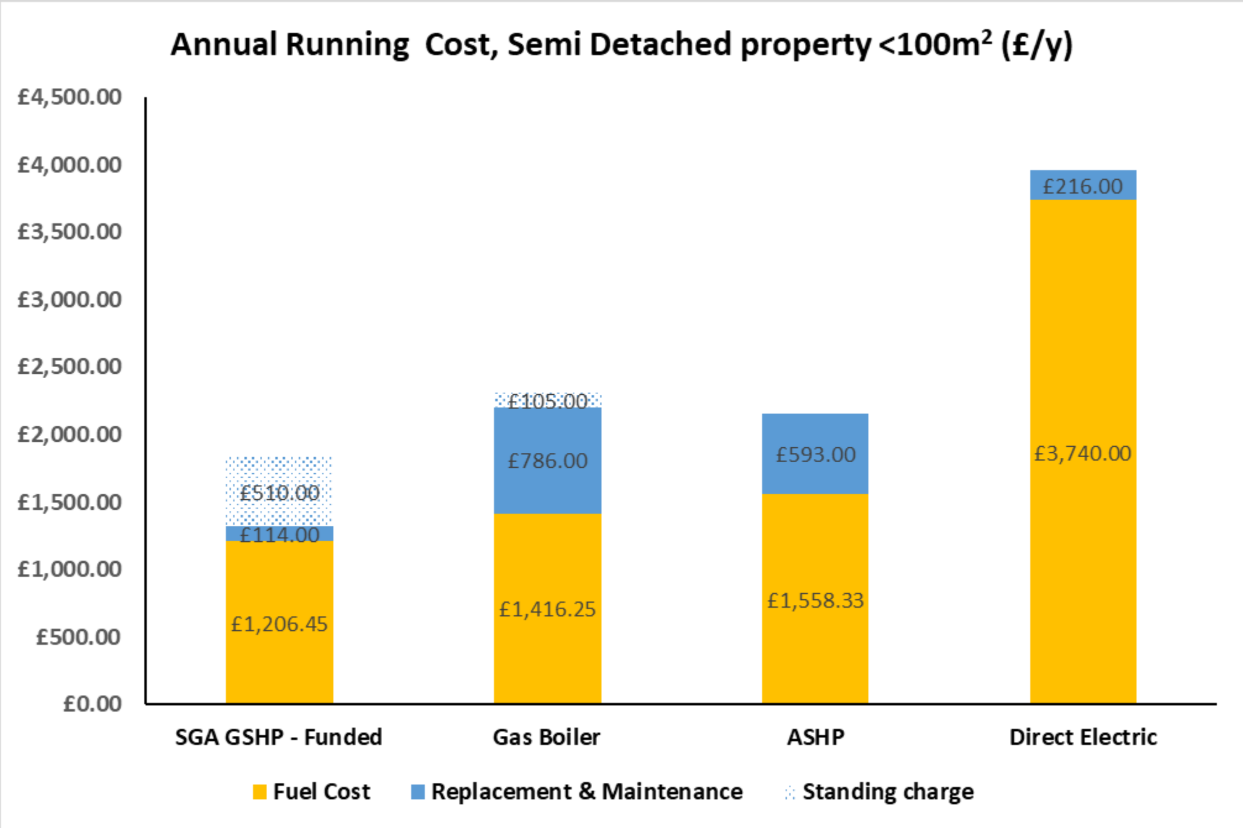
Figure 7-23 shows the capital and year one operational cost to consumer for two different sizes of semi-detached properties. The high standing charge is due to the requirement for a high IRR on investment (6%) from private investment. If the Rate of Return on investment could be lowered in the future, the standing charge to the end user could be lowered, and so the whole-life operational cost to consumer of GSHP+SGA could also reduce.

	GSHP	SGA GSHP - Funded	Gas Boiler	ASHP	Direct Electric
Capital cost of initial installation(£k)	£26.92	£22.09	£4.00	£13.00	£4.00
Grant (£k)	-£6.00	-£6.00		-£5.00	
Paid infrastructure cost (£k)		-£8.08			
Cost to Consumer(£k)	£20.92	£8.01	£4.00	£8.00	£4.00

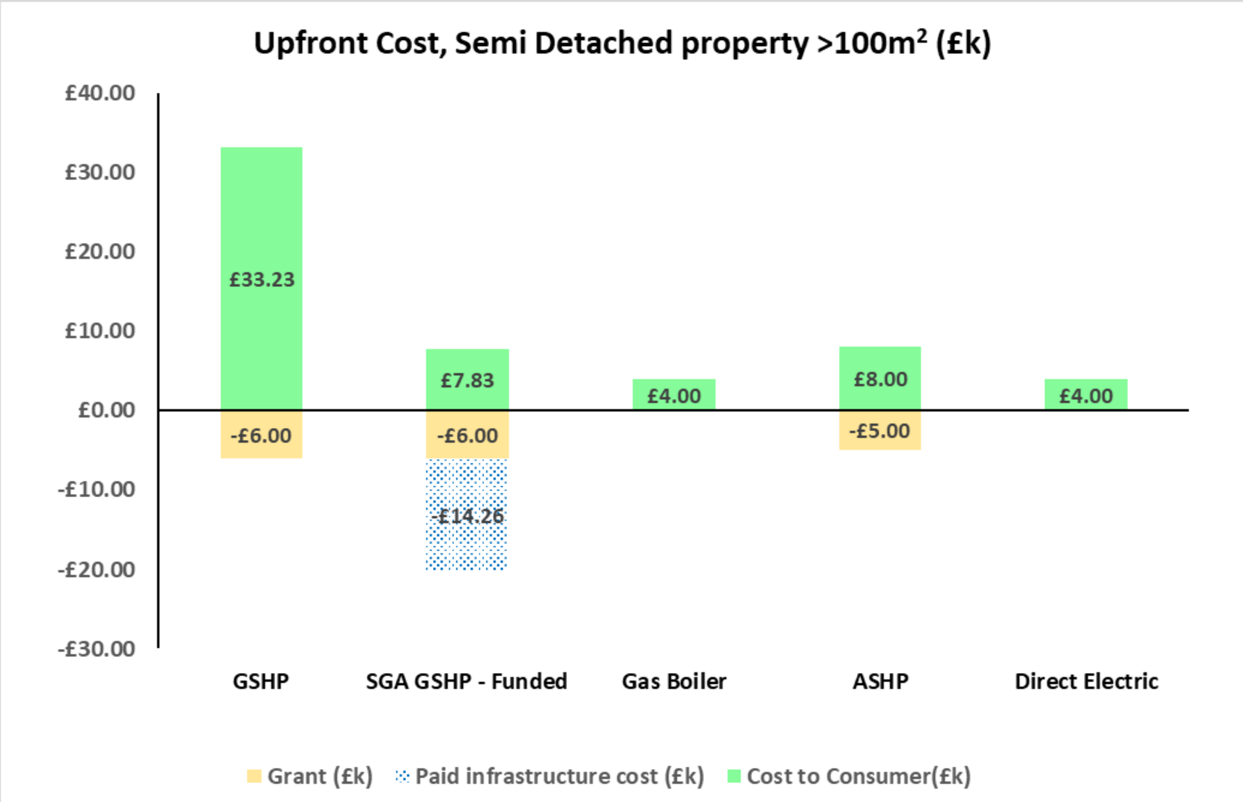
Figure 7-23 Semi-detached houses: costs and running costs.



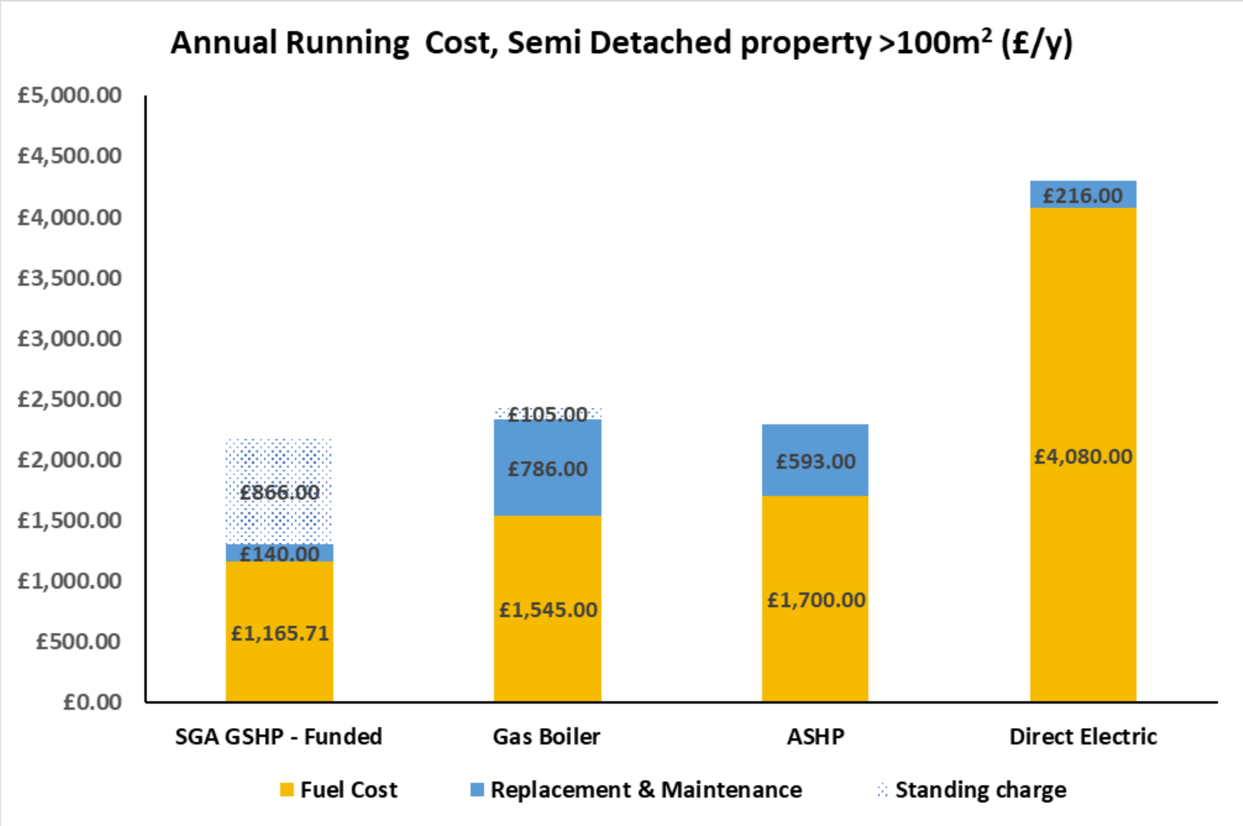
	GSHP	SGA GSHP - Funded	Gas Boiler	ASHP	Direct Electric
Demand (kWh)	11000	11000	11000	11000	11000
COP	3.5	3.5	80	2.4	1
Fuel Cost (Electricity);p/kWh	34	34	34	34	34
Fuel Cost (gas);p/kWh	10.3	10.3	10.3	10.3	10.3
Fuel Cost (£)	£1,206.45	£1,206.45	£1,416.25	£1,558.33	£3,740.00
Replacement & Maintenance (£)	£114.00	£114.00	£786.00	£593.00	£216.00
Standing charge (£)		£510.00	£105.00		



	GSHP	SGA GSHP - Funded	Gas Boiler	ASHP	Direct Electric
Capital cost of initial installation(£k)	£39.23	£28.09	£4.00	£13.00	£4.00
Grant (£k)	-£6.00	-£6.00		-£5.00	
Paid infrastructure cost (£k)		-£14.26			
Cost to Consumer(£k)	£33.23	£7.83	£4.00	£8.00	£4.00



	GSHP	SGA GSHP - Funded	Gas Boiler	ASHP	Direct Electric
Demand (kWh)	12000	12000	12000	12000	12000
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 (£)	£1,165.71	£1,165.71	£1,545.00	£1,700.00	£4,080.00
Replacement & Maintenance (£)	£140.00	£140.00	£786.00	£593.00	£216.00
Standing charge (£)	£0.00	£866.00	£105.00		



Further bill savings can be made by switching to a Heat Pump Tariff or a Time of Use tariff (ToU), such as Octopus Agile. This could be beneficial to consumers as they can avoid consuming (and therefore paying) for electricity at times of peak prices when electricity is scarce, and consume greater volumes when electricity is plentiful, and prices are low. It could also benefit those consumers who are unable to flex their demand: for example, if enough demand is deferred from peak times, this could dampen wholesale price spikes, making electricity more affordable for all. To take the advantage of the ToU tariff, a Phase Change Material (PCM) thermal storage system is included in the cost to the consumer. This way one can maximise the advantage of using PCM.

7.3.4.2 Option 2: Zero Upfront Cost- The cost is spread and then recovered as a loan over 5-year period

In this option the upfront cost is paid for through a consumer loan (loan for home upgrade). In this situation, the annual running cost could go up compared to Option 1 customer offer depending on the loan term and interest rate. Several examples of sample bank loans possible in a 'zero upfront cost offer' and the effect it has on overall costs could 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 £1307 for mid-terraced and £1701 for semi-detached properties for the five years (Appendix"Cost to Consumer calculator" with zero upfront cost). After 5 years, the annual operational cost could be equal to those of Option 1. A comparison table to show the percentage increase in annual repayment cost at different repayment rates is shown below.

Loan Amount for Mid Terraced	£6,022			
Loan rate (%)	0	3.29	5	7
Annual repayment	£ 1,205	£ 1,307	£ 1,364	£ 1,431
% increase		8%	13%	19%
Loan Period	5 years			

Loan Amount for Semi detached	£7,833			
Loan rate (%)	0	3.29	5	7
Annual repayment	£ 1,567	£ 1,701	£ 1,774	£ 1,862
% increase		9%	13%	19%
Loan Period	5 years			

It is evident zero-interest green loans could reduce the 'zero upfront cost' offer by more than £100/year, making heat pump adoption more competitive.

7.3.5 Saving to Upgrade the Electricity Grid and Generation Capacity

The shared ground array solution approach reduces impacts on the electricity network. It is evident that in the long term, shared ground array solution would require the least electricity resource and would therefore require the least investment to prepare the electricity grid for high-density deployment of heat pumps.

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

Considering an energy balance direct electric heating and heat pumps:

- For direct electric heating 1 unit of heating requires 1 unit of electricity.
- For ASHP heating, in general, the Coefficient of Performance (COP) may be in the region of 2.5, where 2.5 units of heat averaged over the year requires 1 unit of electricity. In addition, the electricity network is strained on cold days as ASHPs are less efficient at lower ambient temperatures. Defrost cycles during winter not only reduce efficiency, but have a considerable, sporadic, and highly significant impact on the grid – potentially exacerbated by additional direct electric heating being used to supplement such occasions, albeit this is not a requirement of correctly-sized modern ASHPs.

For GSHP with Shared Ground Array, in general, the Coefficient of Performance (COP) may range from 3 to 5, where 3 to 5 units of heating averaged over the year requires 1 unit of electricity. This efficiency is not affected by ambient temperatures.

Modelling has shown a whole-life value for money with costs for shared ground array is comparable to existing gas boilers and ASHP heating system. However, and significantly, these cost saving estimates do not include any reflection of the extensive savings expected in the reduced requirement to upgrade the electricity grid, and generation capacity. Modelling hypothetical savings to potential future asset investment presents challenges and presenting these as savings to consumers is not straightforward.

Recent study by Aurora 2021: "Decarbonisation of Heat in Great Britain" concluded that in the long term, shared ground array solution would require the least electricity resource and would therefore require the least investment to prepare the electricity grid for high-density deployment of HPs. Nearly £40bn of savings to 2050 on grid upgrades and peak capacity is possible from moving towards shared ground array solution. Regen 2021 studies also concluded significant savings with shared ground array (potentially a third less capacity requirement) compared to other electrical heating system get demonstrated.

7.3.6 WP2 Findings Summary

From this feasibility study it is concluded that shared ground array HP solution with split ownership/street by street business model are potentially the most suitable heat pump solution for "terraced houses" which are hard to treat and are highly space-constrained. Shared Ground Arrays, with third party investment, are also found to be a useful solution to decarbonise and move away from natural gas as a heating fuel for compact semi-detached houses (<100m^2), compared to the alternatives of direct electric heating or air source heat pumps or ground source heat pumps. For large semi-detached houses, ASHP system could be the most cost-effective heating solution for the end user to decarbonise the house in the current financial scenario, if the consumer is unable to pay the upfront cost of the GSHP system. Otherwise, standalone GSHP system is the lowest operational cost heating system for large semi-detached houses.

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 the upfront costs between in-home works and groundworks.
- 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 economic benefit, carbon reduction outcomes and roll-out of shared ground array on a street-by-street basis, can offer consumers with a lower overall cost, better value for money heating system than alternatives using gas boilers, ASHP, or direct electric boilers in near future. This can help to fulfil the council's strong commitment to decarbonization, having declared a climate emergency with a commitment to be carbon neutral by 2030. The offers demonstrate potential high-density roll-out of heat pumps across the UK that can serve properties that would otherwise be unable to convert to heat pumps. Roll out of proposed customer offer to flats and terraced houses can in fact represent 49% of the total UK housing stock[27] in England & Wales and potentially 1/3 less grid capacity requirement and thus savings on future grid upgrade costs.

The described business model significantly unlocks substantial private investment into homes that would otherwise not have been committed to low carbon heat in given time scale. This model also moves the emphasis of funding the low carbon transition from via public-private partnership investment to enable lifetime lower running costs for users, providing a suitable long-term return for investors and eliminating carbon emissions.

To make this even more attractive and accelerate the implementation of shared ground array solution going forwards, the council could include the “shared ground array solution” into the wider agenda to decarbonise housing stock, in the following areas:

- Zoning policy
- Statutory utility rights
- Local authorities or central Government low-cost financing
- Low-cost loans for in-home upgrades
- Rebalancing the relative prices of electricity and gas to 2:1 ratio

7.4 WP3. Electricity Network. Challoch Energy

Challoch has a deep knowledge of the network infrastructure in the Bridgend area through its ongoing work in the region as well as through continuing discussions with NGED at several levels. This, along with analysis of data from both NGED and other DNOs as well as ESC has enabled us to carry out a thorough assessment of the electricity network.

7.4.1 WP3.1 Network constraints

Analysis of the data has given us an overview of the LV network in the region including substation and LV feeder capacities for the specific areas identified. In addition, work undertaken by Buro Happold has supported our work on this work package.

Ultimately, although headroom exists in all substations and feeders, several issues have been identified which could have an impact on the capability of the network to cope with high-density installations of heat pumps without upgrades to the grid. In this region, many houses are connected via a looped supply whereby two houses share a connection, with a second cable linking the meters in the two properties. This configuration is not suitable for installation of heat pumps and NGED could need to install a new connection to the network. Whilst this is not a complicated procedure, installation of heat pumps in an area where there are multiple looped supplies may take longer, dependent on NGED capacity to undertake the work.

Secondly, to be able to guarantee electricity supply should a substation be out of service, substations are linked together. Consequently, there is no guarantee of headroom at any one time.

[27] https://files.bregroup.com/bretrust/The-Housing-Stock-of-the-United-Kingdom_Report_BRE-Trust.pdf

Discussions with NGED indicate they are fully aware of these issues and state in their Low Carbon Heat Strategy that they could be able to accommodate the 628,000 heat pumps expected to be connected to the network between 2023 and 2028.

7.4.2 WP3.2 Network Opportunities

The rise and adoption of LCTs across the country strains current LV networks and threatens their suitability for such demand. As a result, DNOs have responded with various strategies on how to develop their networks for the safe integration of LCTs. NPG's updated code of practice provides detailed insight into how the DNO could adapt their network, especially for heat pumps. Unfortunately, they fail to provide a strategy for network reinforcement while the proposed ADMD method to estimate LCT demand is based on fundamentally wrong assumptions.

Above all, NPG was unable to develop a procedure for cases where customers install more than one LCT, a situation likely to become the norm. Strategies put forth by other DNOs such as UK Power Networks and Electricity North West address these flaws, publishing more robust design procedures. Ideally, DNOs should learn and build upon one another to develop a sound, well rounded design procedure. This is exactly what NIE seeks to do via its open consultation.

DNOs have a unique opportunity to reshape LV network design in a cohesive and collaborative fashion. Working together, they can learn from the various pilot studies conducted and build upon each one's findings. There is a clear opportunity to build a stronger, more resilient network; whether DNOs can successfully coordinate and execute this mission is still to be seen.

7.4.3 WP3.3 Flexibility Offering

Looking at flexibility, ongoing projects across the UK reveal the capacity for heat pumps' demand response depends on strong thermal insulation of buildings. Moreover, flexibility could not be achieved without financial incentives and convenience, such that consumers do not have to go out of their way to be "flexible". In short, for DNOs and the network at large, understanding the role of heat pumps and how best to accommodate them remains a formidable challenge and a work in progress.

7.4.4 WP3.4 Market Structures

The traditional electricity market structure is ill-prepared for the integration of heat pumps and decentralised energy assets. It fails to create a marketplace that incentivises local generation or efficient consumption habits from people who install energy-intensive low carbon technologies such as heat pumps and electric vehicles.

Potential solutions include white labels which leverage a large customer base, such as a heat pump cluster, to develop favourable tariffs that reward flexible and efficient asset operation. Local energy markets provide another effective solution that incentivises the installation of local energy generation to satisfy the demand of the cluster. This displaces strain away from the DNO's wider network, alleviating reinforcement needs. LEMs, however, require the scale of at least an entire community to be successful and the projects can be capital-intensive depending on the technology used. Finally, Energy Local Clubs present a solution that combines the above and are especially well suited for smaller clusters.

As such, it is recommended heat pump clusters begin as a white label, then evolve into an ELC and eventually a full-scale LEM, as the community gradually invests in generation assets along the way. Alternatively, if funding is available, establishing an ELC or LEM from the get-go and investing in the required generation assets is a guaranteed way of creating a self-sustained, renewably fed heat pump cluster, fit for the needs of its consumers.

7.4.5 WP3 Findings Summary

This study demonstrates the need for a cooperative relationship with the local DNO. Positive engagement with NGED could allow us to work together and enable the deployment of heat pumps across the community. Effectively, the ability to characterise local electricity network infrastructure and assess where the most suitable areas are for heat pump deployment hinges on data availability and transparency from the DNO.

Current DNO strategies for the LV network design to integrate heat pumps and other LCTs are not reflective of the unique properties of these new technologies. They do not provide a structured approach for network reinforcement, instead prescribing asset overbuild instead of calculating what is needed. Moreover, rather than build upon each other, DNO strategies fail to work on the learnings of their peers. Combined, a complete, holistic design approach can be derived but individually they fail to address certain threats LCTs pose to their networks.

Looking at flexibility, ongoing projects across the UK reveal the capacity for heat pumps' demand response depends on strong thermal insulation of buildings. Moreover, flexibility could not be achieved without financial incentives and convenience, such that consumers do not have to go out of their way to be "flexible".

As such, the development of "flexibility" offerings is intrinsically linked to new and innovative market offerings. Until specific solutions are developed for local heat pump clusters, it is recommended these group together under a white label, then evolve into an ELC and eventually a full-scale LEM. This allows clusters to pool together and leverage their high-volume consumption and potential relief for the grid to achieve favourable pricing. Evolving towards a LEM, however, requires parallel communal investment in generation assets along the way. If funding is available, establishing an ELC or LEM from the get-go and investing in the required generation assets is a guaranteed way of creating self-sustained, renewably-fed heat pump clusters, fit for the needs of their consumers.

7.5 WP4. Engagement. NuVision Energy (Wales)

7.5.1 WP4.1 Intelligent Survey

The Intelligent Survey was trialled to investigate how efficiently 'in-home' information could be gathered remotely and at scale. Data from the surveys could then be used by the team to support the cluster selection exercise. The survey, presented to homeowners as a 'House Energy Survey Questionnaire', consisted of 38 questions that could be completed remotely using the 'Survey Monkey' online tool.

The survey was distributed via email to all those who attended the community engagement event and left their email address at the Cornelly Community Centre. The survey was also sent to those who did not attend the event but contacted the team having seen the advertisements on Facebook. From the 45 surveys distributed, 18 were returned giving a response rate of 40%.

Of the 38 questions asked, 24 were answered completely by all respondents. The questions which posed most difficulty to respondents were questions centred around their energy bills and energy system usage. One homeowner requested a home visit to help complete the survey as they were not confident in their ability to use online tools. Please see Appendix A.1 for summarised responses to the Intelligent Survey.

Through the survey, it was possible to ascertain an understanding into homeowners' energy usage, building archetype, age and characteristics including type of heating systems and energy saving measures already in place. The survey responses confirmed that all homeowners who responded were concerned about rising energy prices and affordability.

Findings

- The survey was successful in providing 'in-home' data remotely.
- Some homeowners had difficulty in responding to questions centred around their energy usage.
- Data was useful in support of the cluster selection exercise.
- Not all consumers are proficient with computer-based activities.

7.5.2 WP4.2 Community Engagement

7.5.2.1 Facebook Campaign and Short Survey

A Facebook campaign was launched with the objective of reaching as many homeowners as possible with a view to making them aware of the HPR Bridgend project and to invite them to the open days being held at the Cornelly Community Centre. In addition, the '*Affordable and greener heating for your home'* leaflet was delivered to 1,500 homes. Within the leaflet was a QR code and URL link to a short survey. The link to the survey was also embedded in the electronic version of the leaflet contained in the Facebook advert.

The purpose of the survey was to gauge interest and awareness of heat pumps from as many people as possible within the Bridgend target areas. The survey was limited to just four clear questions in order to encourage a good response rate. The Facebook campaign reached 3,373 people in the area. Only 11 survey responses were received, however. The results of the Facebook campaign and an analysis of the short survey are shown in Figure 7-24.

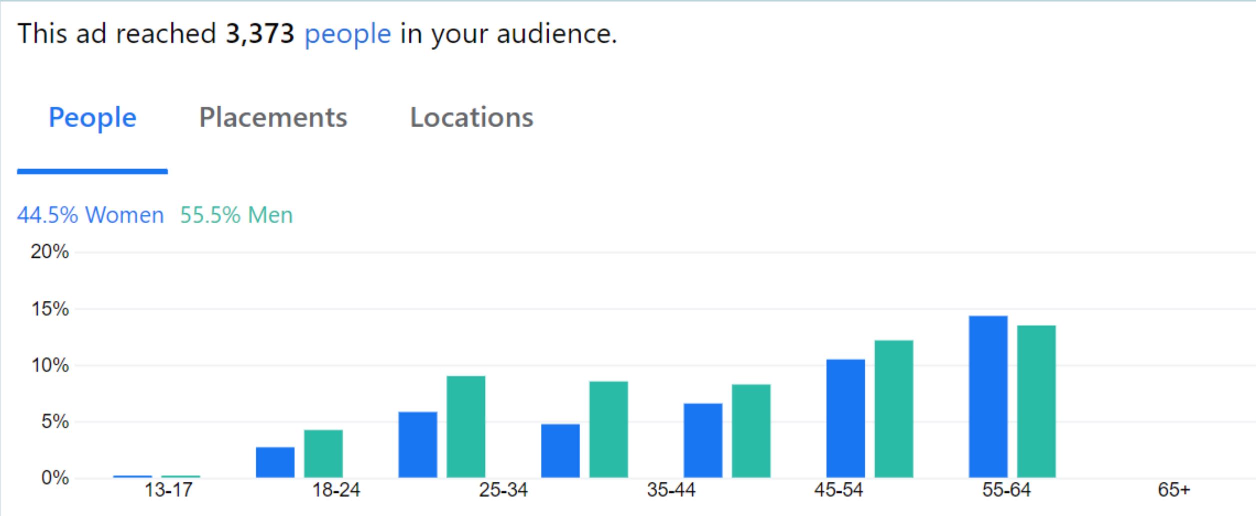
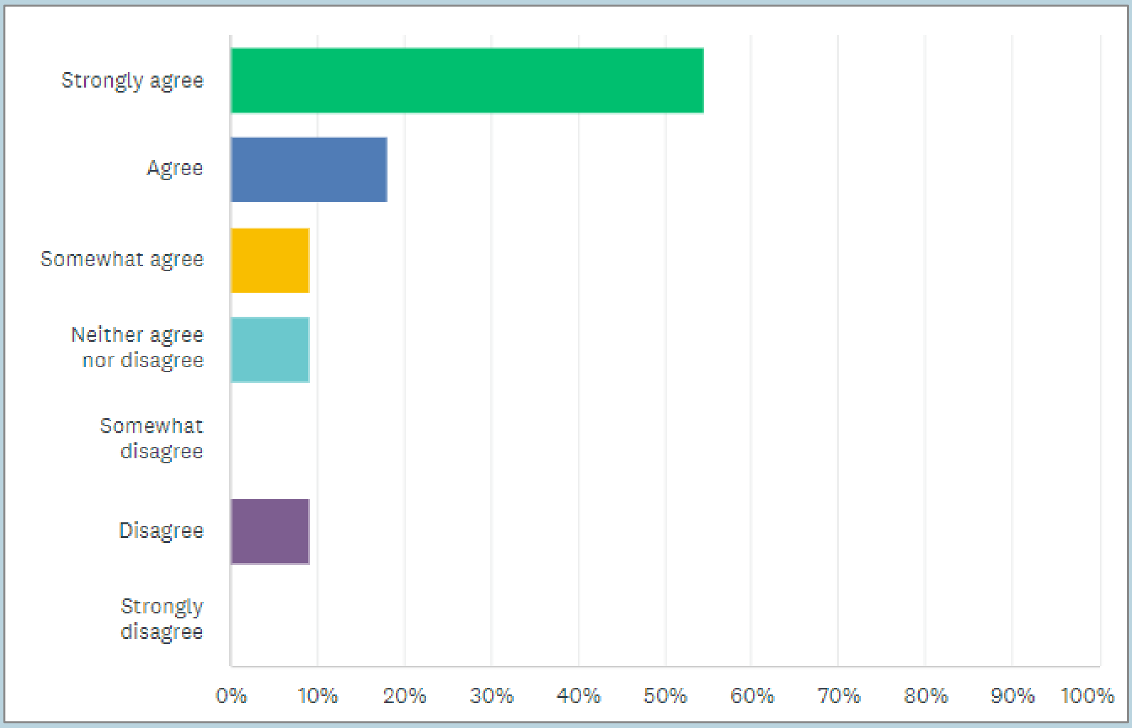


Figure 7-24 Demographic of those who engaged with the Facebook campaign

7.5.2.2 Analysis of Short Survey

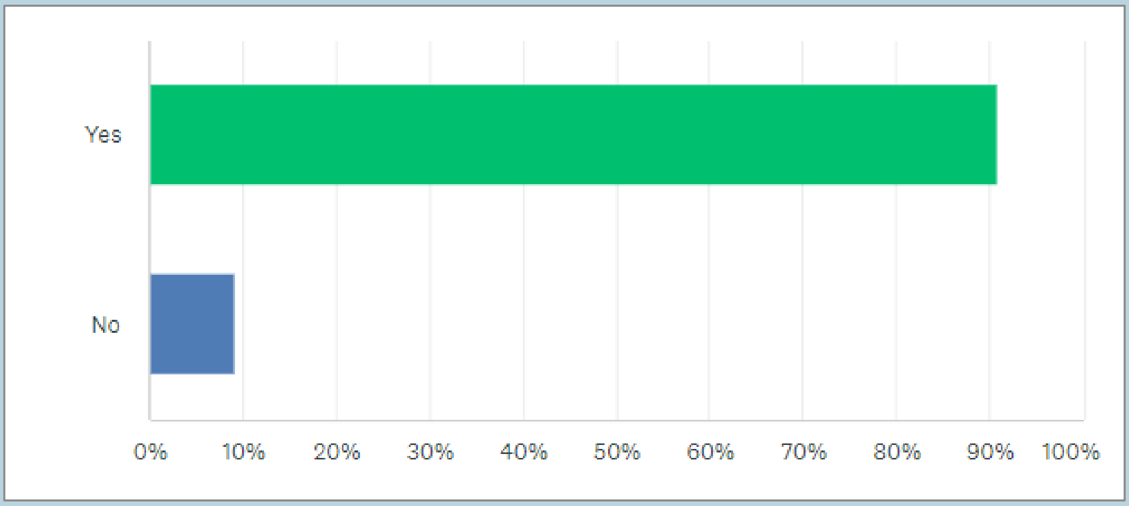
Q1: How much do you agree with the statement, 'The UK needs to move away from Gas boilers as a means to heating our homes'?

11 responded as shown in the table below.



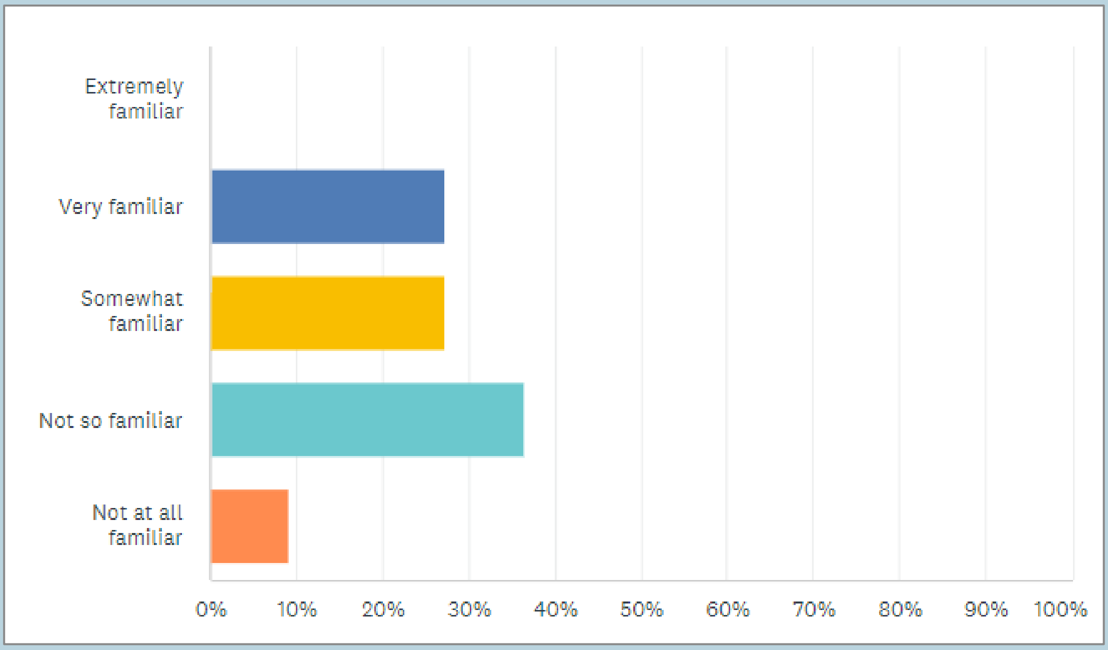
Q2: If a new heating system were to offer greener energy for your home without increasing your energy bill, would this increase your interest in installing a system?

11 responded, 10 respondents said yes, and 1 respondent said no.



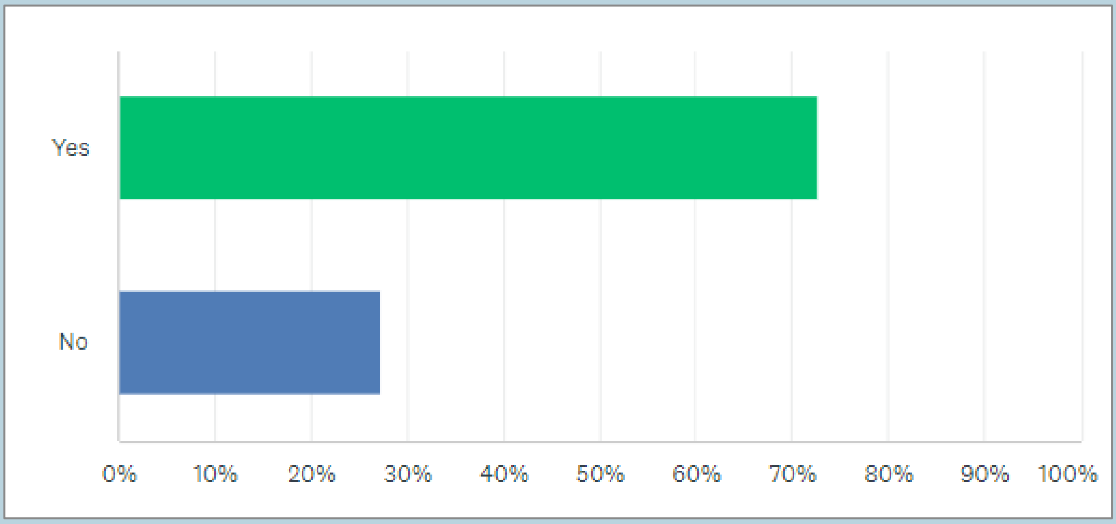
Q3: How familiar are you with Heat Pumps as a means to heating your home?

11 responded as shown in the table below.



Q4: We plan to hold an awareness raising event in North Cornelly Community Hall in September. Would you be interested in attending to learn more about Heat Pumps.

11 responded, 8 respondents said yes, and 3 respondent said no.



Engagement Events

Two awareness raising and capacity building events were held at the Cornelly Community Centre.

The events were attended by 17 families and other stakeholders including Officers and Members from BCBC. A number of other homeowners contacted the team via email to let us know that, whilst they were unable to attend the event, they would nevertheless be interested in receiving information about the project in anticipation that they could become involved at a later date. As a result of this exercise, a total of 44 homeowners responded by leaving their details with a view to being potentially signed up for further consideration should the project proceed to the next phase.

All those who attended the event were given a link to the online Intelligent Survey. From the details provided by homeowners (including those who completed the intelligent survey), the team was able to build a picture of the location of the potential consumers who had shown an interest in being signed up for the next phase. This information helped to inform the team in deciding the final cluster locations. Details of the home locations are presented in

Figure 7-25 and Figure 7-26.

Figure 7-25 North Cornelly and Nottage

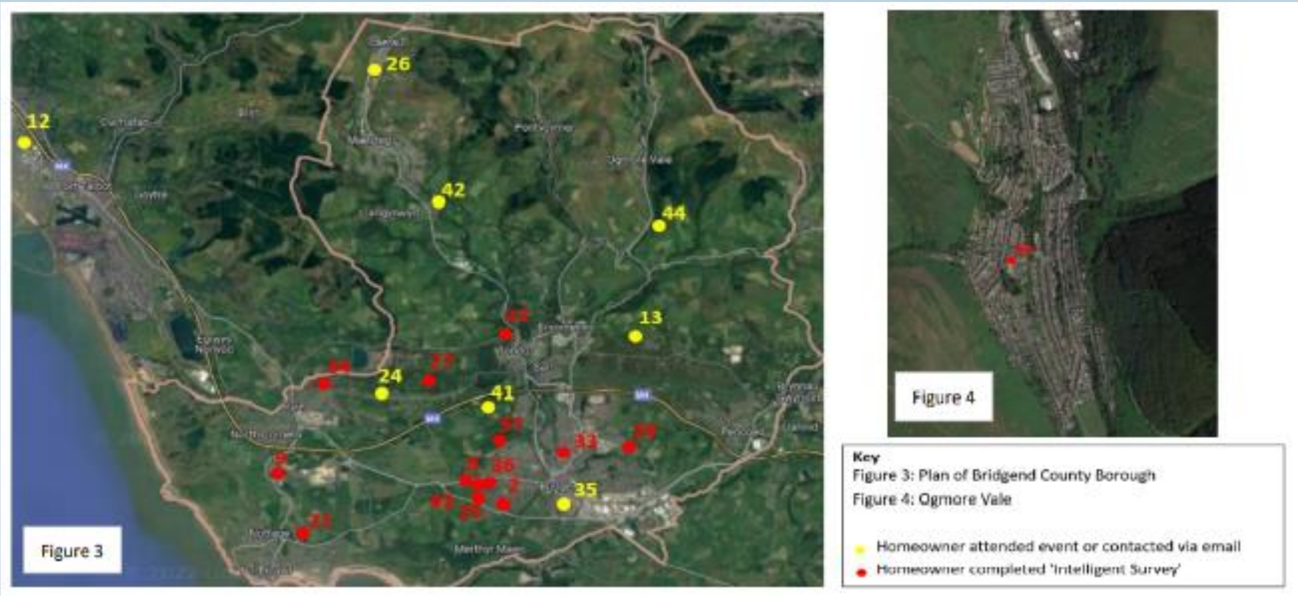


Figure 7-26 Bridgend County Borough and Ogmore Vale

Findings

- Most homeowners who attended the events had learnt about the project via the leaflets that were handed out door-to-door suggesting that this method of communication is more effective that a blanket Facebook campaign when trying to target a specific geographic area.
- Limited responses were received from short survey distributed via a 'blanket' Facebook campaign.
- Homeowners that attended event showed considerable interest.
- Many homeowners who couldn't attend event were keen to participate.

7.5.3 WP4.3 Supply Chain Engagement

Given the current limited uptake within the market, the supply chain for heat pump installations in South Wales is, in our view, adequately supported with both established heat pump installer companies with long track records and a plethora of smaller companies, mostly plumbers, who have moved into renewable technologies and now include heat pumps within their range of services.

There are also companies who supply tailor-made heat pump packages for plumbers and installers and some include an MCS service. These operate alongside the main heat pump companies who distribute their products through builders' merchants or directly through authorized installers.

Training for installers is also well supported with several colleges providing a range of courses in both air, ground and water to water heat pumps. Again, these are complemented by heat pump manufacturers who offer product-specific training.

For ground source heat pumps where boreholes are required there are drilling companies with experience of heat pump systems.

Heat Pump Installers, Suppliers, and Advice

There is high level of expertise in South Wales in the supply chain for the installation of heat pumps and associated equipment and borehole drilling and several companies have indicated that they intend to expand as the UK and Wales decarbonisation agenda gathers momentum.

However, there is a current shortage of skilled installers with practical engineering experience which the training colleges and heat pump manufacturers are addressing by expanding the number of training courses on offer. Key to encouraging uptake on the training courses could be the commencement of an initiative such as the Heat Pump Ready project which would give confidence to companies to send employees on training courses. To this end, we would work with the colleges to promote the training opportunities. There are several established heat pump installers in the area. These organisations have worked for approximately 10 to 15 years and have five or more employees. Their core business is installing heat pumps. The established companies that offer both ground and/or air source heat pump installation are shown in Table 7—7.

Table 7—7 Established heat pump installers

Company	Location
Thermal Earth	Cross Hands, near Carmarthen
WDS Green Energy	Cardiff
Green Heat Wales	Cardiff
Kensa Contracting	Exeter and Cardiff
Johnson Controls	Cardiff

There are also several smaller companies in the area offering heat pump installation. These are mainly sole traders offering an existing trade such as plumbing and are now providing heat pump installation as well.

Table 7—8 Additional heat pump installers

Company	Location
Limitless Energy	Swansea
CMB	Neath
Greener Renewables	Cardiff
Spire Renewables	Caerphilly, near Cardiff

As part of this study, ground-source and air-source heat pumps were considered, therefore heat pump suppliers are included for both types of heat pumps.

Heat pump suppliers who also offer product training and have approved installers are presented in the following table.

Table 7—9 Heat pump suppliers (who include product training and a have approved installers in the UK)

Company	Location
Kensa heat pumps	Ground source only
Nibe	Ground and air source
Daikin	Air source
LG	Air source
Mitsubishi	Air source
Viessmann	Air source
Worcester Bosch	Air source and hybrid
Samsung	Air source
CTC	Air source
Steibel Elstron	Ground and air source
IVT	Ground and air source
Vaillant	Ground and air source

Heat pump suppliers who do not have a training product offering are presented in the following table.

Table 7—10 Heat pump suppliers (with no training product training offering)

Company	Location
Go Geothermal	A well-established supplier of products with a good range of heat pumps
BSS	Operates a nationwide service but only offers heat pumps from selected manufacturers
Wolsey Centre	A nationwide company again with a limited range of heat pump types

Training organisations are listed in the following table.

Table 7—11 Training organisations

Company	Location
Bridgend College	Supported by Bridgend Council for training in renewables
Cardiff and Vale College	An operational heat pump workshop has been built to help in Cardiff
Pembroke College	Covers training in west Wales

Advice centres and organisations offering advice on heat pumps are listed in the following table.

Table 7—12 Advice centres and organisations offering advice

Company	Location
Welsh Government Energy Services	Provides advice to businesses, commerce and the public sector
Ground Source Heat Pump Association	Focuses on ground source systems and drilling companies
Heat pump Federation	A lobbyist and promotor of heat pumps
Heat Pump Association	A trade association for the heat pump industry

Advice centres and organisations that offer advice on heat pumps and boreholes are listed in the following table.

Table 7—13 Advice centres and organisations offering advice

Company	Location
Apex Drilling	Pyle near North Connelly - a well-established driller of boreholes for heat pumps
Denver Drilling Services	Has limited capacity for large scale borehole drilling
Powys Drilling services	Area of operation more central and North Wales
Wizard Ground Works	Area of operation limited to South Wales

7.5.4 WP4.4 Local Government Engagement

BCBC officers have supported the project since its inception and have acted as a communication link between the project team and the local government officials throughout. Officers and Councillors including the Council Leader have supported the engagement events and participated in social media advertising.

Figure 7-27 is a screenshot from the Council Leader’s Facebook page promoting the event. Included in the photograph are members of the project team and three Councillors including the Leader.

In the week after the event, councillors followed up with the community engagement by monitoring any additional responses that came into the community centre from homeowners who may have missed the event.

The commitment given by the local government officials has been instrumental in gaining the support and trust of the community. Their continued support could be key to a successful potential second phase. To this end they could not only support the team with the community engagement activities but could assist with the wider agenda of capacity building.

Figure 7-27 Facebook Messaging

7.5.5 WP4.5 Capacity Building – Community

Capacity building within the community took the form of the provision of educational material and ‘hands-on’ opportunities to explore a ‘mock-up’ heat pump. There were also opportunities to speak with our experienced team members who are expert in heat pump supply, installation, and ongoing maintenance support. Homeowners were made aware of how the HPR Bridgend programme might work and were given an idea of the benefits in participating in the scheme. Home visits were also made to three homes where the homeowners had specifically requested a visit and were interested in learning more.

The educational material focused on describing the HPR Bridgend programme's aims and objectives, what might be involved and how it might impact homeowners (Appendix A.4). The educational resources available on Kensa's website were also used to inform residents. The benefits of heat pumps were explained including how:

- the home value might be improved;
- the carbon footprint of the home would be reduced;
- the home might be cooled during warm periods of warm weather;
- the home would become more energy secure: use renewable energy stored underground, upgraded by the electric in-home heat pump, rather than imported gas with volatile prices;
- a safe & clean home can be established;
- a path to lower bills can be achieved; and
- the project would lead the way for clean and green heating in the UK, with British brands supporting the transition.

Collaboration with HPR Stream 2 activity

The project team has also linked up to collaborate with Veritherm who are involved with the HPR Stream 2 monitoring activity. The idea is that the collaboration could help to further build up capacity within the community. The project team is currently coordinating between homeowners and Veritherm who could undertake:

- An overnight test.
- A three-week in situ test.
- An airtightness test (to measure draughts).
- We could also take property measurements and thermal images.

Veritherm could supply (the householder) with a report which could give:

- An HTC (Heat Transfer Coefficient) figure, which is a precise measure of how quickly a house loses heat (see attached leaflet). This can be used to size a heat pump to replace a gas boiler or electric immersion heater. It can also be the basis for future measurement / specification of the impact of any future retrofit and home improvements.
- Veritherm could spend half an hour with each household explaining the findings and other insights into the property. This can be the basis for identifying energy-saving measures.

7.5.6 WP4.6 Capacity Building - Supply Chain

The project team has interacted with Bridgend College who are embracing renewable technologies with practical training courses in heat pumps etc. and supporting these with a renovated house on the campus equipped with an air source heat pump, PVs, and external wall insulation to demonstrate how a home can be decarbonised. Bridgend College are also working with the Valleys to Coast Housing Association, who are based in Bridgend, on training their in-house personnel in renewable technologies.

The results of this training could take time to feed through into the supply chain, but it is anticipated that as demand increases there could be enough installer companies with the capacity to meet future demands.

7.5.7 WP4 Findings Summary

The study demonstrated that an online '**intelligent survey'** designed to enable homeowners to gather in-home data could be deployed successfully, thus enabling data to be gathered remotely and at scale. The survey technique can be used as a 'first sift' in determining home suitability and in supporting the cluster selection exercise. Some homeowners had difficulty in responding to questions centred around their energy usage and to this end we recommend that the online survey be complemented by a helpdesk facility in support of those who might have queries with the survey, or for those who may not be proficient with computer-based activities.

The **Community engagement** activities focusing on awareness raising and educational events proved essential in gaining 'buy-in' from the community. The Cornelly Community Centre was central and convenient to our target areas and would be ideal to further develop our customer base. While a good response rate was received from the 'Intelligent Survey' (a survey targeted at consumers who had already shown an interest in the project), a limited response was received from surveys that were distributed via the Facebook campaign. Similarly, more potential customers that had received direct mailing attended the events than customers who were targeted via the Facebook campaign. The study demonstrated therefore that leaflet drops and face-to-face door knocking could be an essential part of our community engagement approach.

Homeowners that attended the event showed considerable interest in the project and some demonstrated through their enthusiasm that they would be excellent advocates of the project. Others who couldn't attend the events contacted the team via email to enquire how they could participate. Our approach could be to use these community advocates as technology champions to promote the project within their community.

Our **Supply Chain Engagement** activities demonstrated that given the current limited uptake within the market, the supply chain for heat pump installations in South Wales is adequately supported. Training for installers is also well supported with several colleges providing a range of courses in both air, ground, and water to water heat pumps. However, there is a current shortage of skilled installers with practical engineering experience. The HPR Bridgend team could work with the colleges in their efforts to continue to develop new courses and to interact further with the supply chain to link installers with college courses.

The project benefited considerably from **Government Engagement** support and in particular from BCBC Officers and Councillors who were key to develop the support and trust of the community. Our long-standing relationship with BCBC which has been further strengthened as a result of this project could enable us to continue to build a rapport with the community and to successfully deploy heat pumps at sufficient scale.

Further **Capacity Building within the Community** could be essential to ensure sufficient number of consumers 'buy in' to the project. The feasibility study demonstrated that we have an ideal local facility (in the form of the Cornelly Community Centre) to undertake a range of events. The Centre is large enough to hold evening lectures, daytime 'drop in' sessions and face-to-face meetings in breakout rooms if required. Our team have also demonstrated that home visits may also be appropriate.

The study demonstrated that **Capacity Building within the Supply Chain** can be adequately addressed through the colleges in the area that are actively embracing renewable technologies with practical training courses. Whilst the results of this training could take time to feed through into the supply chain, there is sufficient capacity in the short term to deliver a project of the size envisaged by the HPR Bridgend team.

7.6 WP5. Management and Co-ordination. Buro Happold

7.6.1 WP5.1 Project Management

High-density heat pump deployment projects could require organisations to work cooperatively and to collaborate. The project management findings on the approach taken for this feasibility study underpin the development of methodologies for this goal.

- **Identification of a common goal.** Four separate organisations came together with an interest in supporting the UK's transition to a low-carbon economy – Buro Happold, Challoch Energy, NuVision Energy, and Kensa Contracting. Through the Heat Pump Ready (HPR) Programme, BEIS created an opportunity for organisations to collaborate and explore innovative ways of working to deliver feasibility studies identifying where high-density heat pump deployment is possible. The organisations, which ordinarily would not work closely together on a feasibility study, agreed to work together towards this common goal.
- **Setting clear expectations.** Each organisation has an area of expertise that contributes to the overall project. During the application preparation, the organisations agreed to deliver a work package as part of the overall feasibility study. It was also agreed that project information would be shared between the groups participating. The group used a file sharing platform (SharePoint) to share files.
- **Agreeing milestones.** For each work package, milestones were agreed. Information sharing was integral to achieve the milestones.
- **Leveraging capabilities.** Each organisation's work package was in an area of their expertise. Energy planning was provided by Buro Happold, heat pump technology considerations by Kensa Contracting, electricity grid opportunities and constraints by Challoch Energy, and stakeholder engagement by NuVision Energy.
- **Checking-in regularly**. The overall team met monthly by video conference for progress meetings. Video conferences and emails were used for communication as needed.
- **Encouraging new approaches**. The organisations encouraged each other to share their ideas and experiences for the benefit of the project.
- **Developing strong relationships**. Time was reserved at the beginnings of regular progress meetings to get to know team members better.

- **Encouraging input from key stakeholders**. The Bridgend County Borough Council and Distribution Network Operator were invited to join the team's weekly progress meetings as well as one-to-one video conferences, emails, and calls.

Setting Out

Meetings

At the outset of the project, a set of kick-off meetings were held:

- An internal kick-off meeting with the Buro Happold team, by video conference
- A collaborative team kick-off meeting with the collaborators and BCBC, by video conference
- A project inception meeting BEIS and the collaboration team, face-to-face at the Council office in Bridgend, Wales. This was attended by the BEIS Heat Innovation Team contact, the BEIS Project Monitoring Officer (PMO), leaders from the collaboration team, and Bridgend County Borough Council (BCBC).

A project management document was used to share information in the collaborative team, covering the project description, objectives and aims, work package descriptions, communication channels, and data sharing methods. SharePoint was used as a central online location to store project information, accessible to the collaborative team.

The team used a financial tracker template, provided by BEIS, to summarise the Work Package milestone descriptions and due dates with associated invoicing information. The team planned project milestones so that there would be a deliverable each month, for each work package, demonstrating project progress.

Key Performance Indicators were estimated at the outset of the project, covering topics such as the anticipated impact of the project.

Regular Progress Meetings

Weekly planning and progress meetings were held every Monday with leaders from each collaborator group, by videoconference. These were attended by Buro Happold, Kensa Utilities, NuVision Energy (Wales), and Challoch Energy. Where useful to the agenda, a representative from BCBC also joined.

Monthly progress meetings were held at the end of each month with the BEIS PMO and the HPR Bridgend Project Leader. Each month, collaborators contributed a slide deck on the progress of their work package(s) for the overall presentation.

Recommended Innovative Approach to High-Density Heat Pump Deployment

The HPR Bridgend team applied to BEIS to participate in HPR Stream 1, Phase 2 - heat pump deployment. Each collaborator provided input into the application, considering the findings of their work package and how they relate.

In the drafting of the feasibility study, collaborators also provided direct input on their work package methodology, findings, recommendations, and conclusions.

Key Performance Indicators were estimated at the outset of the project, covering topics such as the anticipated impact of the project.

7.6.2 WP5.2 Advisory Group

Engagement with the advisory group allowed project support from the Council, BCBC and the District Network Operator, NGED.

The advisory group for the HPR Bridgend project consisted of key external stakeholders:

- **Bridgend County Borough Council (BCBC**) is directly sponsoring the project which aligns with BCBC's climate agenda in South Wales. BCBC are providing resource in supporting coordination and deployment of the HPR Bridgend activities as well as wider communications activities to give confidence to consumers there is local government backing.
- **National Grid Electricity Distribution (NGED)** – formerly known as Western Power Distribution and the local electricity utility. NGED provided a letter of support, and engaged with HPR Bridgend via the NGED local network teams (11kV and LV levels) and through their central innovation team.

Bridgend County Borough Council (BCBC)

BCBC provided the following support during the feasibility study:

- BCBC hosted the project kick-off meeting with BEIS at the council office in Bridgend.
- During the project, a representative from BCBC joined the regular weekly team progress meetings where this fit with the meeting objectives.
- BCBC communicated directly with NuVision on stakeholder engagement, on a 1-to-1 basis, agreeing information to be shared on the Council website and Facebook messaging.
- Councillors from BCBC attended the HPR Bridgend event at North Cornelly to engage potential customers.
- BCBC may support the project to connect with Valleys to Coast, a Social Housing Organisation to promote information sharing about opportunities to install heat pumps in Bridgend County in Phase 2 of the project.
- The final face-to-face project meeting could be hosted at the BCBC office to discuss the feasibility study outcomes. BCBC has also offered to host a stakeholder meeting to promote a joined-up approach in Phase 2 of the project.

National Grid Electricity Distribution (NGED)

Discussions with NGED were both positive and informative. They gave a better of understanding of their thoughts regarding innovation as well as policy towards deployment of low carbon heating technologies including heat pumps.

NGED communicated that, in addition to the need for network upgrades, consideration is being given to the role that network attached batteries could play in reducing peak electrical demands on networks. It is possible that a high deployment of heat pumps combined with a battery storage option would allow the delay or even deferment of network reinforcement. However, to enable this approach to be adopted, DNO procedures would need adapting and there is still much work to be done to explore this concept.

Input from NGED is summarised as follows, by the department of NGED that provided the input:

- **Low Carbon Innovation Team.** At the outset of the project, Buro Happold contacted NGED's Low Carbon and Innovation team, requesting information on substation headroom in Bridgend County to better understand immediate opportunities for heat pump planning. The Low Carbon and Innovation team provided a link to their freshly updated website with downloads available showing approximate 11 kV polygon areas and capacity.
- **Policy.** Challoch engaged with several members of the Innovation Team to discuss policy issues related to potential high-density deployment of heat pumps in a specific area i.e., a minimum of 25% of houses connected to a single feeder. NGED indicated that they are open to further discussions about how to make it possible proceed with high-density deployment of heat pumps.
- **Equinox Project.** During the project, the Equinox Project manager spoke at one of the Stream 3 dissemination workshops to the HPR programme representatives on District Network Operator (DNO) considerations for heat pump projects. Of special note was the work in the Equinox Project around Demand Side Response (DSR), where electricity users could consider using less electricity at certain times of day to assist in electricity demand management over the electricity network.
- **Local Electricity Network Planning.** Challoch Energy liaised with NGED planning at the 11 kV level to identify opportunities and constraints on the Low Voltage network in Bridgend County, particularly in areas where high-density heat pump deployment was under consideration as part of this feasibility study.
- **LV Planning.** Challoch also spoke to the LV Planner to better understand the issues surrounding the practicalities of heat pump installation and their impact at the LV level.

7.6.3 WP5.3 Special Purpose Vehicle – Customer Advisory Service

To carry out a high-density heat pump project, an organisation would need to carry out deployment. Of the organisations involved in the feasibility study – Kensa, Challoch Energy, NuVision, Buro Happold - none were in the position to take on this role with the current structures of the existing organisations, considering their strategic goals and available resources.

Therefore, the collaborative team concluded that for the project delivery stage, there would be a need for an organisation to lead the project – this could take the form of a Special Purpose Vehicle (SPV). The rationale for establishing an SPV is to have a legal entity that brings together all participating companies to carry out the deployment of the heat pumps.

A permanent presence by 'The Project/Team' within the county boundary is essential to giving the community confidence that the decarbonisation agenda using heat pumps is being taken seriously and implemented. It is suggested that and SPV be established in the location where a heat pump project is implemented. It could provide a customer advisory service, and experts from the collaborative group could visit and offer advice and help as needed.

For the SPV to be effective, it is suggested to have the support of the Council and to make use of an existing brand where this is available. For example, an SPV established in Bridgend could have the support of BCBC and have access to the existing Low Carbon Communities Brand, which is already known in Bridgend County and supported by the Council.

An SPV could be known by a locally relevant name. Throughout this report, the example SPV is referred to as HP-BONT – bont being the Welsh word for bridge – and the purpose of the SPV being to bridge the gap between consumer and supply chain to enable the scaled uptake of heat pumps and accelerate decarbonisation in South Wales.

In summary, as a delivery organisation, the SPV could carry out the customer advisory service role to support the innovative, coordinated methodology for high-density heat pump deployment. The following is suggested for the SPV, or another leading organisation:

- Responsibilities could include project oversight, governance, quality, customer advisory service, customer relationship, installer relationship, subcontractor relationship
- Be sponsored by the local authority
- Organise marketing branding
- Engage and interact with the community on various aspects of the project
- Leverage additional funds for renovation that fall outside of the eligibility criteria identified heat pump funding, for example, for activities such as house renovation

For a more detailed discussion on how organisations could collaborate, please see the recommended methodology for coordinating high-density heat pump deployment in section 7.6.

7.6.4 WP5.4 Draft Report and WP5.5 Final Report

This feasibility study was delivered as part of the Stream 1, Phase 1 project deliverables. This feasibility study was prepared by the collaborative HPR Bridgend project team. Each collaborator has contributed written sections for the work packages they completed. For each work package, the originator of the work has provided the methodology, findings, recommendations, and conclusions.

Recommended innovative coordinated methodology for high-density heat pump deployment. An application for Stream 1, Phase 2 was submitted to BEIS as part of the project deliverables.

The Phase 2 application was submitted by Challoch Energy, with Buro Happold, Kensa Utilities, and NuVision proposing to support the project as subcontractors.

BEIS provided guidance documentation, and templates for the application, a cost to consumer calculator, and a financial summary sheet.

The team worked closely together to identify where the target number of heat pumps could be deployed, as described in the methodology section of this report, and presented how the team could make this a reality in Phase 2. After agreeing the target, the team completed sections in the deliverable.

Kensa Utility completed the Ground Source Heat Pump and Shared Ground Array Cost to Consumer calculator, Challoch Energy completed the Air Source Heat Pump Cost to Consumer calculator.

Buro Happold coordinated entry of information into the financial tables and overall Gantt chart, team organogram, customer journey flow chart, and data repository spider diagram.

Each collaborator completed written sections in the application, according to the work packages they would cover in Phase 2 of the project, with reference to the customer journey process diagram and data repository spider diagram.

After Buro Happold coordinated a first draft of the material, Challoch Energy carried out a check on the material and made final additions to the submission. Buro Happold submitted the application, with Challoch Energy as the contact for follow up with BEIS.

7.6.5 Stream 3 Participation

The Stream 3 dissemination activities included the following:

- **Introduction to Stream 3.** The Carbon Trust presented on the dissemination activities planned to take place over the project.
- **Cost model development meeting**. The Carbon Trust presented the heat pump cost model for the Phase 2 applications, explained how it was set up to work, and gave an opportunity to provide feedback before it was finalised. The cost model contained assumptions geared towards making it possible to compare the proposed heat pump deployment approaches, such as a cost for electricity. It also included typical building archetypes for which to consider heat pump and heat demand reduction measures. At the end of the calculator, there was a space for the estimation of eligible funding towards heat pumps.
- **Ofgem & Innovate UK strategic Innovation Fund and Heat Pump Ready joint-event.** Due to scheduling issues, this event was cancelled by the organisers.
- **Interaction with Distribution Network Operators.** This talk covered suggested District Network Operator (DNO) approaches to liaison, to support projects to gather information to better understand heat pump opportunities. One of the speakers from National Grid spoke about his experiences with the Equinox Project which featured Demand Side Response (DSR)
- **Stream 1 & Stream 2 joint event.** This in-person event allowed Stream 1 feasibility study participants to meet and discuss heat pumps with the Stream 2 participants working on technology solutions. Out of this interaction, the HPR Bridgend Project connected with the Veritherm group who are looking into the monitoring of buildings to better understand building heat demand, with an eye to optimising heat pump sizing. A connection was also made with Thermodynamic Conversion Systems who are working on emerging heat pump technologies.
- **Heat Pump Installation Quality Assurance (QA).** This workshop included break-out discussion groups to discuss the opportunities and challenges faced around heat pump system design and installation QA. Of interest, the Microgeneration Certification Scheme (MCS) was discussed, and some potential areas for improvement. For example, there is an MCS heat pump calculator available, and perhaps, over time, it could be refined to allow heat pump capacity optimisation.
- **Net Zero Innovation Portfolio (NZIP) & Heat Pump Ready Joint event.** Due to scheduling issues, this event was cancelled by the organisers.
- **Data sharing webinar.** At this talk, the presenters explained that heat pump performance monitoring could be included as part of the project for the customers who have smart electricity meters and opt-in to the monitoring. This could help to gather data to demonstrate the lessons learned and successes of the HPR programme.
- **Learnings workshop.** This upcoming workshop is for sharing project learnings between this project and other Stream 1 projects.

8 Recommended Methodology for Coordinating High-Density Heat Pump Deployment

Key organisations from industry with individual, complementary specialisms can collaborate to deliver a new service model.

Based on the findings of this HPR Bridgend feasibility study, the roles suggested are summarised below:

- **Lead organisation.** Coordination of high-density heat pump deployment, customer advisory service. Could be a Special Purpose Vehicle.
- **Shareholders.** Shareholders could provide oversight and technical expertise into the SPV.
- **GSHP + SGA Contractor.** Shared ground array construction, operation and maintenance could be carried out by a subcontractor.
- **Heat Pump Installers.** ASHP and GSHP.
- **Technical advice – subcontractors**
    - **Energy planning and data platform**. Screening for heat pump suitability and advice on setting up a data repository to manage data.
    - **Engagement.** Community engagement organisation could provide advice and support on engagement with customers, local government, and suppliers such as ASHP installers.
    - **Electricity network**. Electricity network specialist could provide advice on network opportunities and constraints.
- External support
    - **Council** – local government.
    - **Distribution Network Operator.**

A proposed business model for the coordination of high-density heat pump deployment is presented in Figure 8-1 . This was prepared as an example, based on the organisations that participated in the HPR Bridgend feasibility study. A description of the organisations involved is presented in the following section of the report.

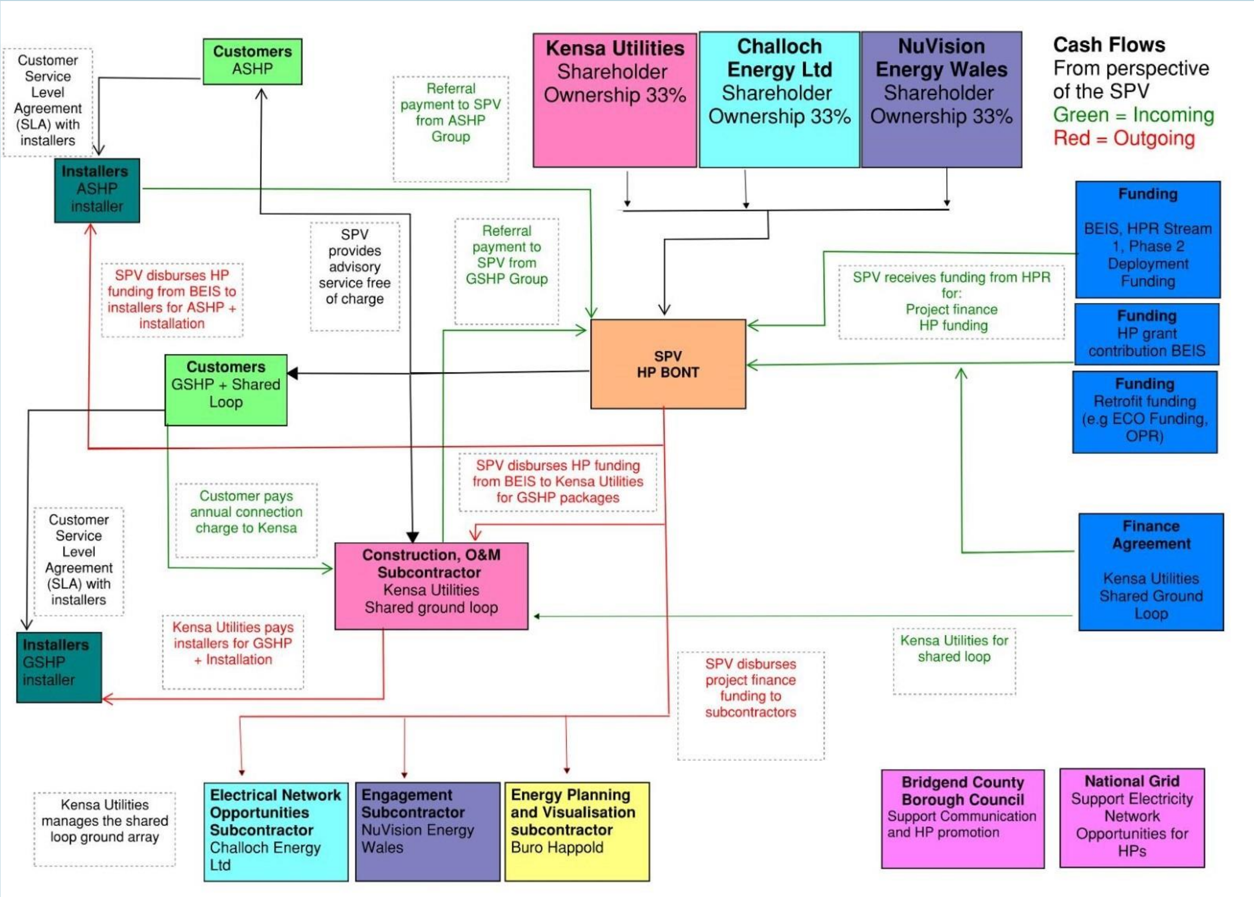


Figure 8-1 Business Model Diagram

A proposed information-sharing diagram is presented in Figure 8-1. This diagram shows inter-dependencies of data sharing in a heat pump deployment project. The names of the organisations shown in the diagram are those of the group involved in the HPR Bridgend Feasibility Study, as an example. A description of the organisations involved is presented in the following section of the report.

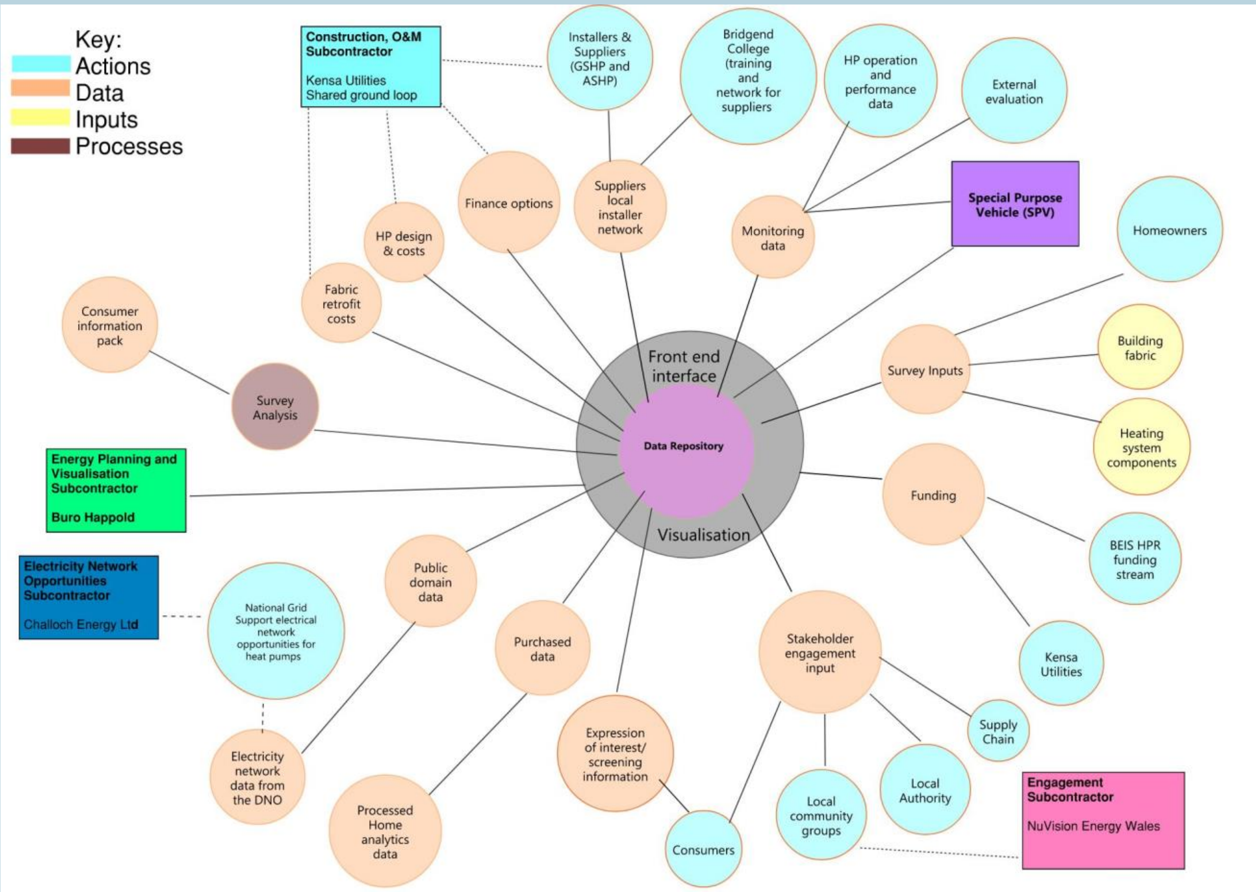


Figure 8-2 Collaboration Diagram – Information exchange

8.1 Lead Organisation – Special Purpose Vehicle (SPV)

Role

Lead organisation, roles and responsibilities suggested:

- Coordination of high-density heat pump deployment
- Service could potentially be provided by a Special Purpose Vehicle (SPV)
- Customer advisory service. Support customers to identify the heat pump suitable for their homes
- Permanent presence. Presence in the county. This is essential in giving the community confidence that the decarbonisation agenda using heat pumps is being taken seriously and implemented
- Expert support. Technical experts from the GSHP + SGA contractor and subcontractors providing technical advice could visit the delivery organisation's local area and offer advice and support as needed
- Access other funding (e.g., ECO funding) which it could utilise to provide additional services to consumers
- Use a data platform to organise project data

Rational

For the collaborative approach, a lead organisation is suggested based on the finding that a legal entity is required to implement a heat pump deployment project. During the feasibility study, it was found that an additional legal entity would be needed in addition to the organisations that participated in the study. The role to be fulfilled by the lead organisation was different from the strategic aims of the organisations that carried out the feasibility study (Challoch Energy, Buro Happold, Kensa Utilities, NuVision Energy (Wales)).

Description

The lead organisation, potentially a Special Purpose Vehicle (SPV), could be established in the project area, and sponsored by the local authority, specialising in offering the heat pump process to consumers.

The rationale for setting up an SPV is to have a legal entity that brings together participating companies to carry out the deployment of the heat pumps in the most efficient way. This special entity could engage and interact with the community on various aspects of the project.

Overall responsibilities could include project oversight, governance, and quality, as well as the customer relationship, installer relationship, subcontractor relationship, governance, and quality. The customer relationship management data base could be held by the lead organisation.

The offering from the lead organisation could include marketing, and branding. The lead organisation or SPV could operate under the banner of an existing brand which is recognised in the area and supported by the Council.

The lead organisation could potentially also leverage additional funds for activities such as renovation that fall outside of the eligibility criteria for the HPR programme.

Through the customer advisory service, the lead organisation could be involved in customer contact, support, home suitability screening calls for heat pumps, and the delivery of HP information and advice packages. It could also invite customers to join an 'interested list' to sign up for GSHP + Shared loop when there is enough interest to form a cluster with a shared loop. For those homes not suitable for GSHP + SGA, ASHP could be considered.

The overheads associated with an SPV may be low where it is established as a non-profit organisation, supported by mature shareholders with established processes. The shareholders could potentially be for-profit shareholders.

The lead organisation could receive funding for heat pumps directly, which it could then provide to the GSHP + SGA contractor or ASHP installer for each installation secured.

8.2 Shareholders

Role

Shareholders could have the following roles:

- Oversight of the lead organisation (e.g., SPV)
- Maintain the vision of the lead organisation to achieve high-density heat pump deployment
- Act as contacts to a network of technical experts to support lead organisation

Rational

During the feasibility study, Challoch Energy, NuVision Energy (Wales) and Kensa Utilities considered the potential to act as shareholders in a new SPV that could carry out a heat pump deployment project.

Description

The lead organisation or SPV could be invested into by the organisations collaborating in a heat pump deployment project.

The investing organisations could also be subcontracted to provide specialist expertise and resources, such as:

- Electricity grid opportunities and constraints (e.g., Challoch Energy)
- Community engagement (e.g., NuVision Energy Wales)
- Heating systems, such as GSHP + SGA (e.g., Kensa Utilities)

The shareholders were envisaged as for-profit shareholders during the feasibility study, based on the business strategy requirements of the organisations involved (e.g., Challoch Energy, NuVision Energy Wales, and Kensa Utilities).

8.3 Energy Planning and Data Platform

Role

An energy planning and data platform subconsultant could provide:

- Screening of homes for heat pump suitability from an energy planning perspective
- Digital planning and analytics
- Host the data platform, using data management systems

Rational

Energy planning can be used to strengthen the approach to high-density heat pump deployment, through suitability screening, and a data platform would be useful to handle the significant amounts of data associated with a heat pump project of this type.

During the feasibility study, Buro Happold acted as the organisation providing input on energy planning and considerations about a data platform for a future heat pump deployment project.

Description

A subcontractor could support with the screening of homes for heat pump suitability from an energy planning perspective. This would involve working with building data and mapping evaluation, collating information on building archetypes, considering energy performance, and current levels of retrofit.

A data platform could be used to identify future clusters of homes where high-density deployment of heat pumps is an opportunity.

BCBC has previously undertaken local area energy planning (LAEP) as one of the UK's pilot local authorities. One of the key outcomes of the LAEP process was to identify areas where 4th and 5th generation heat networks would prove the most viable solution based on heat density and conversely where they would be less suitable and where heat pumps would be the alternative solution. Building on this approach a more granular process of complimentary planning has been proposed which then evaluates those areas where heat networks are not so viable due to heat density, determining properties that would be heat pump ready. This includes for GSHP + SGA (ambient loop clusters) which were not factored into the LAEP process.

The benefits of shared heating are factored into the appraisal which includes determining potential network benefits through efficiencies as well as likely property efficiency measures and indicative costs for the heat networks due to spacing of properties and pipe lengths. Spatial allowances are also considered as it is known in some cases properties could not be able to easily accommodate ASHPs due to lack of space or proximity to neighbours leading to noise issues. In South Wales this is particularly relevant to old industrial areas where terraced homes were built. Similar constraints are seen in other communities in the UK. Other considerations include the proximity of properties to coastal areas and the risk of corrosion on ASHPs resulting in a significant cost increase to consumers. This can be mitigated by GSHPs.

From this information, clusters can be graded for targeting through community engagement. This significantly reduces the overheads for the industry in finding consumers and scale-up, allowing the SPV to be very specific in where it targets deployment.

The data used can also be supplemented with local knowledge and community data which can provide further evaluation of areas more likely to be acceptable to uptake and/or where interest has already been expressed.

The overall process could ensure delivery only in areas that can accept heat pumps, gauge system sizing, and identify target homes for deployment. It is estimated the cost savings for the supply chain could be significant as it typically costs installers an estimated £250 per home average to engage (considering dropout rate) and supply chain capacity is heavily constrained to be able to target volumes of homes needed.

Information and evidence could also be fed back to the lead organisation which can then adjust its low carbon strategy and LAEP based approach to refine where it considers different low carbon solutions viable. This can form an evidence base to and the lead organisation, community groups, and industry.

8.4 Electricity Network

Role

A subconsultant could provide advice to the lead organisation on electricity network opportunities and constraints, providing:

- Liaison with Distribution Network Operator
- Considerations around grid constraints
- Electrical design activities associated with community heating

Rationale

The electricity network is highly constrained in some locations, and this is likely one of the challenges slowing down high-density deployment of heat pumps. During the feasibility study, it was found that DNO engagement is useful to gain an understanding of where there are immediate opportunities to install heat pumps in areas with capacity, and where there are constraints that could be worked on in the future.

During the feasibility study, Challoch Energy acted as the organisation providing input on electricity grid opportunities and constraints.

Description

This subconsultant would have a track record in low carbon energy projects, energy infrastructure research and innovation, and experience delivering on local energy market solutions and community initiatives. It would be beneficial to have experience in deployment in electricity networks in the project location, as well as experience in household energy efficiency measures.

It is suggested that an electricity network subcontractor could engage with the local DNO at several levels. In terms of deployment and practicalities of network capacity, the needs of reinforcement and registration of installation could be all done locally. A DNO committed to enabling heat pumps could facilitate any network reinforcement.

Many houses in South Wales are on looped supplies (one service cable to two houses), thus halving the available capacity for load. With the installation of heat pumps, houses with looped supply would need an upgrade to the service cable provision. The same process would apply to increased load triggering either a feeder upgrade or enhanced capacity in the LV substation. A close working relationship with the 11kV planning team and the LV engineers is beneficial to smooth the process. All heat pump installations are required to notify the DNO via the EVCP & HP Connections Form v3.3 with the obligation to inform the DNO within 28 days of the installation. This is a fit and inform process. What would be subject to more detailed discussions is whether this applies only to installations that are one-off projects or a planned installation of multiple heat pumps.

The second level of engagement is with the DNO and policy teams in terms of flexibility and aggregate services. It is recognised that on really cold days heat pumps operate in a baseload configuration for space heating, but hot water prevision can be scheduled. For the rest of the year, heat pumps can contribute to flexibility services / demand side measures. The integration of these services for the DNO could be via their DSO function and would require some additional policy evolution.

8.5 Engagement

Role

A subconsultant could provide advice to the lead organisation on engagement, providing:

- Community engagement, and advice on the customer journey as it relates to engagement
- Local government engagement
- Heat pump installer engagement

Rationale

Findings of the feasibility study are that engagement is needed to encourage homeowners to consider installing heat pumps, engagement with local government gives confidence to prospective customers, and engagement with the supply chain and installers is likely to support the installation of heat pumps.

During the feasibility study, NuVision Energy (Wales) acted as the organisation providing input on engagement activities.

Description

The engagement subconsultant could be an SME specialising in the project area in community engagement and surveying. Experience in community engagement, survey process development, and installer relationships would be of benefit. Experience in heating system installation including ASHPs would help to support a heat pump project.

This organisation could lead the design of the consumer engagement process. It could also lead the design of the process for ASHP survey management, and monitoring.

The community engagement organisation would apply their expertise and develop a process of community engagement which can be deployed in areas where target clusters have been identified. This includes the following:

- Community communications wider engagement to be disseminated by the lead organisation.
- Wider community engagement in target clusters through a process of multi-media including the potential to utilise a Council website as a portal as well as dedicated website with customer relationship management system (CRM) hosted by the organisation in contact with customers – for example a Special Purpose Vehicle or other organisation. Knowledge can be stored and disseminated to community members on the benefits and opportunities available. This can be used to receive enquiries from interested parties.
- Walk-in centres could be arranged within target cluster areas where community members can be informed through leaflets, direct door-to-door engagement and the use of community champions.
- The format of the centres could include providing information on the options available, benefits case and approach to delivery. Opportunities to also directly engage with the supply chain to sample test products can also be organised.
- Information could be collected from a survey process which could allow follow up and better assessment of the community requirements.

8.6 GSHP + SGA Contractor

Role

A contractor could provide services to the lead organisation, including:

- Shared ground array construction, operation, and maintenance.
- Finance arrangements for GSHP and SGA array available to groups of customers.
- Relationship with GSHP installers. The GSHP installers could be subcontracted to the GSHP + SGA contractor.
- Design of home survey process for home surveys, including wet heating system and retrofit appraisal.
- Ground investigation organisation. Ground investigation may be required to identify constraints.

Rational

Findings of this study are that, compared to ASHP, GSHP + SGA requires less electricity to provide building heat demands, and therefore has a lower impact on grid capacity. Therefore, it is useful to consider including a GSHP + SGA contractor in the collaborative team where this technology is considered, providing a direct route to deployment.

During the feasibility study, Kensa Utilities acted as the organisation providing input GSHP + SGA. Kensa has contractor capabilities.

Description

The GSHP + SGA contractor could be an organisation which deploys GSHP and ambient loop technologies. This could include system development, operations, and financing.

The lead organisation or SPV could provide a commission to the contractor for each GSHP + SGA installation secured.

A specialist heat pump contractor could design detailed home survey to discuss specifics on installations and the process they could go through. This is an important step as the specialist GSHP organisation could be an energy services company (ESCO) which could provide the shared ground loop service directly to the consumer on a long-term agreement.

The contractor could also input into the design of fully-detailed information packs which could be provided to each household as well as further community engagement and site walks to discuss the whole process.

There is an opportunity for the contractor to offer a finance structure where customers who do not wish to pay costs upfront could pay them over a period of time to the contractor through a mechanism of a standing charge.

8.7 ASHP Installers

Role

ASHP Installers could provide the following services:

- Design of ASHP solutions for homes
- Installation of ASHPs

Rational

There are some areas which are suitable for ASHPs, so it is worth including this technology as an option for these areas. Although only a GSHP + SGA contractor was included in the original feasibility study for HPR Bridgend, there is value in engaging ASHP installers as external to the core group to add this flexibility to a heat pump offering.

During the feasibility study, NuVision Energy Wales engaged with local ASHP installers and compiled a list of potential suppliers in the Bridgend area who could work with a heat pump deployment project.

Description

Local Air Source Heat Pump installers could be managed by the lead organisation (e.g., SPV). They could contract directly with the homeowners. These installers would be key external stakeholders to the project.

For the AHSP installations, a commission could be paid by the lead organisation to the installers for each secured heat pump.

Referrals could be made to suitable installers which would hold the direct relationship with the consumers. The installers could be vetted by the lead organisation (e.g., SPV) and appraised of the process including the type of information provided to consumers that has informed their choice. The lead organisation could then remain in an advisory capacity.

The installers could arrange a full survey to determine exact installation requirements and process to then provide a quotation formally to the consumer. At this stage the consumer may seek further guidance and support from the SPV on the process or they may elect simply to continue with the installer.

A process of commissioning could be factored into the business model for installers who successfully sign with the consumer which could be paid to the lead organisation SPV for its service. This could be fully affordable based on the reduced overheads and economies of scale brought to the process. See Section 11 on costs to consumers for information on estimated costs.

Warranties and liabilities could remain with the installer which could reduce the overheads of SPV but also ensure that current industrial practice for installation and certification is not interfered with.

8.8 Council – Local Government

Role

The Council could provide the following support to the lead organisation:

- Communication support (e.g., website and Facebook messaging)
- Endorsement and participation in engagement events

Rational

Support from the Council in the project area is integral consumer confidence in a heat pump project. A finding from the feasibility study was that the involvement of BCBC helped to increase potential customer confidence in the study.

Description

During the HPR Bridgend feasibility study, Bridgend County Borough Council (BCBC) directly sponsored the study, which aligned with BCBC's climate agenda in South Wales. BCBC supported communications activities to give confidence to consumers there was local government backing. The Council was a key external stakeholder to the feasibility study.

8.9 Distribution Network Operator

Role

Distribution Network Operator (DNO) provide the following support to the lead organisation:

- Data regarding electricity network assets, to help assess opportunities for high-density deployment of heat pumps in an area
- Consider future electricity grid planning in an area where high-density deployment of heat pumps is in planning stages

Rational

Support from the local Distribution Network Operator is also integral to the success of a heat pump project. Data from the DNO on network capacity is key to the project.

Description

During the feasibility study, National Grid Electricity Distribution (NGED), formerly known as Western Power Distribution, engaged with the HPR Bridgend feasibility study via both their local network teams (11kV and LV levels) and through their central innovation team.

9 Areas for Innovation

The HPR Bridgend feasibility study recommends the latest in digital planning techniques, community engagement process and community heating as a methodology. It also suggests finance mechanisms that support homeowners in affording the capital expense to improve their homes and to access affordable low carbon heating, not otherwise possible through currently available mechanisms.

This integrated process enables the stakeholders to target high-density deployment of heat pumps in private homes whilst giving communities the confidence they need and enabling them to afford the transition.

The Bridgend area is similar to many areas of South Wales and North Wales, where there is a mix of housing from coastal strip towns to poorer hinterland communities. In some aspects Bridgend has been at the forefront of energy mapping and trialling decarbonisation options. This includes being one of the first LAEP pilots in the UK.

The locality itself presents some challenges which whilst not being exclusive to that area only are testing for a variety of reasons. These include numerous communities in energy poverty and houses of older designs requiring efficiency measures to permit heat pumps to work. Geological limitations are relevant particularly in the valleys where homes are often built with limited access to roads and onto the back of steeply-sloped banks meaning space and access for heat pump installation is limited. Electricity networks are typically very weak in these areas due to lack of infrastructure. The proximity of the coastline means salt erosion will mean normal offerings of ASHPs would have shorter life spans and alternative more expensive options would be advised. All these factors drive a techno-economic solution to be integrated in overcoming them.

9.1 Customer Engagement

Currently, market transactions tend to be very reactive relying on consumers to reach out to installers expressing an interest in an ASHP and then evaluating the offering based on information at hand. Current market feedback is that there is a lack of good information and knowledge on the role of heat pumps in homes, benefits, and considerations for homeowners. Finding an installer can be seen from a consumer perspective to be a gamble similar to finding a builder but with less comfort. It is a transactional process like replacing a gas boiler. There is very little information on shared heating systems, and these are not normally considered by homeowners due to the current industry and subsidy model being tailored for individual homeowners.

An area for innovation is in community engagement, to achieve high-density deployment of heat pumps in domestic properties. The recommended collaborative approach is to work with an organisation specialising in engagement actives. The engagement activities are designed specifically to tackle the need to find and recruit homeowners and to assess their homes for suitability as quickly as possible. During the feasibility study, NuVision carried out this role.

9.2 Installer Engagement

This study - HPR Bridgend - innovated in the installer engagement process by providing the upfront engagement, heat pump readiness surveying and targeting of consumers which would otherwise not be possible by the current supply chain due to the extensive overhead needed. It also identified areas where heat pump installations cannot happen due to grid constraints which would not be visible to installers. However, what it did not do is change the final survey and heat pump installation process that would be undertaken.

Selection and training could be given to installers for heat pump deployment, advising them what the survey and engagement process is, how they may benefit from the referral model deployed and the return expected as a result. ASHP installers could then volunteer to sign up to a project scheme as a participant with a direct agreement with the main organisation (which could be a Special Purpose Vehicle or other organisation). This applies to the ASHP model only as the GSHP +SGA solution could be provided by a specialist heat pump organisation.

For GSHP + SGA, a finance structure could include stepped finance offerings on retrofits, heat system provision and a standing charge designed to recover the upfront investment made by the specialist heat pump organisation. This model could enable those consumers who cannot or do not wish to fund part of the measures themselves to pay for them on a shared ground loop model instead. This process could allow significant gearing on the investment made by HPR programme as private sector investment could be enabled at scale to unlock low carbon heating for households.

9.3 Energy Planning and Data Platform

The innovative approach suggested consists of mapping screening for clusters suitable for high-density heat pump deployment and the set up for a comprehensive data repository.

The evaluation process suggested would use the latest in digital planning techniques, combining multiple sources of information into a digital plan that layers utility network data, domestic building data and community-sourced data. This allows the appraisal of suitable clusters of buildings in areas where network capacity is available to rank areas based on their viability for deployment.

Spatial techniques mean that clusters can be evaluated for their alignment to community heating via shared ground loops as well as individual ASHPs.

9.4 Electricity Network

It is suggested that an electricity network subcontractor could engage with the local DNO at several levels. In terms of deployment and practicalities of network capacity, the needs of reinforcement and registration of installation could be all done locally. There are considerable opportunities for integration of the DNO into the technical solution proposed including local energy market and flexibility solutions.

10 Approach for Mobilisation and Deployment following Recommended Methodology

10.1 Introduction to Mobilisation Approach

The approach to mobilisation and deployment begins by understanding the target area, including understanding the prevalent housing archetypes, variations in social demographics, attitudes, affluence, and climate. The methodology for coordinated high-density deployment and its replicability into other areas is founded on customer engagement, supply chain development and government support/interaction both locally and nationally by the UK government.

Of interest in developing the feasibility study was that the benefits of community heat via shared ambient loops are not typically understood by households. When explained that there are stacked benefits, the consumer interest rises significantly. For example, the systems offer far higher efficiency and resilience during cold spells than ASHPs. The GSHPs can be installed inside properties which protects them from the environment and mitigates any issues regarding outside space.

The recommended approach includes low carbon heating systems with GSHP + Shared loop, which under HPR Bridgend could be further developed to incorporate new commercial models. Much of the upfront capital expense could potentially be paid for under the HPR programme, including light retrofit work on properties, negating the upfront spend normally asked for from consumers.

Light retrofit measures considered in this feasibility study included airtightness, loft insulation, cavity wall insulation, and improved heating controls. The running costs are low, and finance is spread over a long operating period reducing payments. To be able to deploy GSHP_SGA systems requires community buy-in normally on a street-by-street basis. The HPR Bridgend feasibility study community engagement process could enable new approaches to stimulate this engagement on a community basis as well as home by home, providing multi-level accessibility to consumers.

Including ASHPs in the offering could potentially allow the local communities to benefit from the most appropriate heating solution. A finding from the feasibility study is that GSHP + SGA requires a substantial capital cost, and therefore this type of heating system is suggested for properties which are highly space constrained. Due to the expertise available in the feasibility study group, there is far more detail presented in the study regarding GSHP + SGA. However, ASHP is a technology worth considering where space and electricity capacity are not as constrained, to increase the number of households for which heat pumps are considered suitable.

10.2 Scale and Engagement

10.2.1 Number of heat pumps

The objective of the feasibility study was to identify approximately 150 homes suitable for heat pumps in four target cluster areas. The neighbourhoods under consideration included: two areas in North Cornelly, one in Nottage, and one in Ogmore Vale.

10.2.2 Number of potential consumers to engage

Out of a total of approximately 1,500 homes in all four villages, 1,060 are in the most prevalent archetype groups – compact semi-detached homes and terraced homes.

It is suggested to target these building archetypes to allow for replicability in approach between properties and associated efficiencies. Of this group, approximately 30% may be interested in a home survey (approximately 300 home surveys). Of those surveyed, 50% may decide to continue to have a heat pump installed.

Targeted number of homes for heat pump installation are: 40 in North Cornelly and 86 in Ogmore Vale with GSHP and shared ground array, and 18 in North Cornelly and 12 in Nottage with ASHP. It is currently estimated 75% of target installations could be for community heat systems and 25% could be ASHP installations.

The homes in North Cornelly 2 and Ogmore Vale are likely to be relatively close together and suited to GSHP + shared loop. Where customer interest is likely to be more dispersed in North Cornelly 1 and Nottage, they are more suited to ASHP. Where these target numbers for signup are reached, the stage gate could be passed from 2a mobilisation to 2b deployment.

The cost for the shared ground array amounts to ~£1,556,700 of investment (North Cornelly Stage Gate 2, and Ogmore Vale Stage Gate 4). The result of the investment by BEIS would unlock this private investment into homes that would otherwise not have been committed to low-carbon heat during the time scales.

10.2.3 Scaling Up

To allow for scaling up, the availability and constraints with the electricity power grid across the communities selected for consideration (North Connelly, Nottage, and Ogmore Vale) need to be better understood. This could be achieved using data and information from National Grid.

All areas considered in the feasibility study could be explored further for headrooms for additional loadings by heat pumps and categorised for potential heat pump deployment. Grid constraints are an important aspect of all future projects if mass deployment is to be achieved; to upgrade large areas of the national electric grid could require high capital expenditure and programming by the DNO over the years to come.

To realise deployment and scale up it could be important to work closely with the DNO. This could be crucial in the screening for heat pump suitability, electricity network constraints and potential innovative opportunities as well as the need for improved home energy performance and their link to heat pump capability as replacements for gas boilers.

10.3 Survey Methods which Deploying at High-density Unlocks

Deploying at high-density allows a more focused approach to survey methods. From a technical standpoint, this limits the number of different building typologies that need to be considered. It also implies that household suitability surveys can be more efficient and better tailored at an early stage to specific requirements.

As described in section 10.4, the engagement process for heat pump uptake is traditionally very reactive, relying on consumers reaching out to installers. A high-density deployment model helps to reduce this allowing for better and more targeted surveys. This high-density of deployment increases the benefit to community level survey methods and engagements. Being linked both spatially and in terms of typology creates a common narrative to surveys for each of the three priority areas identified. This aids with door-to-door level surveys which are not as tenable over a non-dense deployment area. Key for successful engagement at a door-to-door level is having a community engagement organisation that is embedded in the local community. This proved key in the initial engagement processes of this feasibility study.

High deployment density enables centralised events in each community to be viable which can be a useful point for surveys, including sign-up to monitoring equipment. A high deployment density also means that centralised events in each deployment area can be held with a more equal opportunity for consumers to access it compared to if it was a spatially disparate deployment strategy.

Finally, from a network perspective, high-density focuses surveying and understanding infrastructure. Fewer feeders and secondary substations would be impacted, meaning it could be simpler to carry out detailed surveying of infrastructure. A finding from this feasibility study is that there could be a need to digitise or transform some DNO information for integration into the digital elements of the work.

10.4 Customer Journey

The approach and vision of the HPR Bridgend feasibility study is to provide the areas targeted with a one-stop shop concept to bring together the various elements to support householder decision making for decarbonisation.

The customer journey recommended, following this feasibility is presented in Figure 10-1**Error! Reference source not found.**. This represents an approachable, straight-forward route from contact with the lead organisation (or SPV) through to heat pump installation and receiving an information pack.

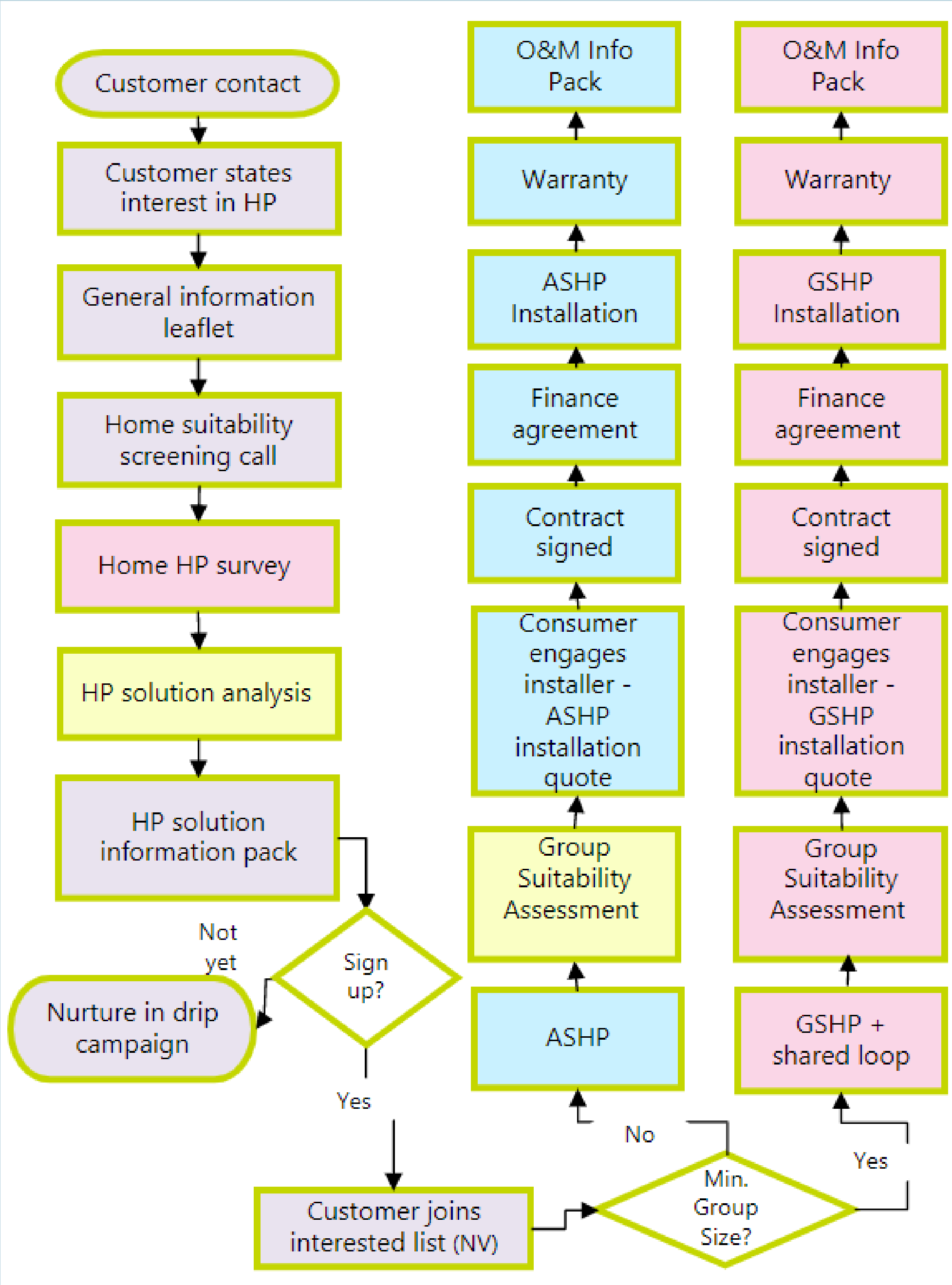


Figure 10-1 Customer Journey

10.4.1 Direct Consumer Engagement and Home Suitability Screening

This could involve a process of direct engagement with consumers to discuss their needs, queries, and aspirations. Some high-level information on the home and consumer requirements could be collected which could assess whether the home is suitable for a heat pump, likely consumption and retrofits required. A CRM hosted by the lead organisation could collect and store information on individual consumers for assessment by the lead organisation team on viability of options. The outcome can be fed back into the planning process to revise the assessment of suitability and grading of properties. Any interest in follow-up could be noted which could then be used to schedule in a Home Heat Pump Study.

Community Engagement

To support this process, additional educational and awareness-raising events could be conducted online as well as at locations in the community. A weekly 'drop-in' online event with collaborators could be available on Microsoft Teams to discuss issues with any homeowners that login to the event.

Customers could be offered a 1-to-1 home suitability screening call where they can discuss their specific property. Where the property is suitable, they could be offered a home heat pump survey to estimate the heat pump size required and what cost-effective energy efficiency measures may be needed. Following the survey, the information could be analysed off-site, and the customer could receive a heat pump solution information pack, recommending the most suitable heat pump for their home (GSHP or ASHP). Where a customer is interested, they can join an 'interested list', and when there are enough people interested, plans can go forward to deploy GSHP or ASHP by passing the stage gate. This process is shown in Figure 10-2.

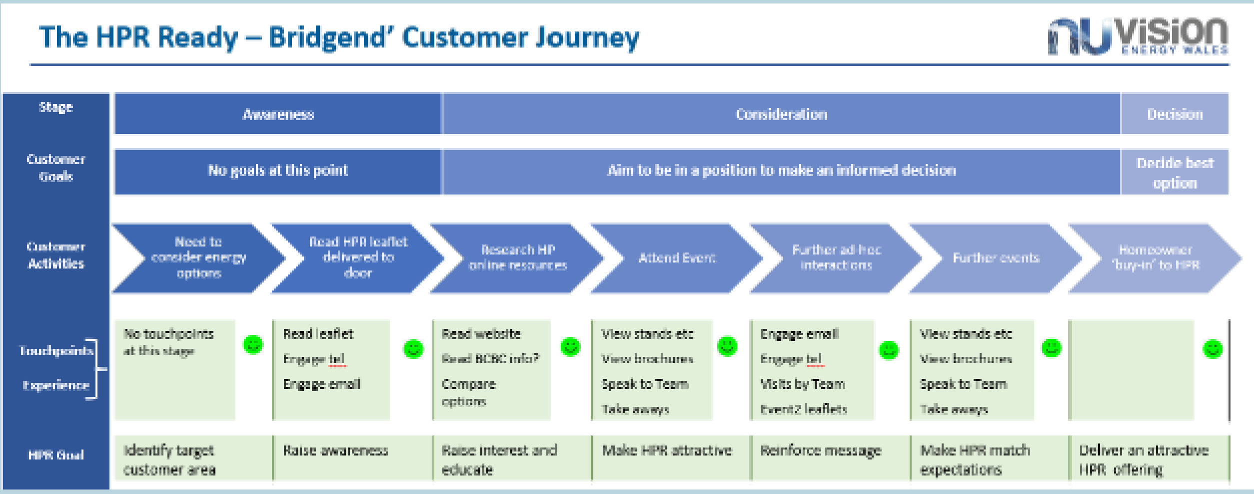


Figure 10-2 Customer Journey to Decision point

Following installation, aftercare includes a warranty, operation and maintenance package, and monitoring (Figure 10-1 Customer Journey Process). The monitoring allows the innovative step of observing how the heat pumps perform to allow more optimised sizing of heat pumps in future installations, reducing capital costs.

10.4.2 Home Heat Pump Survey

For individual households the engagement organisation could arrange delivery of a survey co-designed with Kensa; tailored to specifically finding out the suitability of the property and explaining systems options. This could include a home visit. This involves, for example, evaluating current energy usage, building construction, existing heating system configuration and space for equipment. Retrofit items could also be identified that may be relevant to improving comfort and enabling better heat pump performance. This includes air tightness and light fabric and insulation improvements. For community heat this could typically be undertaken on a street-by-street basis whilst for ASHPs this would be individual homes.

10.4.3 Heat Pump Solution Analysis

The outputs could be fed back into the spatial planning tool as well as updating the CRM which could inform the evaluation process on likely measures to be deployed, heat pump size, homeowners interested and likely package options to be offered. For ambient loop system options working in conjunction with Kensa, system sizing, street layouts and pipe runs could be allocated as this could help determine the potential cluster size and cost as part of the preparation of the techno-economic evaluation. This process then commences the systems design activities and techno-economic evaluation of shared heating which should be done before further interaction with the community.

Challoch could consult with NGED at this point because projected grid impact and connection numbers could need to be determined. Confirmation of available capacity and any work required by NGED to facilitate the deployment at scale can be worked out reducing timescales further down the process. This could also pick up any work not originally factored in such as whether properties have to be unlooped or have their fuse ratings changed.

10.4.4 HP Information Pack

A heat pump information pack could be provided to homeowners to support their decision on whether or not to have a heat pump installed. An initial advisory pack could present the indicative sizing of the heat system, work required, benefits of other work (e.g., fabric retrofits) as well as forecasted billing information and costs.

When considering ASHP, this information pack could be used to inform the choices made by the consumer and stimulate further discussion and assurances needed before direct engagement with the ASHP supply chain.

For the community systems – GSHP with Shared Ground Array - the pack can be tailored to provide both individual home requirements and additional information on the community scheme. This could include for example indicative costs, example commercial agreements, benefits case and work required both inside homes and in the streets. This is deemed important to set expectations on disruption but tied to the benefits case of deployment meaning such disruption is likely to be accepted.

10.4.5 Sign-up

A follow up to discussions with the consumer(s) following issue of the information pack could aim at securing a preliminary signup and expression of interest. For shared heating systems this could be coordinated based on a community approach aimed at creating a buzz of activity within the community. A follow-on community engagement session could be planned as it is anticipated the community cluster may be forming organically at this stage and individuals may wish to share information with their neighbours and questions could be asked. Champions could be assigned to maintain community interest and act as a focal point to the community for continuing to maintain momentum.

10.5 Quality Assurance Method Statement

The recommended approach for quality assurance of heat pump delivery considers four key elements:

- Design
- Installation and commissioning
- Customer handover
- Customer protection

Key suggested aspects of these four areas are outlined in 10.5.1 to 10.5.4.

10.5.1 Design

This approach considers the overall system design it should ensure the system is optimal for the property in question. The key aspects are highlighted in the list below in bold with some key contextual information provided for GSHP + SGA Kensa-specific factors. Although these are Kensa-specific, alternative ASHP solutions should also be considered, and suppliers engaged to ensure that they can fulfil the requirements in bold to a similar high standard.

- **Heat loss calculations.** Following guidance as to MIS-3005-D (Heat Pump Design)[28], room-by-room heat losses are produced for each property archetype. These should be calculated from a survey when retrofitting or from provided floor plans for a development.
- Power Heat Loss Calculation (peak load).
- Space Heating Energy Consumption (annual load).
- **Heat pump sizing.** Heat load assumptions should be updated to suit occupant types where required.
- **Space heating flow temperature and appropriate emitter sizing.** Distribution systems for heat pumps are often sized to 45°C flow temperature, this requires radiators to be oversized according to manufacturers' lower flow temperature output figures. This should be tailored to specific property types and heat pump characteristics.
- **Hydronic design.** All designs are peer reviewed internally before being issued for construction. The Kensa product ensures that designs meet minimum flow rate requirements in all conditions using circulating pumps within the Shoebox heat pump.
- **Integration with heating controls and weather compensation.** Kensa Heat Pumps simply require a switch live signal for heating and hot water. This can be provided via a simple timeclock/thermostat arrangement, or via more sophisticated 'smart' heating controls as specified by the client. Kensa have also pioneered the use of intelligent controls, which have demonstrated load-shifting capability of intelligent controls, reducing running cost by optimising heat pump operation during low cost / low carbon periods, using time of use tariffs. Alternative systems are available with similar functionality and this level of control/flexibility should be considered as a requirement when finalising technology choices at a property level.

[28] https://mcscertified.com/wp-content/uploads/2020/08/MIS-3005-D-Heat-Pump-Design-Issue-1.0-DRAFT-V3.pdf

- **Understanding of the equipment being installed.** It is vital the system designer has excellent knowledge of the product (and ideally experience), this could help ensure designs conform to product and MCS requirements.
- **Efficient hot water production.** Calculate the hot water requirements using either BS 6700[29] or BS EN 806[30]. Calculation methodology should indicatively be based on an occupancy rate for the building of total number of bedrooms plus one person.
- **Integration with other technologies and tariffs.** For Kensa integrating PV directly with the ground array provides the dual benefit of increased electrical yield (due to cooling of the panels) of circa 15% and increasing heat pump efficiency circa 20% by rejecting heat into the ground from the solar thermal element, reducing electrical consumption and therefore heating costs. Although some aspects of this are very tailored to the Kensa system, similar technology integration can take place for ASHP – with PV and the ASHP being able to fill a hot water tank during daylight hours (for example). Appraisal of these integration opportunities should be a key aspect of the design stage.
- **Network connection.** DNO (Wales and West Utilities) Notification - Necessary for retrofit gas displacement. In the case of Kensa all heat pumps are 'connect and notify', meaning no prior permission is required to connect them to the grid.

[29] https://landingpage.bsigroup.com/LandingPage/Undated?UPI=000000000000168435
[30] https://landingpage.bsigroup.com/LandingPage/Series?UPI=BS%20EN%20806

10.5.2 Installation and Commissioning

Effective installation and commissioning are vital for the household experience and for the success of deployment. Again, key items are highlighted below in bold with context provided by Kensa, as suggested in 10.5.1 the principles in bold also apply to ASHP alternatives.

- **Installer qualifications and knowledge –** Any subcontractors must complete a subcontractor approval form which determines their suitability. Qualifications of employees must also be evidenced where required.
- **System certification** – Kensa Contracting has a dedicated compliance team responsible for ensuring all systems receive MCS accreditation in a timely manner following system commissioning. Part BPEC Part L, WRAS, qualified and experienced heat pumps engineer could be on site during the commissioning phase.
- **Ensuring correct hardware is used in installation –** Hardware to be confirmed with a QA check before installation.
- **Weather compensation –** to be included in HP control approach.
- **Minimising disruption –** Kensa's model for this is to put in place a dedicated Project Manager for the installation, identifying product requirements to fulfil the delivery program. Purchase order schedules are produced in line with supply chain lead-in-times, ensuring adequate stocks are delivered throughout the programme. The Logistics Department works closely with our supply-chain to provide advance notice of call-offs based on the agreed Programme of Works to ensure materials are readily available for installation whilst also providing a buffer contingency stock. Any installers and suppliers should have as similarly robust approach to ensure minimal disruption.
- **Monitoring –** Wi-Fi allows Kensa Heat Pumps to access the HP data remotely to aid with diagnostics and performance monitoring. This is becoming increasingly common in heat pumps and should be considered as a standard for deployment.
- **Smart controls –** It is possible to link the Evo to an existing Wi-Fi network enabling remote diagnostics. The Evo could periodically upload performance data to a Kensa server allowing Kensa to interrogate any issues. Again, technology advancement is allowing a greater level of smart controls, and this should be a factor considered in deployment. It is hugely beneficial for unlocking lower tariffs and thereby addressing rising fuel prices and fuel poverty.
- **Good quality workmanship –** At the point of handover of a property, Kensa Contracting (KCL) adopt a snagging process. Commissioning and warranty certification could also be registered. Ensuring that the project has been completed to the satisfaction of the client, based on the scope of works, and KPIs agreed with client is tied in with a Project Completion Sign Off document containing a checklist ensuring the system is installed to the design specifications and operating to requirements. Similar certification processes should be in place regardless of the installer and supplier.
- **Accessibility for maintenance –** There is no requirement for an annual safety inspection or service of the GSHP itself. However, it is good practice to carry out periodic checks on the internal central heating system as would be recommended with any heating system. ASHP maintenance and safety check requirements vary but access is less challenging. Items to be considered include filters are in a suitable state and checking for any ice or snow build up (to ensure efficiency), in many instance the homeowners could be able to perform these checks themselves.

10.5.3 Customer Handover

A historic issue with heat pumps is that not enough guidance is given as to how they should be used, key items and recommendations (provided by Kensa) are outlined below – these generally align to all heat pump systems.

- **Handover documentation -** All related documentation is supplied to the client on install completion and consists of: commissioning checklist, MCS certificate for each install, warranty for the heat pump (5 years minimum) workmanship Guarantee of either 12 or 24 months (whichever is outlined in the contract/quote), Cylinder or Heat Battery Benchmark certificate, and evidence of compliance of any additional or specialist equipment or products installed outlined in the contract/quote or scope of works.
- **System operation and maintenance -** A HP User Information Pack should be given to the resident once the HP system is installed and commissioned, outlining all FAQs and including resident engagement videos explaining the heating system in detail, including potential faults and how to rectify these issues.

10.5.4 Customer Protection

Ensuring customer protection is the final stage and longest-term aspect of quality assurance. As with the above sections, the points below are provided by Kensa but act as a steer to the key recommended items for any deployment.

- **Customer support post-installation.** Customers should be provided with an email address and helpline number.
- **Manufacturer warranty.** Manufacturer warranties should be provided in the handover pack and the Resident Liaison Officer could go through these with the Homeowner.
- **MSC Certified contractor's guarantee.** All heat pump installations to be MCS certified, ideally with a workmanship warranty.
- **Renewable Energy Code of Conduct.** Team ensures consumers have information about the upfront costs, running costs and expected performance prior to any purchase.
- **Maintenance schedules and plans.** Maintenance and servicing (if part of the Contract/Quote or Scope) should be outlined in the handover document and could be communicated by the resident liaison officer as part of the handover of each property.
- **Aftercare package.** Customers should have access to post-installation support (for up to two years in the case of Kensa) as part of the contract and support should be available after this date free of charge.

10.6 Installer Engagement

The approach to installer engagement in section 8.4 is an important area of innovation, which is greatly enhanced and enabled by the high density of heat pump deployment. The early-stage installer engagement allows a build-up of trust in delivery as well as enabling the delivery strategy itself to be informed by installer experience. The approach taken could follow that detailed in 8.4 with early engagement and buy-in to the overall strategy being key to the success of this process.

Depending on the choice of heat pump system, one of two possible consumer journeys could be deployed: ASHP or GSHP + SGA.

10.7 DNO Engagement

A first step of DNO engagement should be to establish with the DNO whether they could form part of the delivery consortium or provide a letter of support for the project. Being part of a consortium generally helps with data sharing arrangements and easier flow of information.

As discussed in 10.2.3, effective DNO engagement is key to the scaling up and deployment of heat pumps. One of the immediate actions is a better understanding of the low-voltage elements of the network. There was a key disconnect between the information available in a tabular format and in a spatial format. The tabular format included information relating to feeder capacity, the load on the feeder, the number of connections on each feeder and the number of feeders associated with each secondary substation. The recommendation for developing the projects further would be to work with NGED so these data can be attributed spatially. The work carried out in this feasibility study to identify three focus areas could help reduce how onerous this task is likely to be.

After the spatial attribution of tabulated data gathered in a feasibility study the next recommended stage would be to collaborate with the DNO to gather further information, nominally the connection point information. This would create the highest resolution link possible between the network and property information.

An area which could assist with this communication and collaboration is a shift towards a standard power model between DNOs. It is likely with National Grid taking over WPD that Power Factory could become the power model used in the Bridgend area. If Power Factory files were supplied this would allow for easy testing of the network impacts for the project team, without having to rely on the open access data which has multiple anomalies. Having a full power model would also allow the combined impacts of multiple areas on the network to be assessed. This enhanced data sharing would allow multiple iterations of scenarios with a high confidence rather than having to rely on a formal quotation from a DNO to understand the impact of heat pump deployment with confidence. Additionally, model outputs could be fed back to the DNO in a format which is compatible with their own modelling – allowing for smooth transfer of data. Whilst this is not likely to be immediately possible it is important to consider longer term recommendations, as the deployment potential for heat pumps in Bridgend extends far beyond the three priority clusters identified.

Regardless of the above, once the initial deployment strategy is in place the DNO (NGED) could need to undertake its own assessment of the network to assess the need for reinforcement. A key element of the stakeholder engagement could be the project team working closely with NGED to decide when to trigger this assessment, as there are costs attached. Mass deployment should be able to streamline this process, making it easier for both the DNO and the homeowners.

As discussed in 10.5.1, engagement with the gas DNO (Wales and West Utilities) is also important. They would need to be notified when a property is connected. As with the electricity network, mass deployment should be able to streamline this process.

10.8 Challenges which the Methodology Overcomes

The methodology proposed could initially address the lack of detailed base information in this feasibility study. The work undertaken in this feasibility study could streamline this process allowing for enhanced data capture to be undertaken quickly. The digitalisation planning approach in particular could help with addressing this challenge.

Digital planning could also help with the issue of engagement. Presenting information to homeowners in an easily accessible format helps buy-in and understanding. However, this raises GDPR issues which is why any outward-facing digital platform is recommended to have different levels of access, for example an occupier could have more information available about their own property than others.

As well as getting people to engage with the uptake of heat pumps, a transparent and easy to access digital presentation of data is also recommended for improving data quality. In previous projects Buro Happold have had useful feedback from occupiers on building stock model inaccuracies. This could lead to better targeting of surveys and understanding of appropriate system design.

Clear digital mapping could also help direct the home heat pump surveys. Attention should be given as to who would be placed to carry out the surveys as some of properties identified in the modelling could be better suited to ASHP rather than a GSHP +SGA system.

11 Costs to Consumers

The HPR Bridgend project offers an inclusive approach to heat pump deployment, to achieve the 25% target uptake of heat pumps. Due to space constraints, there are some properties such as terraced homes that can only consider GSHP with shared ground array solution. With a shared ground array solution, homeowners can share an efficient heating system where land outside the property can be used for the boreholes. There could also be homes where ASHP is a suitable option, and homeowners may prefer this approach. Stakeholder engagement and preferences are key to achieving the high-density deployment of heat pumps.

In this section, we present two 'Cost to consumer' calculators. The first for GSHP with shared ambient loop technology and financing option, and the second for ASHP. Both calculators cover the stage gates for clusters of homes where 25% uptake of heat pumps is targeted: North Cornelly 1, North Cornelly 2, Nottage, and Ogmore Vale.

11.1 Shared Ground Array heat pump solution

11.1.1 Two options to the consumer to pay the upfront capital cost

- Option 1: Upfront capital contribution from the consumer
- Option 2: Zero upfront cost - cost spread to be recovered as a loan over 5-year period

We have included the two types of cost to the consumer calculator for the GSHP system. These costs were derived from Kensa's engineers and design teams, based on experience deploying thousands of heat pumps across the country. However, they also factor in the cost reductions expected to be achieved through the coordinated methodology described in section 5.

11.1.2 Annual operation cost for Shared Ground Array HP solution

11.1.2.1 Electricity Bill

End-users could pay for their heat through their electricity bill, giving them independent control of their heating use and the electricity supplier from which they source their electricity. With flexible and heat pump specific tariffs becoming more commonplace, this allows end-users to benefit from the lower running costs associated with these.

11.1.2.2 Standing Charge

In a shared ground array system, customers could have a contract with a heat infrastructure provider. From commissioning of the heat pumps, a heat infrastructure provider, in this case (Kensa Utilities Ltd.) could charge a standing charge. The cost of operation and maintenance (O&M) of shared ground arrays are covered under the standing charge paid by the end user. There would not be an additional cost in terms of O&M of the arrays from the end user. It would be the heat infrastructure provider's responsibility to ensure delivery of ambient heat needed to run each heat pump, and the provider would conduct repairs and O&M on the shared ground array as required to ensure performance.

Standing charges associated with the shared ground array infrastructure are based on planning work required to drill on the public highway, allowing high-density housing heat pumps, in particular terraced housing to benefit from ground source heat pumps even if they have no available space for boreholes on their own properties or poor access for drill rigs. Working in the highway is more complex and therefore more expensive than individual boreholes within the curtilage of a property.

The capital cost of the infrastructure is spread across a 40-year term, linked to the property. This reduces the upfront cost to the consumer as well as the cost to the individual homeowners.

Ground array infrastructure has an expected lifespan of approximately 100years, whilst owner-occupiers in the UK stay, on average, 16.5 years in a property. By linking the capital cost to the property, rather than the individual, this cost can be passed to the new occupant.

On average, we would expect each service agreement to be financed by 3 households across its term. The agreement with the heat infrastructure provider owning and maintaining the ground array would last for a minimum of 40 years but could roll-over after this until the end user chose to terminate it, ensuring continuity of supply and heat for as long as consumer desired.

The charge to the customer is based on a private investor return on investment agreement. Currently, this is based on providing 6% return on the private investment. This analysis has been carried out assuming an annual CPI index of 2.5%, i.e., with prices fixed in the first year.

11.2 ASHP Solution

For ASHP there are also two options:

- Option 1: Upfront capital contribution from the consumer
- Option 2: Zero upfront cost - cost spread to be recovered as a loan over 5-year period

For ASHP financing would need to be arranged for a heat pump project. Options could be developed with organisations such as mortgage lenders, energy service groups such as the Welsh Government Energy Service (WGES) and the Council, BCBC.

11.3 Additional Funding Sources

A heat pump project may need additional funding sources to fill the funding gap after the provision of the £6000 grant (GSHP) and £5000 grant (ASHP) under the HPR programme. For the ASHP the £5000 grant represents around 40% of the total cost to the householder (installation costs and modest house preparation costs making up the balance).

For GSHP with Shared Ground Array, the £6000 grant represents approximately 27% of the total cost per household. Shared ground array infrastructure equates to the ~48% of total cost which could be funded as utility-style private investment and the remaining 25% could be expected to be paid directly by the customer as an upfront capital cost or, alternatively, the required upfront cost could be paid in form of a loan.

For a project of this type, Kensa Utilities could consider funding the shared infrastructure, and the cost to consumer would be built around a split ownership service model. With the support of the £6000 grant and the infrastructure funded as a new utility by a group such as Kensa Utilities, the end user required upfront cost is reduced by almost 74% which is expected to help engage and recruit more customers for a heat pump deployment project.

This model not only reduces the upfront cost to customer but also significantly leverages private investment capital, moving the emphasis of funding the transition from government to the private sector to enable lifetime lower running costs for users. This provides a suitable long-term return for investors and reduces carbon emissions. This model is tried and tested. It is being implemented by several organisations in the energy sector such as Scottish Power, and Rendesco.

Bank loans could be arranged for GSHP or ASHP (in 'Zero upfront cost offer'): While Kensa Utility does not offer these, Kensa could give several examples of sample bank loans possible and the effect it has on overall costs to the consumer.

Funding for Energy Efficiency Measures: In the case of a shared ground array solution, it is planned to include the cost associated to light touch fabric measures along with the cost of shared ground array. This is possible as the cost per dwelling for light touch fabric measures is small, in the range of £1000 for solid wall terraced properties to £2000 for cavity wall semi-detached houses.

For ASHP system, it would be useful to apply for additional sources of funding for heat reduction energy efficiency measures, as appropriate during a heat pump deployment project. This would be an additional benefit to the project.

Additional funding that could be applied for includes ECO 4 funding for energy efficiency, Optimised Retrofit Programme, and a future CCR Ecoflex which may become available in Wales.

12 Long Term Sustainability

The HPR Bridgend feasibility study has suggested a self-sustainable commercial model, driven by the benefit case of affordable and heat. It includes ASHP for individual households, and GSHP + SGA for communities that would not otherwise benefit from low carbon heating.

12.1 Lead Organisation – Special Purpose Vehicle

The establishment of a lead organisation, such as the HP-BONT SPV suggested in this feasibility study, to lead and be the focus of the HPR Bridgend initiative in Bridgend County Borough was specifically designed to ensure that there would be a long-term impact and continued heat pump deployment in the Bridgend area, as a self-sustaining model.

The shareholders of the SPV could initially be drawn from the collaborative organisations working on the project with each holding a share.

The lead organisation (e.g., SPV) could organise, in the first instance, the house survey work and eventually undertake these surveys when it is self-standing. During a heat pump deployment project, the lead organisation (e.g., SPV) could receive technical support via subcontracts from technical experts in the collaborative group. The services provided by these organisations could be partly used to set up the systems and service offerings that the lead organisation (e.g., SPV) could deploy subsequently. The approach suggested is to equip the lead organisation (e.g., SPV) with the suite of tools needs for long-term impact and deployment at a cost-effective level for households to afford.

12.2 Value – GSHP+SGA

For space-constrained homes, it is recommended to consider GSHP+SGA heating systems.

In terms of value derived from a potential investment made by BEIS under Heat Pump Ready, heat pump deployment projects with GSHP+SGA could deliver significant leverage of the funding by unlocking substantial private investment into low carbon systems, to enable the Shared Ground Array infrastructure to be installed. Not only could these projects stimulate significant uptake in low carbon heat systems but a contractor such as Kensa Utilities could also help fund them commercially, providing financing for CAPEX that would otherwise have to be found by homeowners.

GSHP+SGA heating systems have the potential to unlock communities that would be left behind in terms of affordability. Economies of scale could also be achieved, and the benefits could be passed onto consumers. Options for the future could also include fabric solutions and smart local energy system packages to further reduce operating costs.

12.3 Funding and Investment - Summary

A heat pump deployment project could use the support funding via the HPR programmes to set up the systems and operating structures to be self-standing by the end of the BEIS funding.

The suggested lead organisation/SPV was considered with the aim of deploying the BEIS grant funding for heat pumps (up to £5000 for ASHP and £6000 for GSHP) and increasing the available resources as well as ensuring the householder contributions to capital funding are used optimally.

The lead organisation/SPV could receive a very small licence payment per heat pump deployed, for GSHP and ASHP. In the case of GSHP, this could be via a GSHP + SGA contractor such as Kensa Utilities, and for ASHP, this could be via a referrals scheme where heat pump suppliers and installers value the economies of scale.

The lead organisation/SPV could also leverage funding via the GSHP+SGA contract's (e.g., Kensa Utilities') long term network funding for GSHP+SGA, supporting the deployment of GSHP.

In the context of Bridgend County, a lead organisation/SPV could also seek support funding for renovation via ECO and other programmes such as Optimised Retrofit Programme (ORP) for improving the overall energy demand performance of properties, working with Valleys to Coast (V2C) and BCBC in the social housing sector and via a one-stop approach for private sector housing. The lead organisation/SPV could receive funding for renovation projects via ORP and the local Registered Social Landlord, V2C. The nature of this funding and how it would be administered is in the Year 1 Work Plan. The lead organisation/SPV could also engage with BCBC and Cardiff Capital Region on the use of ECO funds to improve the energy efficiency performance of private housing. In addition, this is a constantly evolving landscape and when relevant further sources of funding could be sought.

The role of the houseowner in providing balance funding could be an option, or loans could be available to bridge this funding gap, payable over a prescribed period (5 years or 10 years), which is similar to funding of boilers currently. Where the homeowner selects GSHP + shared loop, this could appear as an annual connection charge. In the case of ASHPs the additional funding with either be found by the houseowner or via loans. The amount envisaged for either GSHP or ASHP option is likely to be in the range of £3000 to £6500 per house.

12.3.1 Long-term sustainability, beyond the lifetime of the project, without public funding

The business model for GSHP+SGA aims to overcome two key barriers to high-density heat pump deployment:

- A street-by-street implementation using shared ground array infrastructure for high-density GSHP+SGA deployment reduces implementation cost compared to individual GSHP systems.
- By offering the investment in the groundworks as an investment opportunity, the low carbon heating transition becomes of commercial interest.

The basis of the commercial offering in the project is one where consumers pay for upfront costs of in-house works and the ground infrastructures are paid by an external entity. This funding could come via Kensa Utilities Ltd. in this project. Some of this upfront cost to the consumer could be covered by the BEIS grant and the rest can either be paid as a lump sum, covered through financing (e.g., green additional borrowing on mortgage)

The offering made to consumers could be a ground source heat pump with the cost partially covered by the BEIS grant, meaning a typical cost of ~£6500 for the heat pump unit. Ground infrastructure could be paid for through initial investment via a GSHP+SGA contractor (such as Kensa Utilities), paid back by the consumer via the connection fee for the lifetime of the groundworks (or 40 years). Initially this could be at high rates of return (6%) while the offering is proven to commercial markets.

If funding like the UK Infrastructure Bank could be leveraged via a party like a local authority, this could be brought down to 3%, (PWLB Standard Fixed Interest Rates) this would reduce the connection fee by ~40% and make the solution ~15% less expensive than a gas boiler annually becoming a much more attractive proposition for more consumers.

12.3.2 Foundation for Future Project Activities

Funding made available for the Heat Pump Ready Programme could be used to develop project methodologies that can be rolled out in future iterations of the project, including:

- Marketing and customer engagement.
- Consumer journey parties, 'handholding' parties
- System design and survey

All the above costs are typically included in the 'cost of sale', where these costs are recouped from the selling of the product. With the coordinated methodology helping reduce survey costs, stimulate uptake through community engagement, and target ideal clusters, the cost of sale is reduced and therefore replicable outside of HPR Bridgend. This can be adapted to other locations, consumers, and economic areas.

There are several options for funding future iterations of the Bridgend project. If this cost were to be added to the consumer offer, it could be included as part of the upfront cost or charged via the connection fee or split across both options. The split between upfront costs and paying costs back via a connection fee is likely to vary depending on the main consumer archetype(s) in each, with the able-to-pay consumers favouring up-front payments. The tight financial motivations compared to gas boiler systems may make this difficult in most UK homes but the 'consumer pays' option may be viable where there are significant savings for the consumer, such as those that run on oil or electric heating.

12.3.3 The impact of market changes on future projects

Ratio of gas and electricity prices. The BEIS Green Book central projections for gas and electricity costs project that domestic electricity prices could be 4.4 to 4.9 times higher than domestic gas prices throughout the 2020s. In order to break even on fuel costs, and assuming a boiler efficiency of 80%, heat pumps would need to be 350% to 390% efficient, not accounting for the ~£100 per year gas standing charge that would not need to be paid once a home had transitioned to a heat pump or the connection fee for the networked GSHP system.

However, current high gas prices mean that electricity prices are in fact only 3.3 times higher than gas prices, such that heat pumps would only need to be 260% efficient to break even against gas, giving much more scope for the shared ground array GSHP solution with its connection fee model to be on cost parity with a gas boiler.

Guaranteeing that any heat pump system could be cheaper to run in the long term than a gas boiler system is very difficult in the current volatile economic climate, but the reverse is also true: claiming a gas system could be cheaper long term is equally uncertain.

The transition of green levies from gas to electricity would reduce electricity costs by around 5 p/kWh, resulting in annual savings of around £150 (ClimateXChange, 2021).

Heat pump prices decreasing. The expected reduction in heat pump costs is something of a double-edged sword for heat pump deployment currently. Reducing costs could make the technology more attractive but the research conducted by Ipsos noted that consumers were wary or purchasing now if prices were expected to come down rapidly.

Lower Cost Ground Array Finance. Once the networked GSHP model for owner-occupied homes becomes more mature, it is expected that the IRR required for investors to be interested would decrease. In this project it is modelled at 6%, expect to get to 3%-4%. Reducing the IRR to 3%-4% would reduce the connection fee for homes by 25%-35% and is a significant lever in the consumer offer for pulling the annual costs further below that of a gas boiler. These expected rates of returns may not be accessible in the next 2-3 years with inflation and the recent instability in the British pound but could be assumed long term and for institutions like pension funds that look for safe long-term investments.

13 Recommendations

Based on team experiences working on the HPR Bridgend feasibility study, there are several recommendations that can be made for the benefit of other groups and projects aiming to deploy heat pumps at high-density. This section of the document presents recommendations organised by the work package themes of the HPR Bridgend project.

13.1 WP5. Management, Coordination, Special Purpose Vehicle – Buro Happold

Coordination and collaboration were essential to developing the approach to high-density deployment for the HPR Bridgend Feasibility study.

- **Co-ordinator.** To facilitate collaboration, Buro Happold acted as the Project Leader and co-ordinator for the group. Based on our project experience, we recommend that other high-density heat pump projects also make use of the project co-ordinator role.
- **Team Collaboration.** This project had collaborators providing input from different areas of expertise. Energy Planning and Mapping from Buro Happold, Heat Pump technology specialism from Kensa, electricity grid network constraints and opportunities understanding from Challoch Energy, and engagement expertise from NuVision Energy Wales. For upcoming projects, we recommend including these areas of expertise within the core collaborative group, where possible.
- **Team Communication.** This project was set up with a weekly project meeting to discuss progress, issues, and to make decisions. In addition to these meetings, one-to-one calls and emails were also used between the collaborators to cover a variety of topics. We recommend a weekly team call and additional communication as needed for future projects.
- **Monthly milestones.** We found that monthly milestones were useful and would recommend this approach to other projects as well. A month was long enough to carry out a significant amount of work and helped to maintain focus on the key components of the project.
- **External Support.** Integral to this project was the support from Bridgend County Borough Council (BCBC) and the District Network Operator (DNO) National Grid (NGED). The engagement work package was strengthened by the support of BCBC, helping to build trust with community, supplier, and government stakeholders. The electricity grid opportunities and constraints work package was strengthened by support from NGED, who were able to provide a deeper understanding of the issues in the area. We highly recommend requesting project support from Councils and DNOs for high-density deployment heat pump projects.
- **Flexibility on methods of collaboration.** At the outset of the project, the advisory group input, with support from the Bridgend County Borough Council (BCBC) and District Network Operator (DNO), National Grid (NGED) could have been set up as group meetings. Over the course of the project, the Council and NGED suggested their preferred means of communication. BCBC decided to contribute to the project development by attending several of the overall team meetings, one-to-one videoconference calls, and emails. NGED opted to interact and support through one-to-one videoconference calls and emails. We recommend that projects seeking high-density deployment of heat pumps remain flexible on modes of communication to optimise opportunities for collaborators from external groups such as councils and DNOs.

- **Site walk around.** A site-walk around by two of the project collaborators, NuVision and Challoch was helpful to gain direct information about the areas under consideration. A site visit is recommended for heat pump projects to gain deeper insights into the opportunities and constraints of the areas.
- **Special Purpose Vehicle (SPV).** Over the course of the project, the team revisited the concept of establishing an SPV to carry out the deployment of heat pumps. This specific collaboration team decided to make an application for Phase 2 heat pump deployment that included the establishment of an SPV. We recommend establishing an SPV for heat pump deployment where the collaboration team aims to leave a legacy, including an organisation that can roll-out heat pumps over the long-term.

13.2 WP1. Energy Planning – Buro Happold

- **Domestic properties data quality:** Although EPC data was used for the domestic modelling for this feasibility study, more complete and directly applicable data sets are available. For example, packages such as Home Analytics and Parity Projects data contain in-depth fabric and energy efficiency information for domestic properties across the UK. Primarily this would improve the building-level assessment of heat pump suitability and allow a more dynamic approach to combining top-down and bottom-up models. It would also enhance the approach taken to calculating the impact.
- **DNO engagement:** Useful engagement was had with National Grid, however, the quality of data provided was varied. This had a particularly large impact on the substation headroom assessment. Using standard calculations to assess headroom, based on the information provided, some showed demands substantially greater than the rated capacity. This led to uncertainty in the validity of the data. Instead of data manipulation being required to assess the coverage and headroom of each substation, ideally this information would be readily available from the DNO in a GIS compatible format.
- **LV feeder format:** Although the LV feeder layout was provided and used within this project for visual authentication the accuracy of the data could have been improved. LV feeder layouts should be available in shapefile format as the importing process from CAD reduces the reliability of the data. The National Grid is transitioning to be able to supply this information in the required format. This data is key for in-depth electrical assessment and cluster formation.
- **LAEP study data:** LAEP studies should be able to contribute meaningful data to a HPR study. Local authorities should be given data from completed LAEP studies, this would contribute to the feasibility assessment of high-density heat pump deployment and avoid additional data purchasing or modelling – essentially replicating the work of the LAEP. Workflow data should be provided from previous work and not just the final outputs (as recommended in established LAEP methodology templates[31]). If point data cannot be provided, due to GDPR agreements, then the data should be anonymised and scaled up, e.g., to postcode level.
- **Metered data for housing archetypes:** Although domestic demand assessments can be made through various methods, such as those used in this study's methodology, local area metered data should be available for various archetypes for authentication purposes. GDPR agreements should be obtained as early as possible in this process. Whilst this would be useful at this early stage it would become more important in Phase 2.

[31] Template, Checklist and Examples of Local Area Energy Planning – Annexe 1 , Energy Systems Catapult (2022), Available at: https://esc-prod-admin.383apps.com/wp-content/uploads/2022/07/FINAL_LAEP_-Guidance-Annexe-1.pdf

- **Greater archetype coverage:** Set domestic archetypes were provided by BEIS for the techno-economic modelling process. During the energy planning workflow, it was established the provided archetypes did not capture all the dwelling types within the study area. An expansion of the set archetypes would be recommended if this feasibility study was to be repeated. This would enable greater analysis of the building stock in the study area and therefore potential cost-saving implications.

13.3 WP2. Customer Heat Package. GSHP with Shared Ground Array Solution – Kensa

To increase the replicability in the long term and further increase the benefits of shared ground array to end customers and to accelerate the industry, listed levers can be taken into future planning and policy changes.

- **Zoning policy**: Inclusion of shared ground array heat pumps solution to designate zones. This could increase confidence of the sector and could bring real cost declines from longer-term Government signals of certainty.
- **Statutory utility rights**: These rights to work in the road, and indeed deploy boreholes in and below the public roads, could reduce planning delays, costs, and uncertainty, which could lower the ultimate costs to consumers.
- **Low-cost financing of the groundworks** by Local authorities or central Government: Reducing the IRR to 3%-4% would reduce the connection fee for homes by ~25-35% and is a significant lever in the consumer offer for pulling the annual costs further below that of a gas boiler.
- **Low-cost loans for in-home upgrades** for consumers, being developed in other parts of NZIP and through the Green Homes Finance Accelerator (e.g., green mortgages).
- **Proliferation of time-of-use tariffs:** Encouraging and mandating time-of-use tariffs could also see several £100/yr savings on bills, given the flexibility that heat pumps offer. This is especially apparent with GSHPs, as at night (when load shifting is common).
- **Rebalancing the relative prices of electricity and gas** to 2:1 ratio to allow renewable energy to be delivered more cheaply, and aid the economic case for heat pumps versus gas (as is done with fuel duty for diesel vs electricity for EVs).

13.4 WP3. Electricity network opportunity – Challoch

- Establishing a positive relationship with the local DNO is essential to better understand their specific constraints and policies towards low carbon heating strategies. The majority of DNOs could have a strategy for dealing with this, however a good and positive engagement could ensure cooperation at all levels.
- **A full understanding of the local electrical infrastructure** could enable assessment of capacities, though bearing in mind some of the issues mentioned in this report such as looped supplies may also be prevalent.
    - Using LineSearchBeforeUDig is a useful tool which is easy and free to use could give an initial indication to the local electrical infrastructure.
- **DNOs need to collaborate and develop a coordinated LV network design approach** that accounts for the unique characteristics of heat pumps and other LCTs. Collaborating allows them to build on each other's pilot studies and develop a standardized, holistic approach for the integration of LCTs.

- **Household thermal insulation must be assessed and upgraded for flexibility** operations. Heat pumps cannot provide flexibility services unless the home is adequately insulated.
    - Household retrofitting must come before heat pump installation if any flexibility services are to be offered.
- **Heat pump clusters should exploit innovative market structures and onsite generation** to achieve favourable tariffs that incentivise efficient and flexible modes of operation. Small clusters should start as white labels, then transition to Energy Local Clubs, and eventually larger local energy markets; provided the cluster is investing in local generation assets in parallel.

13.5 WP4. Engagement – NuVision

Community engagement

- **Helpdesk**. Offer support in the form of a Helpdesk to those who might have queries with the survey.
- **Intelligent Survey**. This survey technique can be used as a 'first sift' in determining 'in-home' data remotely, however, a follow up survey would be required before final design of the heating system. Home energy questions may be simplified in future.
- **Leaflet drops and face-to-face** communication are essential for a potential Phase 2.
- **Work with the community advocates** identified in this phase to champion the heat pump roll-out in the potential next phase.
- **Follow-up home visits** with respondents is recommended to move them from the awareness and decision-making stage through to sign-up.

Supply chain engagement

- HPR Bridgend team to support the Colleges to continue to develop new courses.
- HPR Bridgend team to interact further with the supply chain to link installers with college courses.

Government Engagement.

- Continued support from BCBC Officers and Councillors could be key to a successful potential second phase.

Capacity Building – Community

- Continue to build on the community events in a potential second phase, focusing on further education and heat pump promotion activities.
- Develop community champions to act as advocates for the programme.

Capacity Building – Supply Chain

- Work with the colleges to further identify the needs of the industry in the Bridgend area.

14 Conclusion

The proposed approach to coordinated-high-density heat pump deployment is possible in the areas identified in Bridgend County. The key reasons are as follows:

- **Stakeholder engagement.** Stakeholder engagement is fundamental to high-density heat pump deployment. NuVision Energy has carried out stakeholder engagement with the community, supply chain, and government. Bridgend County Borough Council (BCBC) is supporting the project and has supported communications regarding the opportunity to learn more about heat pumps. Community members have expressed interest in heat pumps for their homes, and continued engagement to promote sign-up is included in the plan for the next phase of the project. In terms of the supply chain, Kensa Utilities is part of the collaborative group proposed for Phase 2, bringing expertise and capability in Ground Source Heat Pumps (GSHP) and Shared Ground Arrays (SGA). As part of the feasibility work, Air Source Heat Pump (ASHP) installers in the area have also been identified and are interested in Phase 2 opportunities.
- **Improved customer journey.** The customer journey could facilitate heat pump deployment, including customer contact, screening, home surveys, installer communications, installation, handover pack, warranty, and support. To organise this, a customer advisory service could be established in Phase 2, which could act as a convenient point of contact for customers interested in heat pumps. This service could be provided through a Special Purpose Vehicle (SPV), HP-BONT, located in Bridgend. HP-BONT could assist in coordinating heat pump services with customer and supplier contacts.
- **Financial preparation.** In Phase 2, funding could be made available for homeowners for heat pumps. This consists of up to £5k for ASHP or up to £6k for GSHP. This could support homeowners financially to make the choice to have heat pumps installed. For the GSHP + Shared Ground Array (SGA) technology approach, Kensa Utilities is ready to organise aspects of the financing, including private investment for the SGA.
- **Location-suitable heat pump options.** There are many space-constrained homes in Bridgend County, such as terraced homes with highly limited outdoor space, where Air Source Heat Pumps are not suitable. The HPR Bridgend project proposes Ground Source Heat Pumps (GSHP) with Shared Ground Array (SGA) for the locations, making low carbon heating a real possibility for these properties. ASHP are also included in the plan, for homes where there is space available.
- **Electricity grid network opportunity identification.** As part of the feasibility study, areas identified for heat pump deployment are likely to have sufficient electricity grid network capacity to allow for high-density heat pump deployment in the short-term. The Distribution Network Operator (DNO), National Grid (NGED) supports the project.
- **Home heat pump readiness.** In North Cornelly, Nottage, and Ogmore Vale, there are areas where homes are likely to be suitable for heat pumps. This is based on customer interest, the building archetype and energy performance, and suitability considerations for ASHP and GSHP + SGA.
- **Collaboration.** The collaborative project team that produced the feasibility study is ready to proceed with Phase 2 of the project, providing continuity. The team in the next phase could include the SPV HP-BONT, Challoch Energy, NuVision Energy, Buro Happold, and Kensa Utilities.
- **Support.** The project could be supported by Bridgend County Borough Council (BCBC) and the Distribution Network Operator (DNO) National Grid (NGED).

- **Energy planning and data repository.** Screening areas for heat pump suitability is a key component of scalability. At the county and neighbourhood levels, the energy planning methodology identifies which areas to engage to promote heat pump uptake. A data repository approach is recommended to organise the information required throughout the project, and this is included in the Phase 2 plan.
- **Scalability.** The HPR Bridgend project targets 150 homes for heat pump deployment in Phase 2. The approach and methodology used to deploy these initial heat pumps is scalable in Bridgend County and replicable in other areas.

15 List of References

- **ASHP in coastal area**: https://www.thegreenage.co.uk/can-i-get-an-air-source-heat-pump-if-i-live-on-the-coast/
- **Aurora 2021**: https://auroraenergy.wpenginepowered.com/wp-content/uploads/2021/10/20211020-Aurora-Heat-Decarbonisation-Public-summary.pdf
- **Average years in a property**: https://home.barclays/news/press-releases/2018/10/uk-homeowners-stay-put-for-nearly-two-decades--choosing-to-impro/
- **BEIS Clean Heat** 6.7408_BEIS_Clean_Heat_Heat___Buildings_Strategy_Stage_2_v5_WEB.pdf
- **BUS 2022**: https://www.gov.uk/government/statistics/boiler-upgrade-scheme-statistics-september-2022
- **Boiler Efficiency**: https://www.britishgas.co.uk/home-services/boilers-and-heating/guides/boiler-efficiency.html
- **CIBSE**: CIBSE CP1: Heat networks: Code of Practice for the UK https://www.cibse.org/knowledge-research/knowledge-portal/heat-networks-code-of-practice-for-the-uk-cp1-2020
- **ClimateXChange** "Review of gas and electricity levies and their impact on low carbon heating uptake "published September 2021 https://www.climatexchange.org.uk/media/4986/cxc-review-of-gas-and-electricity-levies-impact-on-low-carbon-heating-uptake-september-2021.pdf
- **CODE Report**: https://www.gov.uk/government/publications/cost-optimal-domestic-electrification-code
- **Geological condition**: https:// www.sciencedirect.com/science/article/pii/S0375650519301944
- **Heat and Buildings Strategy**: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1044598/
- **Nesta 2022**: https://media.nesta.org.uk/documents/Estimating_the_couldingness_to_pay_for_a_heat_pump_v1.pdf
- **Regen 2021**: https://www.regen.co.uk/wp-content/uploads/HeatPumpReport_Final_04PDF.pdf
- **PWLB Standard Fixed Interest rates.** https://www.dmo.gov.uk/data/pdfdatareport?reportCode=D7A.2#17087
- **Rendesco.** Ambient heat Network. https://rendesco.com/grants-funding/ambient-heat-network
- **Wallace Whittle:** Design Guidance for Diversity Factors for Ambient Temperature Networks using the Zeroth Energy System https://www.dimplex.co.uk/professional/sites/default/files/gdhv_-_tuv_sud_-_zeroth_diversity_design_guide_-_250821_-_v12.pdf
- **WWF Report**: https://www.wwf.org.uk/betterhomescoolerplanet

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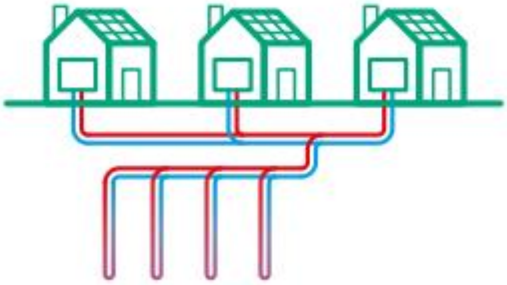
Appendix A Supplementary Information

A.1 Community Engagement Leaflet

How does the Programme work?

We will:

- Assess your home for fabric upgrade.
- Install energy efficient measures in advance of upgrading your heating and cooling system.
- Replace your old boiler with an energy efficient heat-pump system.



What's in it for me?

- **FREE** home energy survey of your home
- **FREE** expert advice on upgrading your home
- **SUBSIDISED** installation of heating system
- Decarbonisation of your home
- Affordable Greener Heating and Cooling system for your home
- Improving air quality within your home
- Warm your home at a healthy temperature
- Helps to support a greener future by phasing out the installation of natural gas boilers

Where can I find out more?

We will be hosting information days at North Cornelly Community Hall:

- **23rd September from 12:00 – 18:00**
- **24th September from 15:00 – 18:00**

Please drop by and speak to our team if you'd like to learn more about the project and how it can benefit you.

Or, please visit www.bridgend.gov.uk/residents/housing/low-carbon-communities/heat-pump-scheme for more information.

Complete our survey

In the meantime you can scan the QR code to complete a short questionnaire and we will get back to you.

SCAN ME!

In partnership with

nuvision ENERGY (WALES) KensaGroup BURO HAPPOLD Challoch ENERGY

A.2 Intelligent Survey Questions and Responses

The intelligent survey questions and responses are presented below.

Q1: How much do you agree with the statement, 'I have concerns about rising energy prices and affordability'?

All 18 respondents had concerns about rising energy prices and affordability.

Q2: What is your average annual gas bill (in £/year)?

All 18 responded and responses ranged from £212 per year and £1,500 per year.

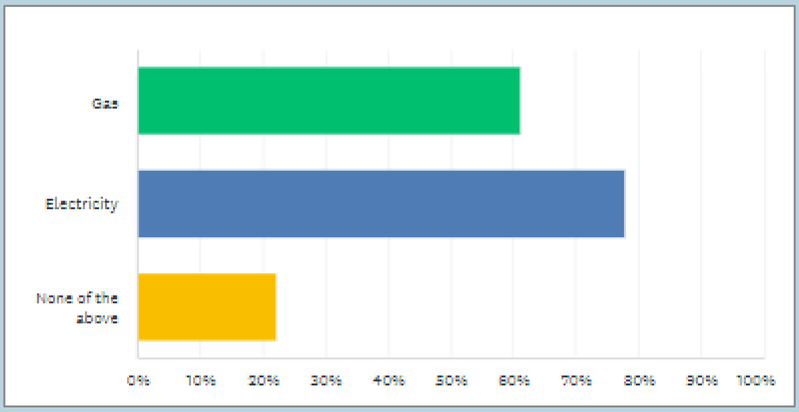
One respondent didn't know, and one didn't have gas.

Q3: What is your average annual electricity bill (in £/year)?

16 responded and responses ranged from £550 per year and £2,000 per year.

Q4: What smart meters do you have?

All 18 responded as shown in the table below.



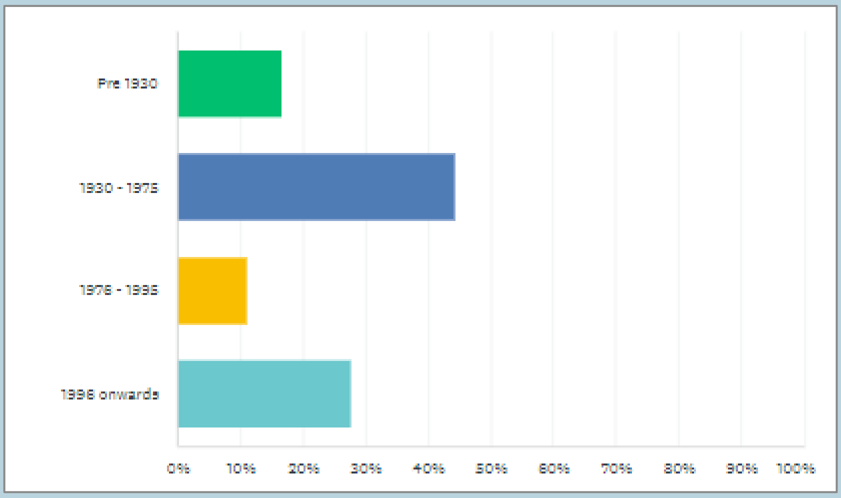
Q5: What is the floor area of your home (in square metres)?

16 responded and responses ranged from 35m^2 to 140m^2.

One respondent didn't know.

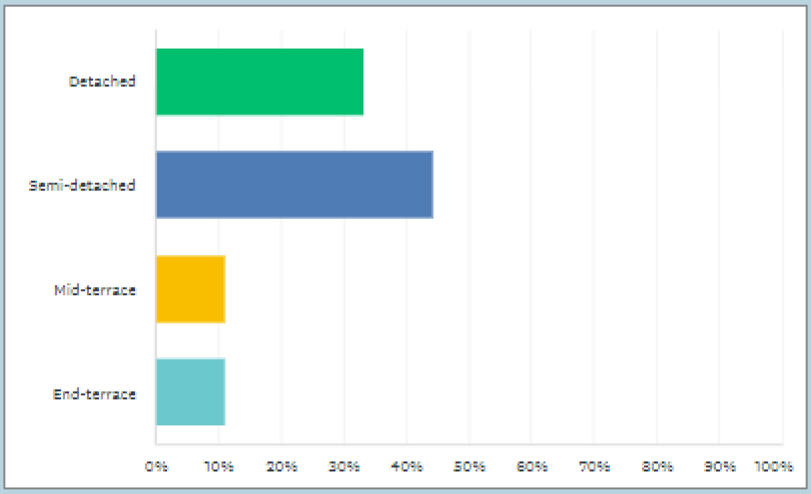
Q6: When was your home built?

All 18 responded as shown in the table below.



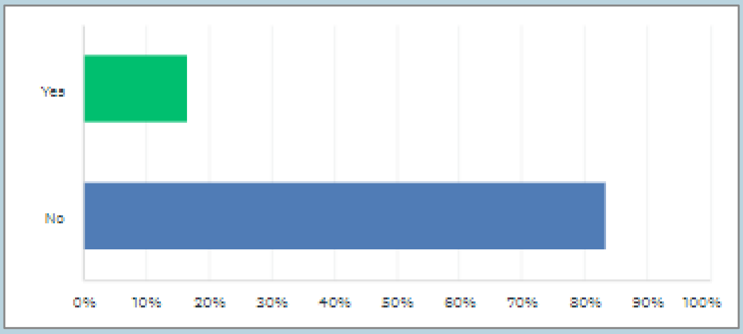
Q7: What type of house do you live in.

All 18 responded as shown in the table below.



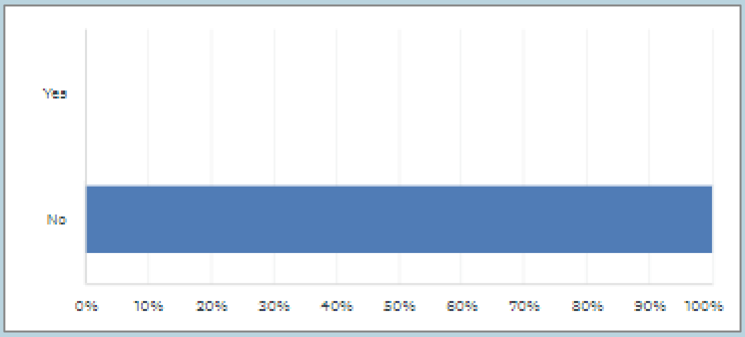
Q8: Does your home have a conservatory?

All 18 responded as shown in the table below.



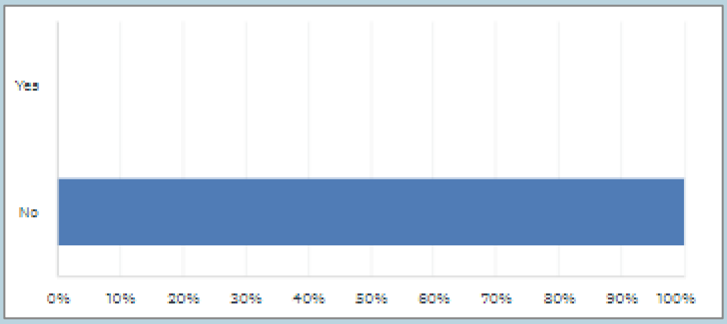
Q9: Does your home have a cellar or basement?

All 18 responded as shown in the table below.



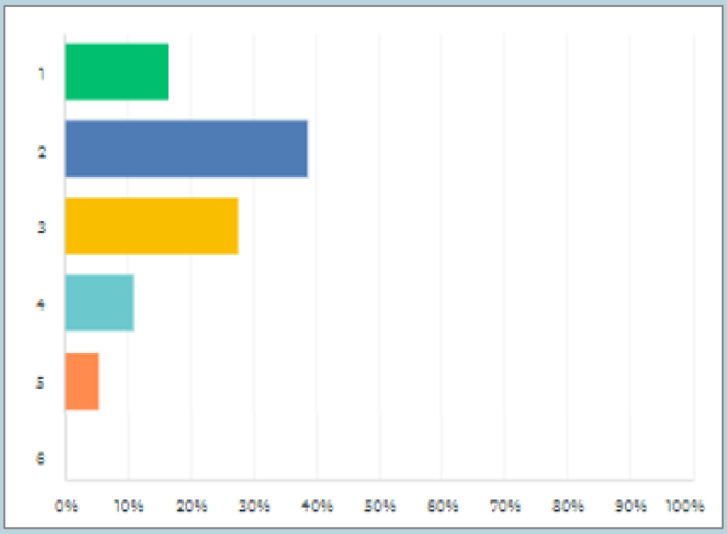
Q10: Does your home have a loft conversion?

All 18 responded as shown in the table below.



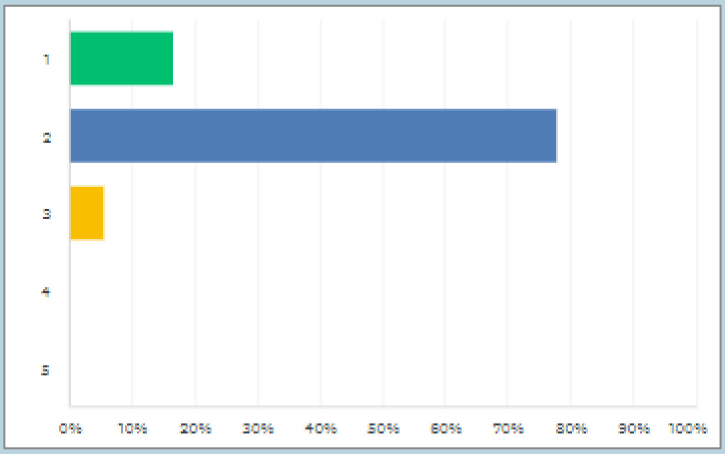
Q11: How many people live in the home?

All 18 responded as shown in the table below.



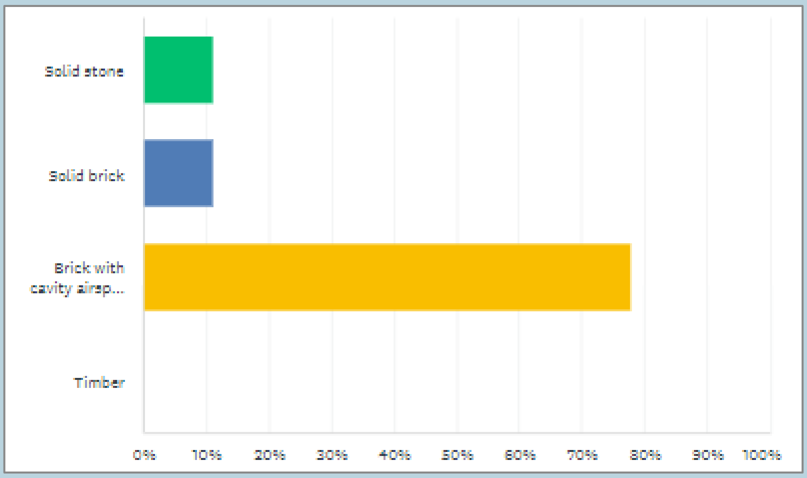
Q12: How many floors does the property have?

All 18 responded as shown in the table below.



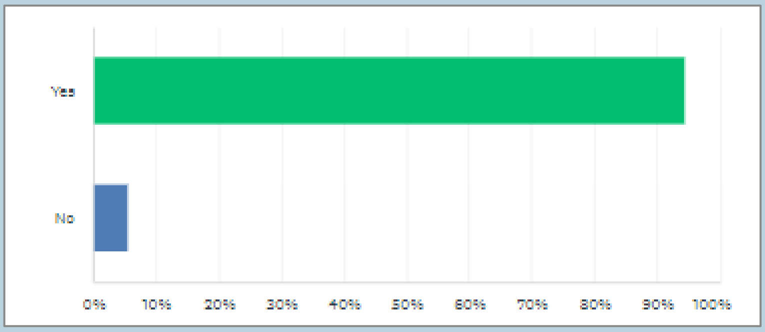
Q13: What are the external walls of your home constructed from?

All 18 responded as shown in the table below.



Q14: Do you have outdoor space at your property for future sustainable heating systems, such as an Air-Source Heat Pump?

All 18 responded as shown in the table below.



Q15: What is the main fuel type for heating your home?

All 18 responded as shown in the table below.

17 responded with Natural Gas and 1 responded with Oil.

Q16: If you have different fuel types for heating and hot water, please describe them here.

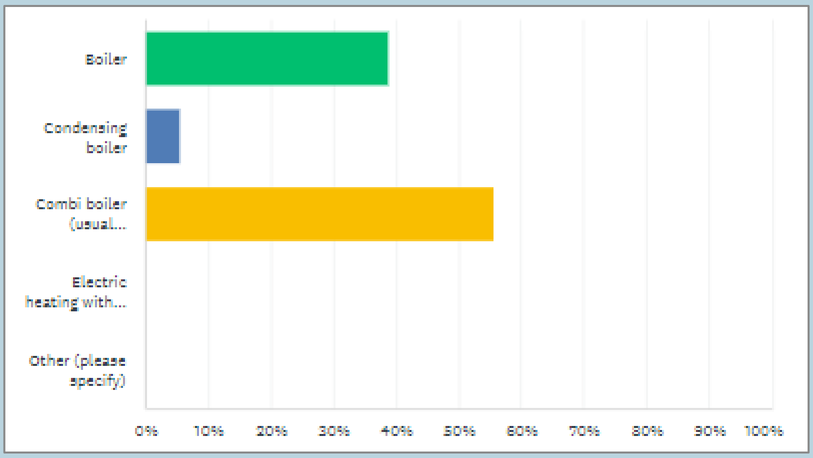
Only 6 responded to this question.

4 had a mixture of devices.

2 stated that the question was N/A

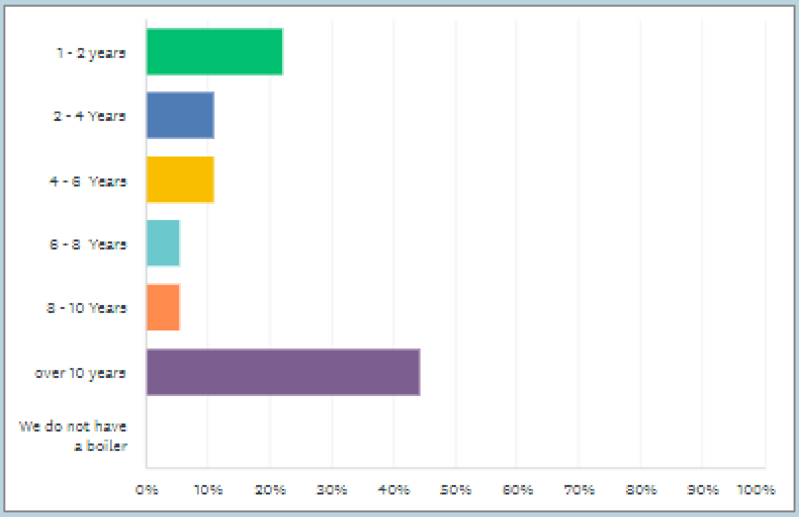
Q17: What is heating system type?

All 18 responded as shown in the table below.



Q18: How old is your boiler?

All 18 responded as shown in the table below.



Q19: Do you often plug in electric radiators or fan heaters to heat your home?

All 18 responded, 5 respondents said yes, and 13 respondents said no.

Q20: Do you have a hot water tank for storing hot water?

All 18 responded, 8 respondents said yes, and 10 respondents said no.

Q21: If you have a water tank, how many days a week do you switch on the immersion heating?

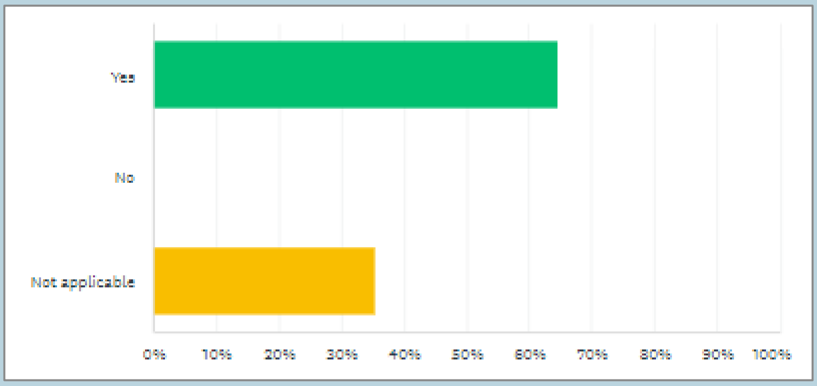
Only 11 responded, of those who responded;

5 said never, 1 said once and 2 said every day.

3 said it didn't apply to them.

Q11: If no water tank is currently available, is there space to install a hot water storage cylinder in the future as part of a sustainable heating system? This could be in a large cupboard or in the loft if no loft conversion has been completed

17 responded as shown in the table below.



Q23: Is there a wet heating system with pipes and radiators?

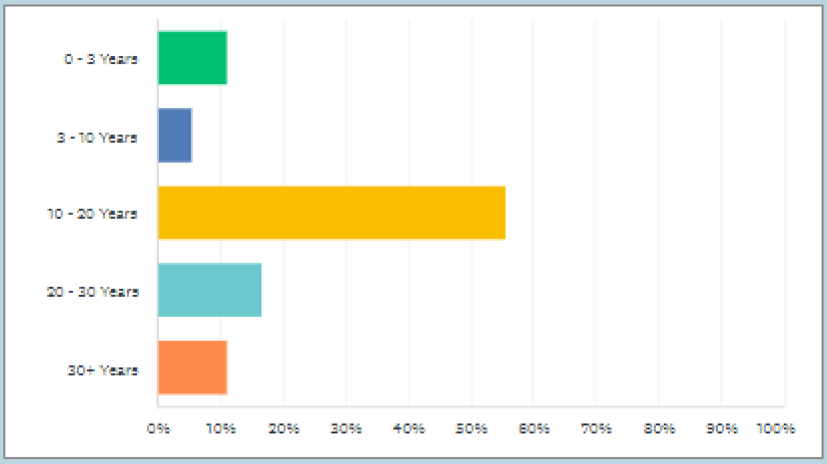
All 18 responded, 17 respondents said yes, and 1 respondent said no.

Q24: What is the diameter of your radiator pipes?

17 responded with 7 stating 10mm, 8 stating 15mm and 2 didn't know.

Q25: What age is your heating system?

18 responded as shown in the table below.



Q26: From your last annual bill, what was the estimated annual fuel use for heating and cooking (in kWh/year)?

15 responded and responses ranged from 686 kWh/year to 18,693 kWh/year.

Q27: From your last annual bill, what was the estimated annual electricity use (in kWh/year)?

14 responded and responses ranged from 1,800 kWh/year to 6,400 kWh/year.

Q28: If you have solar photovoltaic (PV) panels on the roof, could you tell us below how much energy the PV generates in kWh/year?9 responded with 4 giving an actual figure. Responses ranged from 1,610 kWh/year to 4,074 kWh/year

Q29: Again, if you have solar photovoltaic (PV) panels on the roof, can you tell us below the generating capacity of the PV in kWp?

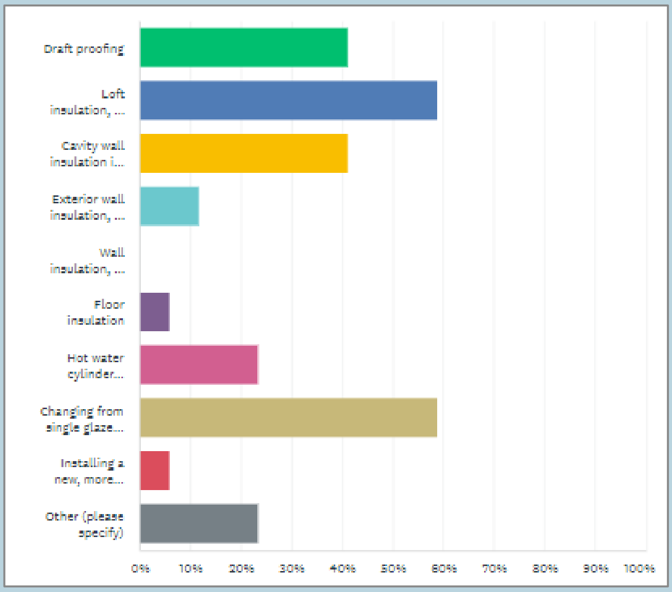
9 responded with 3 giving an actual figure. Responses ranged from 2 kWp to 4 kWp.

Q30: If you do not already have any, would you be interested in having PV if it could reduce your bills?

15 responded, 13 respondents said yes, and 2 respondents said no.

Q31: What energy efficiency measures have already been installed in your home?

17 responded as shown in the table below.



Q32: Do you have or intend to buy an electric vehicle in the next 5 years?

18 responded, 15 respondents said yes, and 3 respondents said no.

Q33: Do you have access to a dedicated parking space?

18 responded, 16 respondents said yes, and 2 respondents said no.

Q34: What is the property ownership type?

18 responded, with 18 stating the property was 'Owner-occupied'.

Q35: Would you be interested in joining a community scheme if one was set up that work with you and other residents in the area to explore options for delivering more affordable energy to your homes?

18 responded, 18 respondents said yes.

Q36: Would you be interested in sharing metered gas and electricity use (hourly or half-hourly data) to improve understanding of heat demand in buildings? This is useful for understanding the type and size of heating system that may suit a home.

16 responded, 15 respondents said yes, and 1 respondent said no.

Q37: In order that we may understand what part of the electricity network you are connected to, could you please leave your postcode below?

18 responded and left their postcode.

Q38: Thank you very much for the time you have taken to complete this survey. If you would like to be kept informed on the progress of this initiative, please leave your email below.

16 responded and left their email address.

A.3 BCBC Web Page

Cyngor Bwrdeistref Sirol Pen-y-bont ar Ogwr
Bridgend County Borough Council

My Account Accessibility Listen with Browsealoud Cymraeg

Search site | Search site

Residents Business My Council

Residents > Housing > Low Carbon Communities > Heat Pump Scheme

Heat Pump Scheme

Heat Pump Ready Bridgend is a new and innovative initiative aimed at bringing affordable and greener heating to your home. It is one of nine projects funded throughout the country by the UK Government's Department for Business, Energy and Industrial Strategy (BEIS) to undertake a feasibility study into the potential for the High Density Deployment of heat pumps in the UK.

The consortium of four companies involved in the project and supported by Bridgend County Borough Council are Buro Happold, Challoch Energy, Kensa Group and Nuvision Energy Wales.

Cymunedau Carbon Isel
Low Carbon Communities
Heat Pump Ready Bridgend
Pwmp gwres barod Pen-y-Bont ar Ogwr

The scheme builds on the latest thinking in Local Area Energy Planning, identifying viable deployment routes for clusters of homes that can participate in heat pump installations, to help facilitate the switch to low carbon heating technologies.

Technologies being considered will include air source heat pumps, ground source heat pumps, or heat pumps working on a shared loop system. An exciting aspect of the project will be the development of new commercial models that will drive down heat costs for the benefit of homeowners. Capacity in the electricity grid network for heat pumps to be installed, as well as electric vehicle charging, will also be assessed and solutions developed to enable the transition.

Should the feasibility study be successful the consortium would then seek additional funding from BEIS to roll out Heat Pumps within homes in the chosen area of Bridgend.

How will it work

The consortium is looking for areas that may be suitable to deploy heat pumps at scale within the county borough. Key to this will be finding sufficient numbers of "Early Adopters" to join the programme.

In the first instance, the consortium will be advertising the project and holding awareness events to gauge the interest within the community. Should sufficient interest be generated within the community the team will apply for further 'Phase 2' funding from BEIS to support the roll out of heat pumps within the chosen area.

What's in it for you

This is a pioneering programme and by being a part of it, you will be helping to decarbonise your community in the first instance and if successful, other parts of Wales and the UK as well. Benefits to you will include:

- FREE home energy survey of your home
- FREE expert advice on upgrading your home
- SUBSIDISED installation of heating system
- Decarbonisation of your home
- Affordable Greener Heating and Cooling system for your home
- Improving air quality within your home
- Warm your home at a healthy temperature
- Helps to support a greener future by phasing out the installation of natural gas boilers

If you're interested

Anyone within Bridgend County Borough is welcome to attend the events and to lodge your interest in the programme.

In the first instance we would welcome you along to our open days at North Cornelly Community Centre:

- 23 September, 12pm - 6pm
- 24 September, 3pm - 6pm

You will have the opportunity to get involved and register your interest onsite.

Alternatively, you can sign up by sending an email to:

simon.minett@challoch-energy.com or Robert.francis@nuvisionenergywales.co.uk

A.4 Educational Material

Heat Pump – Bridgend Scheme
Affordable and greener heating for your home

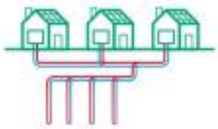
Introduction

Heat Pump Ready Bridgend is a UK Government funded initiative aimed at bringing affordable and greener heating to your home. Our team is tasked with looking at which locations within Bridgend might be suitable to have their heating systems converted from natural gas boilers to electrically driven heat pumps.

The overall aim of the initiative is to drive down heating costs whilst also converting to a greener more sustainable energy source for the benefit of homeowners.

We are in the first part of the project, which is to evaluate the suitability of the Bridgend area to the deployment of heat pumps. A key part of the study as we would like to understand the views of our potential customers. Should there be sufficient interest in the initiative, we would receive additional funding from the Government to install heat pumps in the chosen locations.

As part of our study, we are carrying out questionnaire surveys to check the readiness of homes to be converted to heat pumps. In the first instance and if you are interested, we would ask you to complete a 'no obligation' home survey to give us an early indication of the suitability of your home. You can complete the survey online scanning the QR code below, or alternatively please use the link to the survey: https://www.surveymonkey.co.uk/r/HESQ01 .



Depending on the findings of our study, a variety of systems could be rolled out in the community including air source heat pumps, ground source heat pumps, or heat pumps working on a shared loop system.

Who's involved in Heat Pump Ready Bridgend

'Heat Pump Ready – Bridgend' is one of nine projects funded by the UK Government's Department for Business, Energy and Industrial Strategy (BEIS).

The four companies involved in the project and supported by Bridgend County Borough Council are Buro Happold, Challoch Energy, Kensa Group and Nuvision Energy Wales.

Scan the QR Code

Scan the QR code below to complete your Home Survey and we will get back to you with our assessment.

Cymunedau Carbon Isel Low Carbon Communities — Heat Pump Ready Bridgend / Pwmp gwres barod Pen-y-Bont ar Ogwr | BURO HAPPOLD | Challoch Energy | NUVISION | KensaGroup | BRIDGEND County Borough Council

How will it work

This **First Phase** is aimed at investigating which areas are most suitable to convert to this green heating. Key to this will be finding sufficient numbers of "Early Adopters" to join the programme as customers.

Should sufficient interest be generated within the community the team will apply for further **Phase 2** funding from BEIS to support the roll out of heat pumps within the chosen area.

At this stage we are not looking for a firm commitment to join the scheme, we simply would like to test how many potential customers there might be in the area.

What's in it for you

By completing the home questionnaire during this phase 1 of the project, we can provide you with advice and let you know what would be involved for you in moving from your current heating system to a heat pump option.

Should we be successful with our Phase 2 we would contact you again to see if you were still interested in moving forward with this pioneering programme. You would then be offered a **FREE** home energy survey of your home by one of our professional surveying team followed by **FREE** expert advice on upgrading your home to a heat pump system, again with no obligation to continue with the installation.

Should you then decide to commit to a new heat pump system for your home, we would then arrange for a **SUBSIDISED** installation of the new heating system.

This unique opportunity would allow you to:

- **Improve your home value:** Studies show that installing a heat pump can increase the equity value of your house by around £8,000.
- **Reduce your carbon footprint:** heating is the biggest source of household emissions, and you can save 4.3tCO_2 per year (equivalent to '90% less emission' or the equal to driving 27,000 kilometres in your petrol or diesel car)
- **Cool your home too:** with heatwaves occurring more frequently, heat pumps allow you to have passive cooling, providing comfortable cooling.
- **Be more energy secure:** use renewable energy stored underground, upgraded by the electric in-home heat pump, rather than imported gas with volatile prices.
- **Establish a safe & clean home.**
- **Lock into a path to lower bills.**
- **Lead the community:** This project would lead the way for clean & green heating in the UK, with British brands supporting the transition.

A.5 Lifetime Cost to Consumers

This appendix presents techno-economic considerations for the heat pump solutions considered in the feasibility study.

Assumptions:

- Analysis is carried out from the point of view of that homeowner is the owner of heat pumps and other installed equipment inside the dwelling. This is feasible for both ASHP and Shared Ground Array heat pump system. And it is the end user who will be responsible for the operation and maintenance cost for the system.
- End-users will pay for their heat through their electricity bill, giving them independent control of their heating use and the electricity supplier from which they source their electricity. With flexible & heat pump tariffs becoming more commonplace, this allows end-users to benefit from the lower running costs.
- In case of Shared Ground Array systems, homeowner can hold a contract with ambient loop heat supplier. From the commissioning of the heat pumps, heat supplier, in this case (Kensa Utilities Ltd) would start charging a standing charge. This standing charge would be collected from the end-users directly.
- It would be the heat supplier's responsibility to ensure delivery of ambient heat needed to run each heat pump, and it would conduct repairs and O&M on the shared ground array as required to ensure performance. The cost of O&M of shared ground arrays are covered under the standing charge paid by the end user. There would not be any additional cost in terms of O&M of arrays from the end user.
- The agreement with heat supplier owning & maintaining the ground array lasts for a minimum of 40 years but can roll-over after this until the end user chooses to terminate it, ensuring continuity of supply and heat.
- In our model the analysis is performed for a 40-year period in order to understand the impact of Capital and Operational cost for the end user.
- The analysis has been carried out assuming an annual CPI index of 2.5%, i.e., with prices fixed at a first year.
- The rate of charge to the customer from ambient heat supplier is based on the IRR set by the private investor (6% return on the private investment).
- For the Shared Ground array system, the cost is based on a cluster size of 40 properties and assumes streets with 80% HP uptake. This size of cluster gives the GSHP+SGA solution an opportunity to apply diversity to reduce the total peak heat demand for a cluster which in technical terms help to reduce the total borehole depth and so the capital cost to end user. The effect of 40 homes clustered on an array allows for a saving of 21% per property. Hence boosting towards requirement of 80% sign up on a cluster and diversity effect, given the lower costs to per house for sharing the heat infrastructure.
- Due to availability of BEIS funding for the limited period, the dependency of future expansion of ground arrays is minimised and hence 80% uptake on a cluster will be targeted from the commissioning of array infrastructure.

Lifetime cost estimation

	System Assumptions	GSHP	GSHP - Funded	Gas Boiler	ASHP	Direct Electric
Assumptions	Expected Replacement Schedule (years)	25	25	10	12	20
	Service cost (£)	-£100	-£100	-£100	-£100	-£100
	Service Frequency (years between services)	3	3	1	1	1
	System Efficiency	310	310	80	240	100
	Avg cost over period (p/kWh)	48	48	13	48	
	Y1 cost (p/kWh)	34	34	10	34	

40-year ownership costs, for a single property.

This is based on a semi-detached house >=100m^2, EPC rating of C, and no internal plumbing and fabric efficiency measures required.

	40 Year Lifetime Cost	GSHP	GSHP - Funded	Gas Boiler	ASHP
Costs to Homeowner	Capital cost of initial installation	-£39,232.00	-£28,090.00	-£4,000.00	-£13,000.00
	SGA Funding	£0.00	£14,258.00	£0.00	£0.00
	HPR Grant	£6,000.00	£6,000.00		£5,000.00
	Net install cost	-£33,232.00	-£7,832.00	-£4,000.00	-£8,000.00
	Service, repair & maintenance costs over lifetime (HP side)	-£3,463.54	-£3,463.54	-£9,960.38	-£10,237.06
	Replacement cost over lifetime (Hp side)	-£2,158.32	-£2,158.32	-£21,495.55	-£13,466.67
	Net operating costs	**-£5,621.86**	**-£5,621.86**	**-£31,455.93**	**-£23,703.73**
	Total cost over 40 years (Cost to Homeowner)	**-£38,853.86**	**-£13,453.86**	**-£35,455.93**	**-£31,703.73**

	40 Year Lifetime Cost	GSHP	GSHP - Funded	Gas Boiler	ASHP
Running Costs to Occupier	Fuel costs / year to occupier (Y1 cost, £)	-£1,165.71	-£1,165.71	-£1,545.00	-£1,700.00
	Annual standing charge (Y1 cost, £)		-£866.00	-£105.00	
	Fuel costs to occupier over period	-£65,828.57	-£65,828.57	-£78,000.00	-£96,000.00
	Standing costs to occupier over period	£0.00	-£58,370.61	-£7,077.27	£0.00
	Total cost over 40 years to occupier (£)	-£65,828.57	-£124,199.18	-£85,077.27	-£96,000.00

	40 Year Lifetime Carbon Dioxide Emissions	GSHP	GSHP - Funded	Gas Boiler	ASHP
CO_2 Emissions Comparison	**CO_2 emissions over period (kg CO_2e)**	18,651.43	18,651.43	**178,500.00**	**27,200.00**

Comparison of Heat Pump Technologies

This is based on semi-detached house >=100m², with a cavity wall construction.

	Capital costs	SGA Funding	HPR Grant	Capital cost less (HPR Grant+SGA Funding)	Lifetime R&M	Replacement costs	Fuel costs	Standing charge payments	Lifetime carbon dioxide
GSHP	£ 39,232	£ -	-£ 6,000	£ 33,232					
SGA GSHP - Funded	£ 39,232	-£ 14,258	-£ 6,000	£ 7,832					
Gas Boiler	£ 4,000	£ -	£ -	£ 4,000					
ASHP	£ 13,000	£ -	-£ 5,000	£ 8,000					
GSHP					£ 3,464	£ 2,158	£ 65,829	£ -	
SGA GSHP - Funded					£ 3,464	£ 2,158	£ 65,829	£ 58,371	
Gas Boiler					£ 9,960	£ 21,496	£ 78,000	£ 7,077	
ASHP					£ 10,237	£ 13,467	£ 96,000	£ -	
GSHP	£ -	£ -		£ -	£ -	£ -	£ -	£ -	18651.4
SGA GSHP - Funded									18651.4
Gas Boiler	£ -	£ -		£ -	£ -	£ -	£ -	£ -	178500.0
ASHP	£ -	£ -		£ -	£ -	£ -	£ -	£ -	27200.0

GSHP and Shared Ground Array System – Estimated Cost to Consumer

		Mid-terrace with solid walls	Compact semi-detached>100m2	Compact semi-detached<100m2
Dwelling heat pump	Equipment	£3,308	£4,127	£3,308
	Installation	£1,650	£1,650	£1,650
Cost of heat pump equipment and installation				
Building fabric upgrade	Materials	£600	£0	
	Installation	£400	£0	
Costs related to building fabric upgrade work to improving thermal performance				
Window upgrade	Materials			
	Installation			
Costs related to window thermal upgrades				
DHW storage	Equipment	£1,000	£1,000	£1,000
	Installation	£624	£624	£624
Cost of upgrade to DHW storage required for efficiently utilising the heat pump.				
Heat emitter upgrade	Equipment	£1,800		
	Installation	£1,720		
Cost of upgrading radiators to efficiently utilise the heat pump				
Other ancillary building services related costs	Materials	£11,318	£18,758	£13,581
	Installation	£1,370	£1,380	£1,380
Cost of other building services related to the heat pump installation				
Associated renewable energy generation systems	Materials			
	Installation			
Cost of providing renewable energy generation with the heat pump installation				
Capping of gas supply		£550	£550	£550
Total full cost to consumer		£24,340	£28,089	£22,093

Standalone GSHP System – Estimated Cost to Consumer

		Mid-terrace with solid walls	Compact semi-detached>100m2	Compact semi-detached<100m2
Dwelling heat pump	Equipment	£3,308	£4,127	£3,308
	Installation	£1,650	£1,650	£1,650
Cost of heat pump equipment and installation				
Building fabric upgrade	Materials	£600	£0	£0
	Installation	£400	£0	£0
Costs related to building fabric upgrade work to improving thermal performance				
Window upgrade	Materials			
	Installation			
Costs related to window thermal upgrades				
DHW storage	Equipment	£1,000	£1,000	£1,000
	Installation	£624	£624	£624
Cost of upgrade to DHW storage required for efficiently utilising the heat pump.				
Heat emitter upgrade	Equipment	£1,800	£0	£0
	Installation	£1,720	£0	£0
Cost of upgrading radiators to efficiently utilise the heat pump				
Other ancillary building services related costs	Materials	£18,406	£29,900	£18,406
	Installation	£1,380	£1,380	£1,380
Cost of other building services related to the heat pump installation				
Associated renewable energy generation systems	Materials			
	Installation			
Cost of providing renewable energy generation with the heat pump installation				
Capping of gas supply		£550	£550	£550
Total full cost to consumer		£31,438	£39,231	£26,918

ASHP System – Estimated Cost to Consumer

		% Payable upfront by consumer		Compact semi-detached
Dwelling heat pump		0%	Equipment	£4,000
		0%	Installation	£2,500
Cost of heat pump equipment and installation				
Building fabric upgrade		0%	Materials	£600
		0%	Installation	£400
Costs related to building fabric upgrade work except for windows/glazing				
DHW storage		0%	Equipment	£400
		0%	Installation	£2,000
Cost of upgrade to DHW storage required for efficiently utilising the heat pump.				
Heat emitter upgrade		0%	Equipment	£1,800
		0%	Installation	£1,720
Cost of upgrading radiators and/or other space heating emitters that are required to efficiently utilise the heat pump				
Other ancillary building services related costs		0%	Materials	
		0%	Installation	£1,380
Cost of other building services related to the heat pump installation				
Capping of gas supply		0%		£550
Cost of capping the existing gas supply				
Total full capital cost to consumer			Per dwelling*	**£15,350**
			Total (30 homes)	**£460,500**

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