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Humshaugh Net Zero CIC

RCEF

Low Carbon Feasibility Study

Workstream 4 – Heat Pumps

Final Report

February 2021

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Document Revisions

No.	Details	Date
1	First Draft Report	Dec 2020
2	Second Draft Report following client comments	Jan 2021
3	Final Report	Feb 2021

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Low Carbon Feasibility Study

Workstream 4 – Heat Pumps

(REF: 1601)

Final Report

February 2021

D3 Associates Ltd

Report for

Humshaugh Net Zero CIC

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1 Introduction

Humshaugh Net Zero CIC (HNZ) are engaged in the process of reducing the Parish's carbon footprint and tackling climate change and to achieving the Government and Northumberland County Council Net Zero targets. They have consulted with the local community to ascertain their views and are looking to identify a viable approach to low carbon energy generation, particularly electricity, in the Parish of Humshaugh.

The Rural Community Energy Fund (RCEF) is a £10 million programme to support rural communities in England to develop renewable energy projects. HNZ have been successful with a stage 1 application, the funds being used to deliver this feasibility study. Stage 2 grants are available to further develop identified feasible projects for business development and planning.

1.1 Description of the Brief

Workstream 4 of this study is to assess the potential for the installation of heat pumps within the Parish for the generation of heating and hot water. The key elements in the Scope of Work are:

- Technology review
- Resource analysis
- Performance assessment
- Budget costs
- Identify potential showstoppers
- Funding Options
- Risks
- Summary and recommendations for next steps

2 Technology Review

Heat pump technology has been around since the 19th century and has become increasing important in the challenge to decarbonise the provision of heating and hot water in residential and commercial buildings. This has become more prevalent in the last five years as the carbon emissions from grid electricity have reduced from around 500gCO_2e/kWh to around 220gCO_2e/kWh. The current 2030 target is 100gCO_2e/kWh.

The decarbonisation of the grid allows for the electrification of heat. The most efficient way to use electricity for heating is to employ heat pumps to arrange efficient heat transfer from the air, ground or water to buildings. Heat pumps are the only proven route currently available to lower carbon emissions in heating. They have no carbon dioxide (CO_2) emissions on site and none if the electricity used is from a renewable source. Also, heat pumps have no nitrous dioxide emissions and can therefore contribute to the drive towards improved air quality.

The main difference to a conventional oil or gas heating system is the delivered temperature. Existing heating systems that rely on burning a fossil fuel will operate at around 70^{o}C. Heat pumps operate efficiently at temperatures between 35-50^{o}, above this temperature the efficiencies reduce and can become expensive to run. Therefore, carefully consideration needs to be given to the heating system within the property, it will probably need upgrading to suit the lower temperature. In addition, for older properties before considering a heat pump option priority should be given to upgrading the thermal insulation and reducing draughts.

Due to the introduction of the government's Renewable Heat Incentive (RHI) scheme in 2011 for non-domestic and 2014 for domestic properties the sector has grown significantly. To be eligible for the RHI, the product and installer need to be accredited through the Microgeneration Certification Scheme (MCS)[1], the industry standards organisation.

At present, there are nearly 1000 air source heat pumps and over 800 ground/water source heat pumps certified for use. In addition, there are over certified 250 installers working in the north east, though most will be national companies, ensuring a competitive market.

The numbers of technologies installed throughout the country accredited under the non-domestic RHI up to October 2020[2] are included in table 1 below:

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[1] Available from https://mcscertified.com/

[2] Available from https://www.gov.uk/government/statistics/rhi-monthly-deployment-data-october-2020

Technology Type	No. of Accredited Applications	Capacity of accredited full applications
Small Water or Ground Source Heat Pumps (<100 kW)	1,202	35.1MW
Large Water or Ground Source Heat Pumps (>100 kW)	391	200.5MW
Air Source Heat Pumps	669	27.6MW

Table 1: Non-domestic RHI applications up to October 2020

The numbers of technologies installed throughout the country accredited under the domestic RHI up to October 2020 are included in table 2 below:

Technology Type	No. of Accredited Applications	Capacity of accredited applications
Ground Source Heat Pumps	11,376	149.9MW
Air Source Heat Pumps	49,905	496.4MW

Table 2: Domestic RHI applications up to October 2020

Even though there have been a high number of installations to date, the Department for Business, Energy and Industrial Strategy (BEIS) launched the Electrification of Heat Demonstration Project in August 2019. The aim being "*to raise acceptance and support wider deployment of heat pumps in Great Britain"*. £16.5m has been made available to demonstrate the feasibility of a large-scale roll-out of heat pumps in Great Britain by installing heat pumps in a representative range of 750 homes. Additionally, investigate new products and services designed to overcome some of the barriers to deployment.

In the north east E.ON was successful with a project bid and has installed 250 innovative heat pumps along with a range of innovative secondary technologies, such as thermal stores, to suitable homes in Newcastle. By seeking to understand how heat pumps could appeal to more consumers, the project will demonstrate that heat pumps are one of the smart, personalised and sustainable solutions that will help us in meeting the challenge to move away from fossil fuels and combat the climate crisis. The project findings will make for interesting reading.

Ground source heat pumps are frequently used as a centralised heat source for district or communal district heating schemes. They tend to be focussed where the properties are owned by one provider such as a local authority or social housing group. However, they an ideal form of renewable heating for new build projects.

2.1 Air Source Heat Pumps (ASHP)

Air Source Heat Pumps (ASHP) are commonly used in residential properties as most homes have access to air. They are particularly suitable where outside ground space is limited. There are two types of heat delivery, air to air where the heat is delivered by blowing warm air into a room and the more common air to water where a wet system is used. The wet system can be either a radiator system or underfloor heating. The average output for an ASHP is between 2.5 and 3kW of heat produced for 1kW electricity used by the unit. This is referred to the Seasonal Performance Factor (SPF) or Seasonal Coefficient of Performance (SCOP) and varies dependent on the heat output.

A typical ASHP size for a modern building, with a floor area of about 100m^2, is 5kW. For an older, less well insulated and leaky building, this could double to 10kW. Larger properties and commercial buildings will utilise two or more heat pumps operating in a cascade system. Cascaded heat pump systems are particularly useful to efficiently meet fluctuating heat demands, but each unit can have its own use. For example, one could be dedicated to providing heating while another is providing hot water. This avoids any delay in demand, making the set-up ideal for businesses.

In commercial applications, ASHPs can be over 1MW in size though these are designed to order. For lower heating demands, several ‘off the shelf’ smaller units are used operating in a cascade format; these are ideal for large office buildings or factories, therefore, unlikely to be appropriate for HNZ.

The main pros and cons to installing an ASHP are outlined below:

Pros

- Low carbon footprint when compared to oil, coal or LPG (refer to section 5.1), particularly when used in conjunction with a renewable electricity supply
- An ASHP can operate at temperatures down to -20^{o}C, therefore, appropriate for Humshaugh winters
- Much lower capital costs than GSHPs
- Easy installation process than GSHPs
- Versatile – can be used for heating or cooling
- Can be used for heating and hot water
- Low maintenance costs and long life span, typically 15 - 20 years or more
- Eligible for the RHI
- No fuel storage needed
- Ideal for a new build where underfloor heating can be used
- Domestic schemes benefit from the income received under the RHI

Cons

- The heat supplied is at a lower temperature, than oil or gas boiler heating systems
- Older buildings (pre 2000) will usually require upgrading the insulation properties to avoid high running costs (electricity bills)
- The property will probably need a new heat distribution system (radiators and possibly pipework)
- Lower SCOP than GSHPs, therefore higher running costs
- Lower savings when compared to the current low oil price
- Larger units will require planning permission and an application to the DNO
- Larger commercial units can be noisy

Photo 1: An example of a 5kW Mitsubishi ASHP in a rural location

2.2 Ground Source Heat Pumps

There are different heat types of GSHP, horizontal or vertical loop systems which can be closed or open depending on the heat source. The SCOP of GSHPs is typically 3.5 to 4 so higher than ASHPs, therefore, have a higher heat output for each unit kW of electricity used. However, due to the ground installation capital costs are higher.

2.2.1 Horizontal GSHP Closed Loop

For a domestic dwelling, a horizontal ground loop (slinkies) can be used. The trench is typically around 1.0 – 1.2m deep (below the frost layer) and trenches about 4m apart (so the heat extracted from one trench doesn't affect the other). A closed loop pipework system circulates a heat transfer fluid through the pipework to extract heat from the ground. The pipework is connected to the heat pump housing internally.

Photo 2: Horizontal ground loop (courtesy of CA Heat Pumps Ltd)

Pros

- Lower capital costs than vertical (borehole) systems
- Heat source is more stable and not affected too much by severe winters
- Operates at a higher efficiency than an ASHP, therefore cheaper to run
- Low maintenance costs and long life span, typically 25 years or more
- Excavation could be carried out by the homeowner
- Domestic schemes benefit from the income received under the RHI

Cons

- Requires a large area of land which can be easily excavated. The area depends on the size of heat pump which, in turn, depends on the heat loss of the building. A rule of thumb for a modern building with high insulation levels is $5m^2$ per $1m^2$ of floor area. This can more than double for a poorly insulated and leaky building
- Higher capital costs than ASHP

- Usually only suitable for a single or possibly two properties

2.2.2 Vertical GSHP Closed Loop

An alternative to horizontal loops, where space is limited, is to sink a borehole(s) which can be either closed loop or open loop depending on the geology. The depth and number of boreholes will vary and depend on the ground conditions and the heat demand of the building(s). Boreholes can be up to 200m deep.

Once a borehole is drilled, typically 150mm diameter, a loop of pipe is installed, and the borehole filled with thermal grout to aid heat transfer. The pipe is connected to heat pump located either in an energy centre for a centralised scheme or to an individual unit in each property.

The photo below (courtesy of Kensa Contracting) shows the drilling of a 150m borehole using a tracked rig. In this project one 150m deep borehole serves two bungalows.

Photo 3: Drilling a borehole

Photo 4: Pipework loop installed within a borehole

The main pros and cons to installing a vertical closed loop GSHP are outlined below:

Pros

- More energy efficient than ASHPs as the ground has a higher average temperature than air during the winter heating period
- Lower running costs
- Heat source is more stable and not affected at all by severe winters
- More appropriate than ASHP or horizontal group loop GSHP for communal or district heating schemes as several boreholes can be drilled on the same location to form an array to meet the heat demand
- Closed loop systems are simpler and less risky than open loop with lower maintenance costs
- Domestic schemes benefit from the income received under the RHI

Cons

- Higher capital costs than horizontal systems and much higher than ASHPs, though more cost effective if drilling several boreholes
- Typically, one borehole is required per property (possibly one per two for flats or small bungalows) therefore, many are required for a housing estate

- Access required for drilling rig and a sufficient area required for a borehole array (typically boreholes are 5m apart)
- Is dependent on the underground geology; for commercial systems, a trial borehole is recommended

2.2.3 Vertical GSHP Open Loop

Where an aquifer is located beneath the site there is the option of using an open loop system where the water is abstracted, heat removed, and the cooler water returned in a separate borehole. To confirm the suitability of an aquifer as a heat source, a test borehole will need to be sunk which requires consent from the Environment Agency under section 32 of the Water Resources Act. In addition, to operate an open loop scheme an abstraction licence is required (if the abstraction is greater than 20m3/d) and an environmental permit to discharge water.

To ensure the system is well-designed a hydrogeologist will need to be employed, consideration given to the distance between the abstract and discharge boreholes and an assessment of the gas content, water chemistry and particulates.

Pros

- The heat transfer from water is higher than from the ground
- The return temperature is generally 5-6ºC than ground systems , increasing the efficiency of the heat pump
- The flow of water in the aquifer provides constant energy replenishment
- Higher efficiencies therefore lower operating costs than ASHPs
- Longer lifespans than ASHPs
- Less boreholes, therefore, less land required and lower capital costs than closed loop systems
- Domestic schemes benefit from the income received under the RHI

Cons

- May require drilling a test borehole and report which can cost between £6-£10,000
- Specific expertise is needed to ensure the system will work
- Requires approval by the Environment Agency
- High capital cost compared to ASHPs
- High risk as there is no guarantee the heat source is stable
- Higher maintenance costs, the water source requires constant monitoring

2.3 Water Source Heat Pumps (WSHP)

There are two alternative systems available, open and closed loop. In addition to using an aquifer as described above, other water sources such as standing bodies of water,(for example ponds and lakes) and rivers can be used as a heat source for connection to a heat pump (the heat pump itself is essentially the same unit as for GSHP, however, the actual heat pump will vary depending on the heat source parameters).

A closed loop system is usually used in a pond or lake where a pond mat, a system of pipes similar to slinkies is lowered to the bottom of the water source. The depth of water needs to above 1.2m to avoid freezing.

Photo 5: Pond mat

A similar system can be used in rivers though the mat needs to be physically secured to avoid movement in the current. An alternative are ‘Energy Blades’ (see photo below), which when connected to a heat pump can generate up to 25kW of heat each (photo has 4 units) when installed in flowing water. The systems need to be protected from damage particularly during flood events and will need the Environment Agency and landowner’s consent.

Photo 6: 'Energy Blades'

In an open loop system, river water would be abstracted from the North Tyne, pumped to the heat pump, heat extracted, and the water returned to a discharge point located further downstream. Dependent on the amount of water that could be abstracted, the system has potential access to a large volume of water, hence heat. There are several projects around the UK that use rivers as water sources most notably from the river Thames.

Pros

- Open or closed loop systems could be used
- Potentially a high volume heat source if an open loop system is used
- The heat transfer from water is higher than from the ground
- Higher efficiencies therefore lower operating costs than ASHPs
- Longer lifespans than ASHPs
- No need for boreholes saving on costs compared to GSHP

Cons

- Requires landowner consent for access to the river
- Requires approval by the Environment Agency whether open or closed loop; abstraction and discharge points required for open loop
- Filtration and screens required to prevent fish access in an open loop scheme

- Potential for damage during flood events by moving rocks
- Ideally, the heat demand, i.e., the properties would be adjacent to the river to keep down construction and pumping costs (The George Hotel would be ideal)
- Larger centralised heat pumps require an electrical connection which may be costly, an application will have to be made to the DNO

2.4 Hybrid Heat Pumps

There are numerous alternatives that come under the heading of ‘hybrid’ heat pumps. It can refer to two heating options side by side, for example, a gas boiler combined with and a GSHP. This has the advantage that the heat pump can be set to operate at maximum efficiency and cope with the majority of the heat load, the gas boiler being used to meet the high heat demand in colder weather. Naturally, capital costs are higher as two units are required and the carbon savings lower than a heat pump on its own.

This is an area of particular national interest and research (as referred to in the demonstration project mentioned in Section 2) as it can be an interim step to decarbonising heat similar to hybrid electrical vehicles that have a petrol engine and battery.

For the newer housing estates within Humshaugh, currently using LPG, a hybrid system is an option that will lower carbon emissions. Each property could have an ASHP installed to operate with the existing heat distribution system. This would provide sufficient heat for the majority of the year, only on colder days the gas boiler would be used. If the ASHP is sized to heat all the property all of the time, the radiators upsized, at some point in the future the gas boiler could be removed.

2.5 Communal or District Heating

Communal or district heating networks have been around for many decades. Original schemes would have been coal fired used to generate steam or very hot water (around 95ºC) distributed to homes in steel pipes. Latterly, the preference is for gas fired combined heat and power (CHP) and it’s the selling of the electricity which funds these high capital projects. The heat is still distributed at high temperature though through pre-insulated steel pipes to reduce heat losses.

The focus is now on how to decarbonise heat networks and move away from gas fired CHP. GSHPs with boreholes are generally used for communal or district heating schemes, large commercial projects with high heat demands, or smaller sites where space saving is a priority. Several boreholes are sunk in a ground array and the group of properties connected via pipework in a heat network. This is commonly used in the social housing sector and occasionally for new-build development schemes. Typically, one borehole is required per property. However, in shared ground loop array schemes, one deeper borehole could serve two properties.

There are two main options for the distribution of heat:

Ambient Heat Network

The preferred option for most social housing providers is to install a closed loop borehole array and distribute the water at the temperature it comes out of the ground, i.e., at ambient temperature. Small heat pumps are installed in each property, for example the Kensa 'shoe box' (see photo below), which comes in two sizes, 3 and 6kW, delivers all heating and hot water and is billed at the point of use. This removes the need for individual metering and the administration and management cost of managing a traditional district heating scheme (see below). This also allows the resident to shop around for the cheapest electricity bill to ensure running costs for the system are minimised. The housing provider will add a small charge to the rent to cover the installation and operating costs.

Photo 7: A Kensa 3kW 'shoe box' heat pump (photo courtesy of Kensa Contracting)

The benefits of an ambient loop system are:

- The lower temperature means there are no distribution heat losses and cheaper un-insulated plastic pipe can be used
- Small, mass produced heat pumps, easy to install, operate, maintain and replace
- No requirement for large heat pumps which will need more specialist maintenance and costly to replace and require potentially costly new grid connection
- No need for a heat metering and billing system
- Users have the option to shop around for the best electricity tariff
- Electricity bills can be reduced when combined with solar PV panels

High Temperature Heat Network

If the preferred option is to sell heat to customers to generate an income for HNZ there needs to a centralised energy centre which will generate heat at high temperature; 50-75°C depending on the heat distribution system in the houses. The hot water is distributed to each property through a network of pre-insulated flow and return pipes. For a project to be financially viable, it is beneficial for the heat source to be low cost. There are many examples of small heat networks operated using a biomass boiler, where the wood is locally sourced. An alternative would be to use waste heat if a guaranteed source is available nearby. Neither of these options is appropriate for HNZ.

A low carbon solution is to use a borehole array as a heat source for commercial scale heat pumps. This requires an energy centre to house the heat pumps and associated equipment, the heated water is distributed via a heat network to the properties. To enable customers to be charged, heat meters are installed both at the energy centre and in each home. The capital cost for a scheme could be higher or lower than an ambient heat network and will depend on scale. One large heat pump will cost less than several smaller ones, however, a structure is required to house the unit. Also, pre-insulated pipes are more expensive the un-insulated and a metering and billing scheme will be required.

2.6 Important Considerations for Heat Pumps

The main considerations for a heat pump installation are:

Building

- For an efficient system with low running costs the building needs to be well insulated and draught proof, an EPC of C or higher is recommended
- The heating distribution system needs to be able to operate at around 45°C which in a retrofit scheme usually requires installing larger radiators and possible larger diameter pipework
- Heat pumps are ideal when underfloor heating can be installed which can operate at an even lower temperature due to the large surface area, therefore, they will be cheaper to run
- With a lower temperature system, the heating up of the building may take longer with radiators, an underfloor heating system is usually left on all the time as the floor slab needs to heat up first before the room above

Heat Source

- A sufficient land area for a GSHP using a horizontal loop
- Ground suitable and access required for a vertical GSHP borehole system
- Access to a body of water nearby
- Access to moving air

Heat Pump

- Needs to be sized correctly for the property
- Ensure it is MCS certified
- Can be sited in a safe location, i.e., not easily damaged
- Based on the heat sources available assess the pros and cons of each type of heat pump

2.7 Grid Connection

For properties with a maximum electrical demand of less than or equal to 60A and the installer assesses the supply as adequate, the heat pump can be installed, and notification given to Northern Powergrid (NPG) within 28 days. For other installations, a prior application needs to be submitted to NPG who will assess the adequacy of the supply, any grid reinforcement costs associated with the installation may be recharged to the customer.

For large heat pumps used as part of a communal heating system, a 3 phase supply would be preferrable. Locations of 3 phase supplies is included in the WS6 - Grid Feasibility Report.

3 Resource Analysis

3.1 Air

Naturally, an ASHP extracts energy from the air. The cooler air emitted by the heat pump soon drifts away to be replaced by warmer air. If possible, an ASHP should be sited to the warmer southern aspect of a property rather than to the north. This will result in slightly higher efficiencies, therefore lower running costs. Also, as a heat pump is predominantly used in the winter months a property in a frost pocket may find their system operates with a slightly lower efficiency.

3.2 Ground

3.2.1 Horizontal Ground Loop

Shallow ground heats up by absorbing solar energy, particularly during the summer period, the heat being release during winter. The temperature variation depends on the depth and at around 1.0 to 1.2m rises to 15-17 °C in the summer and stays between 5-7 °C in winter. At around 6m deep the temperature stays the same all year at round 9-11°C.

It would be beneficial to install a horizontal ground loop at a depth deeper than 1.0 to 1.2m where the winter temperature is higher, however, the benefit of improved heat pump performance is offset by the increase in construction costs.

The heat that can be extracted from the ground is typically between 15 to 30W per metre of single pipe, the lower figure represents dry soils, i.e., wetter ground conducts heat better. Installations tend to use loops or spirals within in a trench as it is a most cost effective approach than using single pipes.

3.2.2 Borehole

As stated above, below the top few metres of ground, the temperature of the earth is fairly stable at approximately the annual average air temperature, 9-11°C in the UK. A vertical borehole needs to be drilled to depths of up to 200m depending on the geology to obtain sufficient heat for a heat pump. The transfer of heat from the rock to the borehole installation depends on the thermal conductivity of the bedrock and whether water is present. Typical figures are in the table below (the higher the number the better for a heat pump installation):

Rock	Thermal Conductivity (W/m/K)
Coal	0.3
Limestone	1.5 – 3.0

Shale	1.5 – 3.5
Sandstone	2.0 – 6.5
Granite	3.0 – 4.0

Table 3: Thermal conductivity of rocks

The heat extracted from the rock is gradually replaced over time, however, in a poor design there is the potential to freeze the ground around the borehole. In countries where cooling is required during summer, a borehole installation can be used in reverse and heat extracted from the buildings and 'stored' in the ground for winter use.

Bedrock Geology

To determine the bedrock beneath Humshaugh (without drilling) the British Geological Survey (BGS) GeoIndex Onshore[3] website can be used. As can be seen from the image below the underlying bedrock beneath Humshaugh Parish varies. To the west is the Great Whin Sill (purple), a hard dolerite intrusion, whilst Humshaugh village is above limestone bedrock (light blue). To the north of the village is sandstone (orange). As stated above different geological conditions have different heat transfer characteristics. To determine the actual bedrock structure beneath a location the only way is to drill a test borehole. Whilst this is recommended for a commercial scheme, for a domestic installation where only one borehole would be drilled the BGS can provide a GeoReport based on the data they hold.

[3] Available at https://mapapps2.bgs.ac.uk/geoindex/home.html

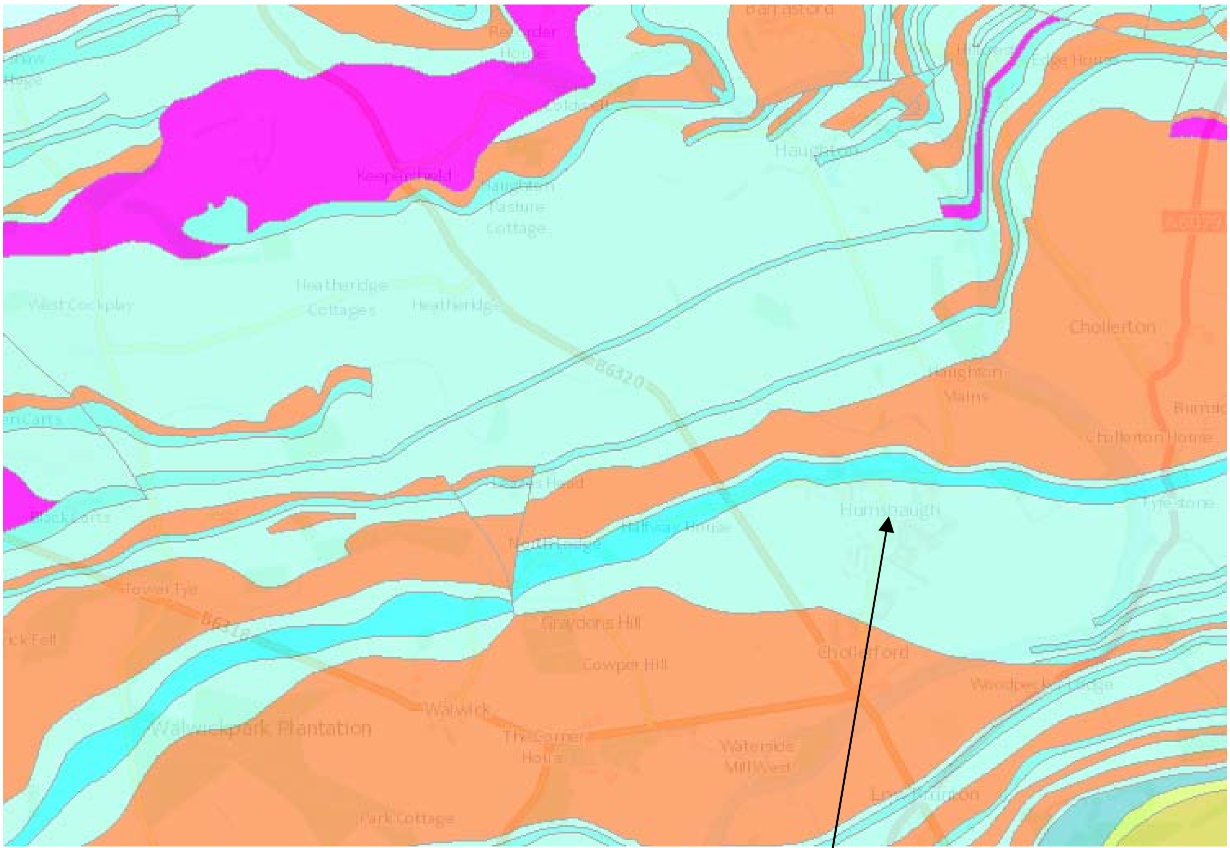

Figure 1: Bedrock geology at 1:50,000 scale (location of Humshaugh)

Former Mine Workings

Another factor to consider before drilling is the presence of former coal mines. The Coal Authority Interactive Map[4] shows the majority of the Parish is in a coal mining reporting area therefore an initial desk top study is required to accompany any planning application. There is a mine entry at the Tower Tye crossroads on the military road (B6318) about 3 miles west of Humshaugh village. The narrow coal out crop runs east to Leazes Head.

[4] Available at http://mapapps2.bgs.ac.uk/coalauthority/home.html

Figure 2: Image from the Coal Authority Interactive Map

Open-loop GSHP viability screening map

BGS in collaboration with the Environment Agency (EA) have also developed a web-based tool that provides an indication of whether suitable conditions exist in a given area for open-loop GSHP[5] which would utilise an underground aquifer . The tool was developed within a GIS and maps the potential for open-loop GSHP installations (heating/cooling output over 100kW) in England and Wales at the 1:250,000 scale.

The tool provides an indication only, however, it does show ground conditions are favourable for an open-loop GSHP system. The EA will always require developers to obtain more detailed, site-specific information, for example by applying for Groundwater Investigation Consent and drilling a test borehole.

[5] Available at https://www.bgs.ac.uk/geology-projects/geothermal-energy/open-loop-gshp-screening-tool/

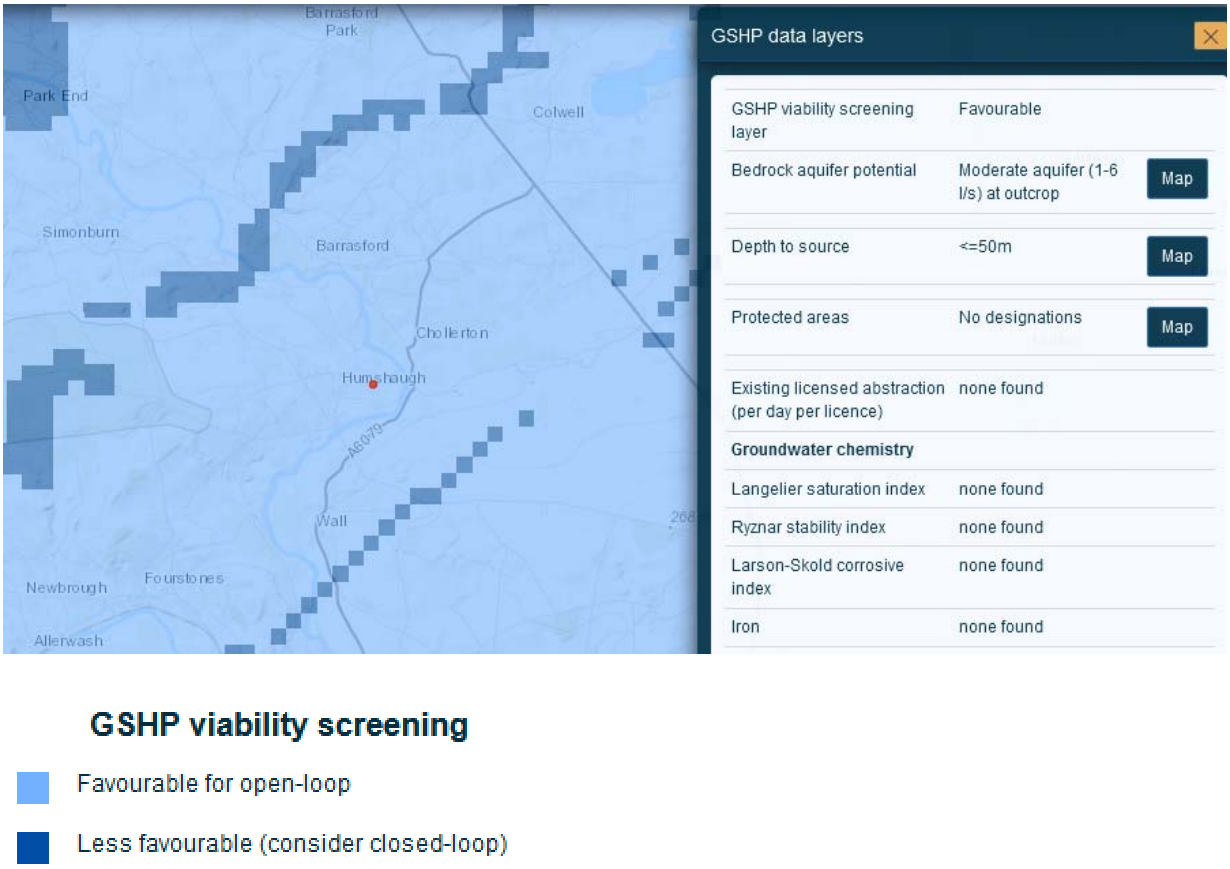

Figure 3: Image from the BGS Open-loop GSHP viability screening map for Humshaugh

Summary

The ground beneath Humshaugh is generally limestone or sandstone which is easily drilled and therefore suitable for GSHP installations. To provide an accurate assessment of the conditions a GeoReport should be obtained. Also, a test borehole may need to be drilled to provide certainty, particularly if an open loop system is considered, to assess the rate of water abstraction.

3.3 Water

The river North Tyne flows along the north and eastern border of the Parish. This is a potential source for heat for use with heat pumps. Water has a high capacity to hold heat in relation to its volume; it readily absorbs heat and readily delivers it, i.e., it has a high transfer rate. It is more efficient for a heat pump to exchange heat with water than air – which enables a WSHP to outperform an ASHP. In addition, river water will be warmer than the air temperatures on cold winter days and thus provide a more attractive input temperature to a heat pump.

4 Performance Assessment

4.1 Estimated Annual Outputs

The seasonal performance factor (SPF) or Seasonal Coefficient of performance (SCOP) of a heat pump is how much heat energy is generated using one unit of electricity over the course of a year. The higher the SPF, the more heat is generated for the same unit of electricity. A typical figure for an ASHP is around 2.5 to 3, WSHP around 3.5 and GSHP around 4. The figures for individual installations do vary and largely depend on the heat source, the temperature of the heating distribution system (the lower the temperature the more efficient and higher SPF it will be) and whether hot water is required.

The reason for the change is the difference in temperature witnessed in each heat source over the seasons. The ASHP needs to be providing the most heat when the outside air temperature falls, whereas the ground stays at much more of a constant temperature, meaning that the GSHP doesn't have to use as much electricity to reach the same temperature.

The output for vertical borehole GSHP systems is slightly higher than horizontal arrays as the temperature deep below ground is more constant all year round. A WSHP will depend on the water source. An aquifer will be at a constant temperature, heated by the rocks around it, a pond, lake or river temperature will vary throughout the year with the air temperature.

4.2 Long Term Output

The SPF of an ASHP will be different for each year as the air temperature changes, particularly between mild and severe winters. Climate change is already having an impact and average temperatures are rising, long term this will result in higher SPFs and lower operating costs.

The long term output from horizontal and vertical GSHP systems should be stable providing the original design is undertaken correctly. There are examples where trenches or boreholes have been installed too close together which can ultimately result in freezing of the ground and the system becoming much less efficient or even failing.

The temperature of water and flow rate of water from aquifers should be stable long term, again, providing the original design is undertaken correctly. The test borehole will establish the current flow rate and temperature though there is a risk of this changing long term usually due to further abstracts in the area affecting the aquifer. The location of the discharge borehole is key to avoid influencing the abstract borehole.

The temperatures of other bodies of water, ponds, lakes and rivers, will change with the air temperature. Still sources will be more susceptible to lower temperatures in cold weather, the designed output needs to be less than the available heat source to avoid lowering the water's average temperature and the SPF.

4.3 Carbon Emissions

The carbon emissions, $KgCO_2e/kWh$, for alternative fuels is included in the table below:

Fuel	KgCO2e per kWh
Electricity	**0.288**
Kerosene	**0.298**
LPG	**0.241**
Pellets	**0.053**
Coal	**0.396**
ASHP	**0.107**
GSHP	**0.082**

Table 4: Carbon emissions for alternative fuels

The figures are based on UK Government GHG Conversion Factors for Company Reporting which includes emissions from Transmission and Distribution.

The figure for grid electricity is falling year by year due to the installation of renewable energy technologies around the UK particularly, large offshore wind farms, solar farms and biomass fuelled power plants. The current 2030 target for the UK is to reduce the carbon intensity of grid electricity to $0.1KgCO_2e/kWh$. This is a main driver to reaching our 2050 targets and is leading to the electrification of transport and heat.

Coal has by far the highest carbon emissions with electricity currently similar to kerosene and LPG. However, as shown in table 4 above if an electric heat pump is installed the carbon emissions reduce to around one third with GSHPs having lower emissions than ASHPs due to their greater efficiency.

For example, from the Humshaugh household carbon footprint survey data for households that have an oil boiler, the average annual oil use is 2267litres which equates to 22,216kWh/year and carbon emissions of $6.62tonnesCO_2e/year$. Replacing the oil boiler with a GSHP would reduce this figure to $1.82tonnesCO_2e/year$, a saving of $4.8tonnesCO_2e/year$.

5 Budget Costs

5.1 Domestic Properties

The following are budget capital costs based on a four bedroomed detached house (not including any internal alterations):

Technology	Capital Cost
ASHP	£9,000 to £11,000
ASHP as a bolt on to a gas boiler	£7,000 to £8,000
GSHP with horizontal ground loop	£14,000 to £19,000
GSHP with vertical borehole	£25,000 to £30,000
WSHP with pond mat	£12,000 to £17,000

Table 5: Indicative domestic budget capital costs

Potential Energy Savings:

The potential savings of installing a standard air source heat pump in an average sized, four-bedroom detached home have been estimated by the Energy Saving Trust (EST) as follows:

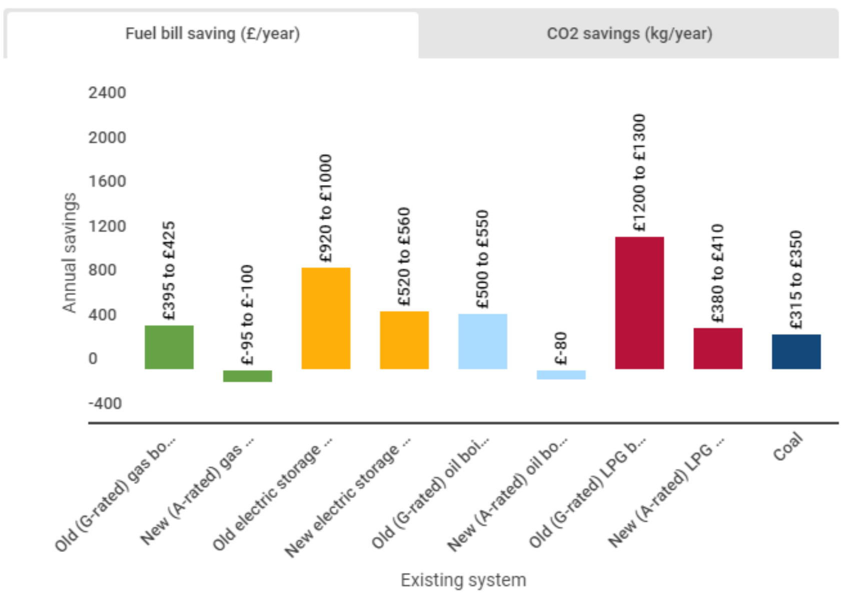

Figure 4: Potential annual savings of using an ASHP (EST)

In the figure above, negative fuel savings indicate a fuel bill increase. Of particular note to Humshaugh residents is the figure for a new A rated oil boiler which, due to the current oil price, is cheaper to run than an ASHP.

The figures for an equivalent GSHP with a horizontal ground loop are:

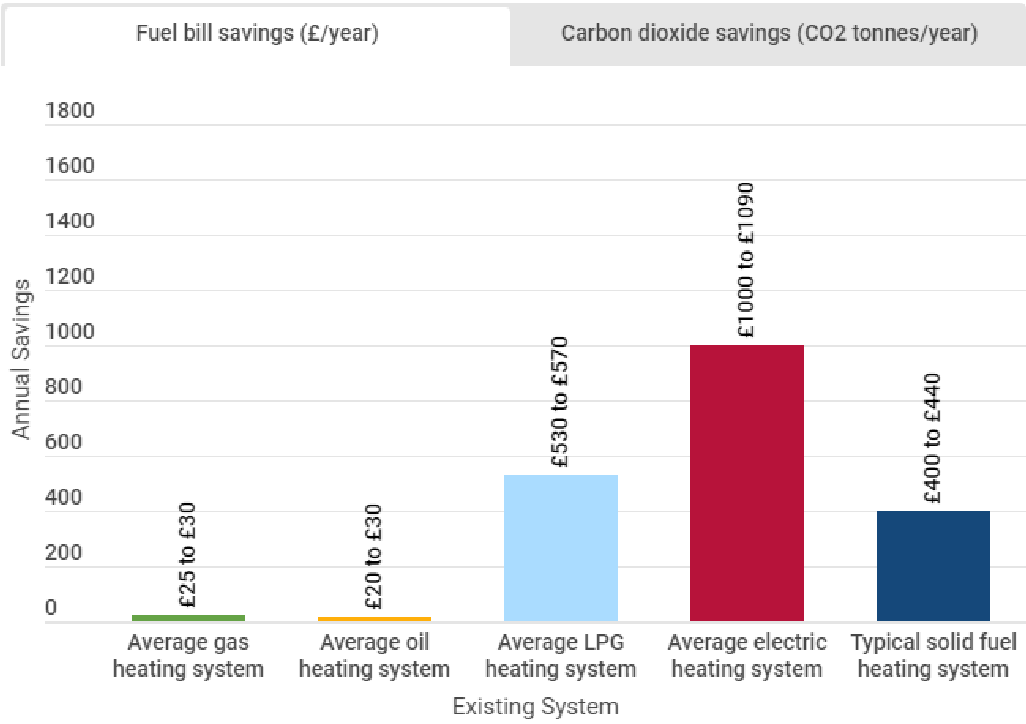

Figure 5: Potential annual savings of a GSHP (EST)

It is expected that the savings for a GSHP system with a vertical ground loop and that of a WSHP would be similar to Figure 5.

In addition, the Nottingham Energy Partnership regularly publish an energy cost comparison table[6]. The figures are based on a medium sized domestic property with an annual heat demand of 16,500kWh. The table below is an extract of data appropriate for Humshaugh (for an explanation of how the costs are calculated refer to the website):

[6] Available at https://nottenergy.com/resources/energy-cost-comparison/

Fuel	Fuel price (p per unit)	Unit	Pence per kWh (after boiler efficiency)	Energy Content (kWh per unit)
Electricity Standard Rate	**19.88**	**kWh**	**19.88 (100%)**	**1**
Kerosene	**29.41**	**litre**	**3.33 (90%)**	**9.8**
LPG	**43.22**	**litre**	**7.21 (90%)**	**6.66**
Pellets	**26.33**	**Kg**	**6.20 (90%)**	**4.72**
Coal	**34.47**	**Kg**	**6.71 (75%)**	**6.20**
ASHP	**19.43**	**kWh**	**7.19 (270%)**	**1**
GSHP	**19.88**	**kWh**	**5.68 (350%)**	**1**

Table 6: Energy comparison based on September 2020 prices

5.2 Commercial Properties

Capital costs for commercial projects are very site specific. Below are budget capital costs for example projects appropriate for Humshaugh:

- Small estate with 4 large luxury houses, shared ground loop array of boreholes requiring 600-900m^2 land, each house has a 13kW heat pump - £90,000 to £100,000
- Small estate with 4 large houses, shared ground loop array of boreholes requiring 600-900m^2 land, centralised heat pump, housed in a structure – £115,000 to £125,000

6 Funding Options

6.1 Renewable Heat Incentive (RHI)

The Government announced on the 28th April 2020 that the non-domestic RHI scheme would close for new applicants from April 2021. However, the domestic RHI for households has been extended to March 2022.

A consultation had been launched to formalise the replacement scheme for the RHI. The Government is proposing a Clean Heat Grant that would commence in 2022, offering funding support of up to £4,000 for each household or business that integrates heating technologies such as heat pumps. An eligible list of technologies applicable for funding support is expected to be outlined.

Under both RHI schemes the income received depends on the type and size of technology installed and is paid over 20 years for the non-domestic RHI and 7 years for the RHI. The general rule of thumb is that for typical installations, the RHI income covers the capital cost. Examples of running costs was detailed in the previous section.

To be eligible for the RHI the heat pump and the installer need to be certified under the Microgeneration Certification Scheme (MCS)[7].

The current domestic RHI tariffs[8] are included in the table below:

Technology type	Tariff Rate 2020/21 (p/kWh)
Biomass	6.97
Air Source Heat Pump (ASHP)	10.85
Ground Source Heat Pump (GSHP)	21.16
Solar Thermal	21.36

Table 7: Extract from the domestic RHI tariffs

[7] Available at https://mcscertified.com/

[8] Available from https://www.ofgem.gov.uk/publications-and-updates/domestic-rhi-tariff-table

6.2 Green Homes Grant

Another current funding stream is the Green Homes Grant[9] which was launched by the government in September 2020. Under the Scheme, homeowners and landlords in England are able to apply for vouchers worth up to two thirds of the cost of upgrading the energy efficiency of their home or installing low-carbon heating. For most people, the maximum contribution will be £5,000. Households on low incomes will be eligible for up to 100% funding, up to a maximum of £10,000. Vouchers must be redeemed by 31st March 2022.

Under the Scheme there are Primary Measures and Secondary Measures. Primary Measures unlock Secondary Measures, and you can't claim more for Secondary Measures than you have for Primary Measures.

Primary Measures include:

- Insulation – loft, cavity wall or underfloor
- Low carbon heating – heat pumps, solar thermal panels or biomass pellet boilers

Secondary Measures include:

- Draught proofing
- Double/triple or secondary glazing
- Energy efficient replacement doors
- Hot water tank thermostats and insulation
- Heating Controls (Smart heating controls, zone controls, intelligent delayed start thermostat and thermostatic radiator valves)

Installers eligible to carry out the works need to have Trustmark accreditation so many local small scale contractors and sole traders are currently not able to deliver work under the scheme.

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[9] To check eligibility, go to https://www.gov.uk/check-eligible-green-homes-grant

7 Statutory Requirements

7.1 Planning

Due to their limited aesthetic impact, domestic GSHPs are likely to be considered ‘permitted development’ by Northumberland County Council (NCC) Planning Department, which means that no planning permission will be necessary. It is nevertheless always a good idea to check with NCC prior to installing any renewable energy technology, particularly in the Conservation Area.

The installation of domestic ASHPs may also be 'permitted development' with no need to apply to NCC for planning permission. There are, however, important limits and conditions which must be met to benefit from these permitted development rights:

- The proposed installation site must not be located in the grounds of a listed building or in a conservation area
- The pump unit must not be placed on a pitched roof
- The unit must be placed more than one meter from the edge of the property
- The pump unit must be smaller than 0.6 square meters

In all cases it is recommended contact is made with NCC Planning Department to confirm whether your individual situation meets the requirements. If the installation is outside of these limits a full planning application needs to be submitted.

All commercial installations will require a full planning application.

7.2 Building Regulations

Normal Building Regulations do apply for heat pump installations. The ability of the heat pump to supply sufficient heat will need to be checked and proven. Building Regulations also apply to other aspects of the work such as electrical installation. It is advisable to use an installer who can provide the necessary advice and submit the required application.

7.3 Environment Agency

The Environment Agency will need to be consulted and permission sought before drilling into an aquifer as described in Section 3. In addition, when considering using the river as a heat source early consultation with the EA is recommended.

7.4 Coal Authority

The majority of the Parish is within the Coal Authority reporting area; therefore, a report assessing the risk of drilling in the area will be required for any planning submission. However, as shown in Section 3, there is only a small area of high risk.

8 Risks

The main risks and mitigation measures have been mentioned throughout the report, they are summarised in the table below:

Risk	Mitigation Measure
Property does not heat up adequately	Check to the existing heating system has been altered to suit the lower water temperature
Heat pump undersized	Ensure the heat pump is sized correctly for your heating demand
Ground freezes	Ensure the heat source is assessed correctly
High electricity bills	Ensure the thermal properties of the building are assessed correctly at the design stage
Planning Officer objects to the installation	Follow the guidance from the Planning Authority and apply for planning permission if necessary
Restricted access to the site for boreholes	Ensure there is a field gate size access, drilling rigs vary, e.g., tracked or lorry mounted
Construction costs rise for trench excavation	Use green field where possible, excavate trial holes along the route, check for services
Failure to install in time to receive the RHI	Commence project in early as installations need to be completed before the domestic RHI closes on 31st March 2022

Table 8: Risks and mitigation measures

9 Summary/Recommendations

The installation of electric heat pumps is a viable option to decarbonise the heating of properties in the Humshaugh Parish. Prior to installing a heat pump, improving the thermal properties of the building should be considered which will lower the heat demand and ensure the heat pump can operate efficiently to avoid high electricity bills.

For domestic properties, the simplest and easiest to install with the least capital cost is an ASHP. This can also be installed as a hybrid system to work alongside an existing gas or oil boiler. The most important aspect to consider is the heating distribution system which will operate at a lower temperature therefore the existing radiators may need upsizing to maintain heat output.

GSHPs are also a viable option, particularly as they receive a higher tariff under the RHI. A horizontal ground loop system is suitable where there is a sufficient area of land, half an acre or more, for the installation. Otherwise, a vertical borehole system will be required which increase the capital costs. GSHPs have a typical SCOP of 3.7 compared to an ASHP of 2.5 therefore they are cheaper to run.

WSHPs are not ruled out, however, they are higher risk projects that require permission from the Environment Agency and also the landowner for river access. In addition, using a water source will require filtration and constant monitoring to avoid fouling of the plant and disruption of the heat supply.

To provide surety over costs for Humshaugh it is recommended specific projects are identified to undertake a more detailed feasibility study. This could be for a single property or a cluster of houses interested in installing low carbon heating systems.

The RHI has been the main driver in recent years for the dramatic increase in heat pump installations. Unfortunately, the non-domestic scheme is closing soon, however, the domestic scheme is open to the end of March 2022. The scheme, paid over 7 years, typically offsets the capital cost of the project and as the running costs are lower for heat pumps than traditional fossil fuel boilers makes projects financially beneficial. For residents on low incomes where the capital cost is an obstacle, it is worth investigating in the Green Homes Grant.