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South Gloucestershire Energy From Mines Masterplanning Report

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EXECUTIVE SUMMARY

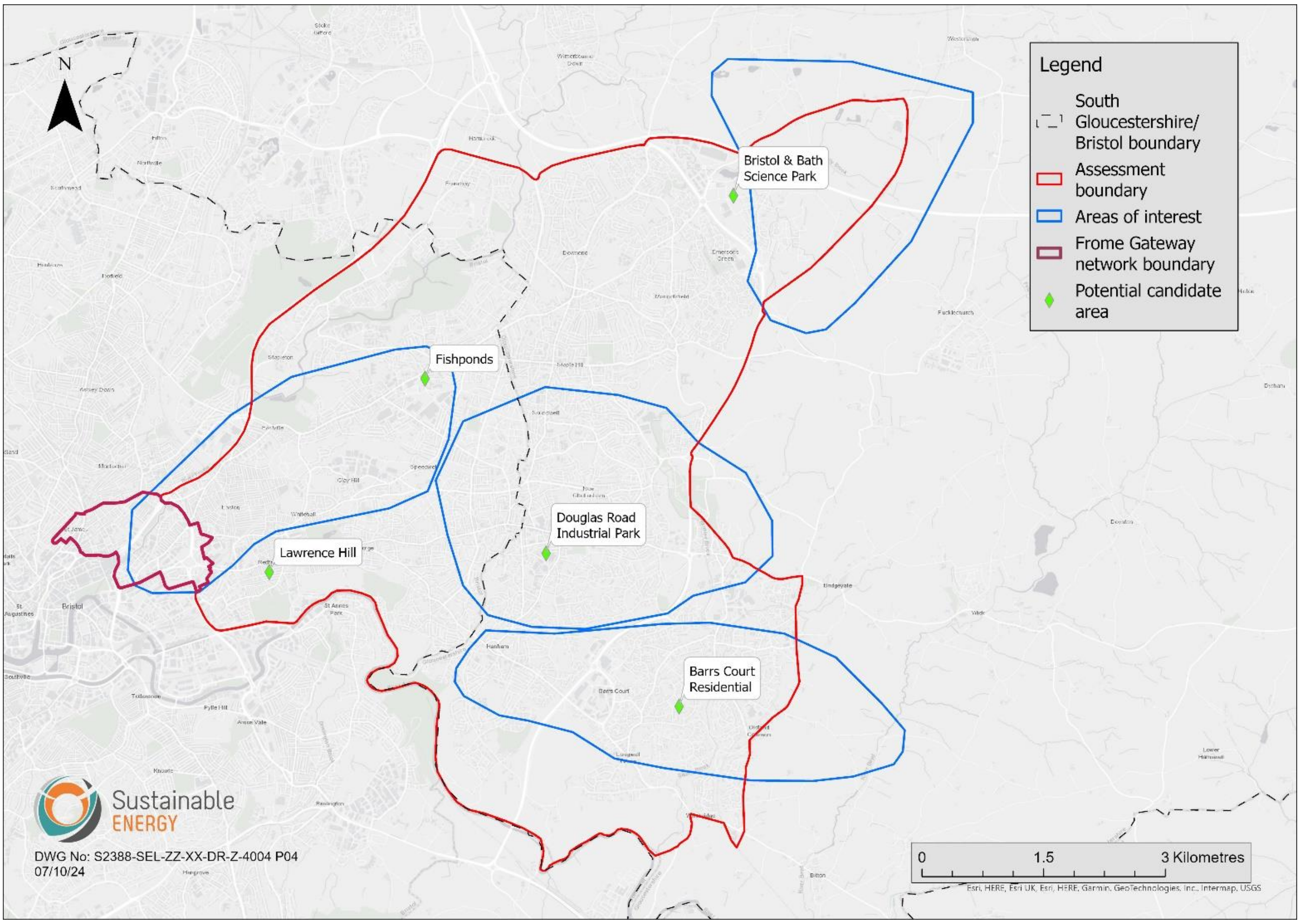
This report presents the findings of South Gloucestershire Energy From Mines Masterplanning study. The project is supported by the South West Net Zero Hub, which is funded by the Department of Energy Security and Net Zero (DESNZ), with additional input from South Gloucestershire Council (SGC). This study should be a key component of the overall CO_2e reduction, heating, and cooling strategy for South Gloucestershire.

Project Background

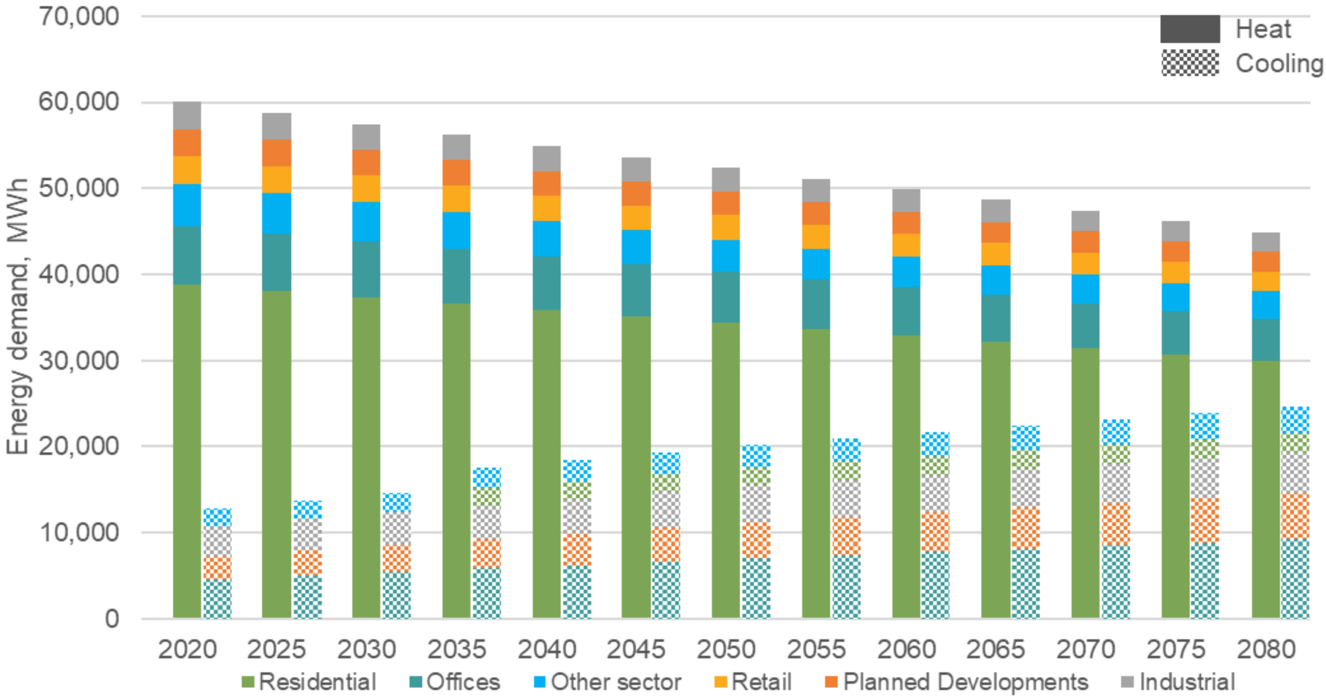
In July 2022, a report commissioned by South Gloucestershire Council from the Coal Authority was published identifying four "Areas of Interest", where multiple coal seams overlapped. This indicates the potential for energy abstraction from these mines, and this study was set up to identify the preferred areas to take forwards.

Energy Demand

Five candidate areas were identified within the assessment boundary, in agreement with the project team, based on a high-level heat density assessment and the Areas of Interest. Four of the candidate areas were selected based on high-level heat density, and a fifth candidate area was selected in a residential-only area to explore this archetype.



Heating and cooling demands for buildings within each candidate area were obtained based on buildings' size and use, using in-house benchmarks derived from hundreds of real-life data points. These energy demands were then forward-projected to account for the effect of climate change and rising temperatures. The methodology for this was based on the CIBSE temperature projections for 2020, 2050 and 2080. Heating and cooling demand models were set up for a range of typical buildings, and the different temperature profiles were applied to obtain a percentage increase/decrease in energy demand. This has the effect of increasing cooling demands and decreasing heat demands. Certain building categories were also assumed to not have a cooling demand until a certain point in the future (selected as 2035), to represent a 'tipping point' where heat waves are common enough that consumers would no longer tolerate a lack of cooling infrastructure. The image below shows an example of the heating and cooling demands over time for the Bristol and Bath Science Park candidate (BBSP) area.



The total current heat demand identified within all candidate areas was 468 GWh, while the 2080 cooling demand identified was 80 GWh. The majority of the heat demand is made up of existing buildings, mainly low-rise residential dwellings.

	Lawrence Hill	Fishponds	Bristol and Bath Science Park	Douglas Road Industrial Park	Barrs Court Residential
Total heat demand, MWh	73,151	153,482	60,030	127,463	53,810
Total cooling demand, MWh	6,827	21,393	24,155	24,392	3,531
Peak demand, kW	40,960	93,230	36,370	76,220	29,650
Cooling demand, kW	13,880	35,110	23,160	27,750	7,850

Options assessment

Four options to serve the heating and cooling demand within each candidate area were assessed. These were: Business as Usual (BAU), individual Air Source Heat Pumps (ASHPs), an ambient network, and a Heating and Cooling Network (HCN).

The BAU option assumes that the heat demand from all buildings is met by gas boilers within each building, and that the cooling demand is met by local chillers (for commercial building) and air conditioning units within dwellings. This option is not considered low-carbon and is included for comparison purposes only.

The individual ASHPs option assumes that ASHPs are installed in each building and that these are capable of supplying both heating and cooling – the latter by reversing the internal heat pump process and adding additional heat emitters to provide space cooling.

The ambient network assumes that individual water source heat pumps are installed in each property, and that these are also capable of supplying both heating and cooling. The heat source for these heat pumps would be an ambient network consisting of a flow and return pipe, between the connected buildings and the mine seam. During the winter, the heat pumps would take heat from the ambient network to heat up the buildings, and the ambient network would take heat from the mines to maintain its temperature. In summer, the process would be reversed, with heat being removed from the connected buildings and stored in the mines.

The HCN option assumes that a centralised heat pump would abstract heating/cooling from the mine, and distribute it to the connected building via a 4-pipe system: a flow and return for heating, and a flow and return for cooling.

A district energy network and an ambient network are reliant on a suitable location being secured for an energy centre and/or for boreholes. Several locations have been identified for the candidate areas as the preferred locations. These areas are: Bristol Ambulance Station (Lawrence Hill), Filwood House and Verona House (Fishponds), land north of Elderflower Drive (BBSP), Moravian Road Business Park (Douglas Road Industrial Park), and Barrs Court Substation (Barrs Court Residential). Engagement with the site owners or local planning team will be necessary to secure potential energy locations were the projects in the candidate areas to proceed further.

Network Assessment

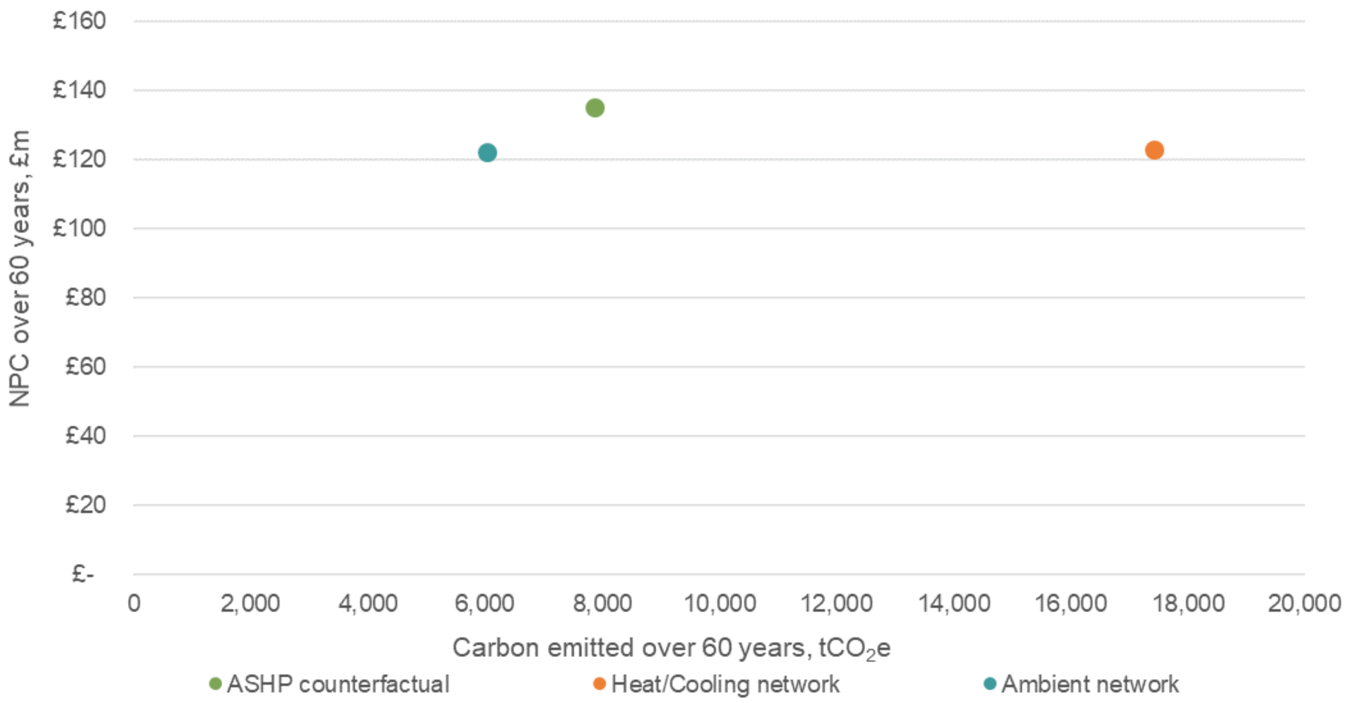
A heat and cooling network (HCN) and ambient network option have been assessed in each candidate area. This assessment accounted for network constraints (road, railways etc), dig type (hard/soft dig), locations of energy centre and connections. A summary of the networks is shown below:

	Lawrence Hill	Fishponds	Bristol and Bath Science Park	Douglas Road Industrial Park	Barrs Court Residential
Network spine trench length - Heat, m	7,281	15,192	11,602	16,170	34,859
Network spine trench length - Cooling, m	6,823	13,085	11,217	15,638	34,859
Network spine trench length - Ambient, m	7,281	15,193	11,602	16,170	34,859
No. of commercial connections	46	79	69	66	-
No. of residential connections	6,024	12,302	4,331	11,618	5,455

Economics

A techno-economic model (TEM) was developed to assess the viability of each of the four options in each candidate area. For each candidate area (with the exception of the residential area), two TEMs were produced: one including for low-rise residential dwellings[1], and one not. This was to assess the economic performance of the low-rise residential against the commercial buildings. The key parameters for the TEM include annual energy demands, peak energy demands, energy centre tariffs, scheme capital costs, operational and replacement costs, and carbon emissions/savings vs the BAU case. For each candidate area, the Net Present Cost (NPC) was calculated. This metric accounts for all discounted capital costs and operational costs over a project lifetime (60 years in this case). For each candidate area, a graph representing the NPC and the carbon emissions was generated to be able to compare the three low carbon options. An example of this type of graph is shown below.

[1] Low-rise residential refers to residential dwellings (including terraces, flats, houses, etc.) with a number of floor levels around or less than 4 floors.



Conclusions

In all scenarios, the ambient network yielded the lowest carbon emissions, followed by the individual ASHPs and then the heating and cooling network. All options yielded a saving of more than 90% compared to the gas boiler BAU.

In order to prioritise which areas should be explored in further detail, the NPCs of each candidate area have been compared against each other, using the ASHP as the benchmark (100%) as this is the most likely to occur without council intervention. The areas with the greatest reduction indicate the greatest potential for a viable network. This is displayed in the table below.

Candidate area	ASHPs	HCN	Ambient	Rank
Lawrence Hill	100%	88%	89%	2
Fishponds	100%	77%	85%	1
Bristol and Bath Science Park	100%	91%	90%	3
Douglas Road	100%	103%	95%	4
Barrs Court Residential	100%	105%	120%	5

The Barrs Court Residential candidate area has a higher NPC for both the HCN and ambient option, indicating that this area is better served by individual ASHPs. For the other four candidate areas, the above table presents the results without low-rise residential dwellings. In all cases, adding low-rise residential dwellings improves the case for individual ASHPs, indicating that these areas are better served by ASHPs. However, a certain portion of low-rise residential can be added to these candidate areas and still maintain a lower NPC for either the ambient or HCN options. This would allow the other benefits of these options to be realised for the low-rise residential, such as reduced electrical grid upgrades, decreased use of high Global Warming Potential refrigerants and avoiding the need to locate an external ASHP unit in each building.

Based on this assessment, the Fishponds area should be the next area of focus, followed by Lawrence Hill, BBSP, and Douglas Road.

Next Steps

Key next steps for the project include:

- Present the findings of the report to relevant stakeholders including SGC senior staff and elected members, if the project is to be progressed

- Ensure the technical and economic work undertaken in this study will provide an evidence base for planning policy
- Progress those identified schemes which offer a saving in comparison to ASHPs to feasibility stage, directing resource to those with the greatest savings (i.e. in order: Fishponds, Lawrence Hill, BBSP and Douglas Road)
- Further engage the Coal Authority to discuss the potential energy centre locations discussed in this study, and determine if further work is needed ahead of a Stage 2 Coal Authority report, including potentially drilling trial boreholes to assess resource availability

Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ASHP	Air source heat pump
AQMA	Air Quality Management Area
BAU	Business As Usual
BBSP	Bristol and Bath Science Park
BGS	British Geological Survey
CAPEX	Capital expenditure
CHP	Combined heat and power
COP	Coefficient of Performance
CO_2e	Carbon dioxide equivalent
DEC	Display Energy Certificate
DESNZ	Department for Energy Security and Net Zero
DHN	District heating network
DHW	Domestic hot water
Dph	Dwellings per hectare
EA	Environment Agency
EC	Energy centre
GIS	Geographic Information System
GHNF	Green Heat Network Fund
GSHP	Ground source heat pump
HCN	Heating and Cooling Network
HIU	Heat interface unit
HNCoP	Heat Networks Code of Practice
HNDU	Heat Network Delivery Unit
IAG	Interdepartmental Analysts Group
IRR	Internal Rate of Return
LCP	Lane Clark and Peacock
LHD	Liner heat density
LTHW	Low temperature hot water
NCC	National Composite Centre
NOx	Nitrogen oxides
NPV	Net Present Value
MWSHP	Mine water source heat pump
OPEX	Operational expenditure
PV	Photovoltaics
RFI	Request for information
RHI	Renewable heat incentive
SHM	Strategic Heat Main
SPF	Seasonal performance factor
SuDS	Sustainable Drainage Systems
TEM	Techno-economic modelling
WSHP	Water source heat pump

GLOSSARY

Ambient loop	A low-temperature water circuit which distributes thermal energy between a source and buildings. Each building is equipped with a heat pump which can provide both heating or cooling. Can sometimes be referred to as 5th generation heat networks.
District heating	The provision of heat to a group of buildings, district or whole city usually in the form of piped hot water from one or more centralised heat source
Energy centre	The building or room housing the heat and / or power generation technologies, network distribution pumps and all ancillary items
Energy demand	The heat / electricity / cooling demand of a building or site, usually shown as an annual figure in megawatt hours (MWh) or kilowatt hours (kWh)
Combined heat and power	The generation of electricity and heat simultaneously in a single process to improve primary energy efficiency compared to the separate generation of electricity (from power stations) and heat (from boilers)
Green Heat Network Fund	The £288m capital grant funding programme for heat networks announced by Government that opened on 1 April 2022
Heat clusters	Buildings / sites grouped based on heat demand, location, barriers, ownership and risk
Heat exchanger	A device in which heat is transferred from one fluid stream to another without mixing - there must be a temperature difference between the streams for heat exchange to occur
Heat Interface Unit	Defined point of technical and contractual separation between the Distribution Network and a heat user
Heat network	The flow and return pipes that convey the heat from energy centre to the customers – pipes are usually buried but may be above ground or within buildings
Heat offtake opportunity	An opportunity to utilise waste heat from an industrial process including EfW plants using heat exchangers
Heat pump	A technology that transfers heat from a heat source to heat sink using electricity (heat sources can include air, water, ground, waste heat, mine water)
Hurdle rate	The minimum internal rate or return that is required for a network to be deemed financially viable
Internal Rate of Return	Defined as the interest rate at which the net present value of all cash flows (both positive and negative) from a project or investment equals zero, and is used to evaluate the attractiveness of a project or investment
Linear heat density	Total heat demand divided by indicative pipe trench length - it provides a high level indicator for the potential viability of network options and phases
Peak and reserve plant	Boilers which produce heat to supply the network at times when heat demand is greater than can be supplied by the renewable or low carbon technology or when the renewable or low carbon technology is undergoing maintenance (also called auxiliary boilers)
Substation	A defined point on the property boundary of the heat user, comprising a heat exchanger, up to which the heat network is responsible for the heat supply
Thermal store	Storage of heat, typically in an insulated tank as hot water to provide a buffer against peak demand

1 INTRODUCTION

1.1 General

This report presents the findings of the South Gloucestershire Energy From Mines Masterplanning Study. The project is supported by the South West Net Zero Hub, which is funded by the Department of Energy Security and Net Zero (DESNZ), with additional input from South Gloucestershire Council (SGC). The work has been conducted by Sustainable Energy (SEL).

1.2 Project Background

South West Net Zero Hub

The South West Net Zero Hub provides strategic and technical support to public sector and community groups to develop, finance, and deliver net zero energy projects. It is funded by DESNZ as part of the government's aim to reach Net Zero emissions by 2050. It manages a variety of initiatives, including housing retrofit schemes, community energy projects, and public sector decarbonisation efforts. The Hub also supports local energy advice programs and helps communities reduce energy costs and carbon emissions.

South Gloucestershire Council

In 2019, South Gloucestershire Council declared a climate emergency and set a plan to achieve Net Zero emissions by 2030, taking into account emissions from production and consumption. South Gloucestershire has identified that decarbonising the existing buildings is the single most challenging aspect in achieving carbon neutrality and meeting national, legally binding emission reduction targets.

South Gloucestershire and Bristol have a long and extensive history of coal mining, which lasted for 150 years up to the 1920s. The previous Mine Heat Feasibility Study conducted by the Coal Authority in 2022 (commissioned by South Gloucestershire Council) has determined that 23 existing mine seams are considered sufficiently extensive for heat extraction within South Gloucestershire. Four 'Areas of Interest' have been identified within or near the study area.

Heat networks are an opportunity to provide lower-cost and lower-carbon energy. SGC would like to explore a low-carbon heat network(s) utilising the available mine source identified within South Gloucestershire/Bristol as a potential decarbonisation strategy. SGC identified that current climate models may have underestimated the impact of global warming on the UK climate, given the record-breaking summer temperatures in 2022. SGC recognised that a low-carbon cooling solution should be explored for potential future cooling requirements.

Project Drivers

The Council's key drivers for investigating a low carbon heat and cooling solution include:

- Reducing carbon emissions
- Improving energy efficiency and security
- Addressing the impact of climate change on summer temperature (overheating)

1.3 Project Scope

SEL was commissioned to undertake a masterplanning study for South Gloucestershire. The scope of the study included the requirements to:

- Determine the study boundaries based on the defined Coal Authority 'Areas of Interest' including looking beyond the marked boundaries where this is appropriate and could potentially add value to the scheme.

- Carry out an initial, high level, assessment of the full study area to determine the most favourable candidate areas for district heating schemes. In particular, a candidate area should be identified which mainly consists of residential properties to understand the potential for heat networks in such an area.
- Agree a suitable number of candidate areas to take to a full assessment.
- Identify and categorise new and existing heating, cooling, and power demands that are appropriate for the development of heat network schemes and present these using GIS mapping.
- Develop and implement a methodology to project the heating and cooling demands into the future, accounting for the effect of climate change on ambient temperatures.
- Determine and assess the full range of potentially relevant low and zero carbon heat and cooling network supply technologies including mine water.
- Determine potential energy centre locations and network routes taking into account the locations of available mine water.
- Identify the key district heating, cooling, and private wire scheme options and undertake a high-level economic assessment. The options appraisal should include an indication of whether the projected demand for heating and cooling is more suited to 4th or 5th generation heat network/s.
- Evaluate and prioritise identified district heating/cooling/private wire scheme options, according to standard HNDU criteria, to provide an initial assessment of whether a heat network is feasible and viable and determine the recommended scheme options suitable to progress a subsequent techno-economic feasibility study.
- Identify next steps for recommended options, including timeframe.
- Identify all risks and issues and rate those risks in terms of their impact and likelihood.

All work is compliant with the Heat Networks Code of Practice[2], and SEL will consider UK and international best practice.

[2] DESNZ CP1(2020) code of practice: CP1 Heat networks: Code of Practice for the UK (2020) (pdf) | CIBSE

2 DATA COLLECTION

This section describes our approach to data collection and stakeholder engagement. Stakeholder engagement is critical to developing successful energy networks and the engagement work carried out to date will need to continue if the project is to progress through subsequent HNDU stages of development.

Key stakeholders were consulted to inform the data collection exercise including representatives from Bristol City Council (BCC), SGC, the South West Net Zero Hub, and Vattenfall as discussed in section 2.2.5

2.1 Assessment Area

In July 2022, the Coal Authority undertook a Stage 1 study in the South Gloucestershire/Bristol area, to assess the energy within mines in the region. Based on the outcome of the study, a total of four 'Areas of Interest' (AOI) were identified with overlapping coal seams, indicating potential for energy abstraction. The four AOIs are shown in Figure 1.

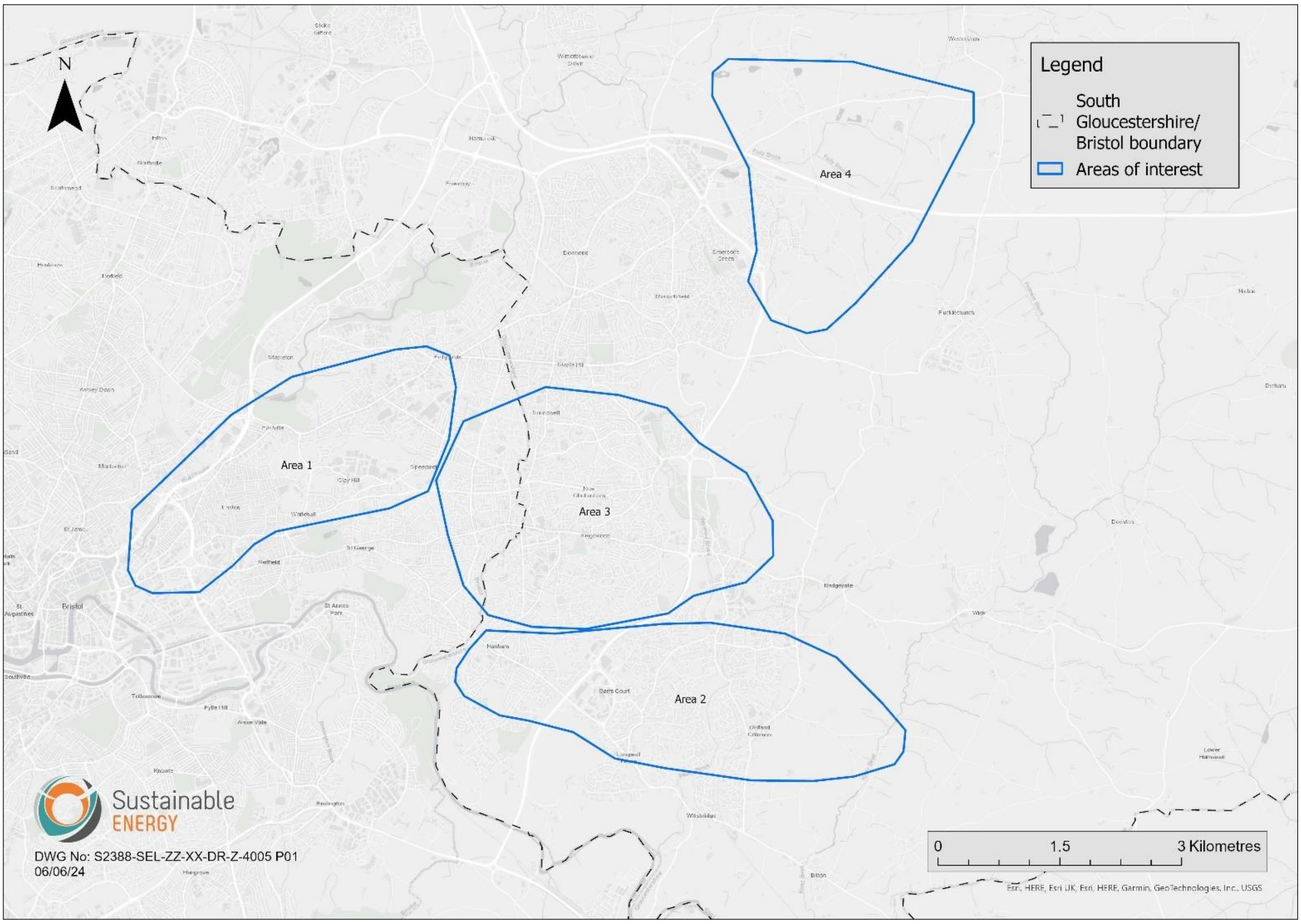


Figure 1: Areas of interest

The assessment area of the study is shown in Figure 2. The assessment boundary was agreed with the project team, and covers most of the areas of interest, considering building density and infrastructure constraints. The Frome Gateway assessment boundary is included for information in the map below, as there is an ongoing district heating network feasibility project being undertaken in the area.

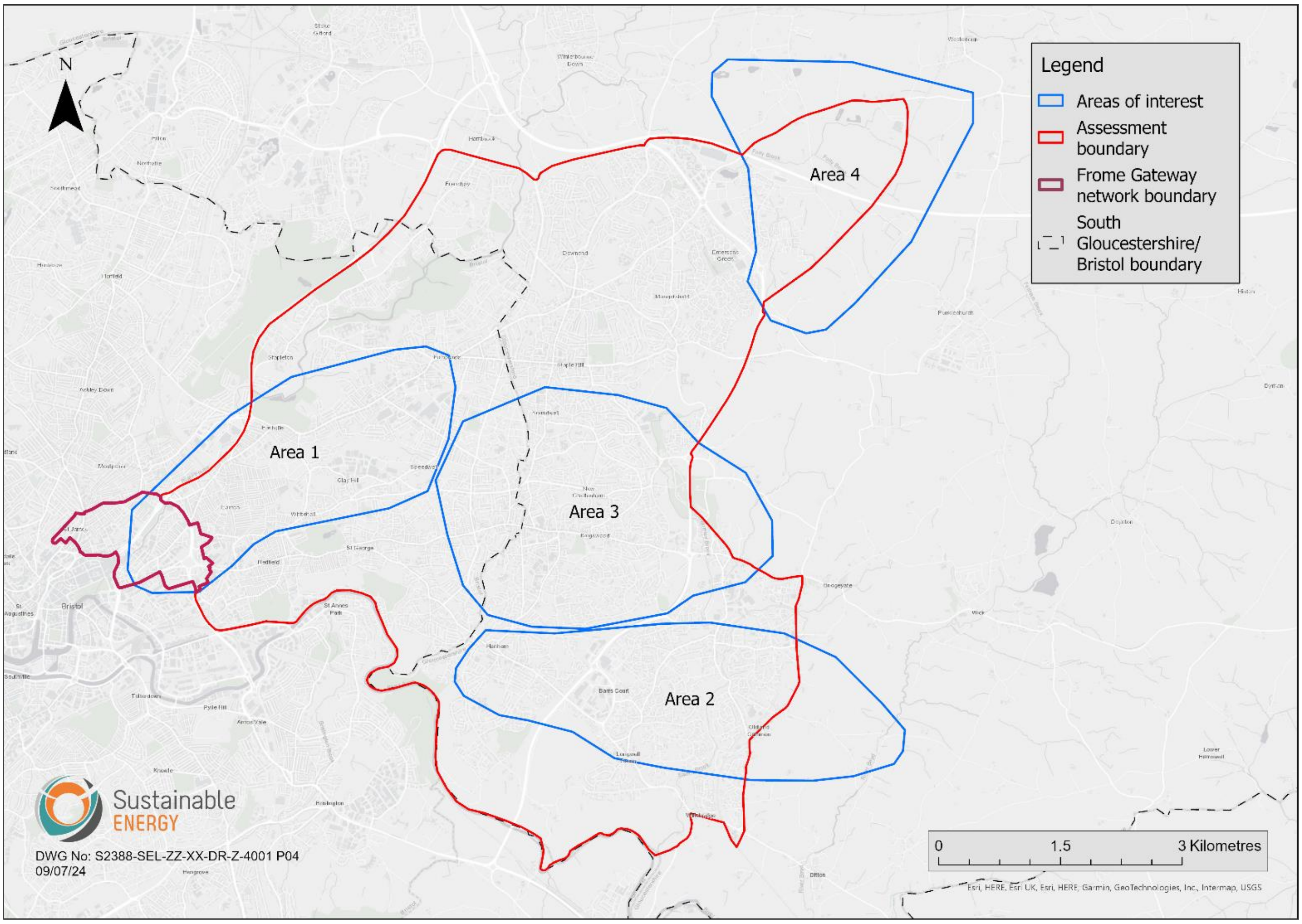


Figure 2: Assessment area

2.2 Identification of Potential Heat and Cooling Network Candidate Area(s)

2.2.1 Planned Developments

Planned developments were reviewed to identify potential heat network connections. Planned developments may provide significant energy demands and potentially lower risk connections to a heat network than privately-owned existing sites. However, there are risks associated with energy mapping and basing network assumptions around planned developments, including:

- Proposed or permitted developments not being built
- Changes to the density, scale, and timing of planned developments
- The heating solution chosen by the developer may not be compatible with district heating (e.g. electric emitters)

Conversely, there may be potential for the density of developments to increase which could improve the viability of networks. Figure 3 shows the planned developments identified within the South Gloucestershire assessment area. Further details of these are in Table 1.

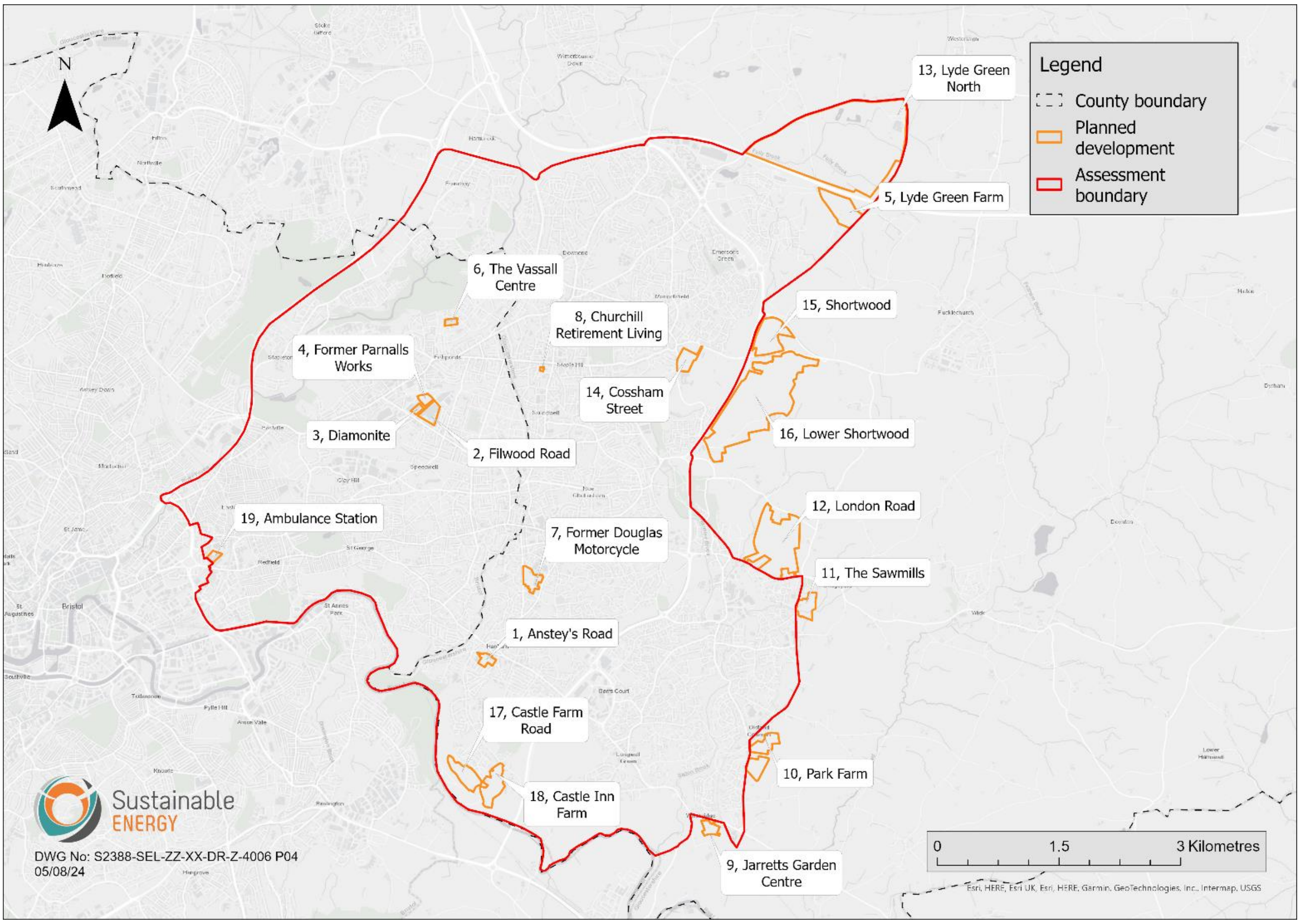


Figure 3: Planned development sites

Table 1: Current information for planned developments

Map ref.	Name	Details of development	Timing
1	Anstey's Road	• 200 dwellings and 650 (GEA) m^2 of commercial space	>10 years
2	Filwood Road	• Re-development of land to provide 255 dwellings	5 – 10 years
3	Diamonite	• 1.02 hectares of residential development • 0.07 hectares of employment land development	>10 years
4	Former Parnalls Works	• 41 senior living units with ancillary accommodation • 2,650 m^2 of commercial space	3 – 5 years
5	Lyde Green Farm	• Development of 393 dwellings	3 – 5 years
6	The Vassall Centre	• Demolition of existing buildings and redevelopment of Vassall Centre site to provide housing for older people	5 – 10 years
7	Former Douglas Motorcycle	• Development of 306 residential units	5 – 10 years
8	Churchill Retirement Living	• 42 retirement apartments	3 - 5 years
9	Jarretts Garden Centre/The Park	• Development to provide 110 residential units	>10 years
10	Park Farm	• Development to provide 350 residential units	>10 years
11	The Sawmills	• Development to provide 110 residential units	>10 years
12	London Road	• Development to provide 1,000 homes	>10 years
13	Lyde Green North	• Development to provide 1,200 homes and 16.1 ha of employment	>10 years
14	Cossham Street	• Development to provide 195 homes	>10 years
15	Shortwood	• Development to provide 280 homes	5 – 10 years

Map ref.	Name	Details of development	Timing
16	Lower Shortwood	• Development to provide 1,400 homes and 11 ha of employment	>10 years
17	Castle Farm Road	• Development to provide 125 homes	>10 years
18	Castle Inn Farm	• Development to provide 145 homes	>10 years
19	Ambulance Station	• N/A	>10 years

The heating and cooling strategy for the planned developments is currently unknown. For sites that do not yet have planning permission, it is unlikely that these developments will be built before the proposed Future Homes Standard comes into effect which will likely preclude new connections to the gas grid. Heat networks and ambient networks can offer a credible alternative to installing individual ASHPs, which should be investigated further by developers.

Planned developments built to the Future Homes Standard for building fabric, but with gas boilers, are generally easier to decarbonise through ASHP retrofits, low temperature district heating or ambient networks. Existing buildings near these planned developments are unlikely to be compatible with ambient networks or low temperature heat networks unless the existing buildings are extensively retrofitted with compatible heat emitters at a significant cost (circa £10k for a typical 2 or 3 bedroom apartment).

2.2.2 Heat Demand Density

To identify the potential candidate areas within the assessment area, a high-level heat demand mapping exercise was carried out using THERMOS[3]. Although this study focuses on both heating and cooling solutions, the UK is a country where significantly more energy is required for heating than for cooling, and therefore this initial demand density assessment was carried out with heating only.

THERMOS identified all existing buildings within the assessment area, assigned a building category to each, and provided the floor area of each building. In-house heat demand benchmarks were then used, alongside some actual data collected from previous projects in the area. This information was then used to create the heat demand density map shown in Figure 4.

[3] THERMOS online district network mapping tool, accessible from: [THERMOS: Tool Access (thermos-project.eu)](thermos-project.eu)

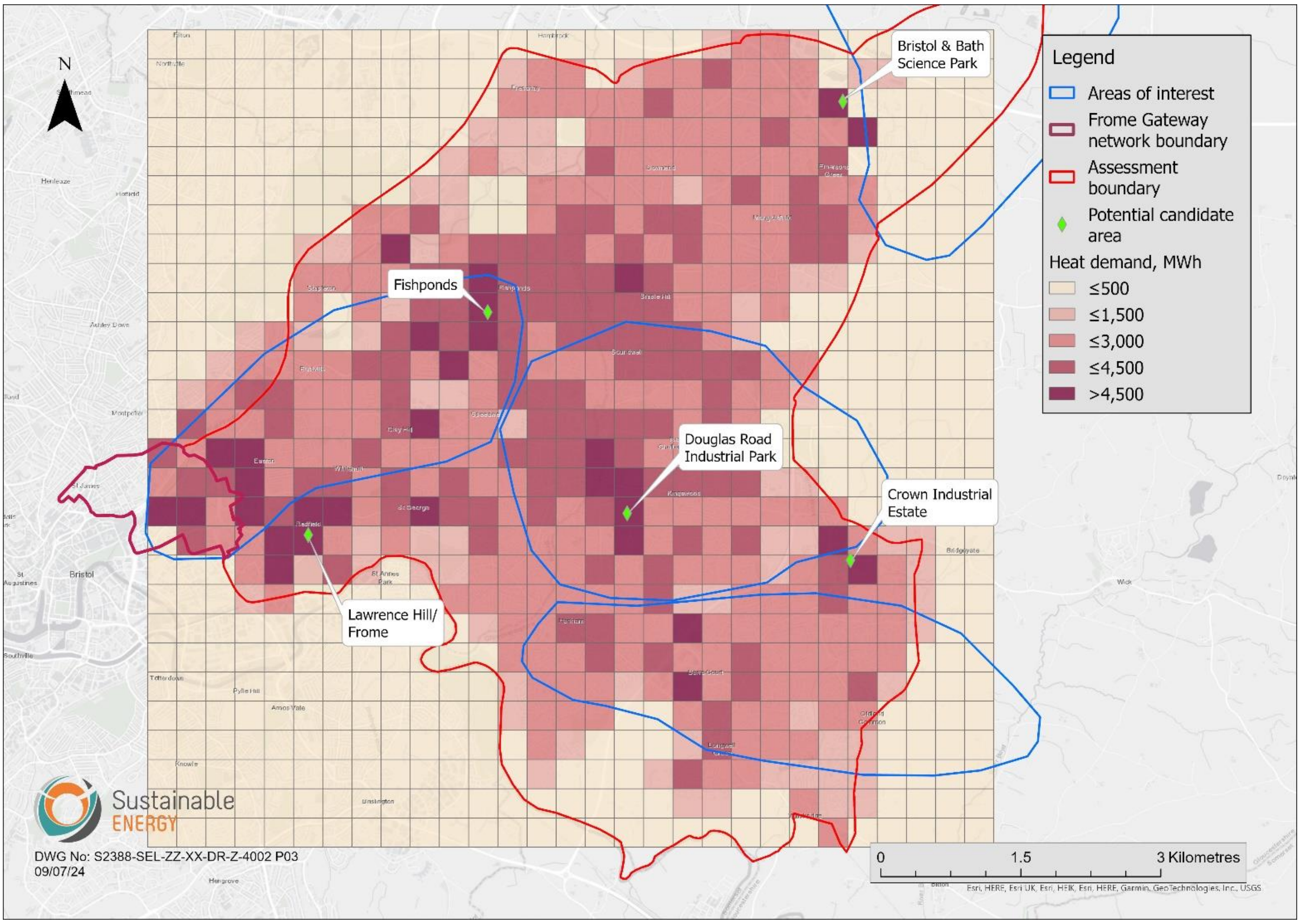


Figure 4: Heat demand density

Based on the heat demand density map, five candidate areas were identified within the proximity of the AOIs and are summarised in Table 2.

Table 2: Candidate area summary

Candidate area	Name	Description	Considered in further assessment?
1	Lawrence Hill	• High density of Council-owned residential tower blocks • Surrounded by high density terraced housing • Key constraint is the Severn Beach railway line • Key demands: ○ City Academy Bristol ○ Council-owned tower blocks	Yes
2	Fishponds	• Mixed residential and commercial site • Surrounded by a mixture of semi-detached and terraced housing • Several commercial and residential developments are planned in the Central Fishponds area • Key demands: ○ UWE Glenside Campus ○ Morrisons	Yes
3	Bristol & Bath Science Park	• Mixed residential and commercial site • Ongoing residential developments on site and several more planned towards the east of the site and north of the M5 • Several more commercial developments are planned at the Bristol and Bath Science Park commercial site	Yes

Candidate area	Name	Description	Considered in further assessment?
		• Key demands: ○ National Composite Centre (NCC) ○ Bristol and Bath Science Park ○ Sainsbury's distribution centre	
4	Douglas Road Industrial Park	• Mixed residential and commercial site • Surrounded by a mixture of semi-detached and terraced housing • Several planned developments • Key demands: ○ Asda ○ Vue	Yes
5	Crown Industrial Estate	• Largely warehouses with low energy demands • Low-building commercial and residential density nearby • Bristol and Bath Railway Path cuts through the edge of the industrial estate, separating the residential demands east of the estate	No

2.2.3 Residential Candidate Area

A focus of the study is exploring the potential to utilise mine water energy to serve residential demands in the South Gloucestershire area. A residential dwelling density map (shown in Figure 5) was developed to identify regions with a dwelling density which is representative of the wider area. Based on the density map, Barrs Court within Area of Interest 2 was identified as an area to explore a residential-only solution. This area is both similar in dwelling density to the wider area and is also located within an Area of Interest with no other candidate area identified.

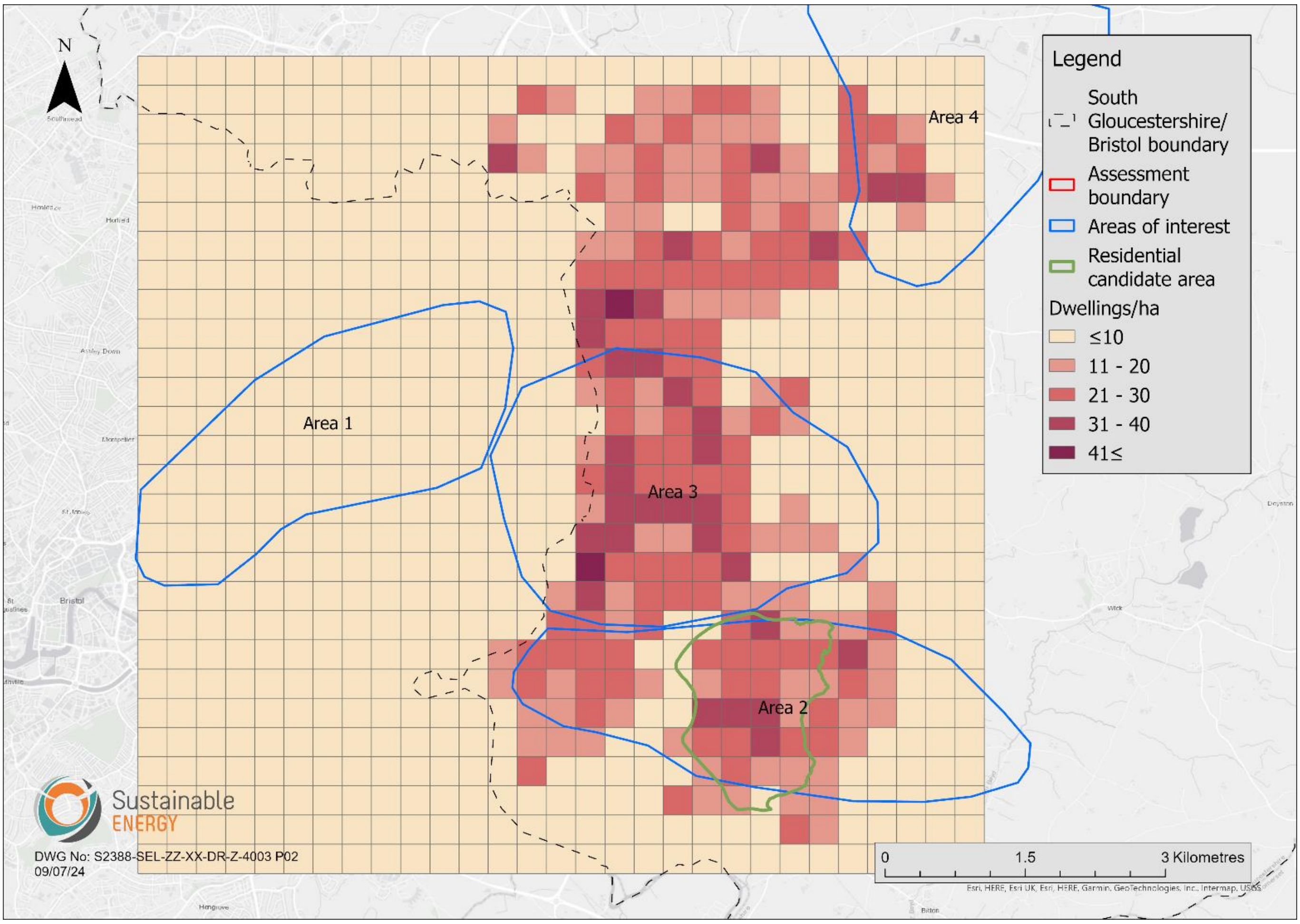


Figure 5: Residential dwelling density map

2.2.4 Existing Sites

Existing sites within the assessment area were identified and energy demands assessed. The following sites have not been included in the energy demand assessment but may be identified as potential connections as the project progresses:

- Sites with annual demands below 50 MWh, unless of strategic importance or within close proximity of other larger demands
- Existing sites within planned development areas

Details of all sites identified and assessed within the energy demand assessment area are shown in Appendix 1: Energy Demand Assessment.

2.2.5 Engagement with Potential Key Stakeholders

Key stakeholders were identified, and contacts were established where possible. A summary of stakeholder engagement to date is shown in Table 3.

Table 3: Summary of engagement with key stakeholders

Contact(s)	Site/Organisation	Role/Interest
Linda Irwin Sam Moore	South West Net Zero Hub	• Project funders • Project manager
Mark Letcher Barry Wyatt	South Gloucestershire County Council	• Local Authority
Emily White Jaymi Louise Cue Jon Buick Beatrice Munby Sam Robinson	Bristol City Council	• Local Authority • Owner of social housing within assessment area
Jon Sankey Sarah Sawyer David Kristensen	Vattenfall	• Joint venture with Bristol City Council to develop heat networks in the area
Anthony Elliott Helen Kenyon Jordan Wild	National Composite Centre	• Large energy user within the Bristol and Bath Science Park, with potential of heat offtake from planned supercomputer
Sam Paice	CFMS	• Operates large computer/data centre within the Bristol and Bath Science Park with potential for heat offtake

2.3 Summary

Five candidate areas have been identified within/near the AOIs for further assessment of the potential for developing a district energy scheme utilising mine energy, as shown in Figure 6.

The five candidate areas identified are:

- Area 1 – Lawrence Hill
- Area 2 – Fishponds
- Area 3 – Bristol and Bath Science Park
- Area 4 – Douglas Industrial Park
- Area 5 – Barrs Court Residential

An aerial view of each candidate area is shown in Appendix 6: Aerial View of Candidate Areas.

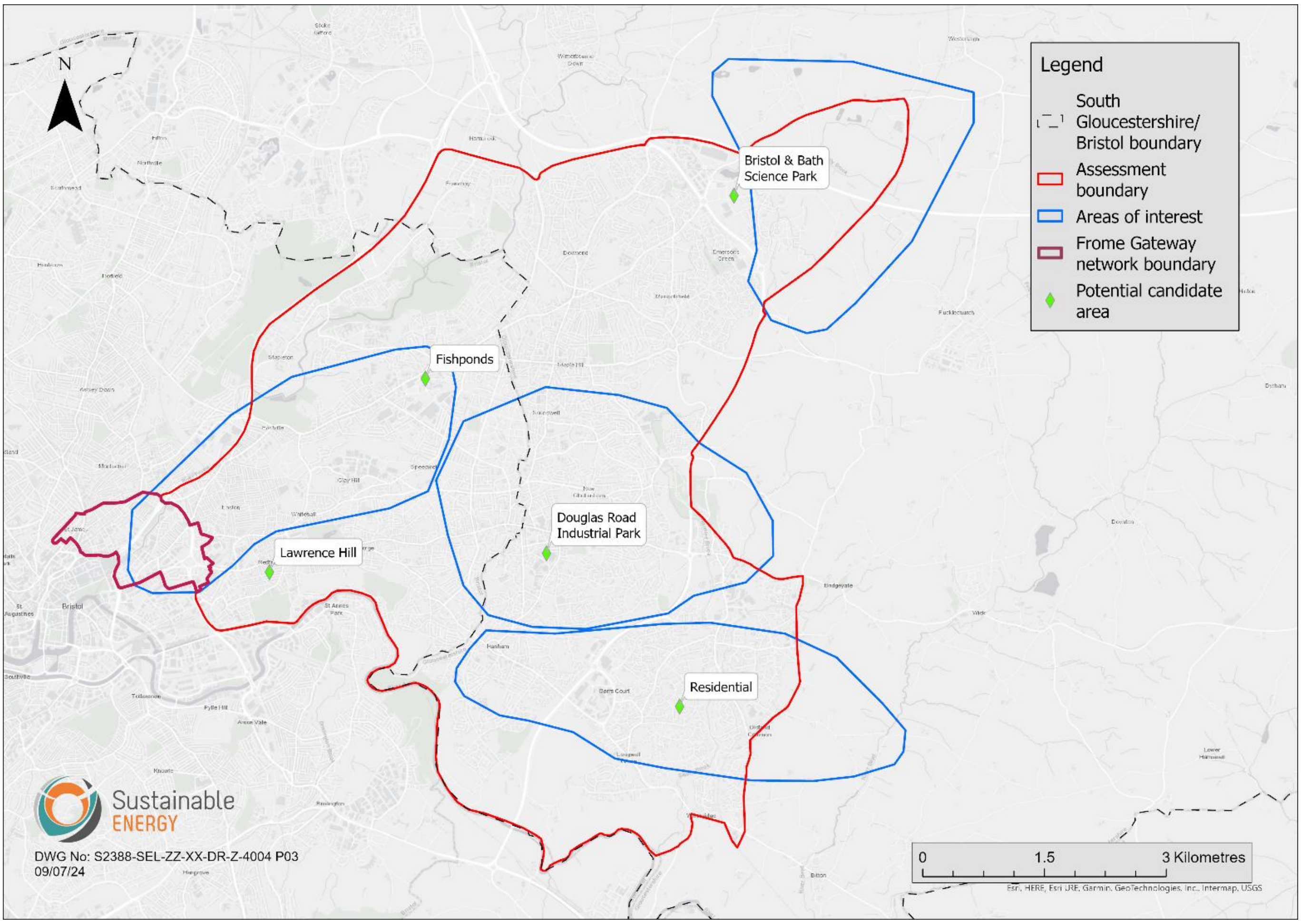


Figure 6: Potential candidate areas

3 ENERGY DEMAND ASSESSMENT

Energy demands for potential network connections within each candidate area have been assessed. Actual energy demand data or data from previous projects have been used where possible. Where actual and previous project energy data was not available, annual energy demands were developed for a selected number of building categories using in-house modelling tools. The energy demand benchmark has been based on the energy profile created for different building categories identified and applied to the potential network connections within the candidate area. Details for the energy demand benchmarks can be found in section 3.1.2.

The energy demands were modelled to consider Objective 2.1 of Heat Networks Code of Practice to achieve sufficient accuracy of peak and annual heat demands.

3.1 Energy Demand Forecasting

Due to climate change, the average temperature in the UK is due to rise over the coming decades. This will lead to a shift in energy demand, reducing the annual heat demand (due to milder winters) and increasing the cooling demand (due to more extreme heat in the summer). The energy demand assessed for each candidate area was projected to account for this change, using temperature profiles provided by CIBSE[4]. These profiles provide hourly temperatures for a typical year in 2020, 2050, and 2080 under 'low,' 'medium,' and 'high' carbon emission scenarios. The 'high' scenario was used, as the temperatures observed since 2020 have already exceeded the 2020 high carbon emission temperature prediction.

3.1.1 Projected Energy Demand Benchmark

Hourly heating and cooling demand models were generated for generic buildings for a selected number of building categories. The energy demand models consider building fabric, occupancy patterns, hot water demand, heating/cooling setpoints and timings, and heat gains from equipment, lighting and solar. Different temperature profiles were then applied to obtain heating and cooling demands in 2020, 2050 and 2080. From these, percentage increases/decreases in cooling/heating demands were derived and applied to all energy demands within the candidate areas.

The heat and cooling demand benchmarks for these building categories are shown in Table 4. Other building categories were benchmarked based on the category shown in Table 4 with additional considerations (e.g., warehouses typically have ~10% of the total floor area reserved for office use). Additionally, office and retail have a significantly higher cooling demand due to IT equipment (Offices) and process cooling (Retail).

Table 4: Key energy demand benchmarks generated using in-house modelling tools

Category	Heat demand benchmark, kWh/m²			Cooling demand benchmark, kWh/m²		
	2020	2050	2080	2020	2050	2080
Hotel	137	126	116	14	23	31
Office	116	101	84	38	59	77
School	116	101	86	4	5	7
Retail	129	115	94	33	39	42
Semi-detached	94	83	72	6	7	7
Terraced house	108	96	83	6	7	7

[4] CIBSE Weather Data

3.1.2 Tipping Point

It has been assumed that a number of building categories did not include cooling infrastructure in 2020, such as residential and school buildings. Therefore, although there is currently a small demand for cooling in these buildings, it is currently not met, and occupants may be enduring overheated conditions for short periods. However, as the climate changes and leads to more frequent and severe heat waves, occupants are more likely to require some form of cooling system. It has been assumed that most cooling systems will be required at a similar time, likely following a series of particularly hot summers. This "tipping point" has been assumed to be in 2035 in agreement with the client, although the timing for this is uncertain. Cooling demand for these building categories has been assumed to be zero prior to the 2035 tipping point. It has been assumed that other building categories already have cooling systems, and therefore have a cooling demand from 2020.

3.1.3 Energy Demand Forecasting Example

An example of energy demand forecasting and the effect of the "tipping point" is shown in Figure 7.

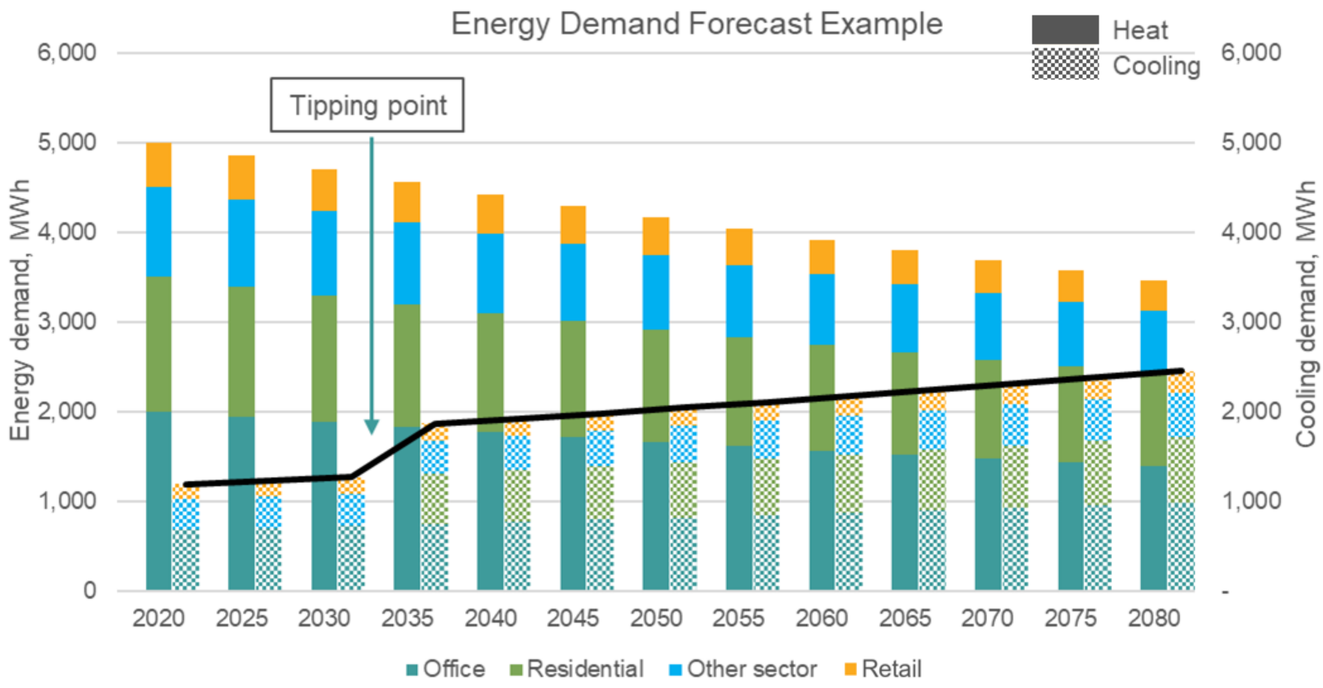


Figure 7: Example of the effect of climate change on energy demands

3.2 Energy Demand Assessment Results

Geographic Information System (GIS) software was used to map the key heat and cooling demands for each candidate area. The symbols show the site location and graduate in size according to energy demand to depict the nature of the energy loads within the heat map area. The larger the symbol, the larger the energy demand. Aerial views of each area are shown in Appendix 6: Aerial View of Candidate Areas.

Unless otherwise specified, the heat demands shown in the remainder of the report are from 2020 and the cooling demands are from 2080.

3.2.1 Candidate Area 1 – Lawrence Hill

3.2.1.1 Area 1 Heat Demand

The building heat demands for all potential connections are shown in Figure 8. An aerial view of the area is shown in Appendix 6: Aerial View of Candidate Areas. The total 2020 heat demand within the assessment boundary is 72,737 MWh; the largest heat demand is Croydon House. Table 5 shows the top five commercial heat demands under individual ownership (sites/buildings that are under single ownership). The total heat demand for the top five demands within the energy demand assessment area is approximately 5,859 MWh.

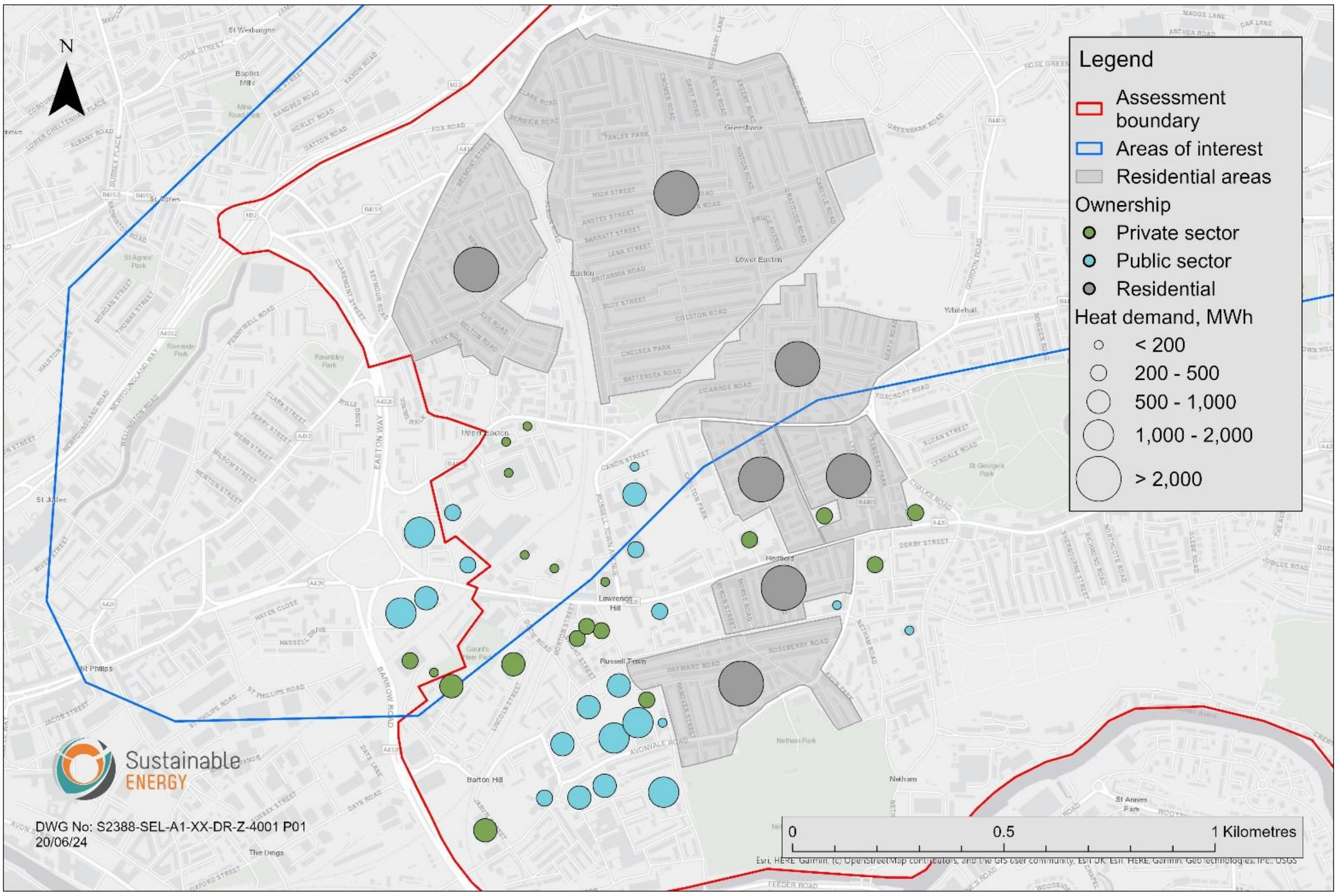


Figure 8: Lawrence Hill heat demand – 2020

The heat demands within the assessment boundary are categorised as public sector, private sector and residential. Within the candidate area, 6,024 dwellings are identified with a total heat demand of 52,952 MWh, or 72.8% of the total demand in the area, as shown in Figure 9.

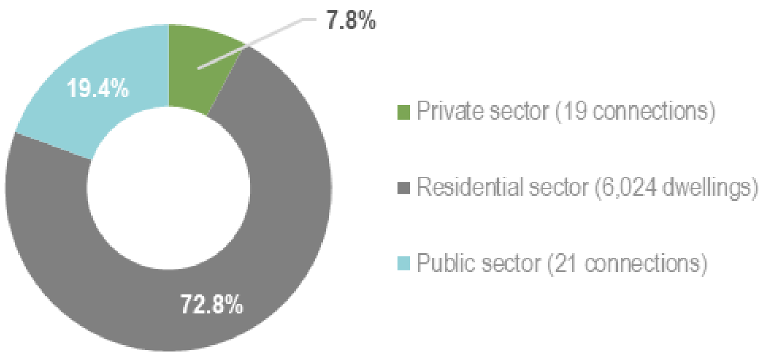


Figure 9: Lawrence Hill heat demand split by ownership

Table 5: Top five largest commercial heat demands within the candidate area - 2020

Rank	Name	Ownership	Building use	Annual heat demand, MWh	Source of data
1	Croydon House	Public sector	Residential	1,339	Estimated using heat demand benchmark
2	Barton House	Public sector	Residential	1,269	
3	Kingsmarsh House	Public sector	Residential	1,174	
4	Ashmead House	Public sector	Residential	1,068	
5	Corbett House	Public sector	Residential	1,010	

3.2.1.2 Area 1 Cooling Demand

The cooling demands for all potential connections are shown in Figure 10. The 2080 total cooling demand within the assessment boundary is 7,251 MWh. The largest commercial cooling demands arise from Aldi and Lidl. Table 6 shows the top five commercial cooling demands under individual ownership (sites/buildings that are under single ownership), the total cooling demand for the top five commercial sites within the energy demand assessment area is approximately 2,701 MWh.

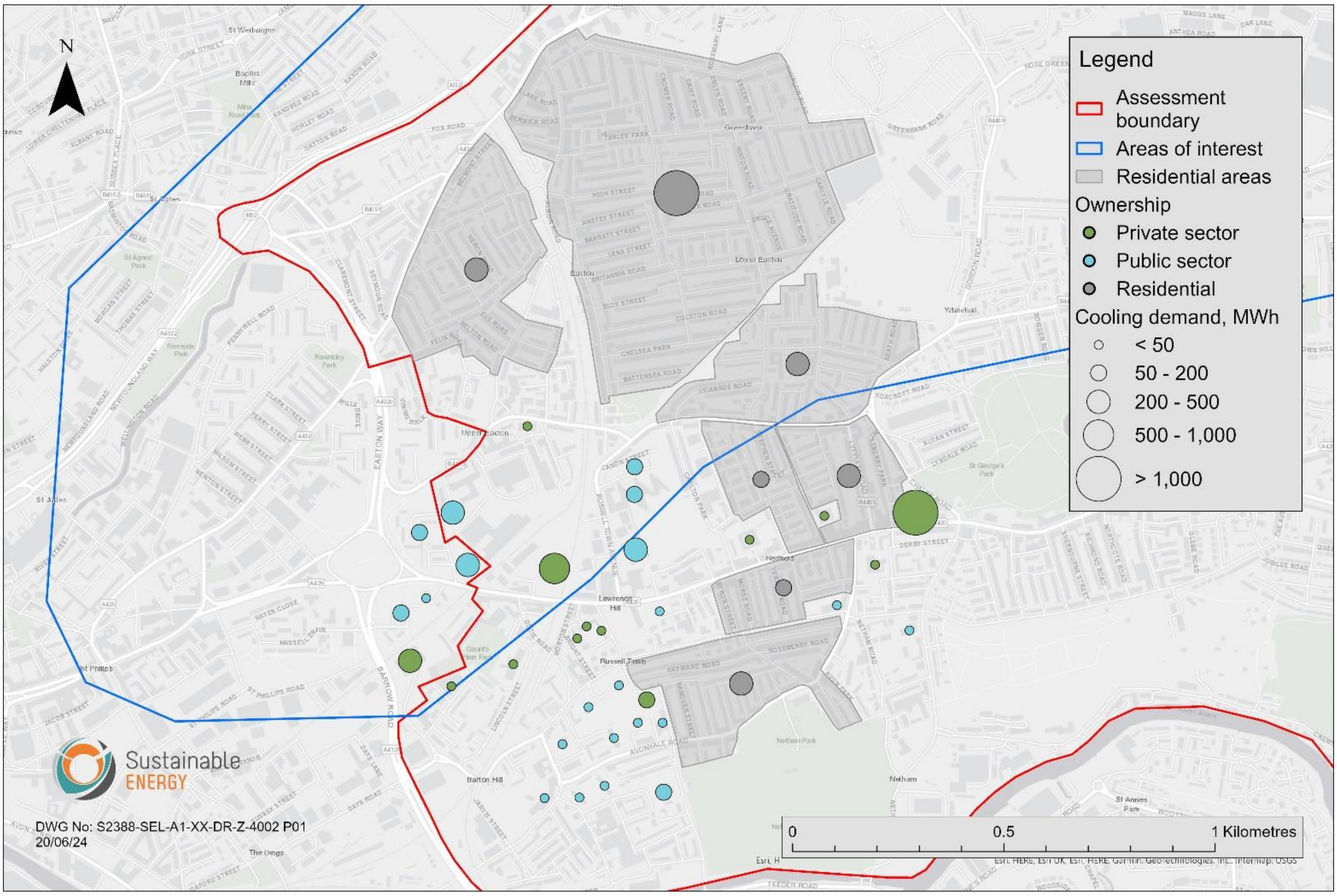


Figure 10: Lawrence Hill cooling demand - 2080

The cooling demands within the assessment boundary are categorised as public sector, private sector and residential. Within the assessment boundary, the private sector accounts for 34.9% of the total demand, while the residential sector accounts for 44.3% of the total demand, as shown in Figure 11.

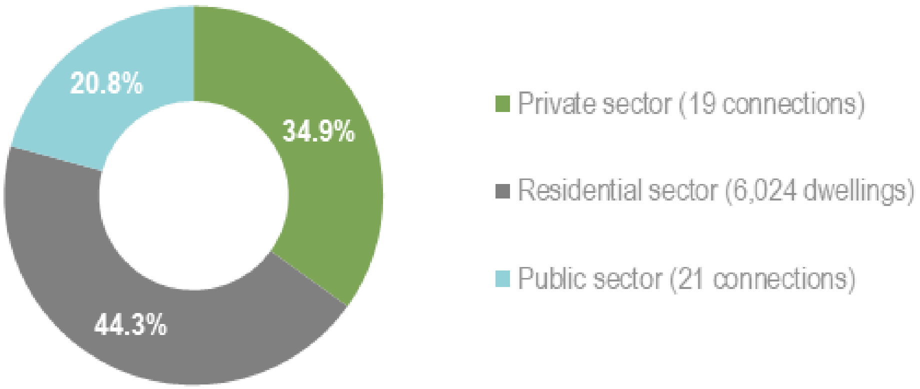


Figure 11: Lawrence Hill cooling demand split by ownership

Table 6: Top five largest commercial cooling demands within the candidate area - 2080

Rank	Name	Ownership	Building use	Annual cooling demand, MWh	Source of data
1	Aldi	Private sector	Retail	1,103	Estimated using cooling demand benchmark
2	Lidl	Private sector	Retail	842	
3	Berkeley House	Public sector	Office	284	
4	Jubilee House	Public sector	Office	243	
5	City Academy Sports Centre	Public sector	Leisure	229	

3.2.1.3 Area 1 Energy Demand Forecast

The projected heating and cooling demand for the Lawrence Hill candidate area was derived based on the CIBSE predicted temperature profile under high carbon emission scenarios; this is shown in Figure 12. The heat demand in 2080 decreased by 19% compared to 2020 figures, while cooling demand increased by 218% (accounting for the tipping point) during the same period.

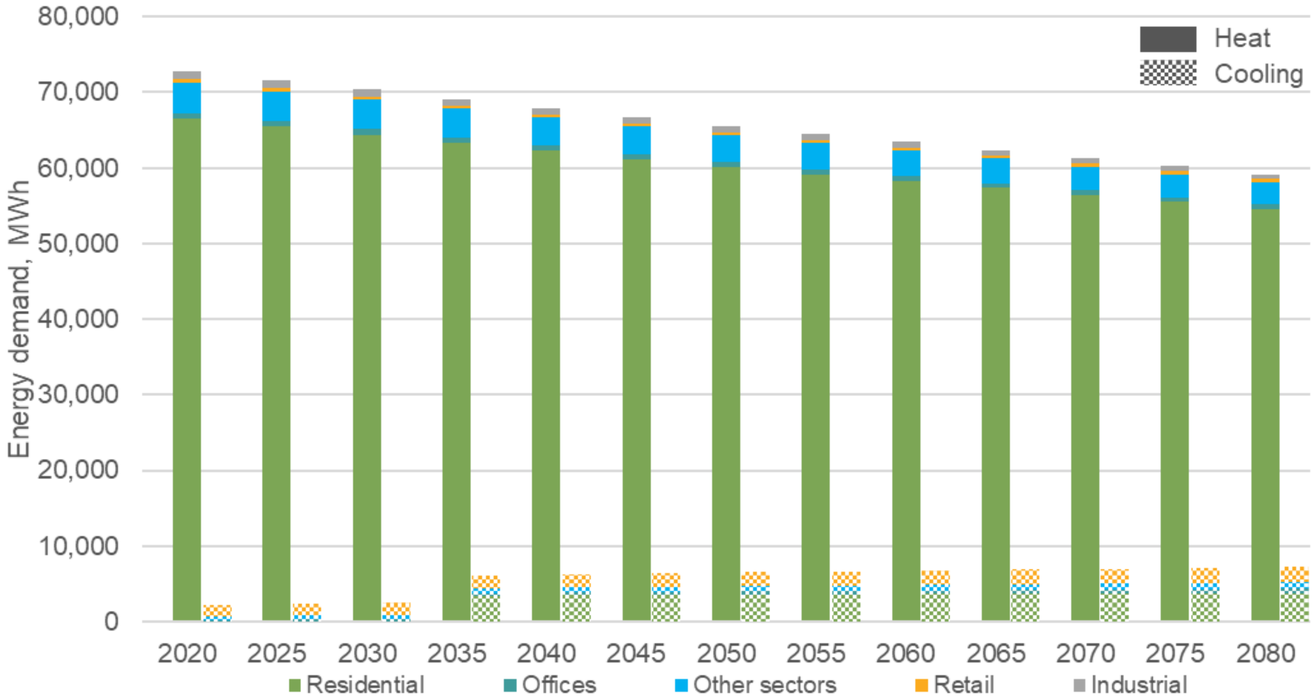


Figure 12: Lawrence Hill energy demand projection

The “Other sectors” category includes buildings from the public sector, healthcare, hospitality, hotels and education.

3.2.2 Candidate Area 2 – Fishponds

3.2.2.1 Area 2 Heat Demand

The heat demands for all potential connections are shown in Figure 13. An aerial view of the area is shown in Appendix 6: Aerial View of Candidate Areas. The total 2020 heat demand within the candidate area is 149,217 MWh; the largest existing commercial heat demand is the UWE Glenside Campus. Table 7 shows the top five heat demands under individual ownership (sites/buildings which are under single ownership). The total demand from the top five heat demands within the energy demand assessment area is approximately 13,811 MWh.

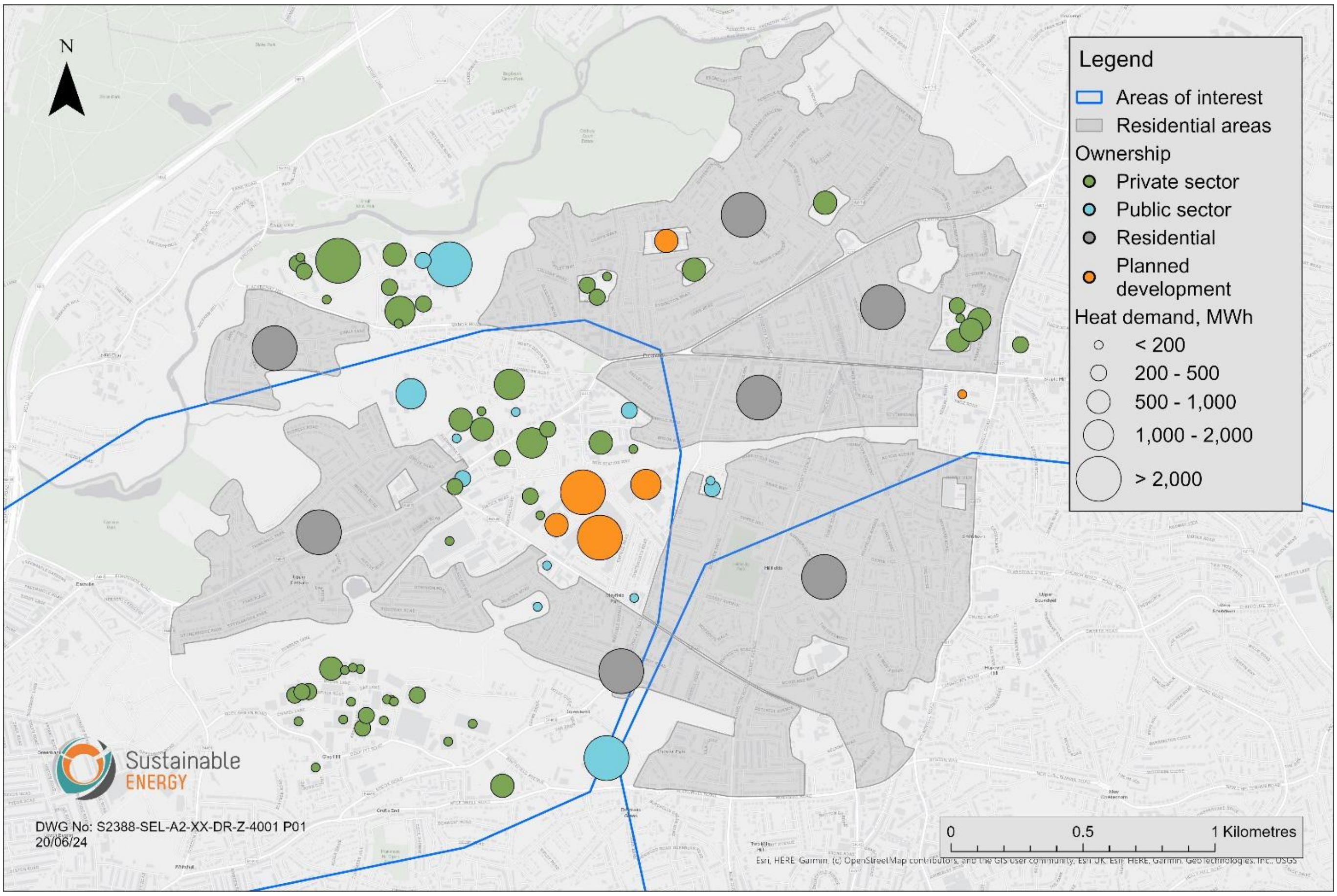


Figure 13: Fishponds heat demand - 2020

The heat demands within the assessment boundary are categorised as public sector, private sector, planned development and residential. There are 12,302 dwellings within the candidate area, with a total heat demand of 109,338 MWh, these account for 73.3% of the total demand in the area, as shown in Figure 14.

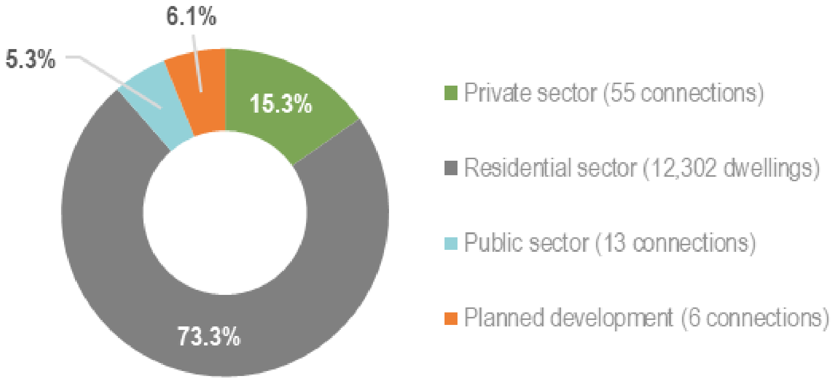


Figure 14: Fishponds heat demand split by ownership

Table 7: Top five largest commercial heat demands within the candidate area - 2020

Rank	Name	Ownership	Building use	Annual heat demand, MWh	Source of data
1	Filwood Road Development	Planned development	Residential	3,646	Estimated using heat demand benchmark
2	UWE Glenside Campus	Private sector	Education	3,448	
3	Fromeside Unit	Public sector	Healthcare	2,361	
4	Former Parnalls Works	Planned development	Residential / Office	2,310	
5	Bristol Brunel Academy	Public sector	Education	2,046	

3.2.2.2 Area 2 Cooling Demand

The cooling demands for all potential connections are shown in Figure 15. The total 2080 cooling demand within the assessment boundary is 21,635 MWh; the largest commercial cooling demand arises from Morrisons. Table 8 shows the top five cooling demands under individual ownership (sites/buildings which are under single ownership), the total cooling demand for the top five commercial sites within the energy demand assessment area is approximately 11,673 MWh.

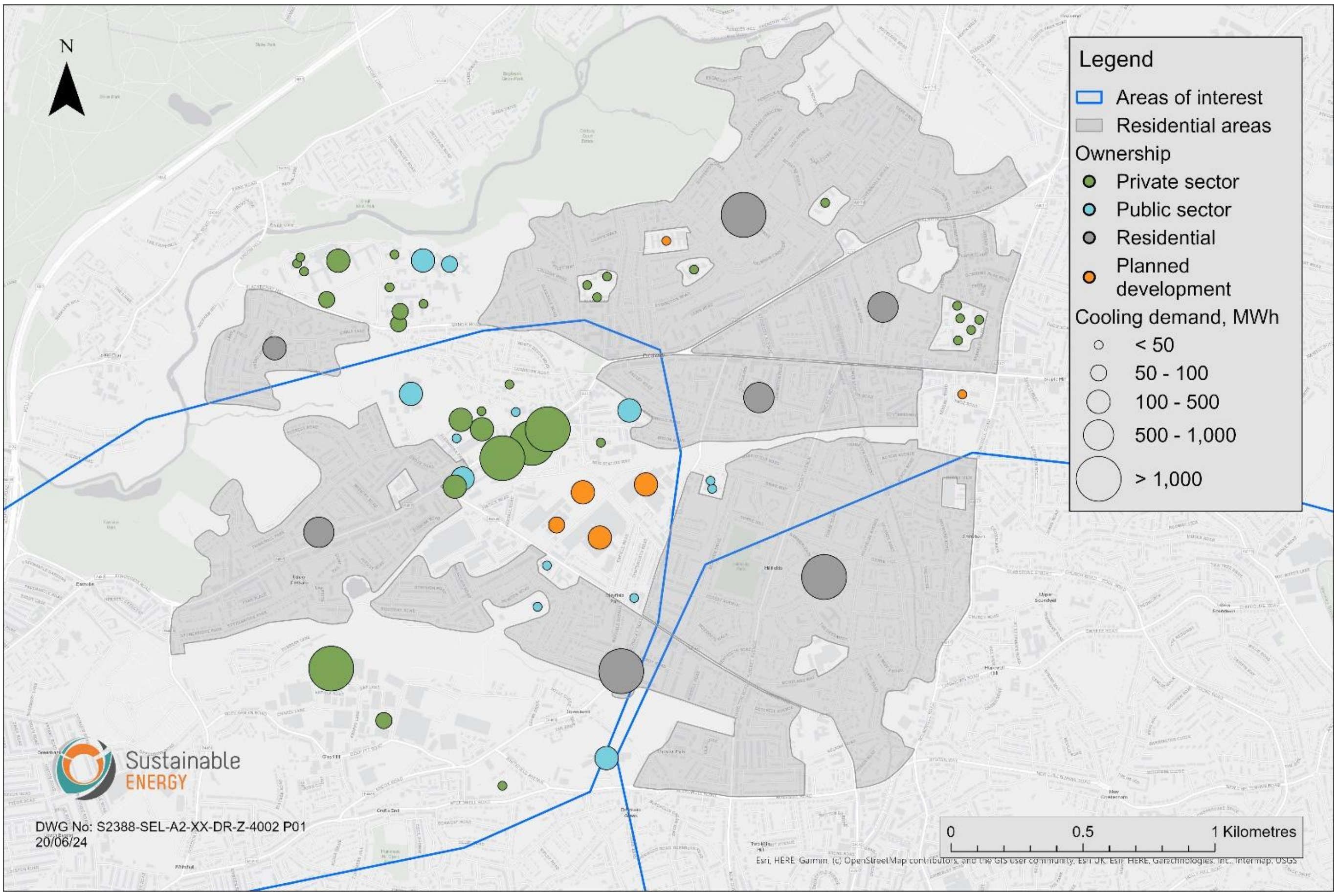


Figure 15: Fishponds cooling demand - 2080

The cooling demands within the assessment boundary are categorised as public sector, private sector, planned development and residential. Within the assessment boundary, the private sector accounts for 60.4% of the total heat demand, while the residential sector accounts for 31.5%, as shown in Figure 16.

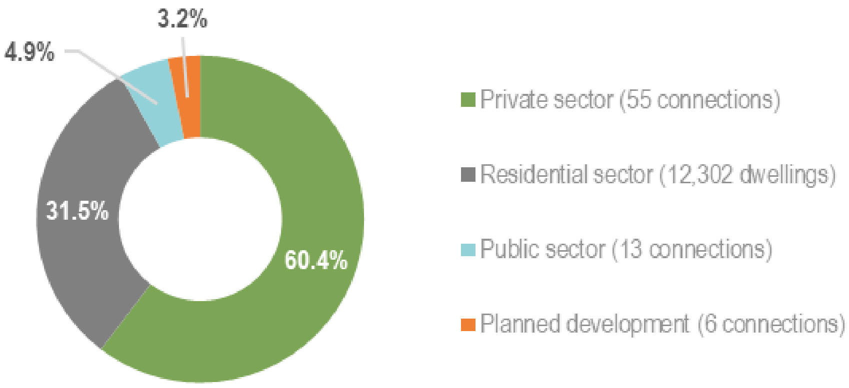


Figure 16: Fishponds cooling demand split by ownership

Table 8: Top five largest commercial cooling demands within the candidate area - 2080

Rank	Name	Ownership	Building use	Annual cooling demand, MWh	Source of data
1	Morrisons	Private sector	Retail	4,688	Estimated using cooling demand benchmark
2	Rajani Superstore	Private sector	Retail	4,405	
3	Lidl	Private sector	Retail	1,202	
4	Aldi	Private sector	Retail	1,029	
5	JD Gyms	Private sector	Leisure	349	

3.2.2.3 Area 2 Energy Demand Forecast

The projected heating and cooling demands for the Fishponds candidate areas have been derived, based on the CIBSE predicted temperature profile under high carbon emission scenarios and are shown in Figure 17. The heat demands in 2080 decreased by 19% compared to 2020 figures, while cooling demands increased by 121% (accounting for the tipping point) during the same period.

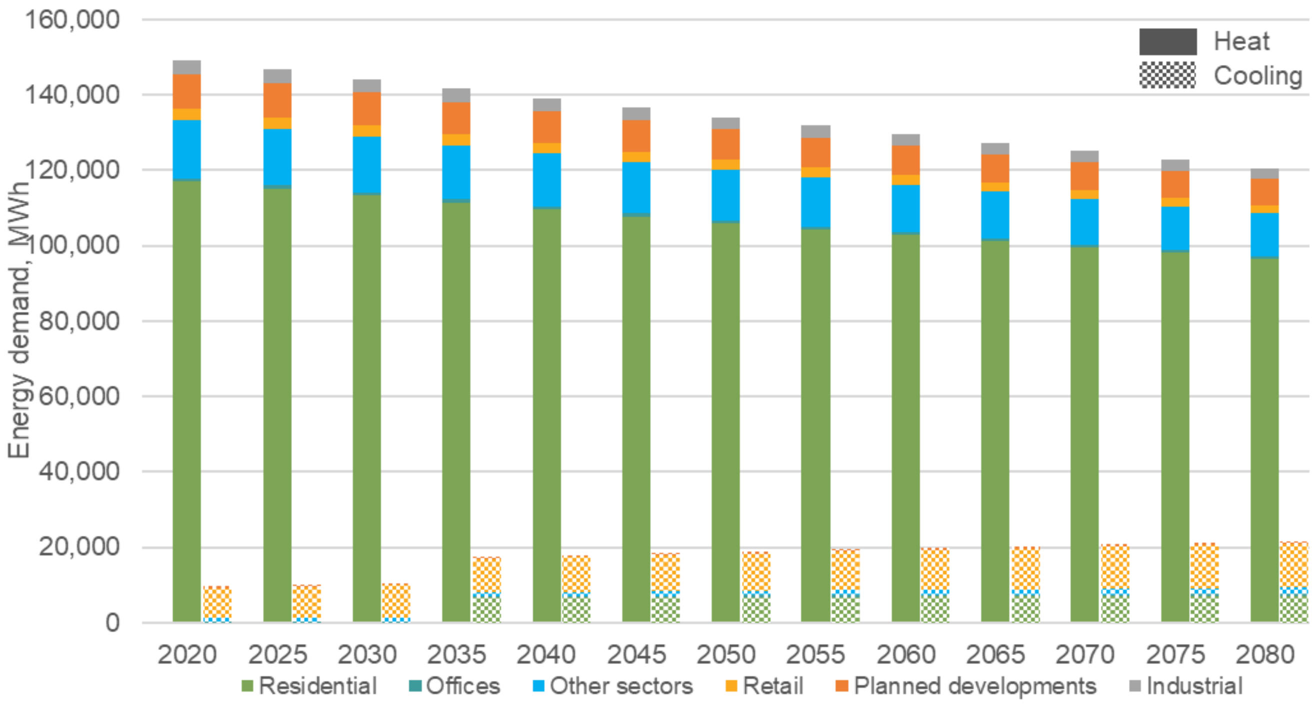


Figure 17: Fishponds energy demand projection

The "Other sectors" category includes buildings from the public sector, healthcare, hospitality, hotels and education.

3.2.3 Candidate Area 3 – Bristol and Bath Science Park

3.2.3.1 Area 3 Heat Demand

The heat demands for all potential connections are shown in Figure 18. An aerial view of the area is shown in Appendix 6: Aerial View of Candidate Areas. The total 2020 heat demand within the assessment boundary is 60,030 MWh; the largest commercial heat demand arises from the Bristol and Bath Science Park. Table 9 shows the top five heat demands under individual ownership (sites/buildings which are under single ownership), the total heat demand for the top five demands within the energy demand assessment area is approximately 6,248 MWh.

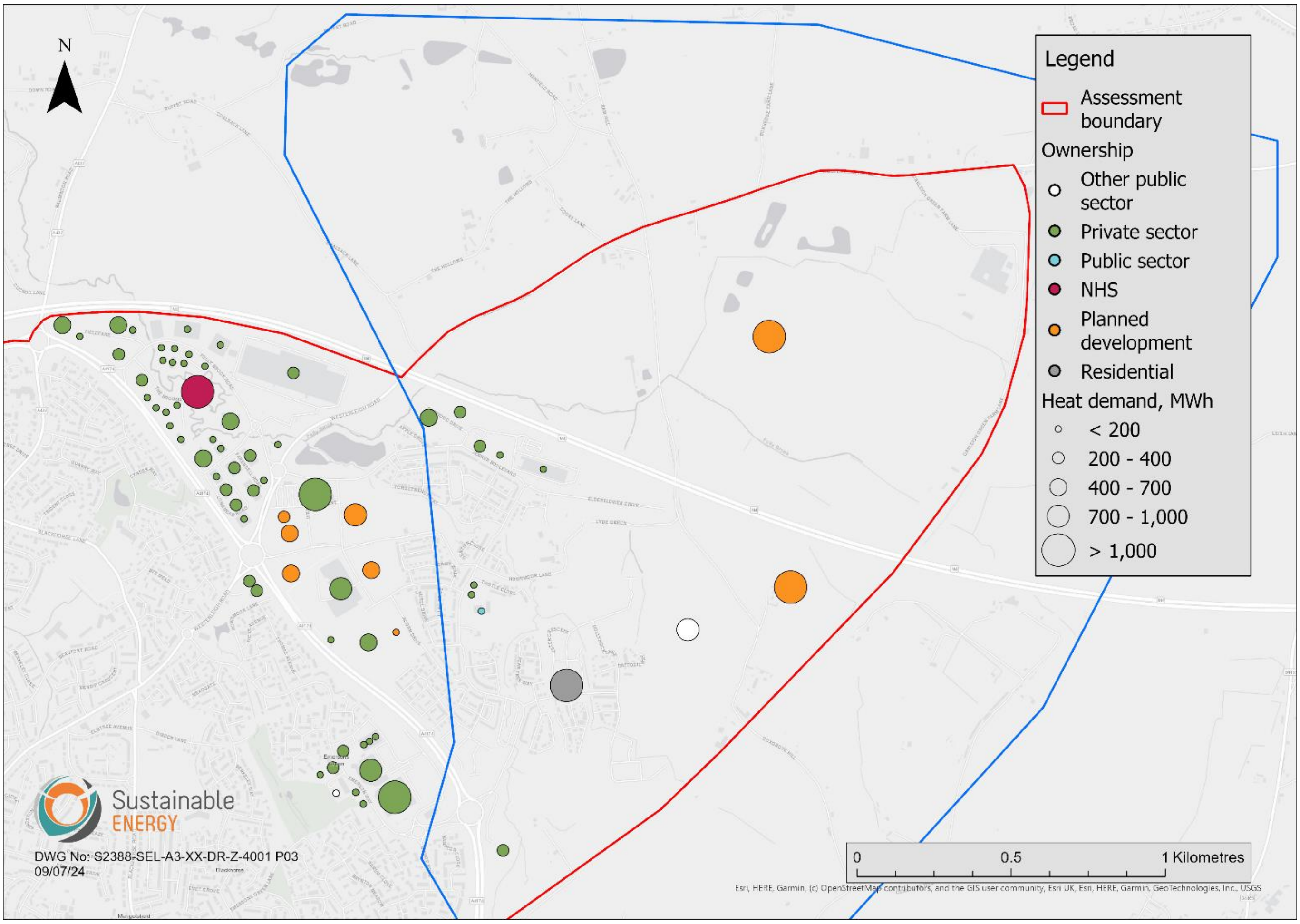


Figure 18: Bristol and Bath Science Park heat demand - 2020

The heat demands within the assessment boundary are categorised as public sector, private sector, NHS, planned development and residential. Within the assessment boundary, the private sector accounts for 25.5% of the total heat demand. There are 4,331 dwellings identified in the candidate area, including 1,593 dwellings that are part of the Lyde Green development, these have a total heat demand of 38,895 MWh which accounts for 64.8% of the total demand in the area, as shown in Figure 19.

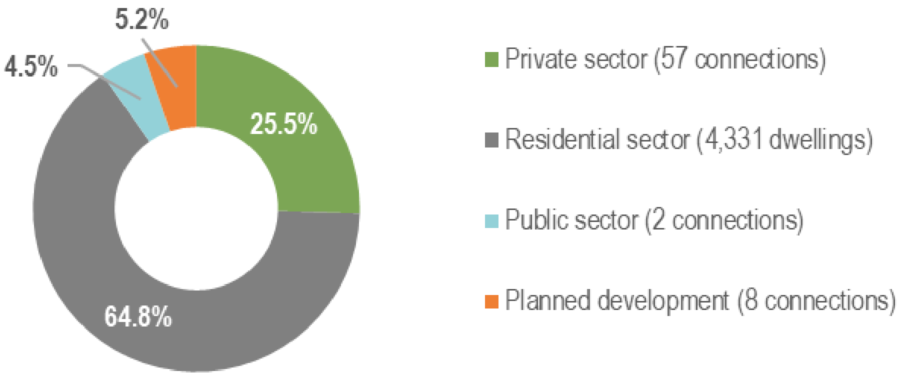


Figure 19: Bristol and Bath Science Park heat demand split by ownership

Table 9: Top five largest commercial heat demands within the candidate area - 2020

Rank	Name	Ownership	Building use	Annual heat demand, MWh	Source of data
1	Bristol and Bath Science Park	Private sector	Office	1,574	Estimated using heat demand benchmark
2	Emersons Green NHS Treatment Centre	NHS	Healthcare	1,382	
3	Sainsbury's	Private sector	Retail	1,359	
4	New Lyde Green Secondary School	Other public sectors	Education	975	
5	Bristol and Bath Science Park Plot B	Planned development	Office	960	

3.2.3.2 Area 3 Cooling Demand

The cooling demands for all potential connections are shown in Figure 18. The total 2080 cooling demand within the assessment boundary is 24,155 MWh. The largest commercial cooling demands are the Bristol and Bath Science Park and Sainsbury's Distribution Depot. Table 10 shows the top five commercial cooling demands under individual ownership (sites/buildings that are under single ownership), the total cooling demand for the top five commercial sites within the energy demand assessment area is approximately 13,007 MWh.

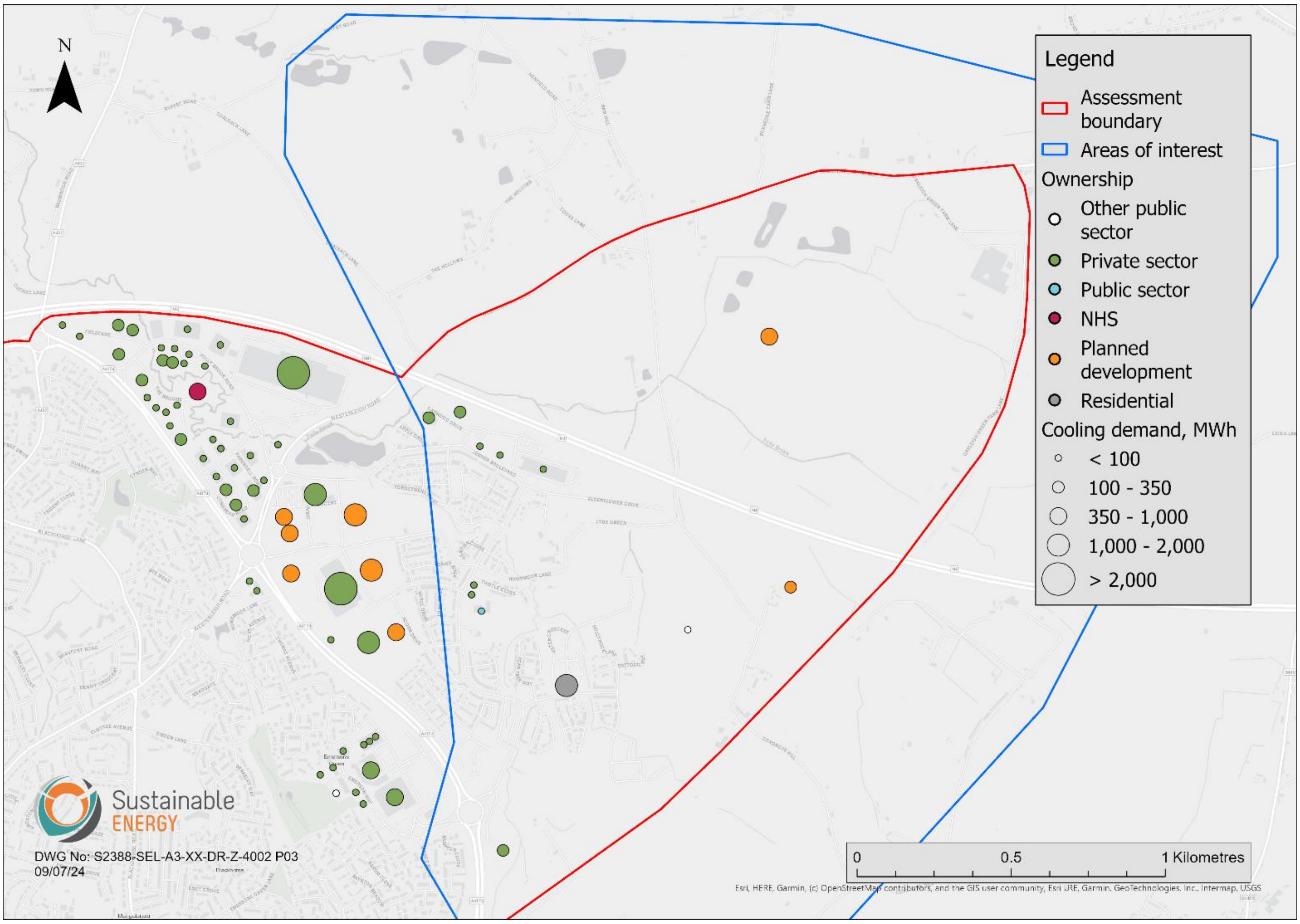


Figure 20: Bristol and Bath Science Park cooling demand - 2080

The cooling demands within the assessment boundary are categorised as public and private sector, NHS, planned development and residential. Within the assessment boundary, the private sector accounts for 63% of the total demand, while the residential sector accounts for 12.5%, as shown in Figure 21.

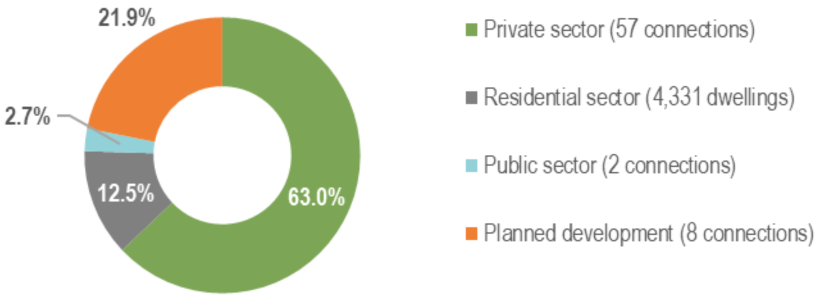


Figure 21: Bristol and Bath Science Park cooling demand split by ownership

Table 10: Top five largest commercial cooling demands within the candidate area - 2080

Rank	Name	Ownership	Building use	Annual cooling demand, MWh	Source of data
1	Sainsbury's Distribution Depot	Private sector	Warehouse	4,571	Estimated using cooling demand model
2	National Composites Centre		Office	3,779	
3	Bristol and Bath Science Park Plot C	Planned development		1,993	
4	IAAPS ltd	Private sector		1,484	
5	Bristol and Bath Science Park			1,179	

3.2.3.3 Area 3 Energy Demand Forecast

The projected heating and cooling demands for the Bristol and Bath candidate area have been derived based on the CIBSE predicted temperature profile under high carbon emission scenarios, and are shown in Figure 22. The heat demand in 2080 decreased by 25% compared to 2020 figures, while cooling demand increased by 92% (accounting for the tipping point) during the same period.

The other sector categories for heating include buildings from the public sector, healthcare, hospitality, hotels and education.

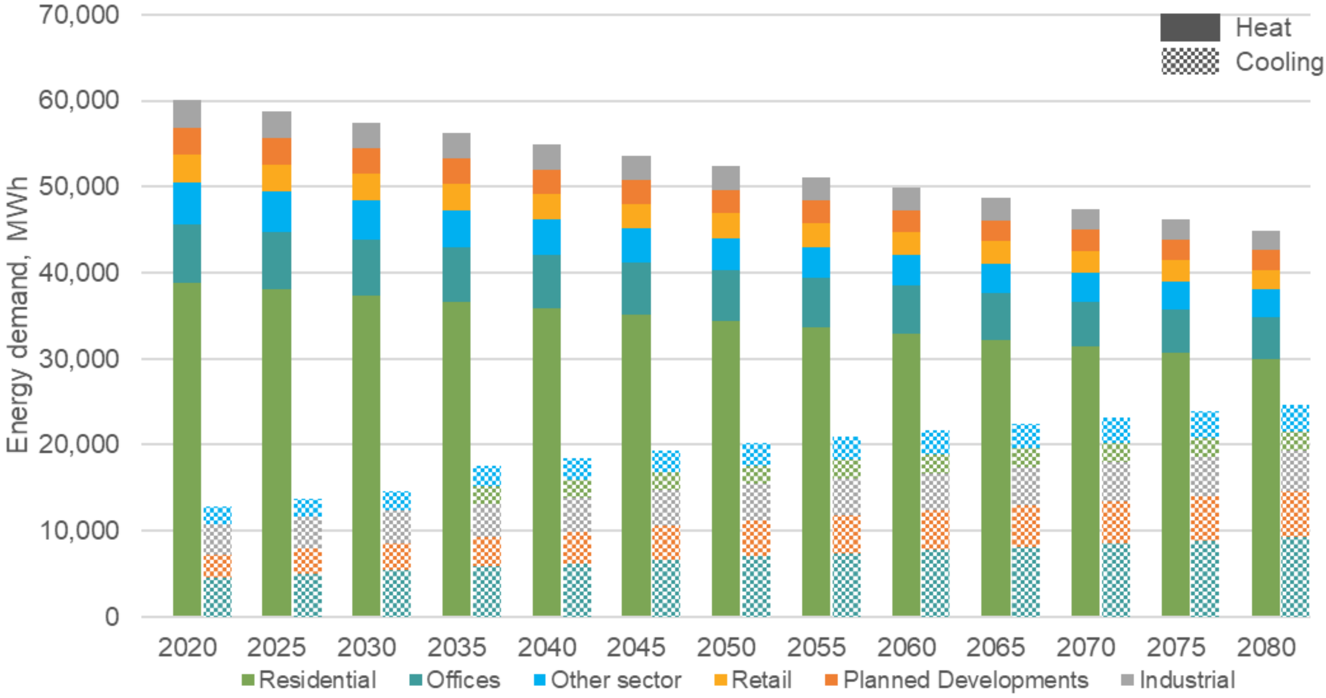


Figure 22: Bristol and Bath Science Park energy demand projection

3.2.4 Candidate Area 4 – Douglas Road Industrial Park

3.2.4.1 Area 4 Heat Demand

The heat demands for all potential connections are shown in Figure 23. An aerial view of the area is shown in Appendix 6: Aerial View of Candidate Areas. The total 2020 heat demand within the assessment boundary is 127,463 MWh. The largest existing commercial heat demands are Asda and Vue. Table 11 shows details of the top five commercial heat demands under individual ownership (sites/buildings that are under single ownership), the total heat demand for the top five demands within the energy demand assessment area is approximately 7,170 MWh.

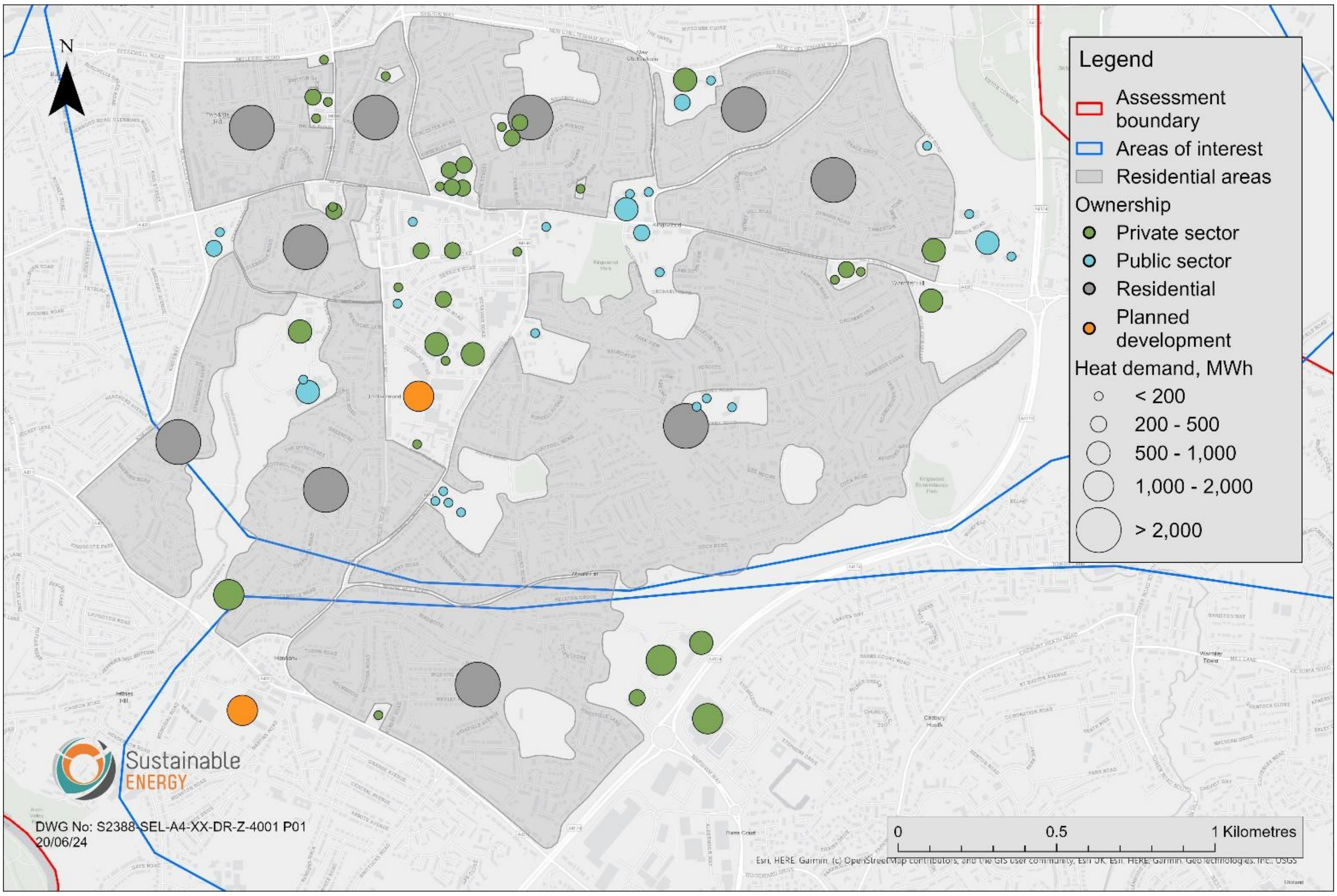


Figure 23: Douglas Road Industrial Park heat demand - 2020

The heat demands within the assessment boundary are categorised as public and private sector, planned development and residential. Within the assessment boundary, the private sector accounts for 13.7% of the total heat demand. There are 11,618 dwellings identified in the candidate area, with a total heat demand of 103,817 MWh which accounts for 90.6% of the total demand in the area, as shown in Figure 24.

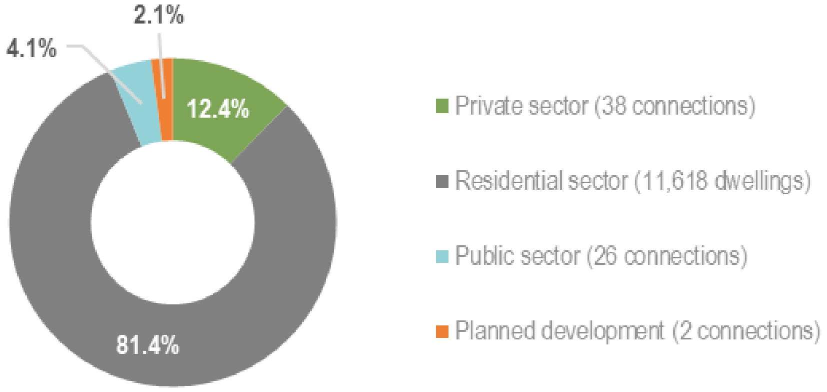


Figure 24: Douglas Road Industrial Park heat demand split by ownership

Table 11: Top five largest commercial heat demands within the candidate area - 2020

Rank	Name	Ownership	Building use	Annual heat demand, MWh	Source of data
1	Asda	Private sector	Retail	1,738	Estimated using heat demand model
2	Vue		Public	1,723	
3	Former Douglas Motorcycle	Planned development	Residential	1,359	
4	Anstey's Road Development		Residential / Office	1,342	
5	Magpie Court	Private sector	Healthcare	1,008	

3.2.4.2 Area 4 Cooling Demand

The cooling demands for all potential connections are shown in Figure 25. The total 2080 cooling demand within the assessment boundary is 25,763 MWh. The largest commercial cooling demand is Asda. Table 12 shows details of the top five commercial cooling demands under individual ownership (sites/buildings that are under single ownership). The total cooling demand for the top five commercial sites within the energy demand assessment area is approximately 16,351 MWh.

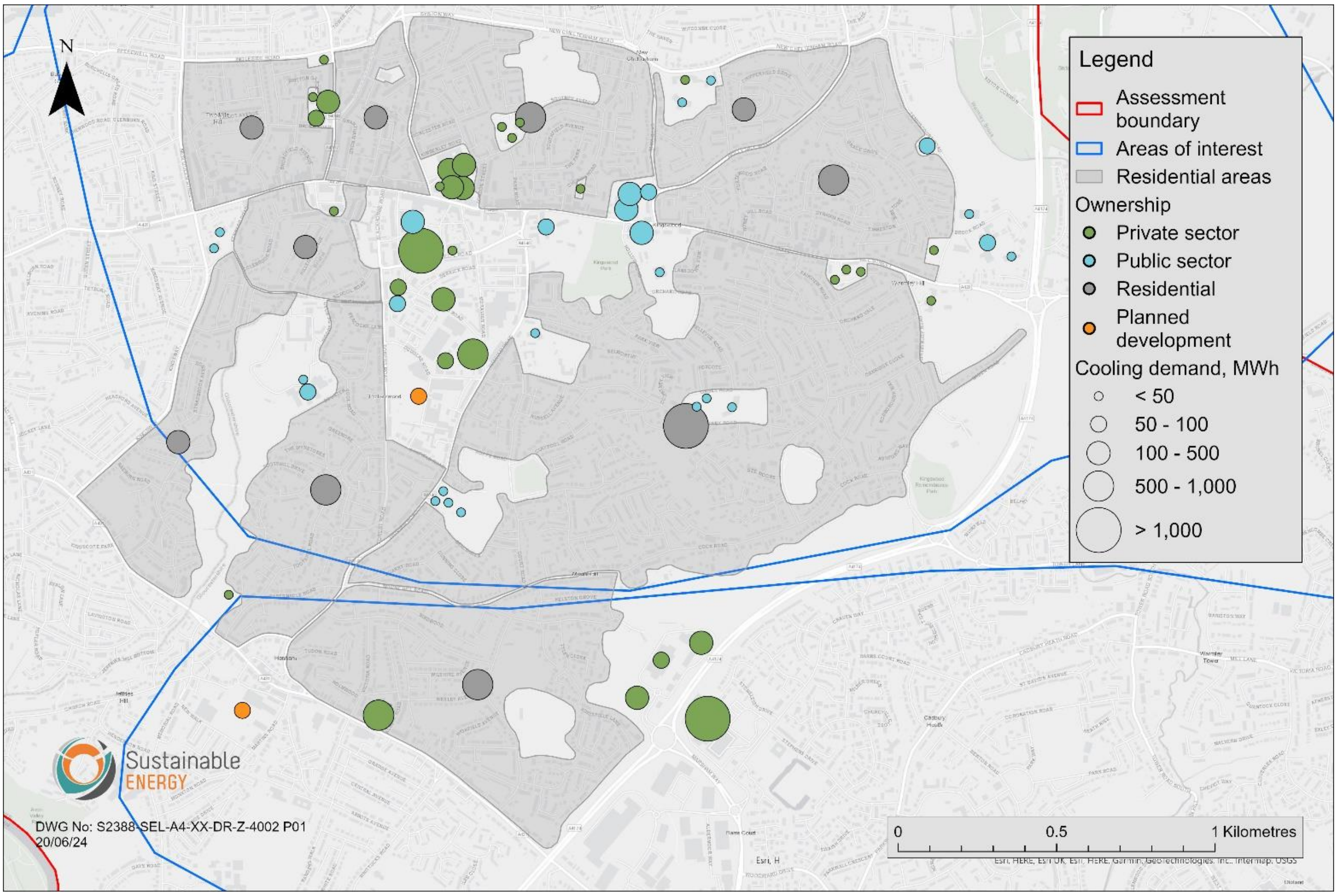


Figure 25: Douglas Road Industrial Park cooling demand - 2080

The cooling demands within the assessment boundary are categorised as public and private sector, planned development and residential. Within the assessment boundary, the private sector accounts for 69.6% of the total heat demand, while the residential sector accounts for 24.1%, as shown in Figure 26.

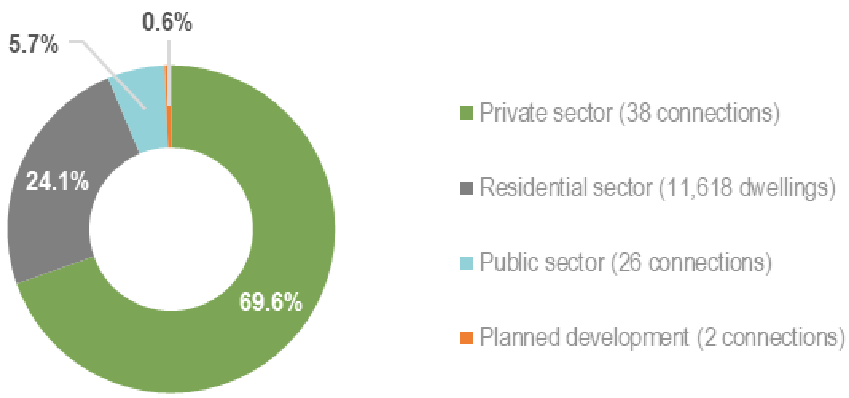


Figure 26: Douglas Road Industrial Park cooling demand split by ownership

Table 12: Top five largest commercial cooling demands within the candidate area - 2080

Rank	Name	Ownership	Building use	Annual cooling demand, MWh	Source of data
1	Asda	Private sector	Retail	12,994	Estimated using cooling demand model
2	Lidl (Halls Road)	Private sector	Retail	1,605	
3	Lidl (High Street)	Private sector	Retail	788	
4	Ministry of Fitness	Private sector	Public	524	
5	Kingswood Civic Centre	Private sector	Public	440	

3.2.4.3 Area 4 Energy Demand Forecast

The projected heating and cooling demands for the Douglas Road Industrial Park candidate area were derived, based on the CIBSE predicted temperature profile under high carbon emission scenarios; these are shown in Figure 27. The heat demand in 2080 decreased by 19% compared to 2020 figures, while cooling demand increased by 82% (accounting for the tipping point) during the same period.

The other sector categories for heating include buildings from the public sector, healthcare, hospitality, hotels and education.

Figure 27: Douglas Road Industrial Park energy demand projection

3.2.5 Candidate Area 5 – Barrs Court Residential

A total of 5,455 residential dwellings were identified as potential connections within the Barrs Court Residential candidate area. The majority of these dwellings are semi-detached houses and terraced houses, as shown in Figure 28.

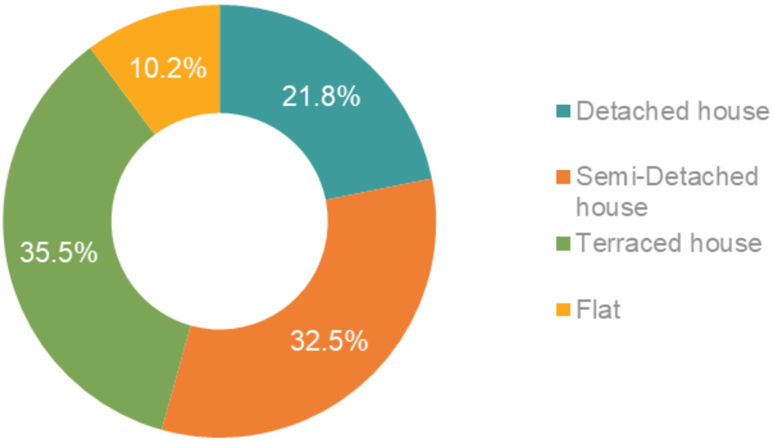


Figure 28: Dwelling type within the residential candidate area

3.2.5.1 Area 5 Heat Demand

The building heat demands for all potential connections are shown in Figure 29. An aerial view of the area is shown in Appendix 6: Aerial View of Candidate Areas. The total 2020 heat demand within the assessment boundary is 53,810 MWh.

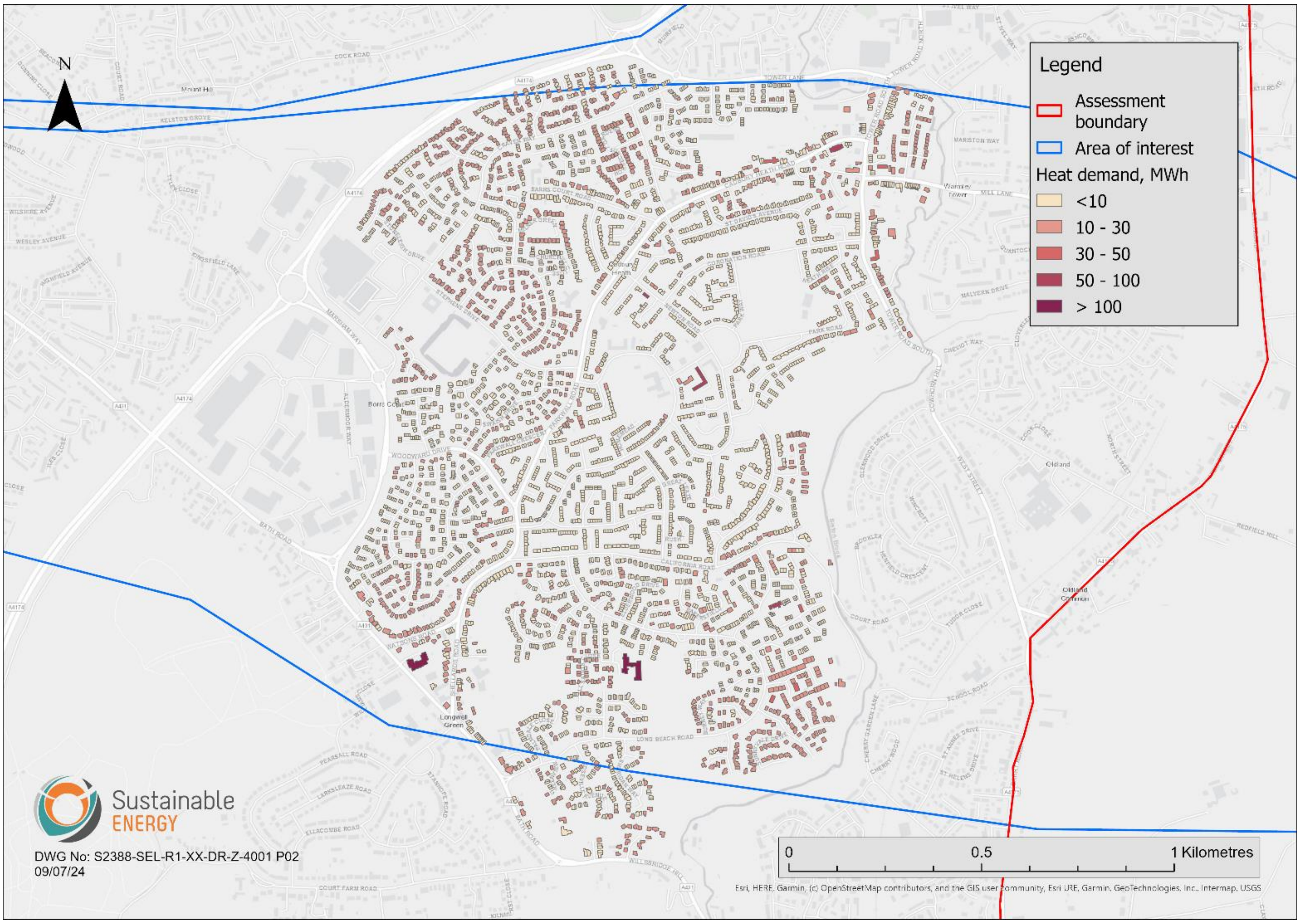


Figure 29: Residential heat demand - 2020

3.2.5.2 Area 5 Cooling Demand

The building cooling demands for all potential connections are shown in Figure 30. The total 2080 cooling demand found within the assessment boundary is 3,531 MWh.

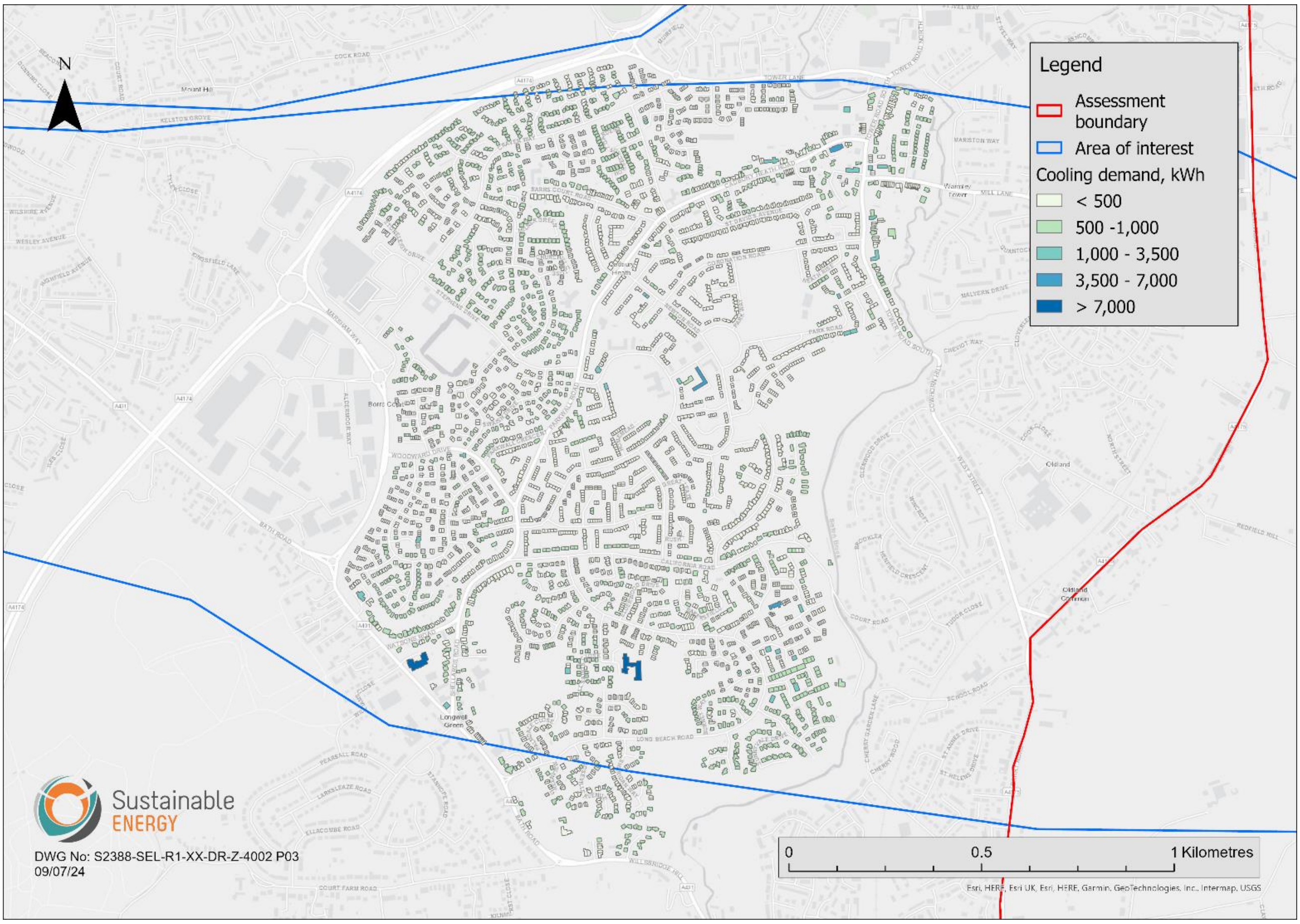


Figure 30: Residential cooling demand - 2080

3.2.5.3 Energy Demand Forecast

The projected heating and cooling demands for the Barrs Court Residential candidate area were derived based on the CIBSE predicted temperature profile under high carbon emission scenarios; these are shown in Figure 22. The heat demand in 2080 decreased by 23% compared to 2020 figures, while cooling demand increased by 7% (accounting for the tipping point) between 2035 and 2080.

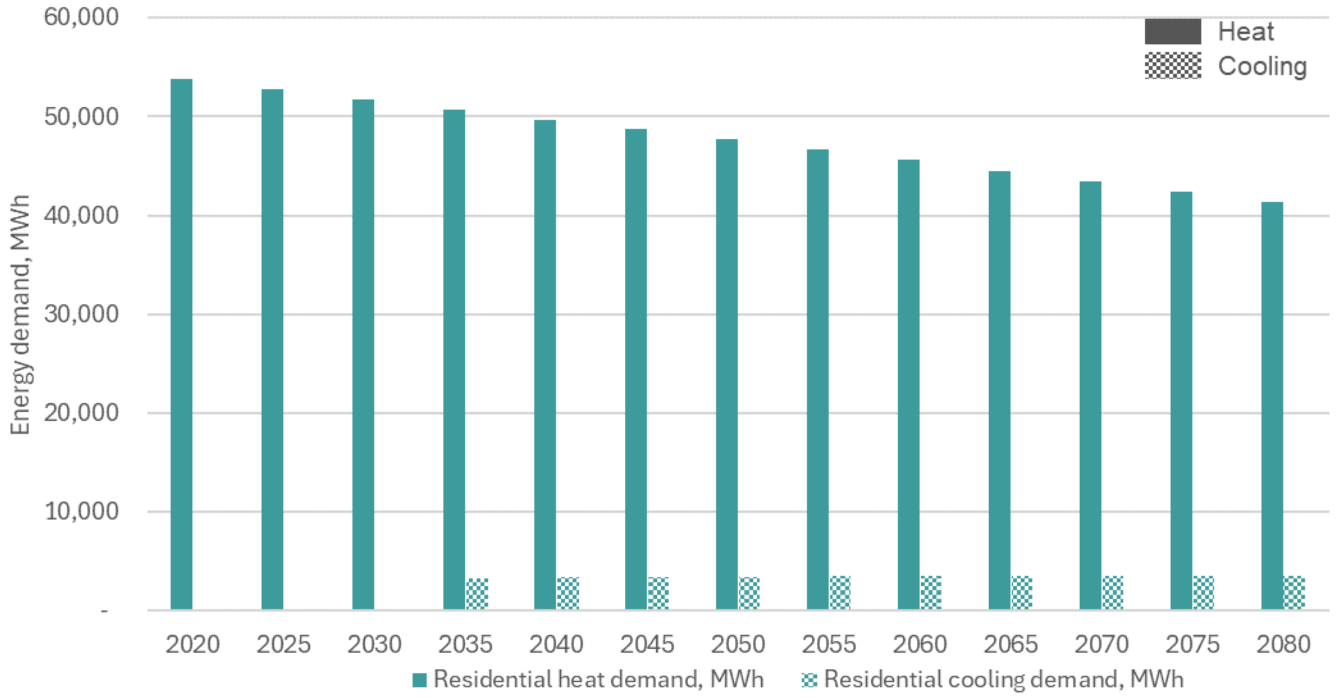


Figure 31: Bristol and Bath Science Park energy demand projection

3.3 Summary

The energy demand summary for each candidate area is shown in Table 13.

Table 13: Candidate area energy demand summary

Candidate areas	No of connections	2020 Heat demand, MWh	2080 Cooling demands, MWh
Lawrence Hill	• 40 commercials • 6,024 dwellings	72,737	7,251
Fishponds	• 74 commercials • 12,302 dwellings	149,217	21,635
Bristol and Bath Science Park	• 69 commercials • 4,331 dwellings	60,030	24,155
Douglas Road Industrial Park	• 66 commercials • 11,618 dwellings	127,463	25,763
Barrs Court Residential	• 5454 dwellings	53,810	3,531

4 CANDIDATE AREA SCHEME OPTION ASSESSMENT

4.1 Renewable and Low Carbon Scheme Options

For each candidate area, four options were assessed to supply the heating and cooling demands, as follows:

- Mine water heat and cooling network
- Mine water ambient network
- Individual ASHP
- Business as usual

With the exception of the business as usual (BAU) options, all options have the potential to meet the client's key priorities by providing low-carbon heat and cooling to buildings within the assessment area. This section discusses each option and considers possible risks, benefits, and disbenefits.

4.1.1 Mine Water Source Heat and Cooling Network

A mine water source heat and cooling network would utilise centralised water source heat pumps (WSHP) to generate both heat and cooling, using the mines as the source. Figure 32 illustrates a mine water source energy centre supplying a heat only network. To provide cooling, another flow and return primary distribution network will be required to distribute coolth to individual connections, and a cooling interface unit (CIU) will be required within each connecting building. The risks, benefits and disbenefits of the heat and cooling network (HCN) option are shown in Table 14.

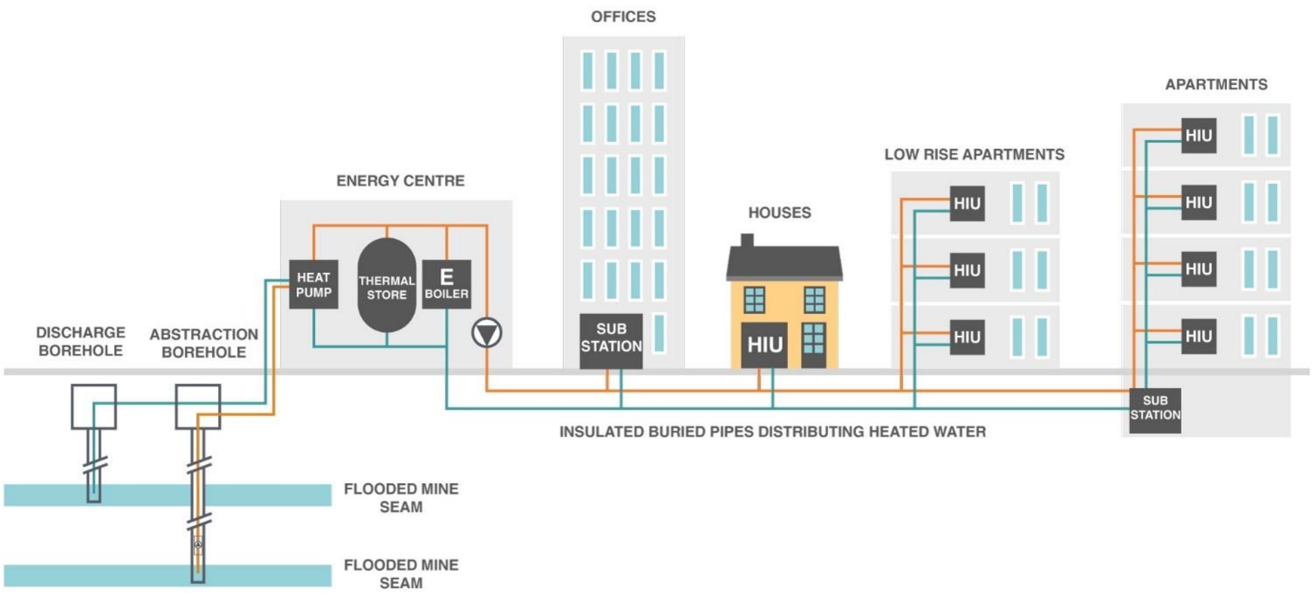


Figure 32: Indicative arrangement of a mine WSHP energy centre supplying a heat network

4.1.1.1 Mine Water Abstraction and Reinjection

Mine water would be abstracted via an 'open-loop' system. The mine water is pumped up from the well or borehole and passed through a plate heat exchanger before being re-injected back into the mine. The mine water will have to be recirculated therefore it is important that mine workings which the boreholes abstract and reinject to are hydraulically connected. To avoid 'short-circuiting' of recirculated mine water, there should be sufficient flow spacing between abstraction and reinjection boreholes. This is commonly achieved by using different seams within the same mine as shown in Figure 33. However, if the boreholes are far enough apart, it may be viable to abstract and reinject from the same mine seam. There are 42 mine seams recorded across the AOI, and 23 seams are considered sufficiently extensive to be utilised as potential heat sources. This assessment assumes that the mine resources are unlimited, with a constant mine water temperature of 15°C throughout the year, based on the previous study 'Mine Heat Feasibility Review' conducted by the Coal Authority.

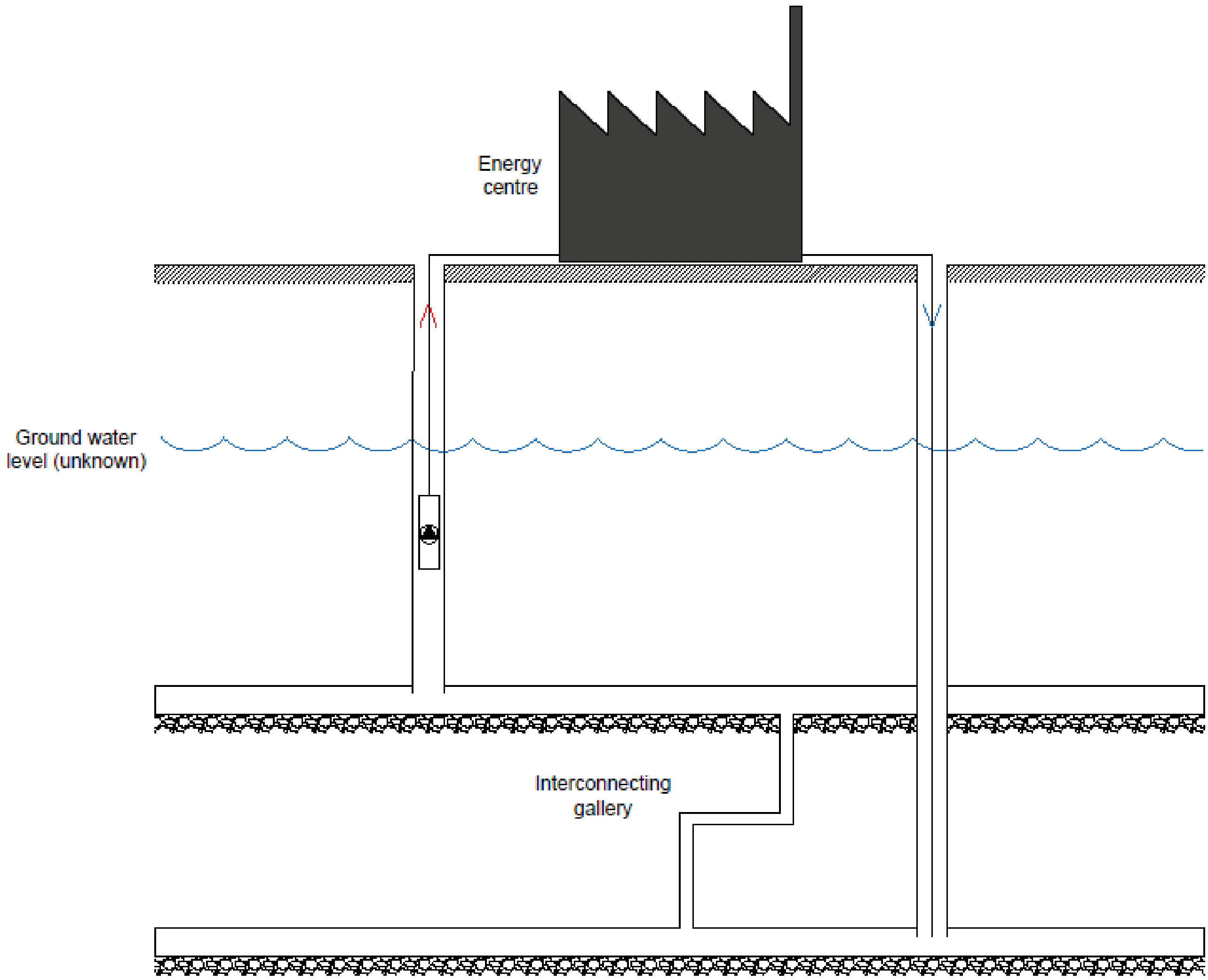


Figure 33: Mine seam abstraction and reinjection

4.1.1.2 Centralised Mine Water Sourced Reversible Heat Pumps

The heat pumps will comprise packaged units connected within the energy centre to three main circuits: the mine water source circuit and the primary heating and cooling circuits. The mine water source circuit operates by running a low-temperature, low pressure refrigerant fluid through a heat exchanger to extract the heat/coolth from the mine water. The heat pump is configured such that it is capable of providing both heating and cooling simultaneously if required. During heating mode, the refrigerant fluid 'absorbs' the heat from the mine water and boils at low temperatures, and the resulting gas is compressed to increase the temperature. The gas is then passed through another heat exchanger, where it condenses, releasing its latent heat to the primary heating circuit. During cooling mode, the process is reversed, providing chilled water for the cooling network. The energy centre will also house water filters for the mine water to avoid fouling of the heat exchangers within the heat pumps.

The heat pump refrigerant circuit will be hermetically sealed and subject to the F-gas directive and the working fluid will be a low global warming potential (GWP) refrigerant. More details on the advantages and disadvantages of different refrigerants can be found in Appendix 4: Heat Pump Refrigerant.

The capacity of the heat pumps has been sized to find the optimum balance between heat generation capacity, capital cost and maintenance cost, based on previous project experience.

4.1.1.3 Peak and Reserve Boilers

Peak and reserve boilers have been sized to meet peak demand and are assumed to only operate for short periods of time. The capacity is based on an n+1 philosophy to provide redundancy and enable the boilers to operate at maximum efficiency across the range. The also ensures that the failure of any single unit will not prevent the peak heat demand of the network from being met.

The economics assessment assumes that gas boilers are installed. The installation of electric boilers could also be considered in the future to decrease the network's carbon intensity or in the event of a gas boiler ban or increase in gas prices (either through commodity costs or through taxes designed to disincentivise fossil fuels). However, based on the current energy market and prices, the installation of electric boilers would negatively impact the network economics as it would result in higher operating costs due to increased electricity consumption at the energy centre and the requirement for a larger electricity connection capacity. This also significantly increases the risk associated with the resilience and reliability of the centralised heat pumps (if the heat pumps are unavailable for significant periods, the operation of electric peak and reserve boilers may be an unacceptable risk for O&M contractors obligated to deliver heat at a specific price).

A sensitivity assessment will be conducted for the HCN option to compare the socioeconomic benefits of electric boiler peak and reserves against the gas boiler base case.

4.1.1.4 Waste Heat Recovery Heat Pump

A waste heat HP operates similarly to a mine water source heat pump, but instead of having a mine water source circuit, there is a waste heat recovery circuit that absorbs heat from the waste heat exhausts of industrial sites such as data centres. The waste heat recovered would have a higher source temperature in comparison to mine water, resulting in a higher heat pump COP.

4.1.1.5 Strategic Heat Main

Certain candidate areas are near the proposed Strategic Heat Main (SHM) route. To connect to the SHM, a substation is required at the energy centre. This will take heat from the SHM and distribute it from the energy centre to individual connections via the primary distribution heat network. A heat purchase tariff will be charged based on the amount of heat delivered from the SHM.

4.1.1.6 Heat and Cooling Network Connection

It has been assumed that all network connections will be indirect (where a heat exchanger separates the heat and cooling network hydraulically from the building’s heating/cooling systems). This is preferable to direct connection as the building heating systems are protected from the high pressures in the heat network, and the buried heat network is protected from the potentially poor water quality in some buildings. The hydraulic separation also provides a useful break for commercial discussions around maintenance responsibilities.

An example of a typical arrangement for the heat and cooling substations connection is shown in Figure 34.

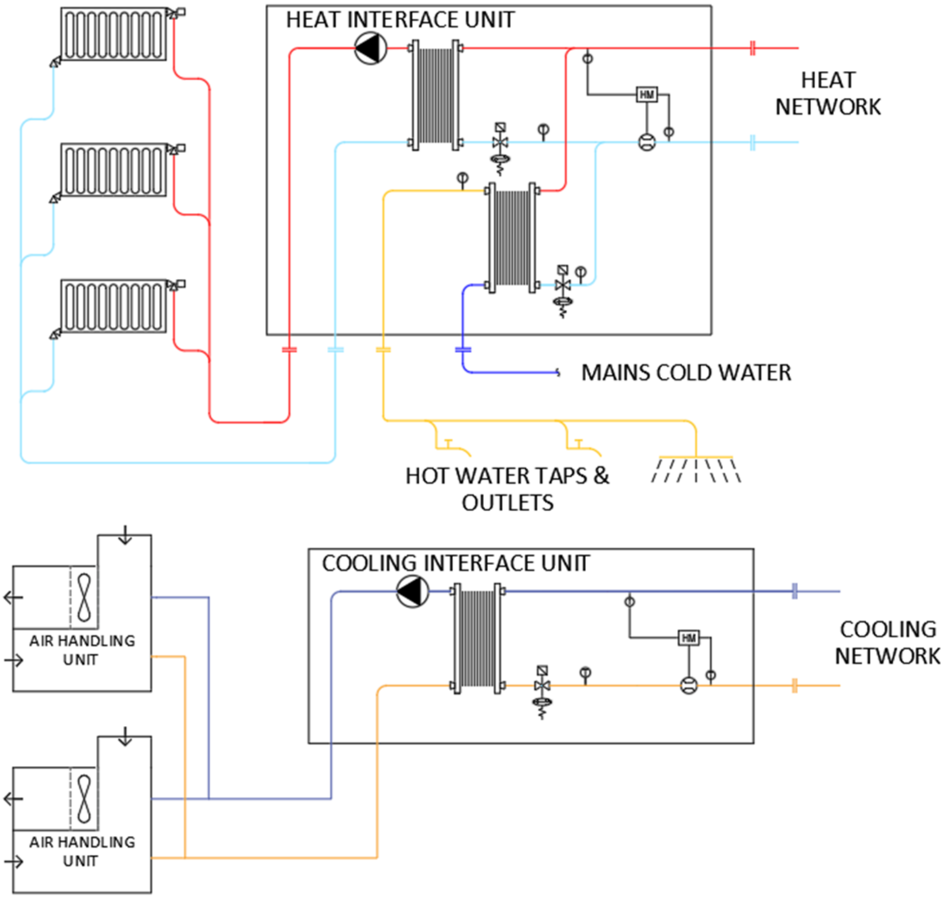


Figure 34: Example of a HCN building connection

It has been assumed that the network operator will own and maintain the substations (the heat exchange equipment between the heat/cooling networks and the building's heating/cooling systems). The substation includes heat exchangers, control valves and heat metering; the substation can include one or more plate heat exchangers (PHEs), depending on the size, turn-down and redundancy required for each building. Typically, two PHEs are installed in parallel, each installed at 60% of peak load, providing a full thermal range, with some redundancy to permit service and maintenance of individual PHEs.

The substation package will include:

- Means of flow measurement and test points on both sides for commissioning purposes
- Filtration to protect the heat exchangers
- Flushing, filling and draining details
- Pressure relief, control and instrumentation to allow the supplier to control and monitor the supply of heat

Table 14: Specific issues, risks, benefits and disbenefits for MWHCN

		Viability consideration	Risks	Benefits	Disbenefits
Minewater source heat pump	Technology	• HP capacity depends on the availability and accessibility of the mine heat capacity		Higher efficiency than alternatives, and significantly less heat pump capacity required due to diversity and peak and reserve boilers	
	Heat resource	• Access to minewater required • Currently minewater levels, temperatures and flowrates are uncertain, requires further testing by CA for confirmation • Subject to contractual agreements with the CA	Reliant on accessing two separate but interconnected seams	If correctly designed and modelled, temperature of heat resource likely to be stable and sustainable	
	Cooling	• Cooling provision during summer		Cooling would allow for recharging of the minewater, increasing performance	Providing cooling requires an additional network of flow and return pipes, increasing costs and space required
	Demand side response	• Potential to respond to grid carbon intensity and prices by utilising heat pump and thermal storage		Potential economic and/or social benefit from demand side response	
	Plant operation	• Minewater would need to be pumped up to the energy centre			
	Distribution	• A 4-pipe solution is required to provide both heating and cooling solutions	High CAPEX associate with additional set of pipes	Thermal network would allow for reduced peak demand through diversity	Increased utility congestion occurs in roads with a 4-pipe buried solution
	Impact on the site	• Energy centre required to generate heat and cooling	Possible public opposition to energy centre building and visual impacts	No replacements to existing heat emitters required	Visual impact of the energy centres Disruption to nearby buildings from borehole drilling and energy centre construction

4.1.2 Mine Water Ambient Network

A mine water source ambient network would utilise distributed WSHP systems (located within each building) to generate the heating and cooling required at each connection. The ambient network would use the mine water to rebalance itself, abstracting heat when there is a surplus of heating demand, and rejecting heat when there is a surplus of cooling demand. To do this, plate heat exchangers would be used to exchange energy between the mine water and the water/glycol mix running through the ambient network. Similarly to the mine water source heat and cooling network, the key consideration for a mine water source ambient network solution is the accessibility to different mine seams. Figure 35 illustrates an ambient network delivering heat and cooling from the mines to individual connections, where WSHPs generate heat and cooling on site. Additional cooling distribution units, such as a fan coil unit, may need to be installed for cooling distribution in buildings where these are not yet present. The risks, benefits and disbenefits of the ambient network scheme option are shown in Table 15.

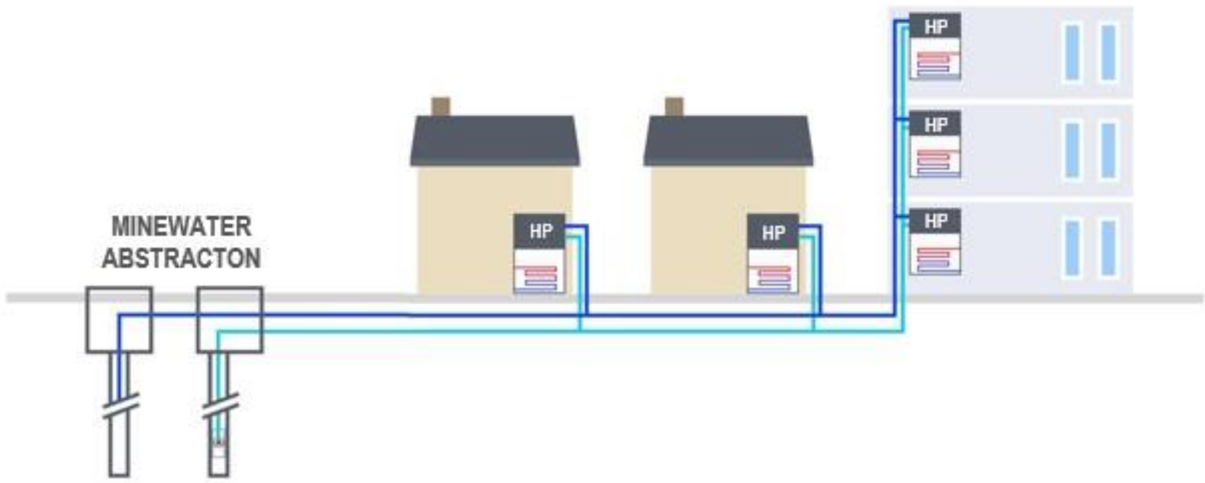


Figure 35: Indicative arrangement of a mine source ambient network

4.1.2.1 Pumping Station

A pumping station is required to circulate the ambient water around the ambient loop for networks larger than around 25-40 dwellings as the circulation pumps at each dwelling/connection would not be powerful enough to draw the water through the whole network. The pumping station is also required as the mines are a central source, and the heating/cooling from them needs to be distributed throughout the ambient network.

A plate heat exchanger is required at the pumping station to separate the ambient loop from the mine water to reduce fouling. An ambient network should include strategically placed differential pressure sensors at the indices of the network (typically the connections furthest from the pumping station); the pumping station will then be controlled to maintain the required differential pressures at these points to ensure efficient pump operation.

4.1.2.2 Ambient Network Connections

In the ambient network solution, the heat pumps installed in each building will be capable of simultaneously producing the required heat and cooling demand. An example of a typical arrangement for a reversible HP connection at the individual building level is shown in Figure 36.

Existing building connections are likely to have heat emitters (e.g. radiators, air handling units etc) and hot water circuits that are designed to operate at higher temperatures than the ideal heat pump operating conditions. Therefore, to ensure the heat pumps operate at optimal efficiency, the heat emitter and hot water systems within the connecting buildings should be upgraded. Also, where cooling emitters are not already installed, these will be required for cooling distribution within the building or dwelling, such as air handling units.

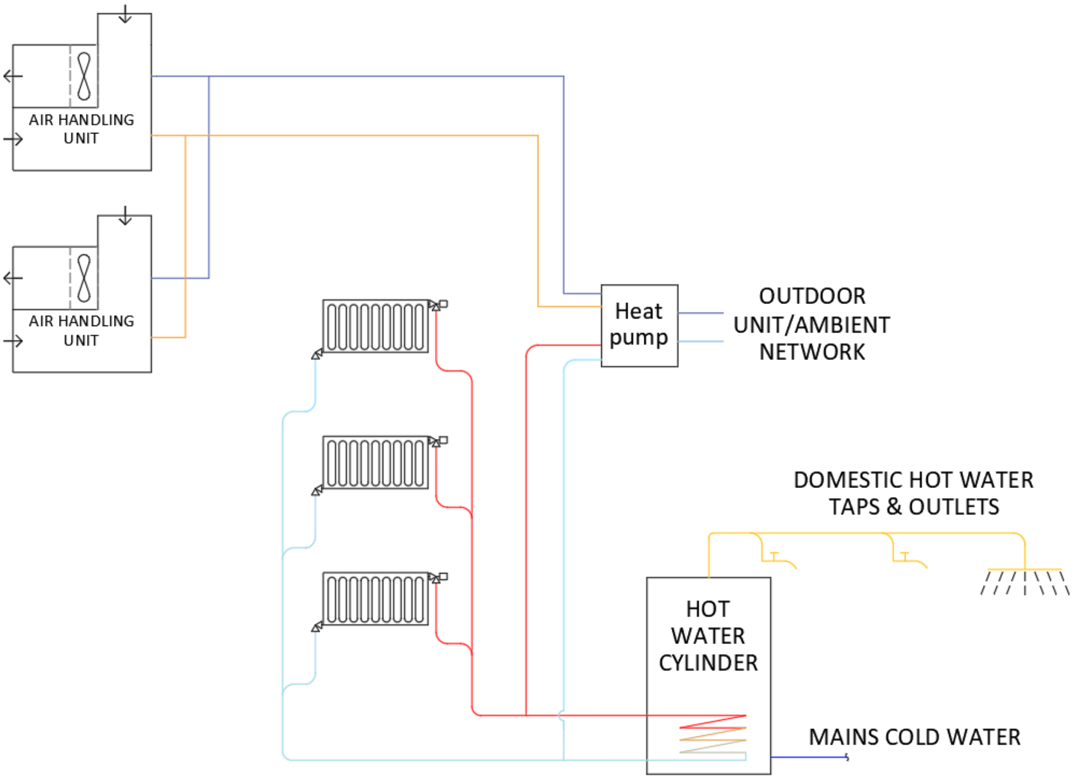


Figure 36: Example of a typical ambient network solution

4.1.2.3 Individual Reversible WSHP

The heat pumps will be packaged units connected within individual buildings to two main circuits: the ambient network circuit and the heat emitter and hot water circuits. The heat pump operates by running a low-temperature, low-pressure refrigerant fluid through a heat exchanger to extract heat or cooling from the ambient water. The individual heat pumps are configured such that they are capable of providing both heating and cooling simultaneously if required. During heating mode, the refrigerant fluid ‘absorbs’ the heat from the ambient network and boils at low temperatures, and the resulting gas is compressed to increase the temperature. The gas is then passed through another heat exchanger, where it condenses, releasing its latent heat to the primary heating circuit. During cooling mode, the process is reversed.

The heat pump refrigerant circuit should be hermetically sealed and subject to the F-gas directive. The working fluid should be a low Global Warming Potential (GWP) refrigerant, however in practice most manufacturers of smaller heat pumps utilise higher GWP refrigerants due to technical considerations (e.g. lower operating pressures). More details on the advantages and disadvantages of different refrigerants can be found in Appendix 4: Heat Pump Refrigerant.

The heat pumps have been sized to meet the peak heat and cooling demand of the individual buildings.

4.1.2.4 Hot Water Cylinder

A hot water cylinder is required for all individual heat pump solutions to provide instantaneous heat on demand. This will require additional space within each building (that does not already have one), which should be accounted for in the planning and design phase of the heating system.

Table 15: Specific issues, risks, benefits and disbenefits for an ambient network

		Viability consideration	Risks	Benefits	Disbenefits
Ambient Network	Technology	• Heat pumps located at each building connection • Pumping station required to deliver ambient water to individual connections	Smaller heat pumps may use higher GWP refrigerant than centralised units	Ambient network allows for gradual expansion and installation of heat pumps and network.	Higher heat pump capacity required due to reduced diversity Smaller heat pumps at connections will have lower efficiency than centralised energy centre
	Heat resource	• Access to minewater required • Currently minewater levels, temperatures and flowrates are uncertain, requires further testing by CA for confirmation • Subject to contractual agreements with the CA	Reliant on accessing two separate but interconnected seams	If correctly designed and modelled, temperature of heat resource likely to be stable and sustainable	
	Cooling	• Cooling provision during summer via ambient loop		Reversible HP system to provide both heating and cooling	
	Demand side response	• Potential to respond to grid carbon intensity and prices by utilising heat pump and thermal storage	Demand side response is unlikely to be taken up by all connections on the network	Potential economic and/or social benefit from demand side response	
	Plant operation	• Heat will be generated from HP installed in each connection alongside buffer tanks that will supply heat demands below the modulation limit of the heat pumps	Smaller heat pumps at connections may not be operated in most efficient manner	All of network heat and cooling demand will be met by renewable technology	Electricity price at connections likely to be higher than at the energy centre leading to higher OPEX
	Distribution	• Two pipe solution to provide ambient mine water to individual connection		Only a set of flow and return pipes needed instead of 4 pipes from an HCN solution	Larger pipes required compared to HCN due to smaller ΔT from the network
	Impact on the site	• Higher heat cost to customers • Space required at each building • Heat demand is not diversified, and significantly larger heat pump capacity required	Existing plant rooms in each building may not have enough room to accommodate the HP units	No requirement for large energy centre	External plant rooms may be required to house heat pumps at individual buildings, significant heat and cooling emitter upgrades required

		Viability consideration	Risks	Benefits	Disbenefits
		• Higher capacity electricity connections required for each dwelling	Grid capacity required across site may increase costs or render individual heat pumps not feasible		

4.1.3 Individual Reversible ASHP (Counterfactual)

Individual reversible ASHPs at the building level would provide both heating and cooling to the building. Individual ASHPs can be beneficial in areas where the density of buildings is too low for a networked solution to be viable. They are also not dependent on accessing a heat and cooling source such as groundwater.

However, individual ASHPs are often less efficient than larger-scale heat pumps, resulting in higher operating costs. As individual reversible ASHPs must be sized to meet the peak demand of each building, the overall installed heat pump capacity will be much higher than a centralised option, which benefits from diversity. This will result in larger electricity grid connection requirements that could lead to expensive grid reinforcement. Additionally, a higher peak demand for electricity in winter will increase the demand for generation and storage, negatively impacting the grid and leading to higher marginal costs. Individual reversible ASHPs will also require additional space at each building to house the air heat exchangers and heat pumps (e.g. large commercial buildings may need rooftop space to house the air heat exchanger, while individual dwellings or low-rise apartments may need to install the outdoor units on the external wall). Figure 37 illustrates the individual ASHP arrangement to provide heat in different building types. The risks, benefits and disbenefits of the individual reversible ASHP scheme option are shown in Table 16.

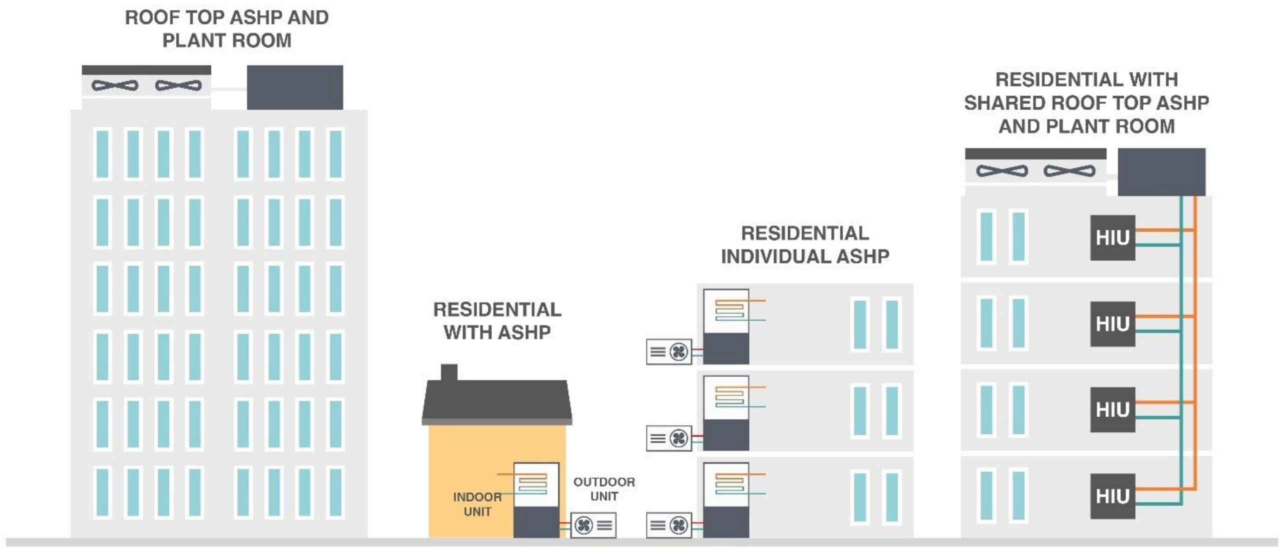


Figure 37: Indicative arrangement of ASHPs at each building to provide heat and cooling

4.1.3.1 Individual Reversible ASHP

The heat pumps will be packaged units connected within individual buildings to three main circuits: the external unit circuit and the heat and cooling circuits within the building. The heat pumps operate by running a low-temperature, low-pressure refrigerant fluid through a heat exchanger to extract heat or cooling from the ambient air. The heat pumps are configured such that they are capable of providing both heating and cooling simultaneously if required. During heating mode, the refrigerant fluid ‘absorbs’ the heat and boils at low temperatures, and the resulting gas is compressed to increase the temperature. The gas is then passed through another heat exchanger, where it condenses, releasing its latent heat to the primary heating circuit. During cooling mode, the process is reversed. The refrigerant fluid absorbs heat from the indoor environment and evaporates, turning into a low-temperature gas. This gas is then compressed to increase its temperature and pressure before passing through a heat exchanger, where it releases the absorbed heat to the ambient air, cooling the indoor space.

The heat pump refrigerant circuit should be hermetically sealed and subject to the F-gas directive. The working fluid should be a low Global Warming Potential (GWP) refrigerant, however smaller heat pumps are more likely to utilise higher GWP refrigerants as these typically can operate at lower pressures, therefore saving costs. More details on the advantages and disadvantages of different refrigerants can be found in Appendix 4: Heat Pump Refrigerant.

The heat pumps have been sized to meet the peak heat and cooling demand of the individual buildings.

4.1.3.2 Hot Water Cylinder

A hot water cylinder is required for all individual heat pump solutions to provide instantaneous heat on demand. This will require additional space within each building (that does not already have one), which should be accounted for in the planning and design phase of the heating system.

4.1.3.3 Individual Reversible ASHP Building Connections

Similarly to the ambient network option, an individual ASHP solution would require individual heat pumps to be installed at each dwelling/building. Therefore, the typical individual reversible ASHP building connection arrangement is similar to that of an ambient network WSHP, as shown in Figure 36. The key difference between ASHPs and ambient WSHPs is that an ASHP will require an outdoor unit for heat/cooling exchange, instead of connecting to an ambient network.

Existing building connections are likely to have heat emitters (e.g. radiators, air handling units etc) and hot water circuits that are designed to operate at higher temperatures than the ideal heat pump operating conditions. Therefore, to ensure the heat pumps operate at optimal efficiency, the heat emitter and hot water systems within the connecting buildings should be upgraded. Also, where cooling emitters are not already installed, these will be required for cooling distribution within the building or dwelling, such as air handling units.

Table 16: Specific issues, risks, benefits and disbenefits for individual reversible ASHPs

		Viability consideration	Risks	Benefits	Disbenefits
Individual ASHP	Heat Source	• Heat output and economics will be negatively impacted by low external air temperature in cold winter periods • Potential opposition to ASHPs (perceived visual, noise and cold plume impact)		Not dependant on accessing ground water and so reduced project CAPEX and disruption	Ongoing disruption from visual and noise impacts during operation
	Cooling	• Potential to provide cooling in each building		Reversible HP system to provide both heating and cooling	No potential to share heating and cooling across buildings
	Plant operation	• Higher Global Warming Potential (GWP) refrigerants are more likely to be used in smaller heat pumps	Plant may not be operated and maintained in the most efficient manner, and may use higher GWP refrigerants which are not disposed of correctly at end of life		
	Impact on the site	• Higher heat cost to customers • Space required at each building • Heat demand is not diversified, and significantly larger heat pump capacity required • Higher capacity electricity connections required for each dwelling	Grid capacity required across site may significantly increase costs or render individual ASHP not feasible	Does not impact development build-out rates or changes to planned development	Additional space required at each building (external for evaporators and internal for heat pump and DHW storage), significant heat and cooling emitter upgrades required, significant grid reinforcement and distribution costs may be required
	Noise	• Acoustic assessment and attenuation required			Acoustic attenuation will negatively impact CAPEX

4.1.4 Business As Usual (BAU)

In this scenario, the BAU will assume gas boilers are installed in all assessed buildings, and that cooling demands are met with chillers within each individual building. Figure 38 illustrates the individual gas boilers in different building types.

Figure 38: Indicative arrangement of BAU scenario with individual cooling systems

Due to the use of gas boilers for heating, the BAU is not compatible with the Council's climate reduction targets. The outdoor chiller unit will require additional external space for installation (e.g., rooftop of large commercial buildings or hung from the external wall of a residential dwelling). The risks, benefits and disbenefits of the BAU scheme option are shown in Table 17.

4.1.4.1 Individual Gas Boiler

The BAU scenario assumes individual gas boilers are installed in all identified potential network connections. A gas boiler produces heat by burning natural gas to heat water, which is then circulated through pipes to radiators or underfloor heating systems. Gas boilers, especially modern combination boilers, offer efficient heating and domestic hot water on demand without the requirement for a hot water cylinder, unlike heat pumps which require a hot water cylinder to store the latent heat. However, the use of natural gas as a heat source has significant environmental impacts due to high carbon emissions. Additionally, irrespective of the fact that modern combination boilers can achieve a high system efficiency of 90%, they are less efficient than a conventional air source heat pump system with a COP of 2.4 and above (where 1 unit of electricity is used to generate 2.4 units of heat). There are also plans to ban new gas boiler installations in the UK from 2035 in response to the Net Zero target set for 2050.

The gas boilers have been sized to meet the peak heat demand of the individual buildings.

4.1.4.2 Individual Chiller

Chillers operate by circulating refrigerant through a closed loop system to provide cooling for individual buildings. The refrigerant absorbs heat from indoor air, causing it to evaporate into a low-pressure vapor. This vapor is then compressed to increase its temperature and pressure, transforming it into a high-pressure gas. As this gas moves through the condenser coil, it releases heat to the outdoor air or water, condensing back into a high-pressure liquid. After passing through an expansion valve or capillary tube to decrease pressure, the refrigerant enters the evaporator coil again to absorb more heat from indoor air, continuing the cooling cycle. This process, facilitated by refrigerant phase changes, is essential for extracting heat from indoor spaces and transferring it outside, thereby cooling the building effectively using ambient air as the cooling source.

Chillers differ from ASHPs in that they are designed to operate at different temperature ranges. An ASHP must be able to generate hot water at circa 55-60°C, whereas a chiller will likely only be designed to output temperatures of 40-45°C. This limits the refrigerant choice for ASHPs.

The chillers have been sized to meet the peak cooling demand of the individual buildings.

Table 17: Specific issues, risks, benefits and disbenefits for BAU

		Viability consideration	Risks	Benefits	Disbenefits
BAU	Heat Source	• Individual gas boiler is assumed to be installed at each building to provide cooling • Low cost of heat • High carbon emission	Gas boiler ban to take place in 2035	Lower cost of fuel and maintenance in comparison with alternative systems	Any existing system installed will likely be replaced with low carbon alternatives after 2035
	Cooling	• Individual chiller is assumed to be installed at each building to provide cooling			Cooling equipment to be installed in addition to gas boilers
	Plant operation	• Natural gas is considered a fossil fuel with high carbon content			
	Impact on the site	• Lower heat cost to customers • Space required at each building • The carbon target will be unable to be met		No replacements to exiting heat emitters required	

4.2 Summary

There are four viable scheme options (including counterfactual and BAU) identified to provide both cooling and heating solutions to the existing and planned building stock within the five candidate areas. These options are:

- Mine water source heat pump heat and cooling network
- Mine water source ambient network
- Individual reversible ASHP (counterfactual)
- Individual gas boilers and chillers (BAU)

Apart from the BAU scheme, all other scheme options could provide the low-carbon solution that the Council needs to meet its climate targets. A techno-economic assessment of all scheme options for each candidate area is presented in section 6 Candidate Area Techno-Economic Modelling to identify the preferred solution for each candidate area.

5 ENERGY CENTRE AND NETWORK ROUTE ASSESSMENT

An energy centre is a building or plant room housing heat/cooling generation technologies, network distribution pumps and/or all ancillary items. A suitable energy centre site should be selected from a range of options, comparing criteria such as: proximity to energy load and sources, visual impact, noise disturbance, flue emissions and air quality impact, the viability of fuel supply and electricity connection, and space for both initial and future plant.

5.1 Existing and Planned Energy Sources

5.1.1 Mine Water

This study assesses the potential of utilising mine water heat to provide low-carbon heating and cooling to the candidate areas, and follows on from the "Kingswood, South Gloucestershire – Mine Heat Feasibility Review" report, which was produced by the Coal Authority (CA) to assess the possibility of using flooded mine workings as a heat source.

23 mine seams were identified across the AOI that are considered sufficiently extensive for heat extraction. The exact location of the mine seams and the availability and capacity of supply are unknown at this stage. As the project progresses, a detailed assessment should be undertaken to determine the location of the mine seams as well as the potential capacity available; this study assumes that the heat capacity within the mine seams is not a limiting factor to the size of the network proposed.

The CA report indicates that the mine seams have a depth of approximately 100m and 600m across the study areas, with water temperatures expected to range between 11 °C and 24 °C. This study assumed that the mine water is accessible at 2-300m depth and the temperature remains constant at 15°C throughout the year.

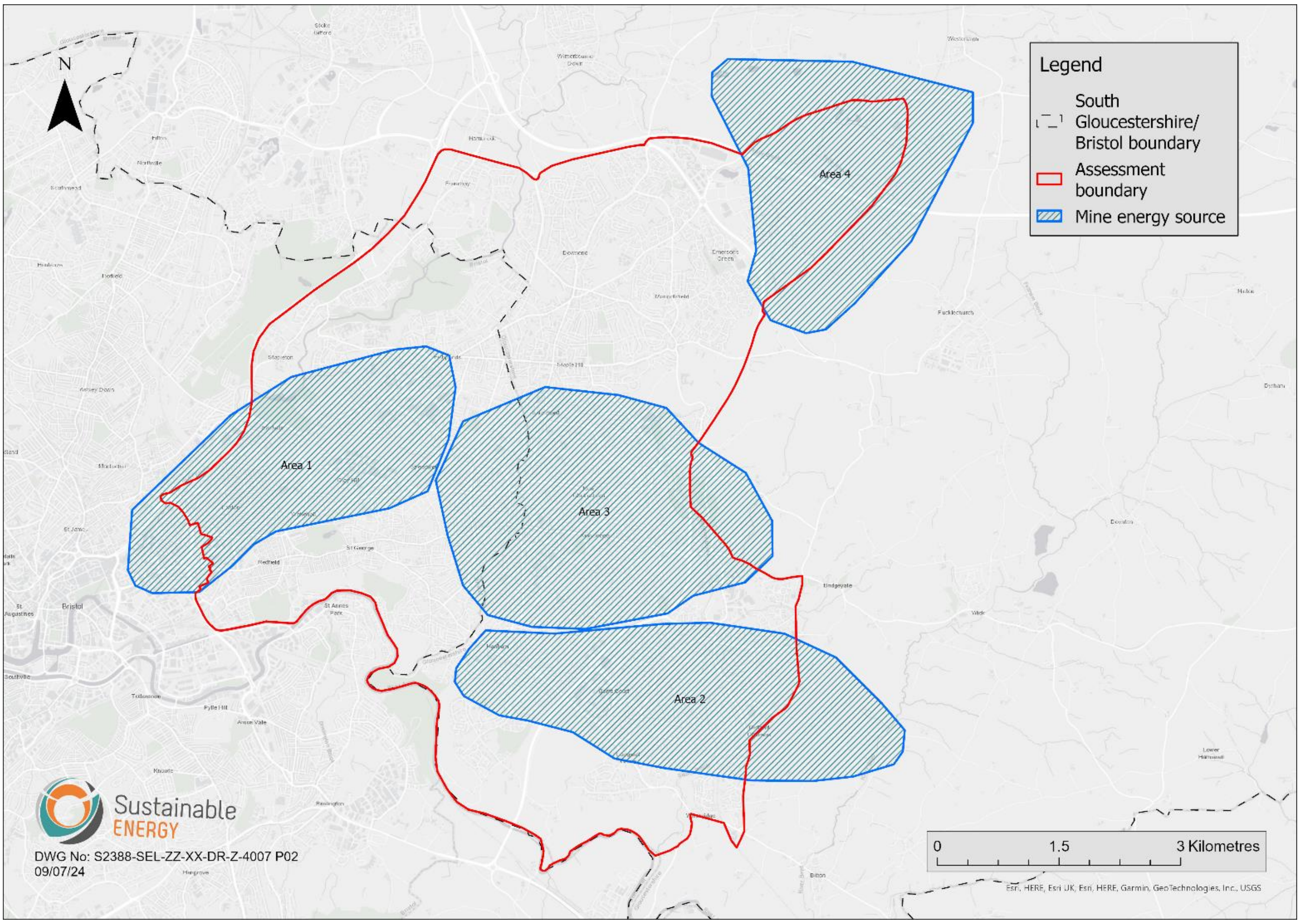


Figure 39: Mine water heat resource across the assessment boundary

5.1.2 External Energy Sources

5.1.2.1 Strategic Heat Main

The Strategic Heat Main (SHM) is a proposed heat transmission main which aims to transmit heat from energy-from-waste (EfW) and industrial plants in Avonmouth-Severnside to energy consumers in Bristol City Centre and potentially South Gloucestershire.

The most recent 'Bristol Strategic Heat Main Detailed Feasibility Study' by Buro Happold suggests that the strategic heat network route could potentially connect to Fishponds, one of the candidate areas in this study. The Buro Happold study also suggests that the SHM could provide heat loads within St Paul's in Bristol City Centre, which is near to the Lawrence Hill candidate area. These two areas could therefore potentially be served by the SHM.

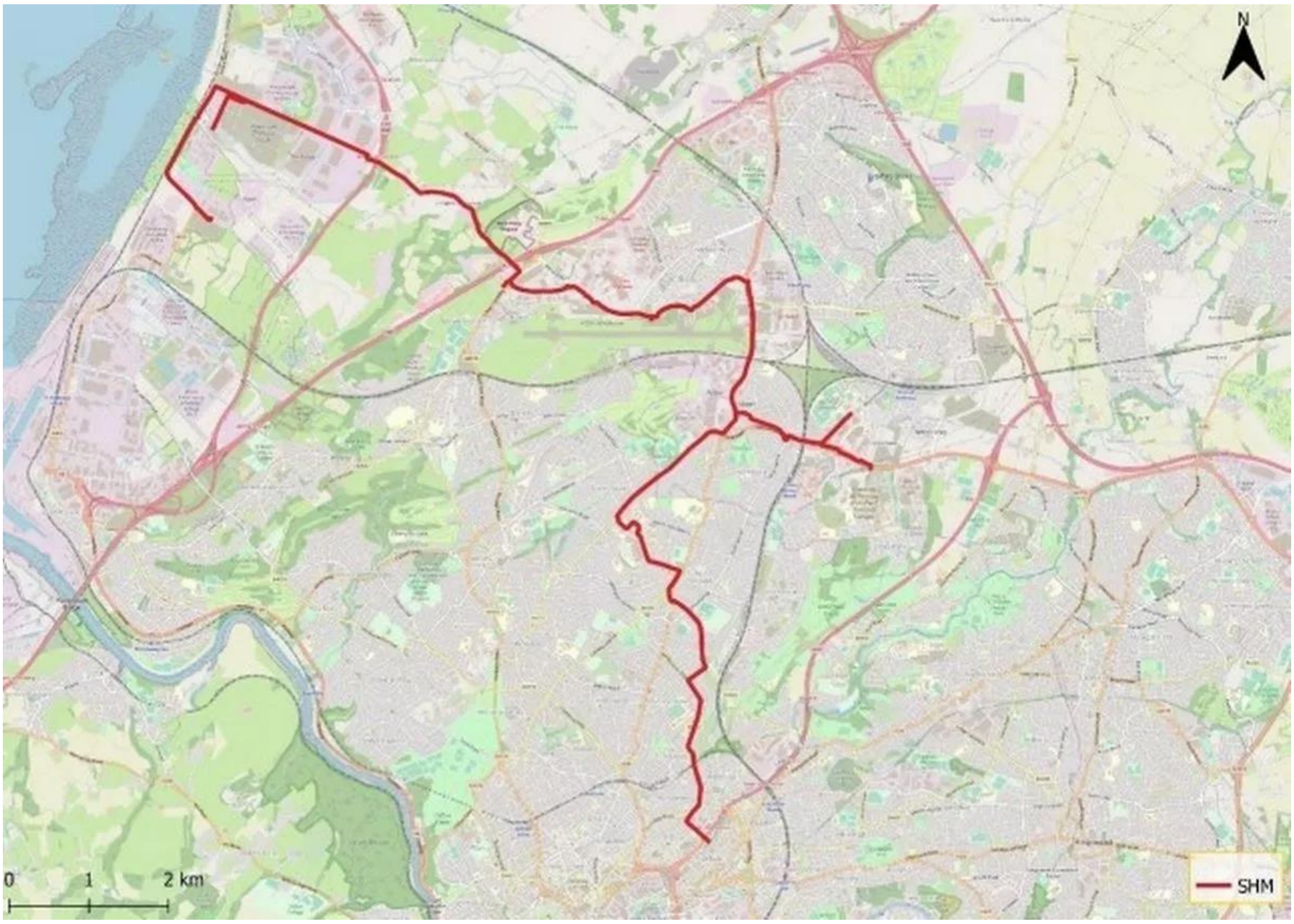


Figure 40: Indicative route for the SHM (Image: City Leap)

5.1.2.2 Waste Heat

Waste heat refers to heat generated by industrial processes, data centres/supercomputers, and retail chillers that are typically rejected to the atmosphere. Waste heat in urban areas usually takes the form of low-grade heat, i.e. circa 40°C or below. Low-grade waste heat can be used as a heat source for centralised heat pumps providing a higher temperature source compared to ambient air, therefore increasing the performance of the system.

Data Centre

Two data centres/supercomputers have been identified within the BBSP candidate area, including the National Composite Centre computer and the Centre for Modelling Simulation computer. Data centres/supercomputers have strict uptime requirements and therefore discussions with the operators should be undertaken to determine the optimal arrangement for all parties.

All potential waste heat opportunities with significant capacity in the candidate areas are shown in Table 18.

Table 18: Waste heat sources

Site name	Candidate area	Waste heat source	Estimated capacity (accounting for heat pump)
NCC	Bristol and Bath Science Park	Data centre / supercomputer	6,667 kW
CFMS			150 kW

5.2 Potential Energy Centre Location

5.2.1 Candidate Area 1 – Lawrence Hill

Figure 41 and Table 19 provide details of the potential energy centre locations identified for the Lawrence Hill candidate area.

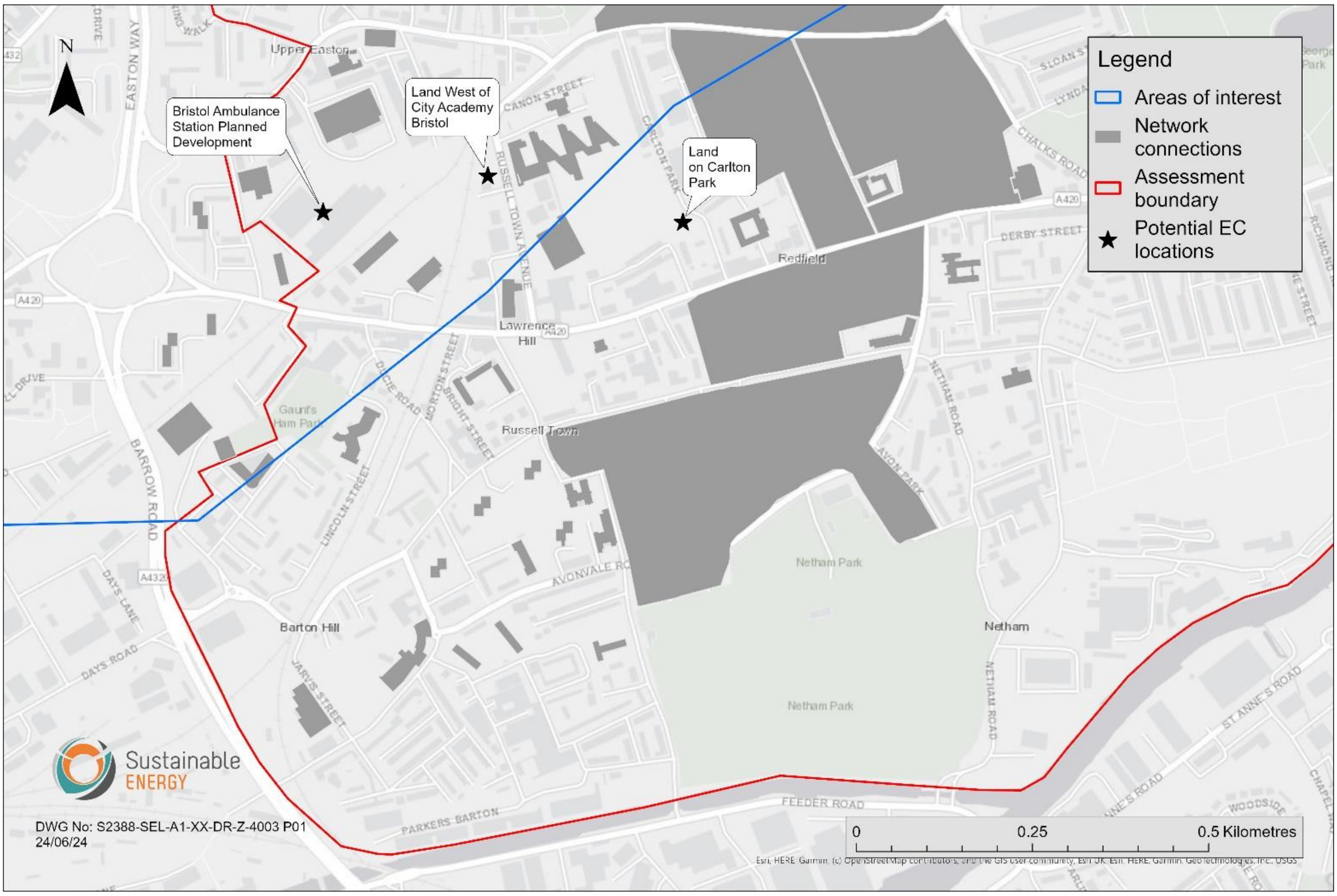


Figure 41: Lawrence Hill potential energy centre locations

Table 19: Potential energy centre locations

Location	Land ownership	Current use	Comment
Bristol Ambulance Station Planned Development	Private-owned	Industrial estate / planned development	Timing of planned development uncertain
Land West of City Academy Bristol	Private-owned	None	Disused site Close proximity to railway
Land on Carlton Park	Council-owned	None	Just outside of AOI, may not be able to access mine seams

The preferred energy centre location was determined to be the Bristol Ambulance Station planned development. There is no current planning application for the Ambulance Station; however, based on previous project experience from Frome Gateway, it is known that the site is allocated for potential future developments. Discussions with the Bristol planning team and the developer should take place to secure the location as an energy centre.

5.2.2 Candidate Area 2 – Fishponds

Figure 42 and Table 20 provide details of the potential energy centre locations identified for the Fishponds candidate area.

Figure 42: Fishponds potential energy centre locations

Table 20: Potential energy centre locations

Location	Land ownership	Current use	Comment
Filwood House & Verona House Planned Development	Private-owned	Industrial estate / planned development	Existing industrial site Part of the local plan for redevelopment, with no detailed planning application released publicly at the time of the project

The preferred energy centre location was determined to be Filwood House and Verona House, which is an industrial site with existing commercial offices and warehouses. Based on desktop research, the Filwood House and Verona House site is to be part of the redevelopment site known as 'Atlas Place,' which is subject to future development under 'Bristol City Council's emerging Local Plan (2019); however, no current detailed planning application has been submitted for this site. If the project were to proceed further, engagement with the landowner should take place to determine the planning status of the site and its availability to be utilised for a potential energy centre. Details of the site can be found in Appendix 3: Site Survey.

5.2.3 Candidate Area 3 – Bristol and Bath Science Park

Figure 43 and Table 21 provide details of the potential energy centre locations identified for the BBSP candidate area.

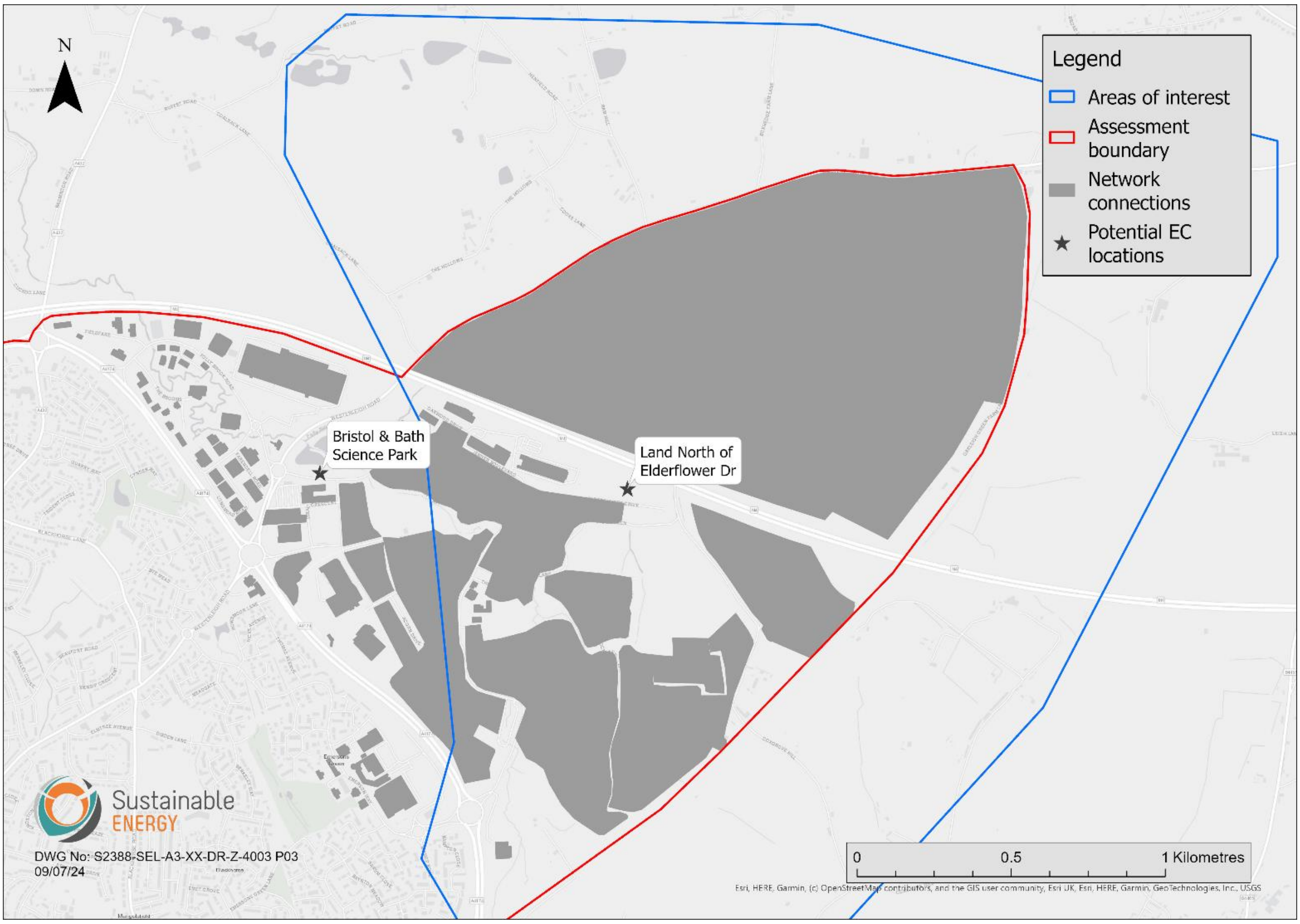


Figure 43: Bristol and Science Park potential energy centre locations

Table 21: Potential energy centre locations

Location	Land ownership	Current use	Comment
Land North of Elderflower Dr	Private-owned	Greenfield/Potential development	No planning application submitted since the masterplan back in the early 2000s
Bristol & Bath Science Park	Council-owned	Green space	Green space between Lyde green lake and BBSP commercial site A narrow strip of land, potentially not suitable for an energy centre

The preferred energy centre location was determined to be the land north of Elderflower Drive. The site appeared to be disused based on site visits and online searches, as no detailed planning has been published since the BBSP master plan dating back to the early 2000s. If the project were to proceed further, engagement with the landowner is required to determine the planning status of the site and its availability to be utilised for a potential energy centre. Details of the site can be found in Appendix 3: Site Survey Report.

5.2.4 Candidate Area 4 – Douglas Road Industrial Park

Figure 44 and Table 22 provide details of the potential energy centre locations identified for the Douglas Road Industrial Park candidate area.

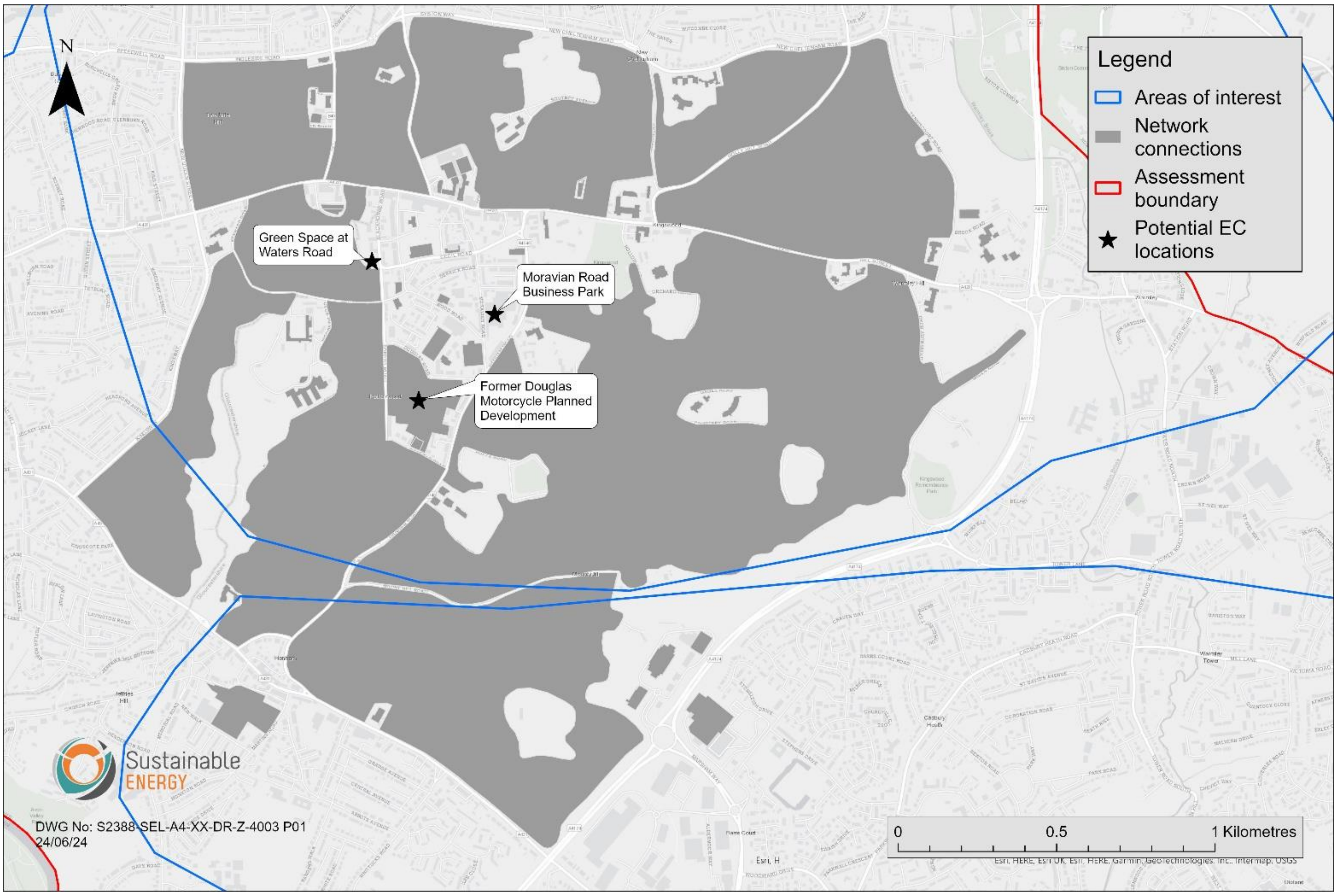


Figure 44: Douglas Road Industrial Park potential energy centre locations

Table 22: Potential energy centre locations

Location	Land ownership	Current use	Comment
Green Space at Waters Road	Public-owned	Green space	Close proximity to residential properties
Former Douglas Motorcycle Planned Development	Private-owned	Ongoing development site	Some work on the development has already started, other buildings are yet to be demolished Would require some land purchase.
Moravian Road Business Park	Private-owned	Disused office space	Existing buildings need to be demolished

The preferred energy centre location was determined to be Moravian Road Business Park which is a business park located in the centre of the candidate area. Based on the information gathered from online research and site visits, the Moravian Road Business Park has been in a state of disuse for a long period and is currently subject to an outline planning application for the construction of up to 140 dwellings. Engagement with the planning team should take place to secure a location for an energy centre if the project proceeds. Details of the site can be found in Appendix 3: Site Survey Report.

5.2.5 Candidate Area 5 – Barrs Court Residential

Figure 45 and Table 54 provide details of the potential energy centre locations identified for the Residential candidate area.

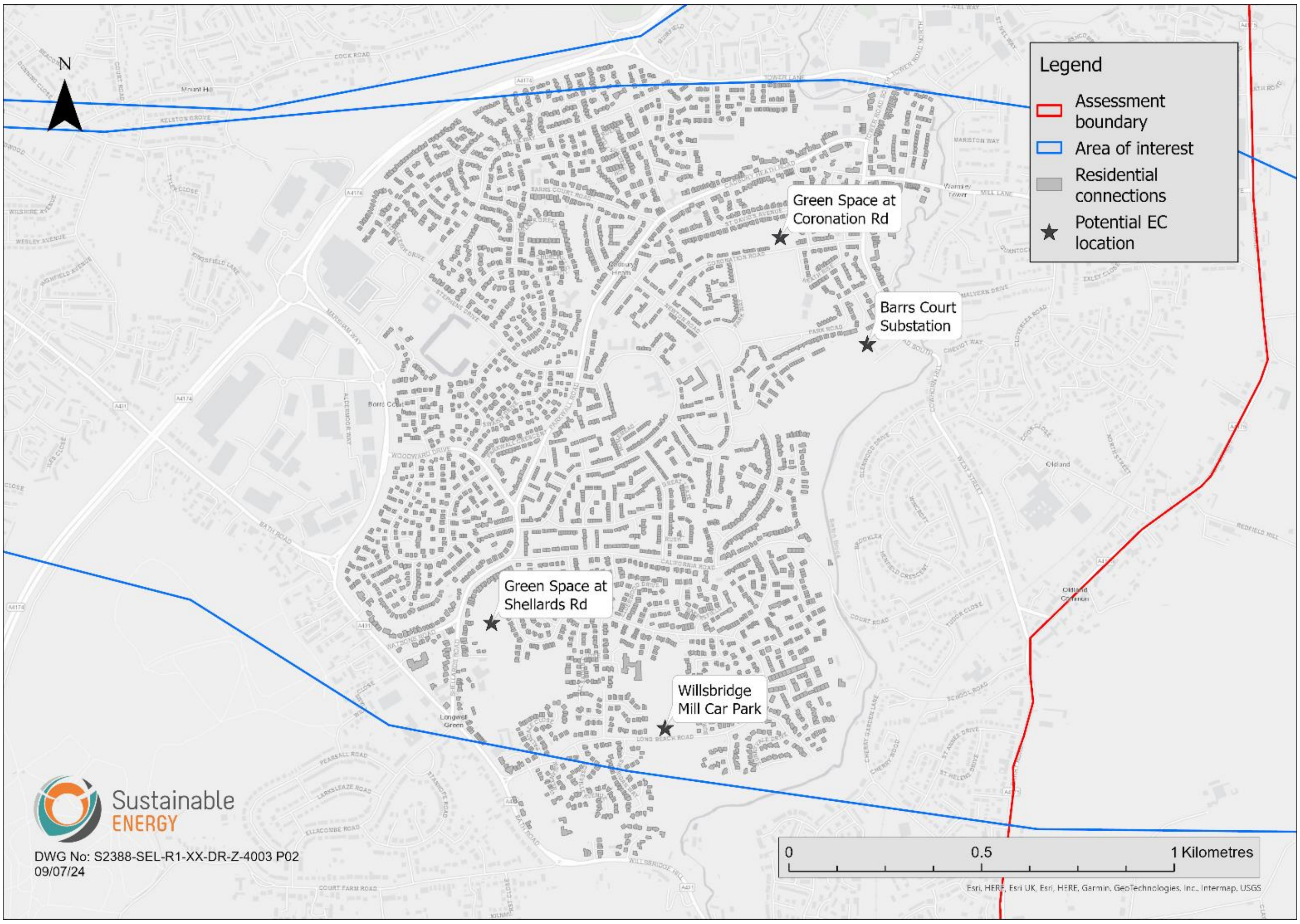


Figure 45: Barrs Court Residential candidate area potential energy centre locations

Table 23: Potential energy centre locations

Location	Land ownership	Current use	Comment
Green Space at Coronation Rd	Council-owned	Green space	Fenced-in green space Disused land
Barrs Court Substation		Recycling centre	A portion of the land beside the substation is council-owned Currently used as a recycling centre
Green Space at Shellards Rd		Green space	Large green space between residential clusters
Willsbridge Mill Car Park		Car park	Free car park, access to Willsbridge Mill and Willsbridge Valley local nature reserve

The preferred location for the energy centre was determined to be the Barrs Court Substation site, which is currently used as a recycling centre. Early engagement with the SGC waste team should take place to explore the possibility relocating the recycling centre if the project proceeds. Details of the site can be found in Appendix 3: Site Survey Report.

5.2.6 Summary

Several potential heat sources, including mine water, waste heat, and the SHM have been identified within the candidate areas. The key focus of this study is to develop a low-carbon heating and cooling solution utilising the existing mine seams identified by the Coal Authority, and so this study assumes that mine water is the primary low-carbon solution for all candidate areas. However, it is also understood that there are a large number of potential connections within each candidate area, and additional heat sources other than mine water may be needed to meet the required heat demand. Where applicable, the opportunity to utilise these additional heat sources, including data centre waste heat and SHM, will be assessed alongside the mine water source for a centralised solution.

The preferred energy centre locations have been selected accounting for the location of any available heat sources identified. The preferred energy centre location for each candidate area is within or in close proximity to the AOI identified by the Coal Authority, where mine seams are accessible. The preferred energy centre locations identified for each candidate area are:

- Candidate Area 1 – Lawrence Hill: Bristol Ambulance Station planned development
- Candidate Area 2 – Fishponds: Filwood House and Verona House planned development
- Candidate Area 3 – Bristol and Bath Science Park: Land North of Elderflower Drive
- Candidate Area 4 – Douglas Road Industrial Park: Moravian Road Business Park
- Candidate Area 5 – Barrs Court Residential: Barrs Court Substation

5.3 Key Potential Constraints

A desktop study for the proposed network route for each candidate area has been undertaken. Detailed network routing assessment and potential constraints identified within each candidate area are shown in section 5.4.

5.3.1 Terrain

Figure 46 shows the variation in elevation across the proposed energy demand assessment area. Changes in elevation are unlikely to pose a risk to the development of a network or affect the location of the energy centre in each candidate area.

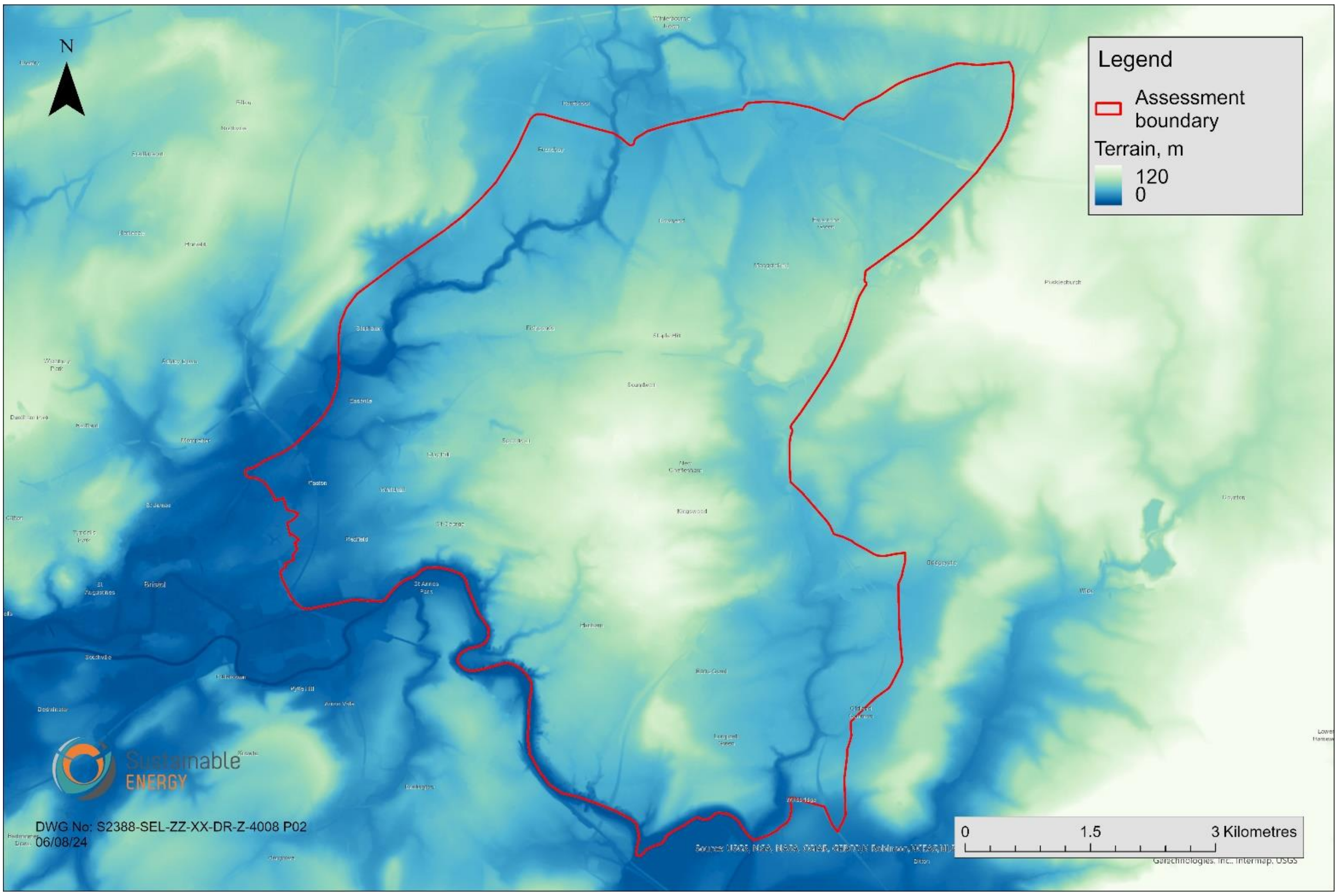


Figure 46: Terrain constraints

5.4 Heat Network Route Identification

To assess the network route in each candidate area, the web-based network routing tool THERMOS was used. THERMOS can determine an optimal route between a selected energy centre and a number of selected connections, accounting for dig type, costs, and energy demand. Network routes to all commercial connections were drawn using THERMOS, before being sense-checked and amended as appropriate.

Residential Network Routing

The THERMOS tool has limitations when modelling different types of residential properties, and therefore a different approach was used to assess low-rise residential areas. The Barrs Court Residential candidate area was identified as the lowest dwelling density of all candidate areas (20.4 dwellings/ha), whereas the residential portion of the Lawrence Hill candidate area was identified as the highest density (56.8 dwellings/ha). A full THERMOS model was generated to obtain network sizes and lengths in these two areas, which were then used as benchmarks for the remaining candidate areas.

Figure 47: Google Earth images of the Barrs Court Residential candidate area (left) and residential properties in Lawrence Hill (right)

An assessment of network feed length to individual residential connections (m/dwelling) was undertaken based on Lawrence Hill and the Barrs Court Residential candidate areas. In areas with higher residential density, a shorter feed length is required to connect each residential connection, whereas areas with lower residential density will require longer feed pipe lengths. Each candidate area was assigned a dwelling density somewhere between these two extremes. The residential feed length required to connect to each residential connection for each candidate area is shown in Table 24.

Table 24: Residential feed pipe connection length

Candidate area	Residential density	Feed length per dwelling, m/dwelling
Lawrence Hill	High	4.4
Fishponds	Low	6.5
Bristol and Bath Science Park	High	5.5
Douglas Road Industrial Park	Medium	5.8
Residential	Low	7.4

It was assumed that the final feed pipe to each property was shared between two houses, and the network pipe would enter the property at the nearest edge as illustrated in Figure 48. This significantly reduces network length and associated losses, in line with objective 2.5.1 of the Heat Networks Code of Practice.

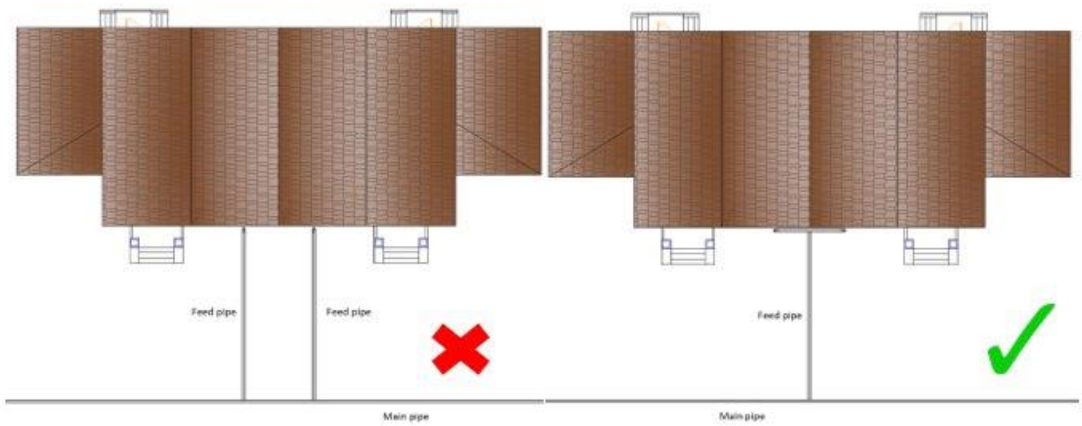


Figure 48: Assumptions for feed pipe connections to residential properties

5.4.1 Candidate Area 1 – Lawrence Hill

5.4.1.1 Key Potential Constraints

The key potential constraints within the Lawrence Hill candidate area are the railway and major roads (A420, A4320, and A432) as shown in Figure 49.

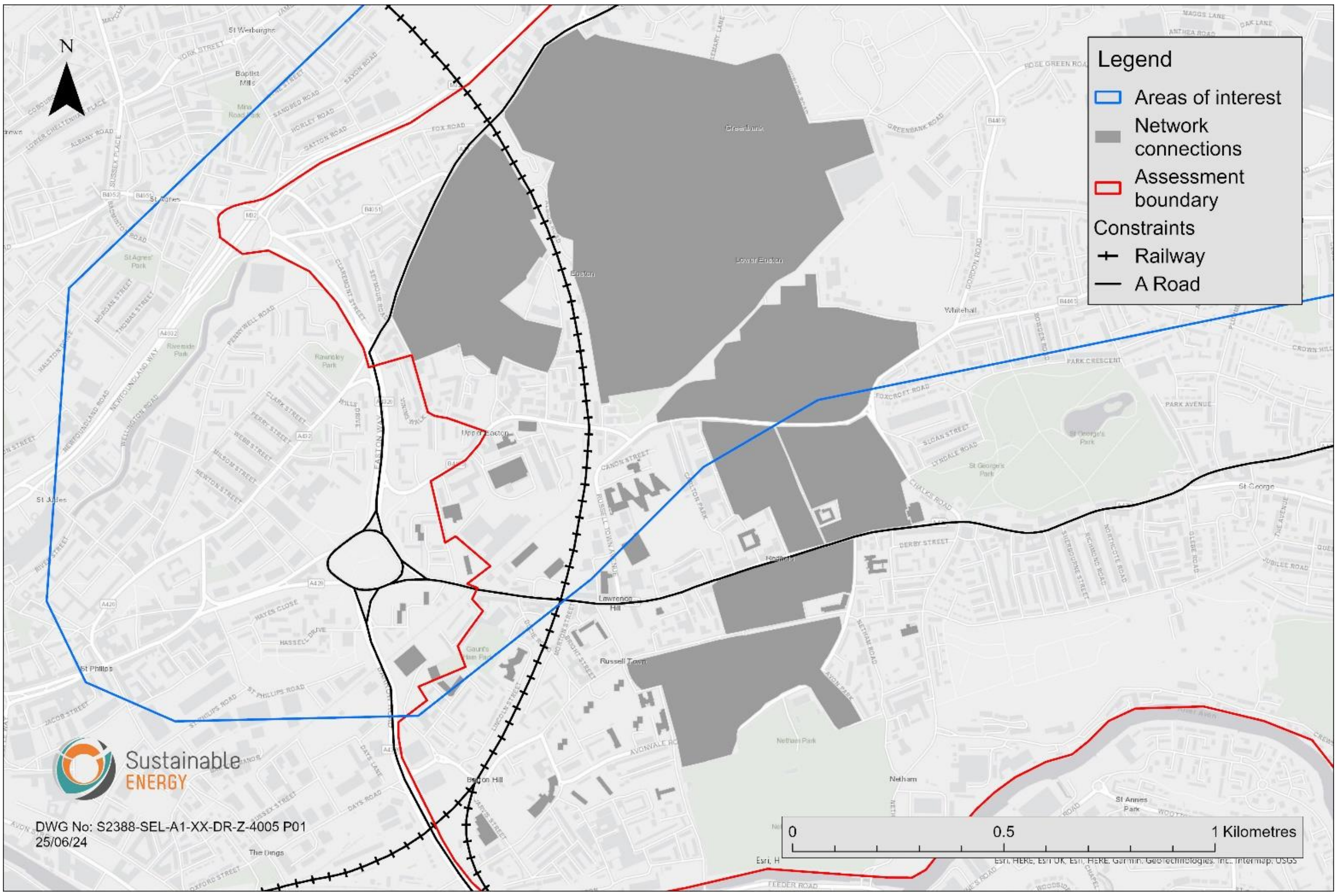


Figure 49: Lawrence Hill network constraints

5.4.1.2 Network Route Identification

Site terrain and land ownership, and potential natural and infrastructure constraints have been assessed for the Lawrence Hill candidate area. The proposed network route, including building connections, is shown in Figure 50; the ambient network option has the same network routing as the heating and cooling network.

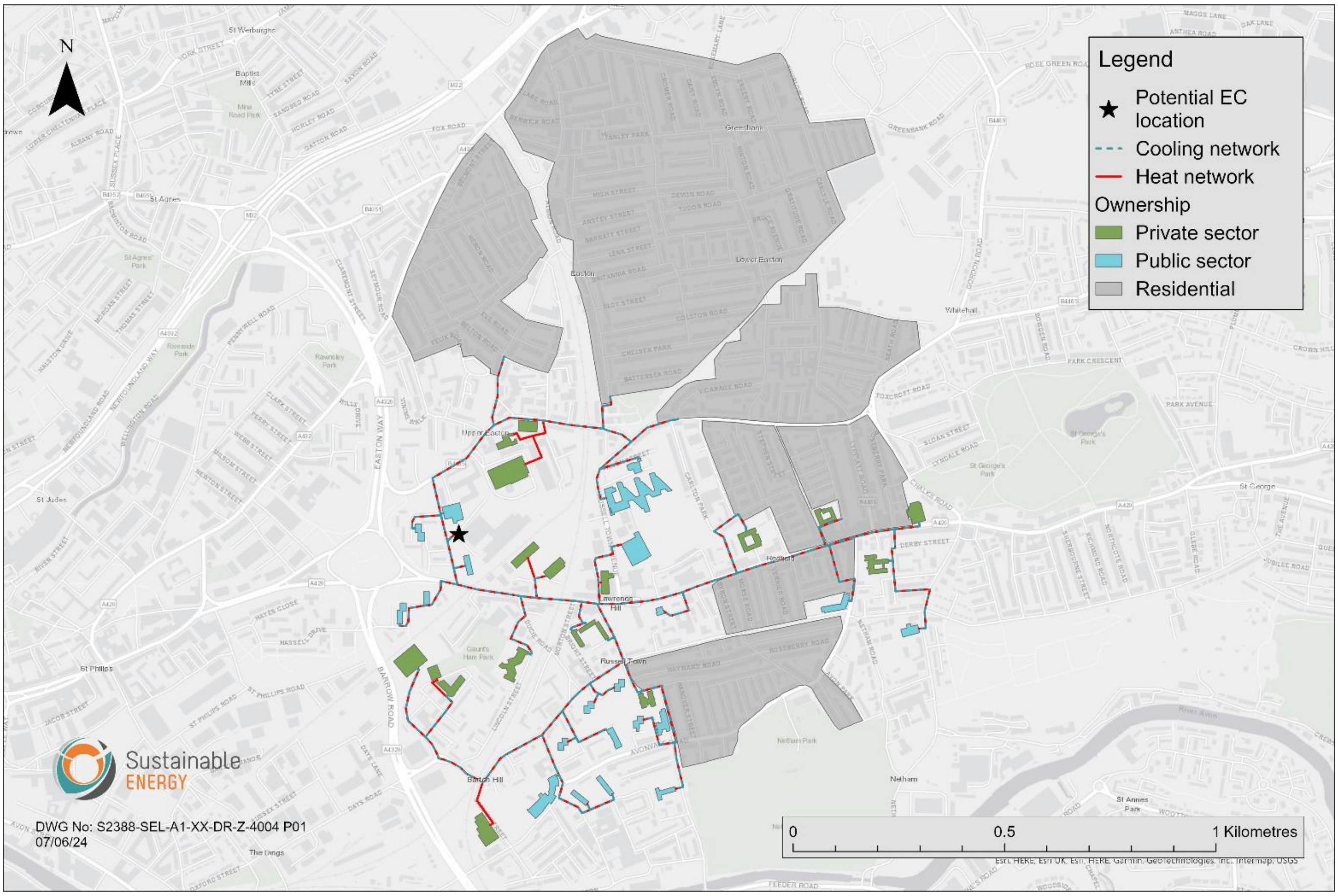


Figure 50: Lawrence Hill proposed network route

5.4.2 Candidate Area 2 – Fishponds

5.4.2.1 Key Potential Constraints

The key potential constraint within the Fishponds candidate area is the A432, as shown in Figure 51. Also, the River Frome runs along the edge of the candidate area, but this forms a natural boundary to the north.

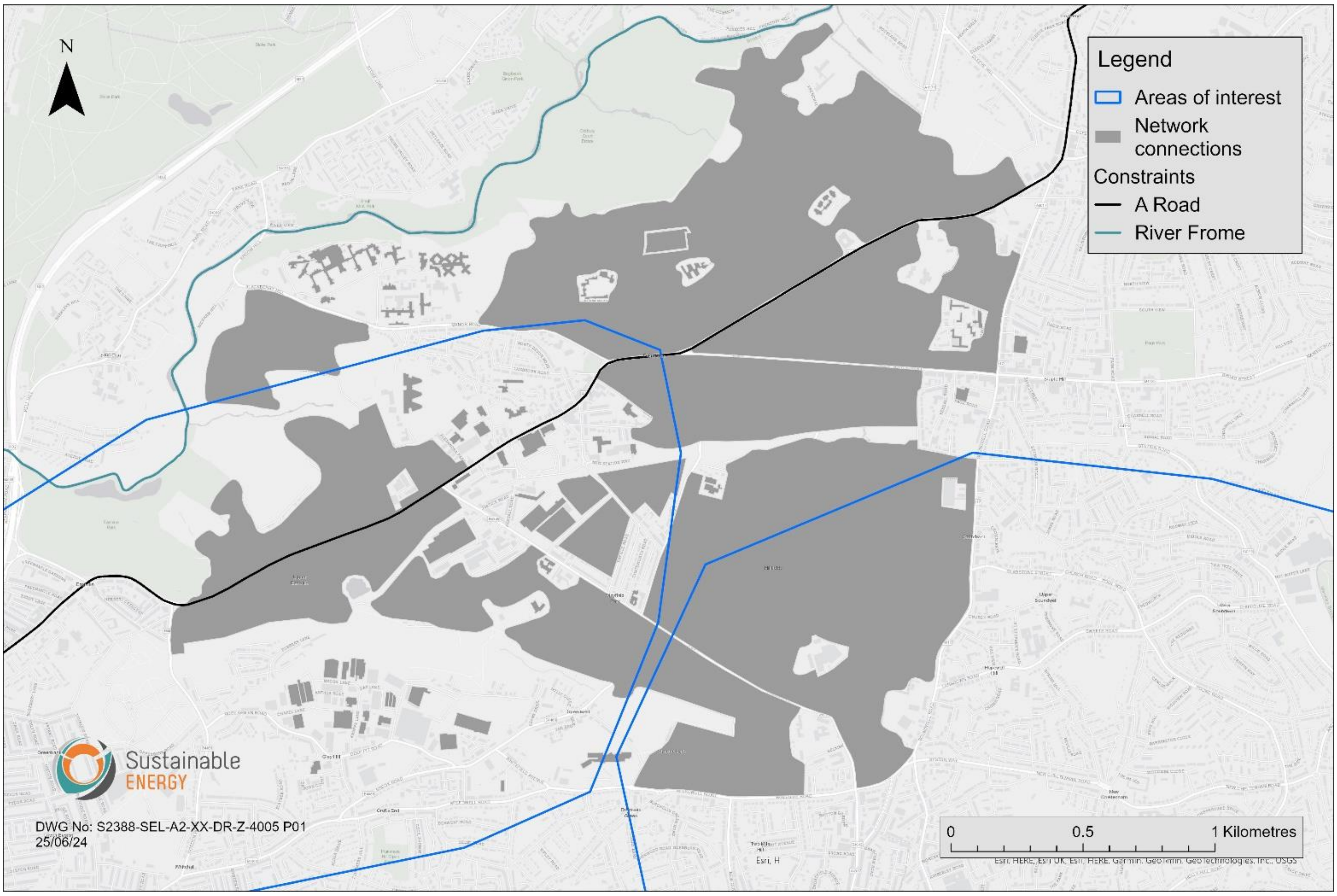


Figure 51: Fishponds network constraints

5.4.2.2 Network Route Identification

Site terrain and land ownership, and potential natural and infrastructure constraints have been assessed for the Fishponds candidate area. The proposed network route, including building connections, is shown in Figure 52. The ambient network option has the same network routing as the heating and cooling network.

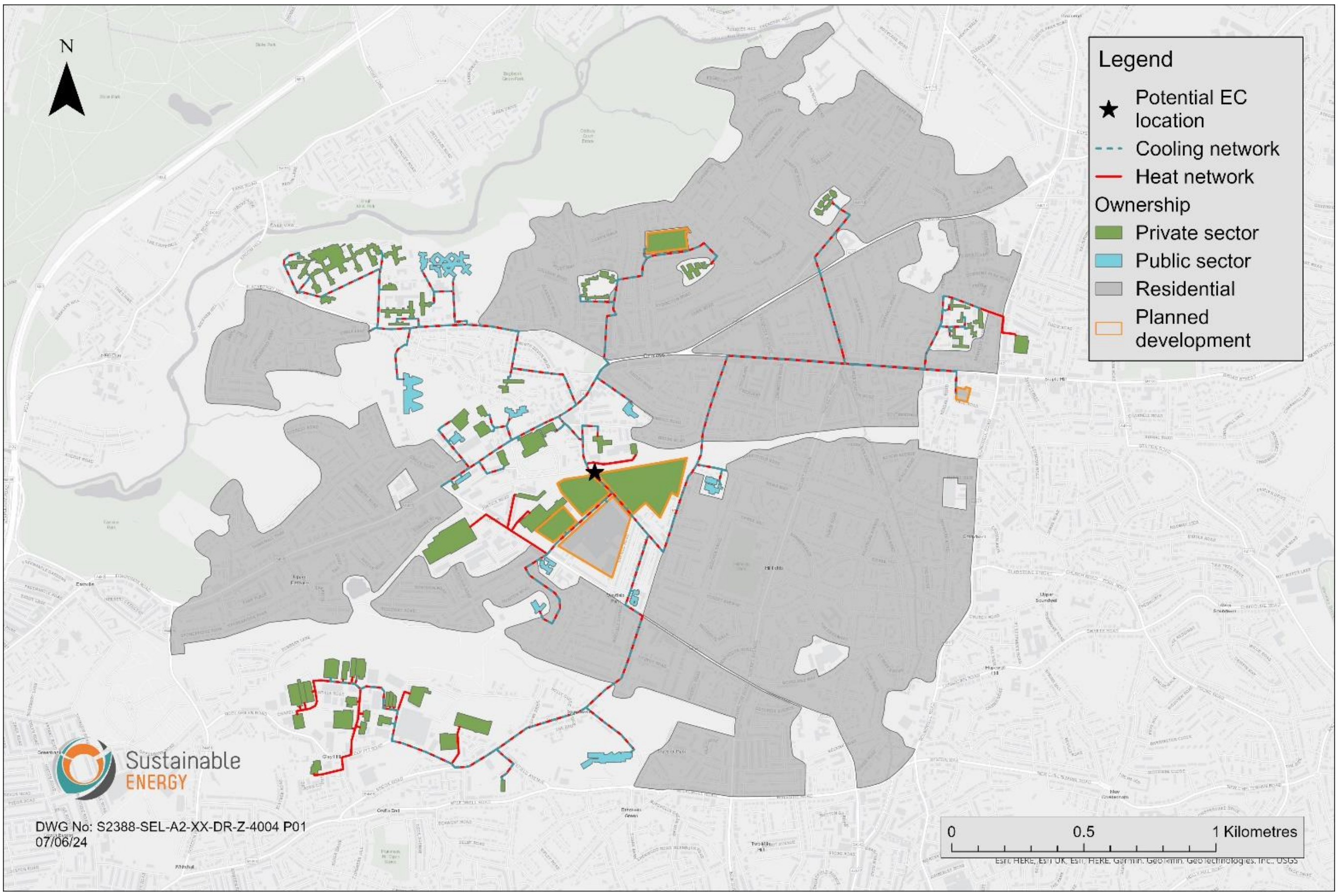


Figure 52: Fishponds proposed network route

5.4.3 Candidate Area 3 – Bristol and Bath Science Park

5.4.3.1 Key Potential Constraints

The key potential constraints identified within the BBSP candidate area are the M4 motorway, roundabouts along the A4174, and the Lyde Green Lake (and associated water course), as shown in Figure 53. The M4 separates the residential development at Lyde Green North from the rest of the BBSP connections. An underpass was identified that connects the development to BBSP, but further assessment is required to determine the viability of this as a network route.

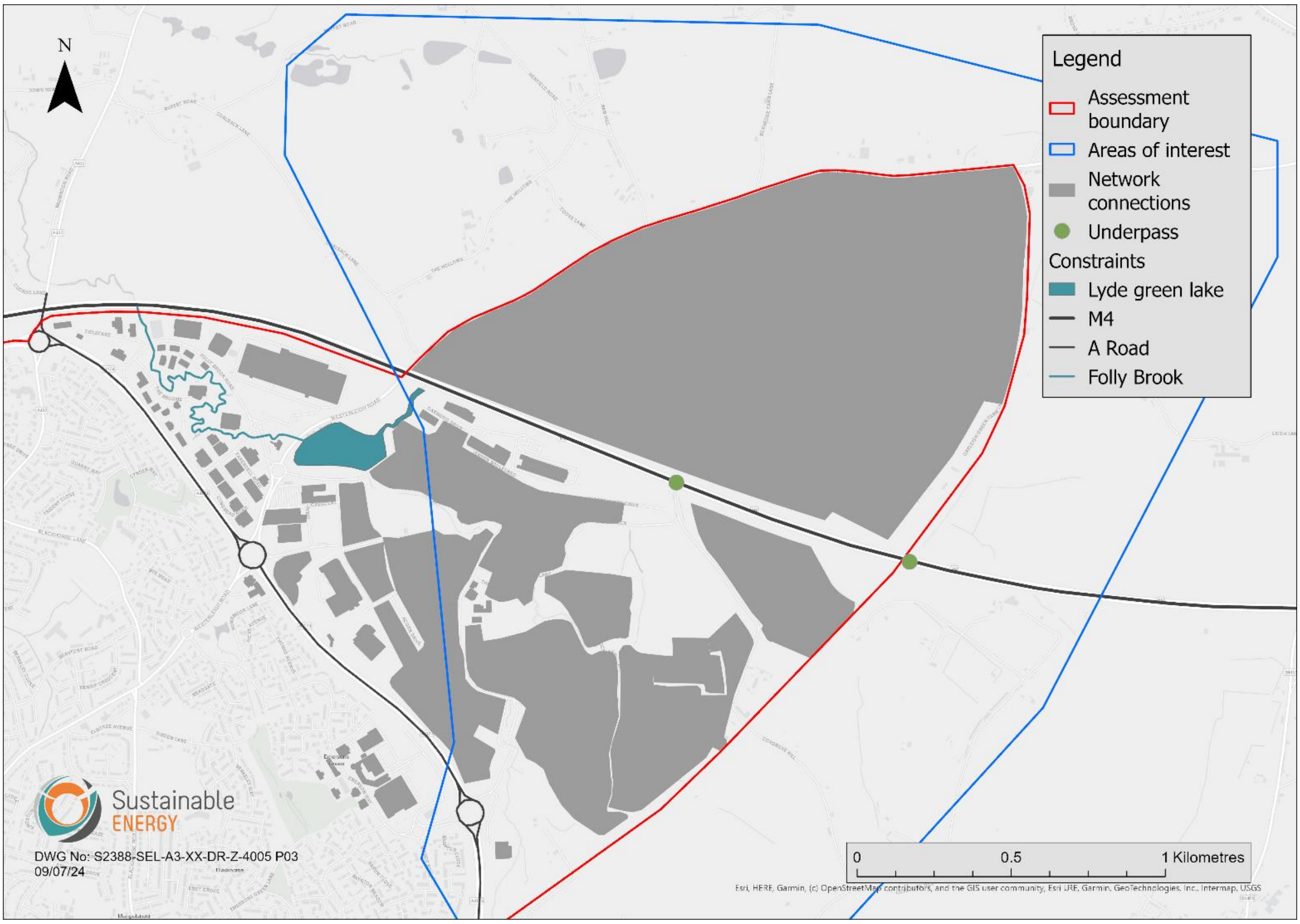


Figure 53: Bristol and Bath Science Park network constraints

5.4.3.2 Network Route Identification

Site terrain and land ownership, and potential natural and infrastructure constraints have been assessed for the BBSP candidate areas. The proposed network route including building connections is shown in Figure 18. The ambient network option has the same network routing as the heating and cooling network.

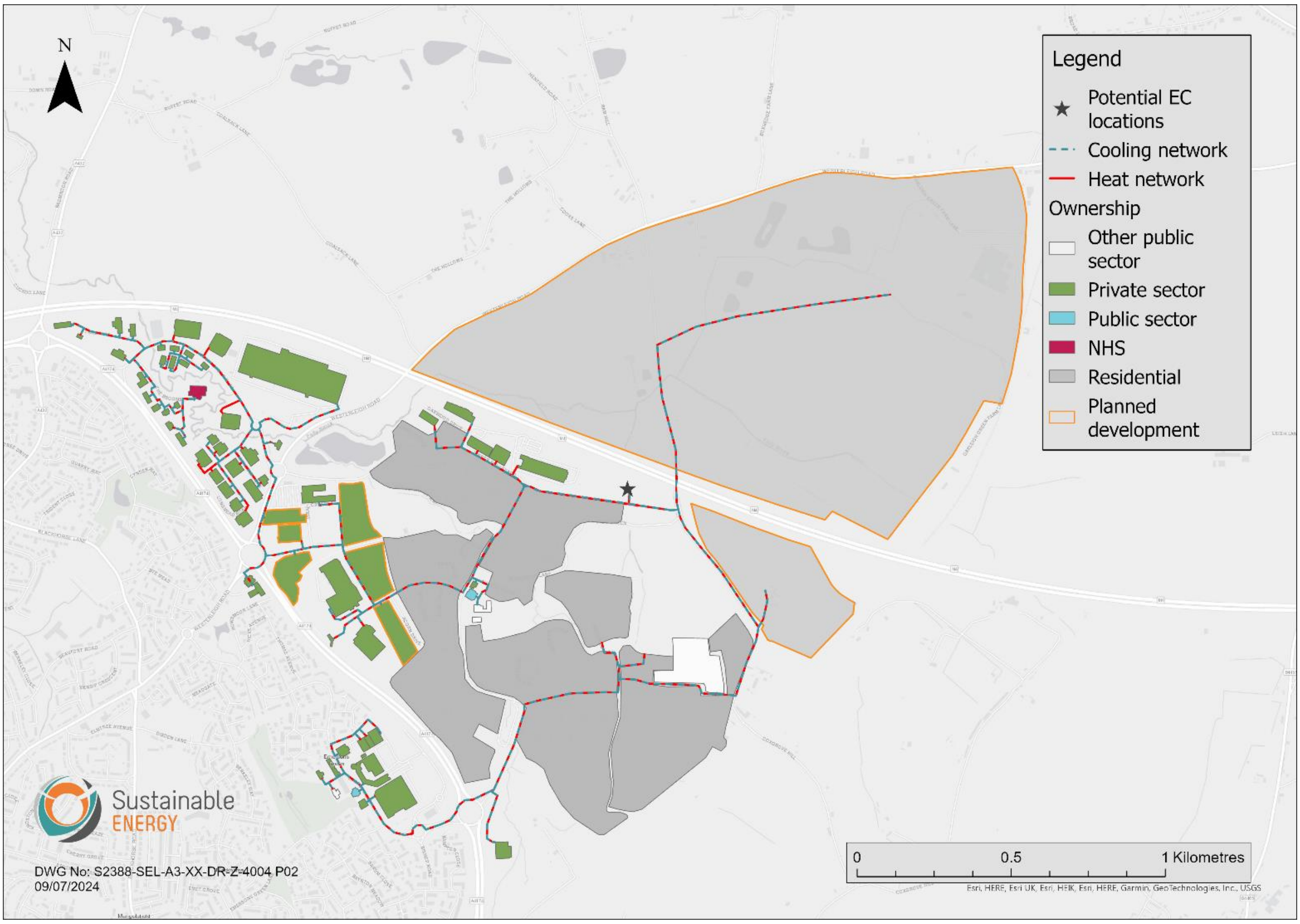


Figure 54: Bristol and Bath Science Park proposed network route

5.4.4 Candidate Area 4 – Douglas Road Industrial Park

5.4.4.1 Key Potential Constraints

The key potential constraints within the Douglas Road Industrial Park candidate area are major roads (the A420, A431, and A4174) as shown in Figure 55.

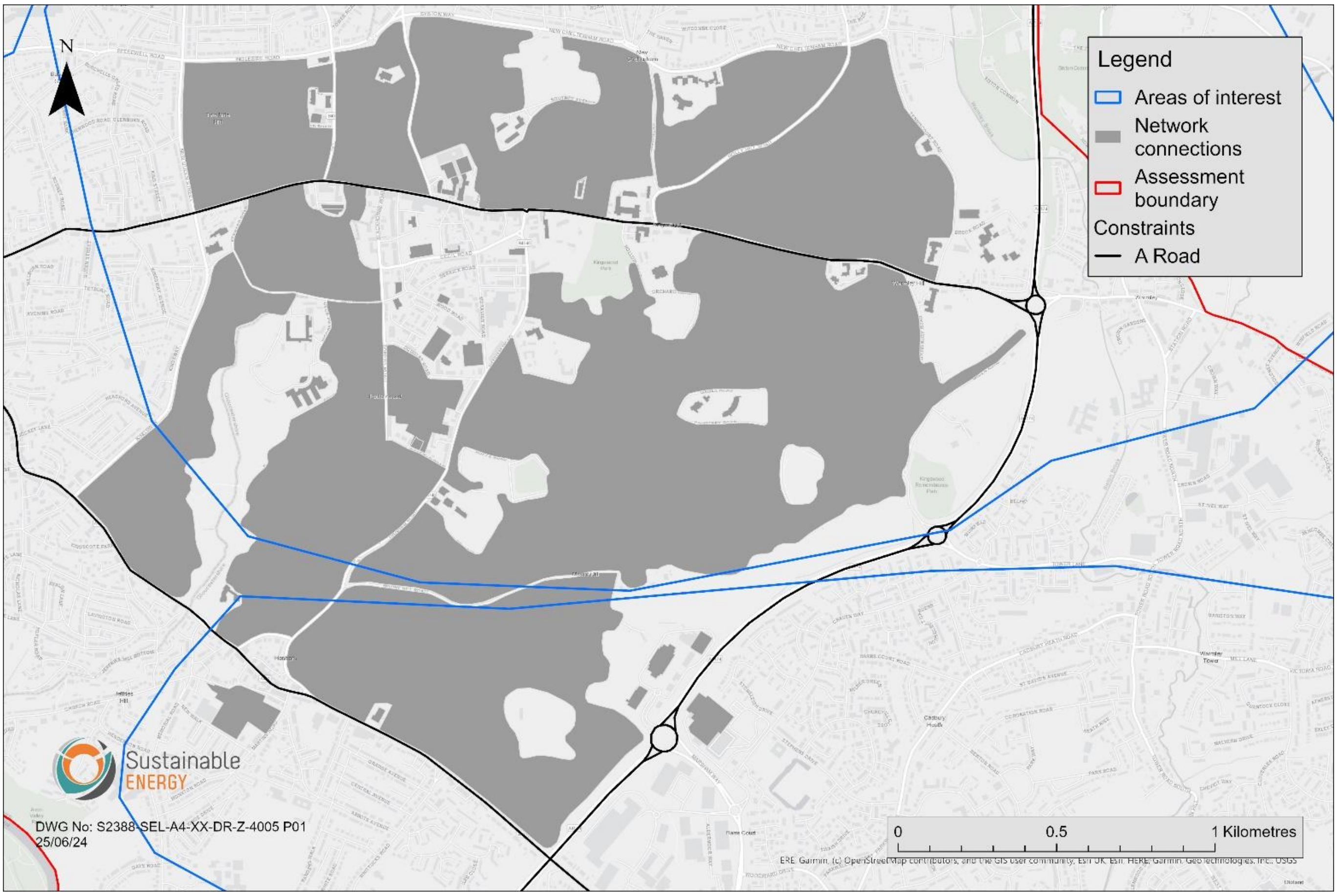


Figure 55: Douglas Road Industrial Park network constraints

5.4.4.2 Network Route Identification

Site terrain and land ownership, and potential natural and infrastructure constraints have been assessed for the Douglas Road Industrial Park candidate area. The proposed network route, including building connections, is shown in Figure 40. The ambient network option has the same network routing as the heating and cooling network.

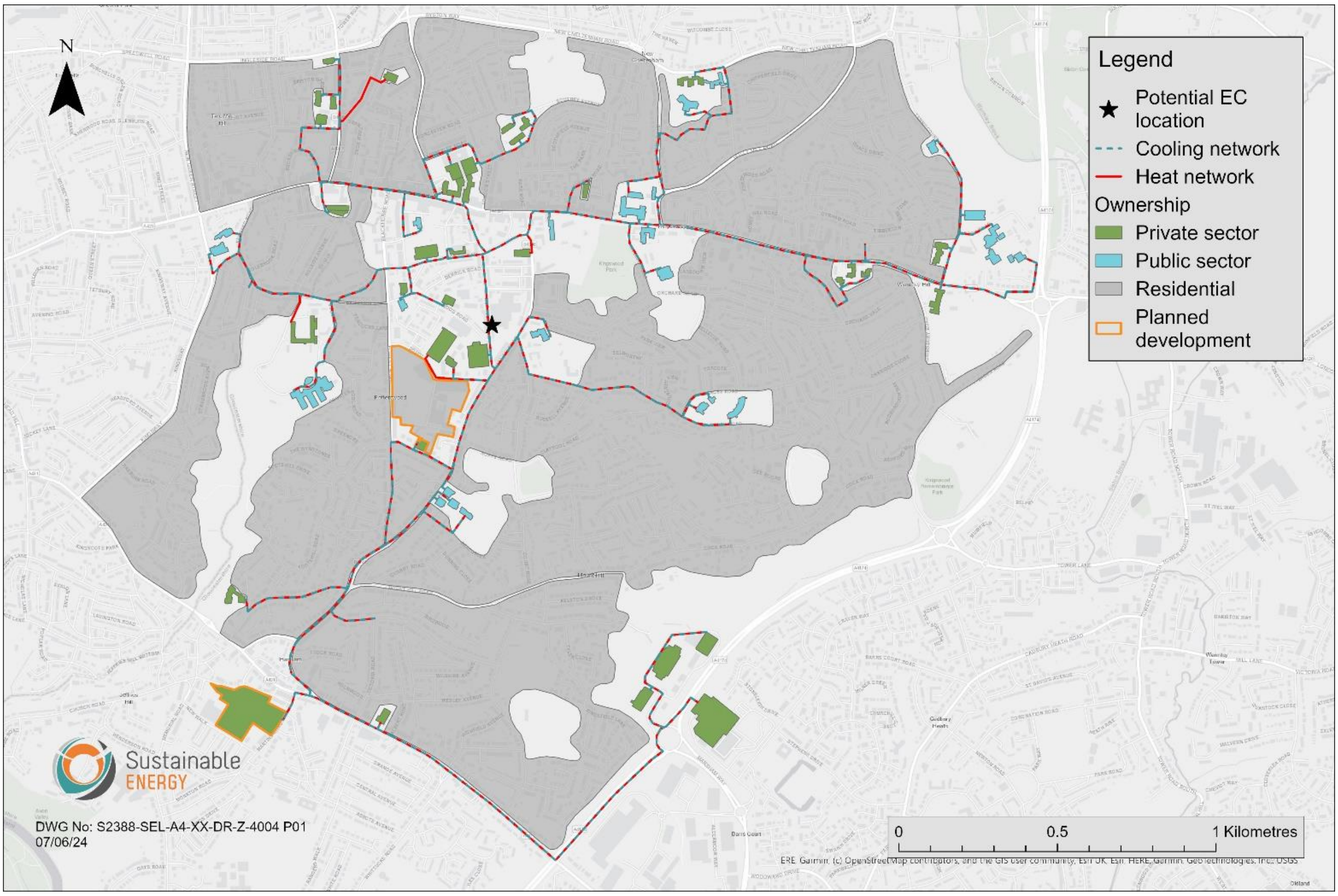


Figure 56: Douglas Road Industrial Park proposed network route

5.4.5 Candidate Area 5 – Barrs Court Residential

5.4.5.1 Key Potential Constraints

The key potential constraints identified within the Barrs Court Residential candidate area are the roundabouts along the A4174, and the Siston Brook as shown in Figure 57, but as these are mainly located along the edge of the Barrs Court Residential candidate area they form a natural boundary.

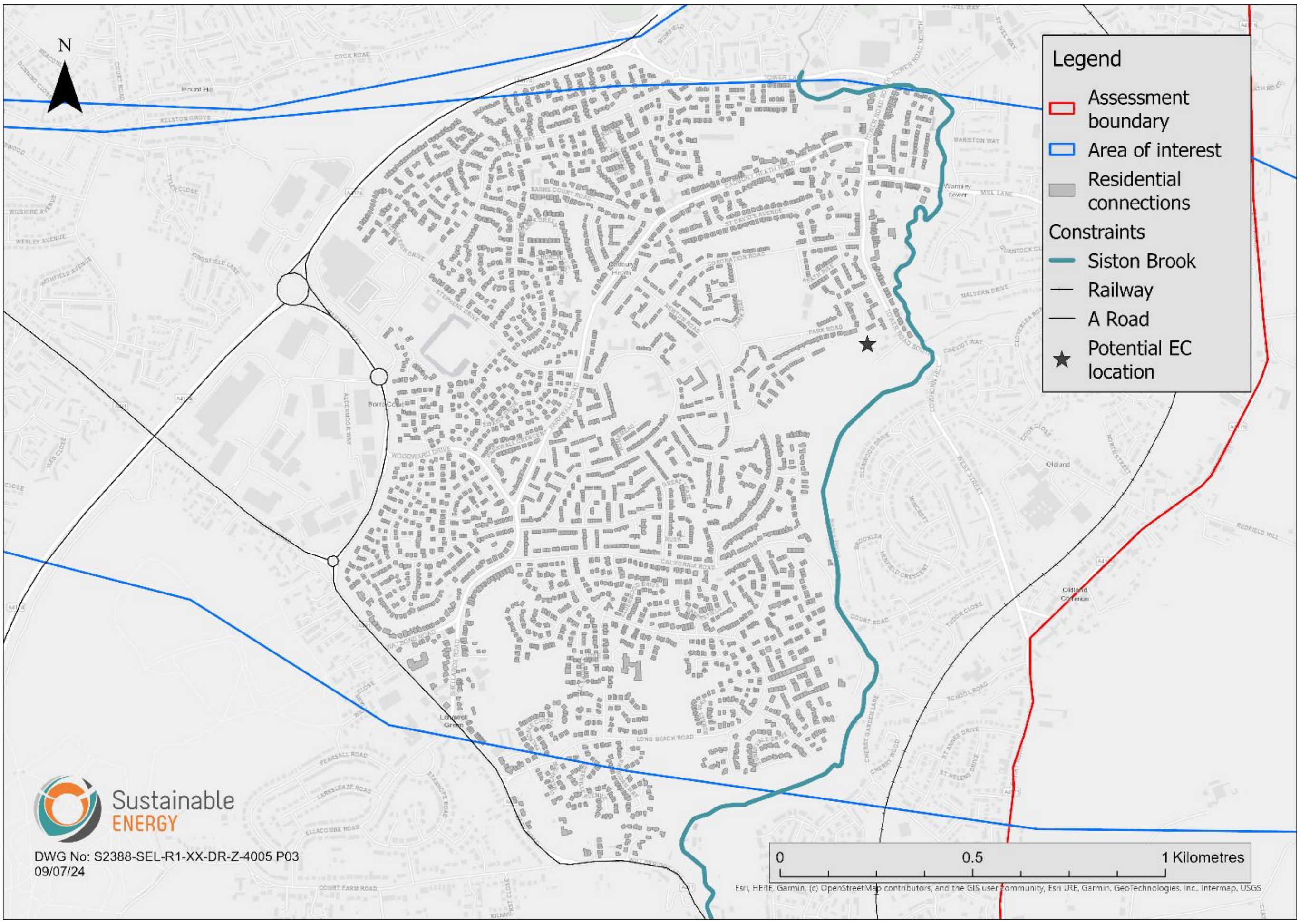


Figure 57: Barrs Court Residential candidate area network constraints

5.4.5.2 Network Route Identification

Site terrain and land ownership, and potential natural and infrastructure constraints have been assessed for the Barrs Court Residential candidate area. The proposed network route including building connections is shown in Figure 58. The ambient network option has the same network routing as the heating and cooling network.

Figure 58: Barrs Court Residential candidate area proposed network route

5.5 Energy Centre and Network Capacity Summary

It is proposed that energy centres/pumping stations for each candidate area will be constructed within potential planned development sites or Council-owned land.

Backup gas boilers will be used to provide heat at times of peak demand (if this exceeds the capacity of the heat pumps and thermal stores) for the heat and cooling network (HCN) option, or as a reserve heat source during times of heat pump maintenance or failure. The heat network control system will prioritise heat from the heat pumps and thermal stores over the peak and reserve boilers, to maximise low-carbon heat use. It is assumed that the peak and reserve boilers will only contribute 5% of the total network heat demand.

To reduce the network CO_2e intensity in the longer term, electric boilers could be installed in place of gas boilers. However, the use of electric boilers will increase the scheme OPEX as electricity costs are higher than gas costs. A summary of the energy centre capacity and footprint for each candidate area is shown in Table 25.

Table 25: Energy centre capacity summary

	Lawrence Hill	Fishponds	BBSP	Douglas Road Industrial Park	Barrs Court Residential
Preferred Energy Centre Location	Bristol Ambulance Station	Filwood House & Verona House	Land North of Elderflower Dr	Moravian Road Business Park	Barrs Court Substation
Required heat capacity (HCN), kW	14,640	33,330	13,000	27,250	10,600
Required cooling capacity (HCN), kW	9,020	22,820	15,100	18,040	5,100

	Lawrence Hill	Fishponds	BBSP	Douglas Road Industrial Park	Barrs Court Residential
Required peak and reserve boiler capacity, kW	17,970	40,910	16,000	33,440	13,010
Approx. energy centre footprint (HCN), m^2	3,037	7,144	3,408	5,778	2,055

6 CANDIDATE AREA TECHNO-ECONOMIC MODELLING

A Techno-Economic Model (TEM) has been constructed to assess the economics of each option for each candidate area. The key assumptions for the TEM and key parameters are shown in Appendix 2: Key Parameters and Assumptions.

The sensitivity of all key assumptions and energy tariffs has been assessed, see section 6.2. The TEM provided with this report allows key variables to be revised and the associated impact assessed.

As some candidate areas have significant demands from low-rise residential properties, these are likely to have outsized effects on the project's economics. This section therefore presents the TEM outputs for each candidate area, for two scenarios: with low-rise residential and without low-rise residential.

6.1 Model Structure

Figure 59 shows an overview of the tabs included in the TEM. Tabs relevant to the standard user are shown in grey. These tabs include the key model inputs and variables and display the key results from the model. Tabs that involve technical inputs and calculations are shown in green, while the tabs that involve financial inputs and calculations are shown in orange. A user guide and a full list of assumptions have also been included in the TEM.

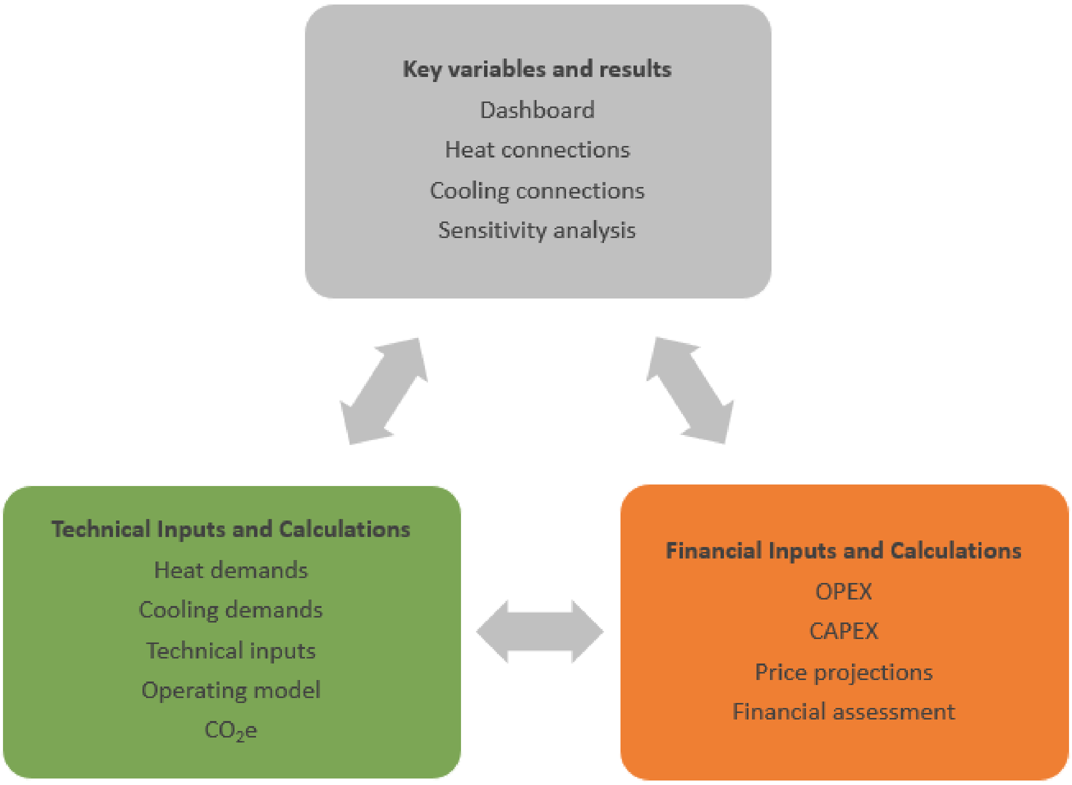


Figure 59: Techno-economic model structure

6.2 Key Assumptions

6.2.1 Energy Price Projections

The TEM uses the 2023 DESNZ central scenario price projections for natural gas and electricity, for both commercial and domestic users. These prices are used for each building on the network in the cases of ambient networks, individual ASHPs and BAU, as in these options the building will be purchasing either electricity or gas to meet their energy demands. In the case of the heating/cooling network (HCN), the energy centre will purchase gas and electricity to generate heating and cooling to serve the network demands. The projected changes in prices for electricity and natural gas for residential, services and industrial are illustrated in Figure 60.

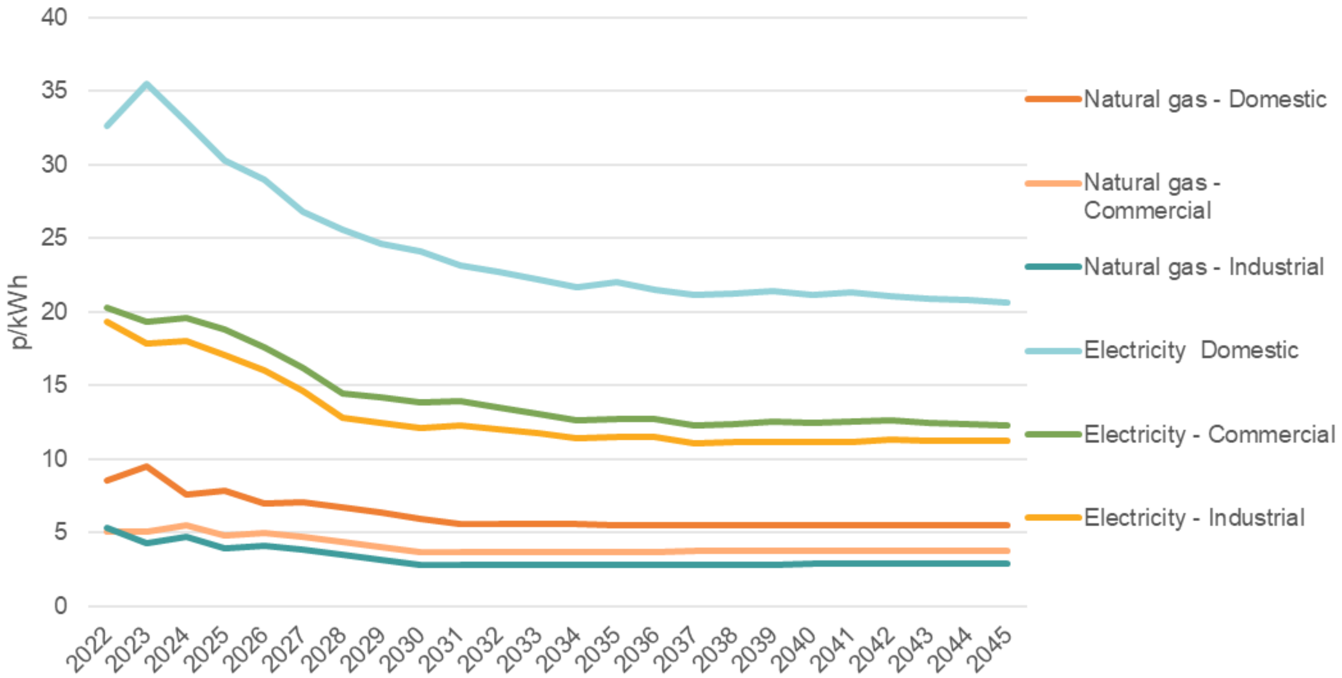


Figure 60: DESNZ[5] price projections – central scenario, updated 2023

The above projections indicate that, in the long term, energy prices will stabilise beyond 2026. The DESNZ low and high scenarios, as well as a fixed indexation rate, have also been assessed for the network option and their effect is shown in the sensitivity section. Additionally, the projected trend may be affected by policy changes over time, such as modifications to the electricity market from market balancing or the Review of the Electricity Market Arrangements (REMA) initiative.

6.2.2 Initial Capital and Replacement Costs

Technology replacement costs are modelled on an annualised basis and consider the capital costs, expected lifetime, fractional repairs and the length of the business term. Details of the expected equipment lifetime are shown in Appendix 2: Key Parameters and Assumptions.

Capital costs for key plant items are based on a combination of previous project experience, quotations for recent similar works and soft market testing and budget quotes.

For options with networks, costs were estimated using a breakdown of each network pipe. This accounts for pipe size, pipe length, and hard/easy dig conditions. These quantities have then been multiplied by the average rates taken from numerous quotations obtained for similar work.

Contingency has been applied to each element of capital expenditure as appropriate. A breakdown of capital costs and contingency values for each phase is shown in Appendix 2: Key Parameters and Assumptions.

6.2.3 Environmental Benefit and Impacts – CO_2e Emission Assessment

CO_2e intensity projections for grid electricity and natural gas are shown in Figure 61. Two CO_2e projections for grid electricity have been considered:

- DESNZ long run marginal figure (commercial)
- DESNZ long run marginal figure (domestic)

[5] Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal - GOV.UK (www.gov.uk)

The long run marginal emissions factors consider the marginal plant for electricity generation. The projections are based on assumptions of future economic growth, fossil fuel prices, electricity generation costs, UK population and other key variables which are regularly updated. Each set of projections takes account of climate change policies where funding has been agreed and where decisions on policy design are sufficiently advanced to allow robust estimates of policy impacts to be made. The CO_2e emissions for the electricity grid are expected to reduce over time due to the increase in wind, solar and nuclear power.

These figures have been used for all electricity imported from the grid (i.e., for heat pump and energy centre electricity demand). The long run marginal figures have been used for grid electricity import and the natural gas figures have been used for the counterfactual CO_2e emissions and the gas boilers in the HCN option.

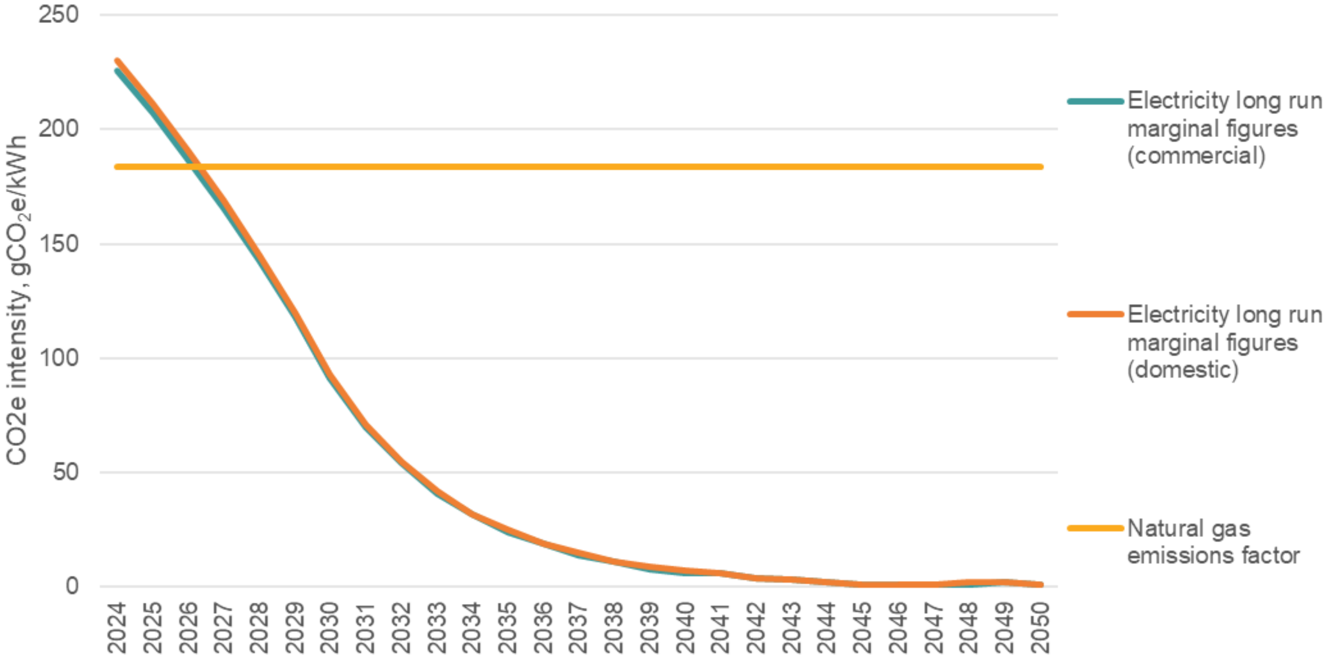


Figure 61: CO_2e emissions projections[6], updated Nov 2023

6.2.4 NPC and Social NPC

Net Present Cost (NPC) represents the total cost of the project, including capital costs, operational expenditure, and replacement costs, over its lifetime, considering a discount rate over time (3.5% in this case). A lower NPC indicates that the scheme is potentially cheaper to deliver and operate.

The social NPC helps to identify the wider benefits of the scheme for the community, namely CO_2e savings and air quality improvements from not burning gas. The social NPC is determined by monetising the CO_2e savings and the improvements in air quality from implementing one of the low-carbon options in comparison to the BAU. The economic value of the carbon savings and air quality improvements are then included in the project cash flow, and offset some of the capital, operational and replacement costs. In the BAU scenario, the social NPC is therefore equal to the NPC as there are no CO_2e savings or air quality improvements.

These figures are based on DESNZ figures and projections and are in £/tCO_2e for carbon savings and p/kWh of gas/electricity for air quality improvements. These account for the reduction in future costs of mitigating the effects of climate change, and the reduction in healthcare costs associated with the improved air quality by removing individual gas boilers across the city.

The DESNZ carbon price projections include low, central, and high scenarios. The carbon price and air quality damage costs used in this assessment are shown in Figure 62.

[6] Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal - GOV.UK (www.gov.uk)

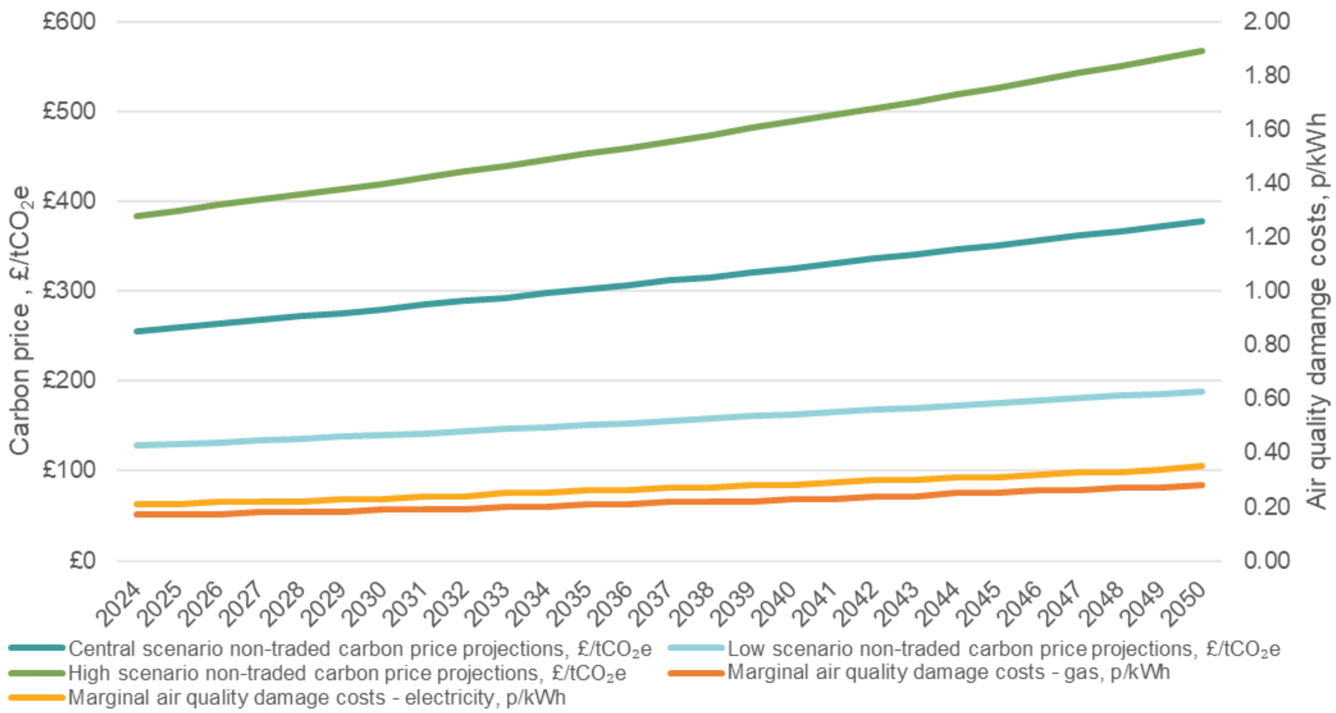


Figure 62: Carbon price and air quality damage costs

Based on the figures above, most of the social benefits are from the CO_2e savings, with the improvements in air quality yielding circa 3% of what the carbon savings achieve.

In summary, the social NPC is calculated as below:

$$Social\ NPC = NPC - CO_2e\ savings - Air\ quality\ savings$$

6.3 Techno-Economic Output

6.3.1 Candidate Area 1 – Lawrence Hill

Network Summary

The heat and cooling demands shown are for 2020 and 2080, respectively. A summary of all the network scheme options for the Lawrence Hill candidate areas is shown in Table 26.

Table 26: Network summary – Lawrence Hill with residential connections

	BAU	Individual ASHP	MWSHP	Ambient Network
Total heat demand (excl. losses), kWh	73,151,027			
Total heat demand (incl. losses), kWh			79,003,109	
Total cooling demand (excl. losses), kWh	6,826,741			
Total cooling demand (incl. losses), kWh			7,099,810	
Network spine trench length - Heat, m			7,281	
Network spine trench length - Cooling, m			6,823	
Network spine trench length - Ambient, m				7,281
Low carbon heat capacity, kW	-	40,960	14,640	40,960
Low carbon cooling capacity, kW	13,880	13,880	9,020	13,880
Gas boiler capacity, kW	40,960	-	17,970	-
% heat demand met by low carbon / technology	-	100%	95%	100%

Economic Assessment

The economic performance of all scheme options for the Lawrence Hill candidate area is shown in Table 27 and Figure 63.

Table 27: Economic assessment – Lawrence Hill with residential connections

	BAU	Individual ASHP	HCN	Ambient Network
Capital costs (including contingency), £	£71,826,451	£150,323,623	£249,047,687	£194,849,399
Discounted OPEX – 60 years, £	£157,169,598	£195,110,596	£123,276,777	£159,249,101
Discounted REPEX – 60 years, £	£52,408,645	£59,362,292	£11,543,165	£44,206,476
Net Present Cost – 60 years, £	£275,618,099	£401,883,433	£368,625,978	£395,245,943
Levelised cost of energy – 60 years, p/kWh	14.7	21.4	19.6	21.1
Total carbon saving against BAU, tCO_2e	-	818,006	777,995	821,603
Social NPC – 60 years	-	£275,903,583	£268,159,889	£248,837,129

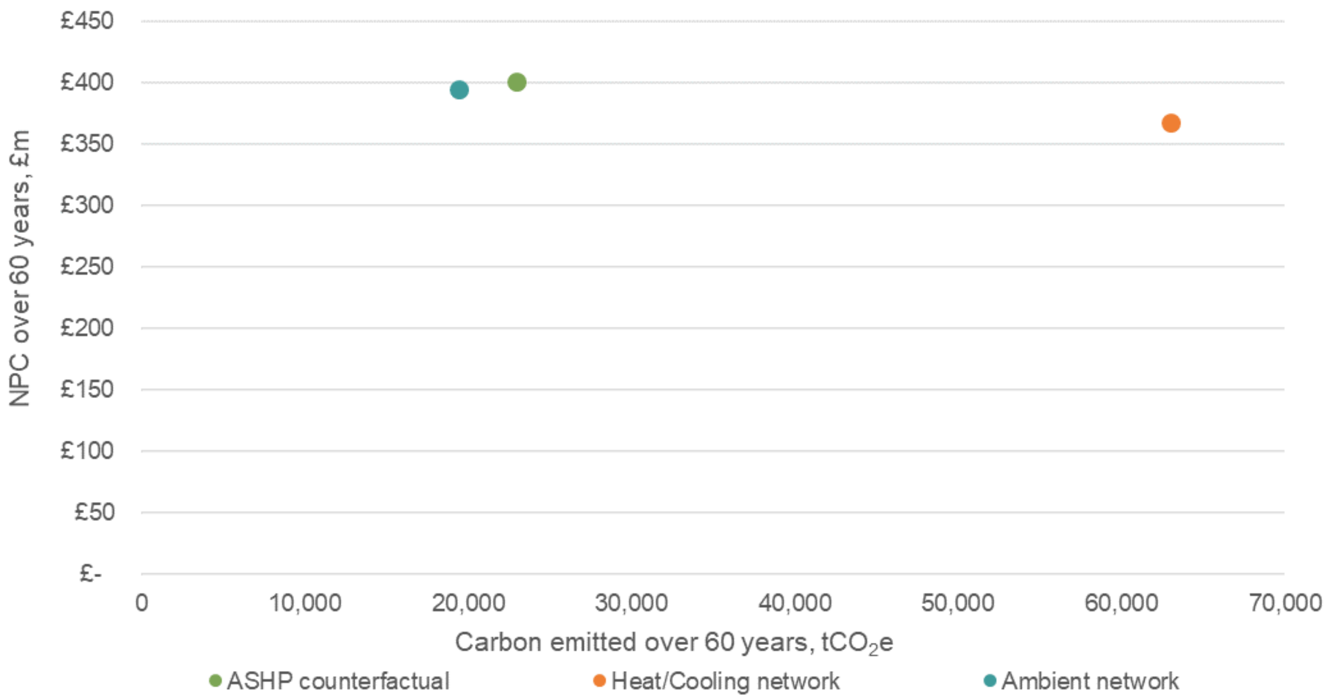


Figure 63: NPC vs Carbon emission – Lawrence Hill with residential connections

CO_2e Assessment

The carbon performance of different network scheme options is shown in Figure 64 and Table 28.

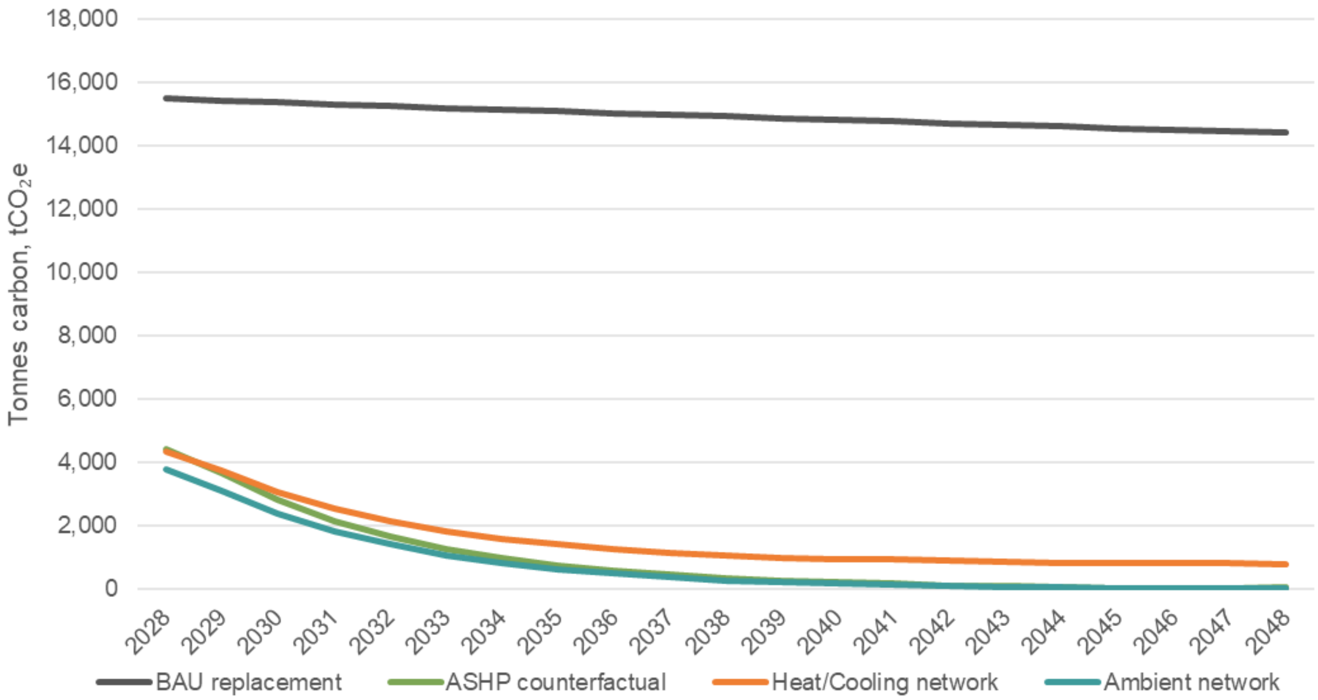


Figure 64: Scheme options lifetime carbon emissions over 20 years – Lawrence Hill with residential connections

Table 28: Scheme options carbon emissions – Lawrence Hill with residential connections

Scheme option carbon performance	BAU	Individual ASHP	HCN	Ambient network
Carbon intensity of energy delivered in year 2030, gCO_2e/kWh	210.8	38.7	41.9	32.8
Carbon intensity of heat delivered in year 2030, gCO_2e/kWh	216.3	39.3	42.8	33.6
tCO_2e savings against BAU over 60 years	-	818,006	777,995	821,603
Total carbon emitted over 60 years, tCO_2e	840,983	22,977	62,988	19,380
First year CO_2e savings, tCO_2e	-	11,044	11,124	11,719

6.3.1.1 Lawrence Hill Without Residential Connections

Network Summary

A summary of all the network scheme options for the Lawrence Hill candidate areas without residential connections is shown in Table 29.

Table 29: Network summary – Lawrence Hill without residential connections

	BAU	Individual ASHP	HCN	Ambient Network
Total heat demand (excl. losses), kWh	20,199,081			
Total heat demand (incl. losses), kWh			21,815,008	
Total cooling demand (excl. losses), kWh	3,615,256			
Total cooling demand (incl. losses), kWh			3,759,866	
Network spine trench length - Heat, m			6,858	
Network spine trench length - Cooling, m			6,400	
Network spine trench length - Ambient, m				6,858
Low carbon heat capacity, kW	-	9,710	3,470	9,710
Low carbon cooling capacity, kW	5,670	5,670	3,690	5,670
Gas boiler capacity, kW	9,710	-	4,260	-
% heat demand met by low carbon / technology	-	100%	95%	100%

Economic Assessment

The economic performance of all scheme options for the Lawrence Hill candidate area is shown in Table 30 and Figure 65.

Table 30: Economic assessment – Lawrence Hill without residential connections

	BAU	Individual ASHP	HCN	Ambient Network
Capital costs (including contingency), £	£13,092,451	£47,220,550	£50,203,753	£45,844,326
Discounted OPEX – 60 years, £	£28,989,693	£40,004,186	£34,787,169	£34,238,408
Discounted REPEX – 60 years, £	£9,170,291	£10,358,824	£2,734,983	£6,733,236
Net Present Cost – 60 years, £	£49,978,006	£97,223,080	£85,076,372	£86,419,471
Levelised cost of energy – 60 years, p/kWh	9.1	17.7	15.5	15.7
Total carbon saving against BAU, tCO_2e	-	221,458	210,132	222,170
Social NPC – 60 years	-	£62,368,766	£51,458,335	£52,556,803

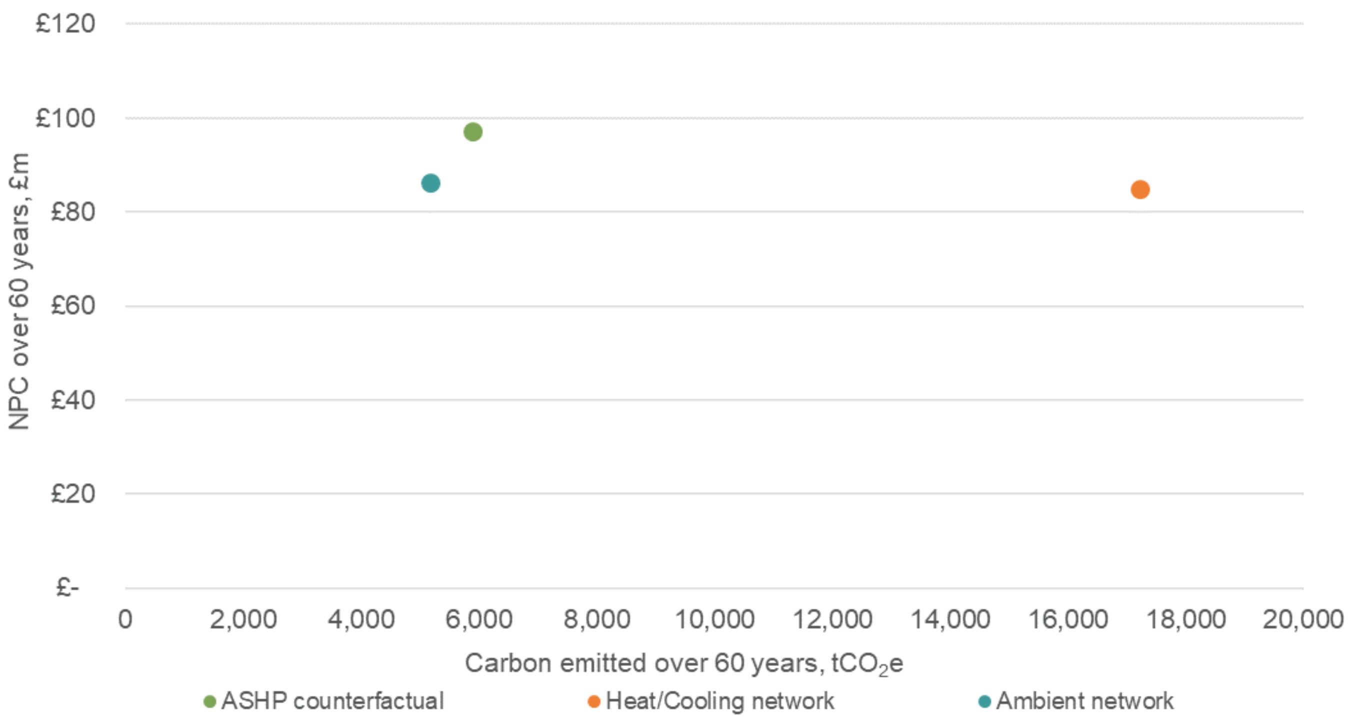


Figure 65: NPC vs Carbon emission – Lawrence Hill without residential connections

CO_2e Assessment

The carbon performance of different network scheme options is shown in Table 31 and Figure 66.

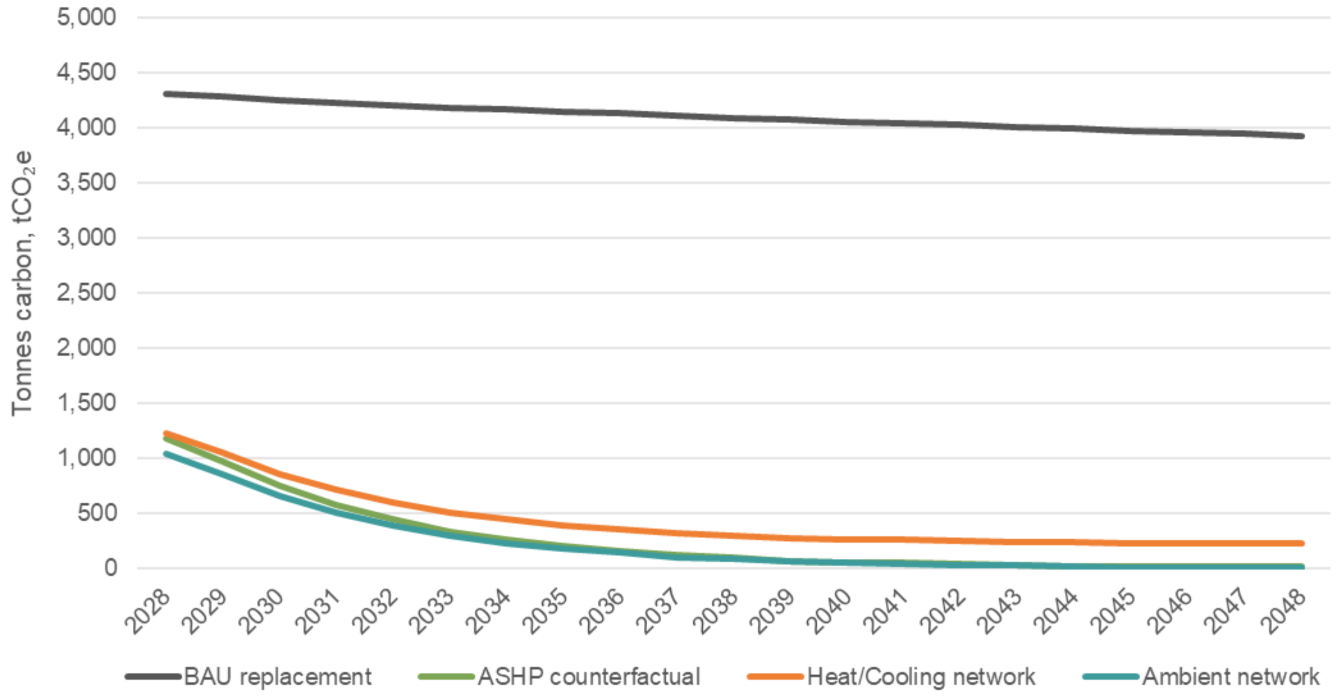


Figure 66: Scheme options lifetime carbon emissions over 20 years – Lawrence Hill without residential connections

Table 31: Scheme options carbon emissions – Lawrence Hill without residential connections

Scheme option carbon performance	BAU	Individual ASHP	HCN	Ambient network
Carbon intensity of energy delivered in year 2030, gCO_2e/kWh	197.6	34.7	39.8	30.6
Carbon intensity of heat delivered in year 2030, gCO_2e/kWh	216.3	36.4	42.8	33.4
tCO_2e savings against BAU over 60 years	-	221,458	210,132	222,170
Total carbon emitted over 60 years, tCO_2e	227,349	5,892	17,218	5,180
First year CO_2e savings, tCO_2e	-	3,128	3,083	3,265

6.3.1.2 Candidate Area 1 – Summary

The ambient network provides the greatest carbon savings, however all three low-carbon options yield more than 90% carbon savings compared to the BAU.

With low-rise residential connections, the heating and cooling network yields the lowest NPC of the low-carbon options (see Figure 63). Without low-rise residential connections, both the HCN and the ambient network options were identified as the lowest-cost solutions with similar NPCs (see Figure 65).

Removing the low-rise residential also has the effect of increasing the cost of the individual ASHP option, relative to the networked options. This effect indicates that if low-rise residential connections were assessed separately, it would be cheaper to serve them by individual ASHPs. Although HCN and ambient networks can achieve higher efficiencies, the upfront CAPEX to install the buried networks to low-rise residential (and therefore low heat density) connections is too high, yielding a higher NPC despite the increased efficiency.

6.3.2 Candidate Area 2 – Fishponds

Network Summary

The heat and cooling demands shown are for 2020 and 2080, respectively. A summary of all the network scheme options for the Fishponds candidate areas is shown in Table 32.

Table 32: Network summary – Fishponds with residential connections

	BAU	Individual ASHP	MWSHP	Ambient Network
Total heat demand (excl. losses), kWh	153,482,369			
Total heat demand (incl. losses), kWh			165,760,959	
Total cooling demand (excl. losses), kWh	21,393,035			
Total cooling demand (incl. losses), kWh			22,248,757	
Network spine trench length - Heat, m			15,192	
Network spine trench length - Cooling, m			13,085	
Network spine trench length - Ambient, m				15,193
Low carbon heat capacity, kW	-	93,230	33,330	93,230
Low carbon cooling capacity, kW	35,110	35,110	22,820	35,110
Gas boiler capacity, kW	93,230	-	40,910	-
% heat demand met by low carbon / technology	-	100%	95%	100%

Economic Assessment

The economic performance of all scheme options for the Fishponds candidate area is shown in Table 33 and Figure 67.

Table 33: Economic assessment – Fishponds with residential connections

	BAU	Individual ASHP	HCN	Ambient Network
Capital costs (including contingency), £	£160,624,435	£350,343,249	£641,492,089	£484,052,280
Discounted OPEX – 60 years, £	£335,342,229	£410,578,034	£263,303,957	£332,305,567
Discounted REPEX – 60 years, £	£116,689,829	£129,699,859	£26,272,537	£95,783,888
Net Present Cost – 60 years, £	£599,422,808	£884,271,488	£887,945,149	£905,457,680
Levelised cost of energy – 60 years, p/kWh	14.7	21.6	21.7	22.1
Total carbon saving against BAU, tCO_2e	-	1,711,981	1,628,466	1,719,933
Social NPC – 60 years	-	£620,436,902	£639,236,822	£637,150,178

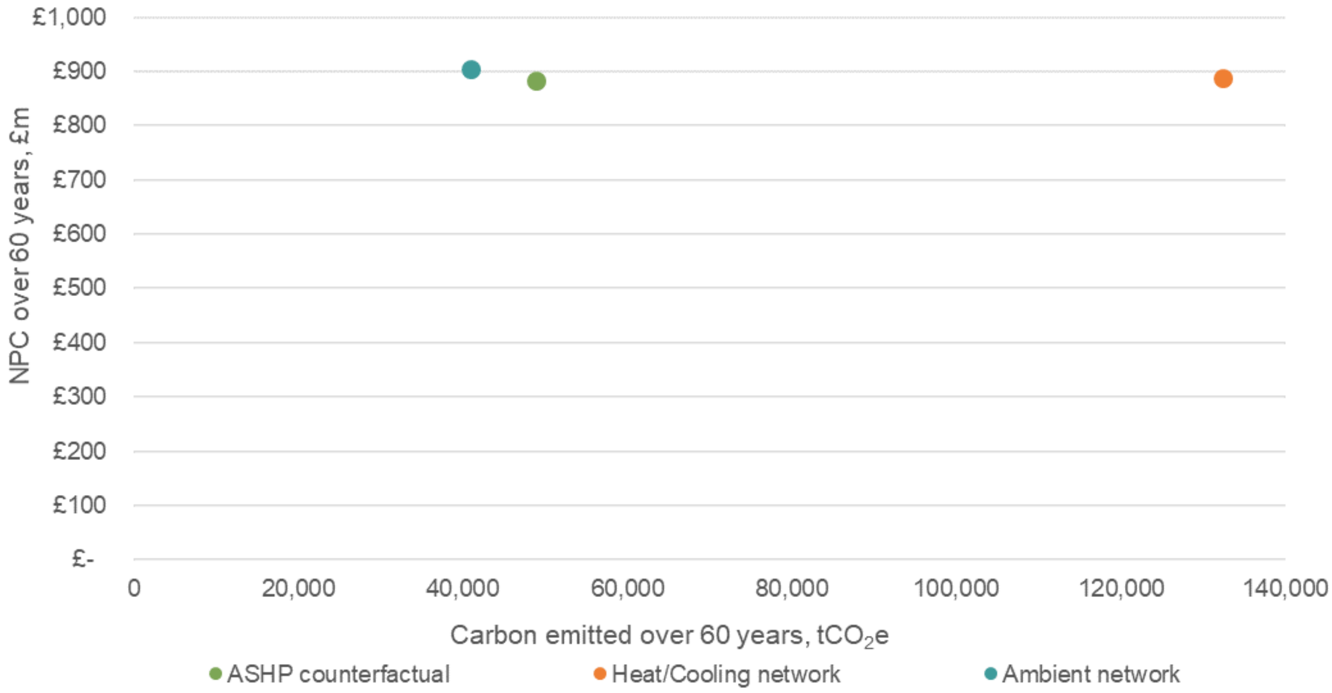


Figure 67: NPC vs Carbon emission – Fishponds with residential connections

CO_2e Assessment

The carbon performance of different network scheme options is shown in Figure 68 and Table 34.

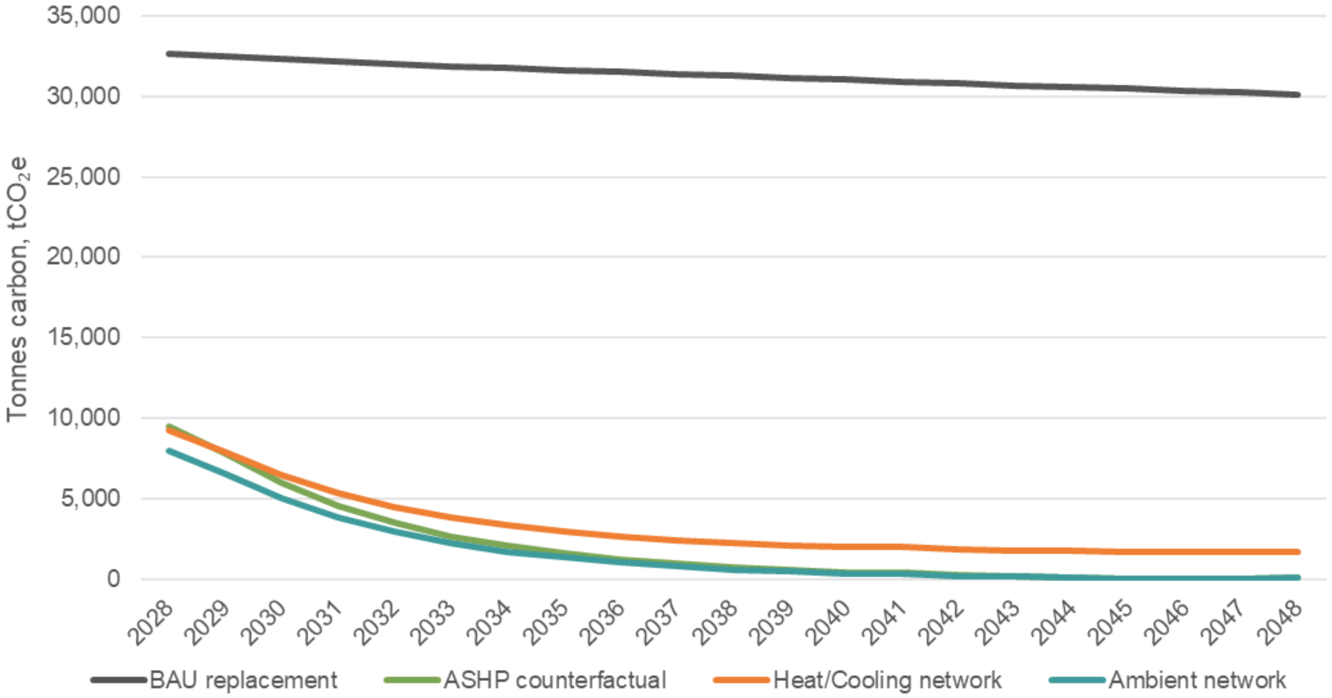


Figure 68: Scheme options lifetime carbon emissions over 20 years – Fishponds with residential connections

Table 34: Scheme options carbon emissions – Fishponds with residential connections

Scheme option carbon performance	BAU	Individual ASHP	HCN	Ambient network
Carbon intensity of energy delivered in year 2030, gCO_2e/kWh	203.9	37.9	40.8	31.9
Carbon intensity of heat delivered in year 2030, gCO_2e/kWh	216.3	39.3	42.8	33.7
tCO_2e savings against BAU over 60 years	-	1,711,981	1,628,466	1,719,933
Total carbon emitted over 60 years, tCO_2e	1,760,861	48,880	132,396	40,928
First year CO_2e savings, tCO_2e	-	23,184	23,404	24,690

6.3.2.1 Fishponds Without Residential Connections

Network Summary

A summary of all the network scheme options for the Fishponds candidate areas without residential connections is shown in Table 35.

Table 35: Network summary – Fishponds without residential connections

	BAU	Individual ASHP	HCN	Ambient Network
Total heat demand (excl. losses), kWh	44,144,654			
Total heat demand (incl. losses), kWh			47,676,226	
Total cooling demand (excl. losses), kWh	14,567,270			
Total cooling demand (incl. losses), kWh			15,149,961	
Network spine trench length - Heat, m			15,095	
Network spine trench length - Cooling, m			12,974	
Network spine trench length - Ambient, m				15,095
Low carbon heat capacity, kW	-	28,980	10,360	28,980
Low carbon cooling capacity, kW	17,890	17,890	11,630	17,890
Gas boiler capacity, kW	28,980	-	12,710	-
% heat demand met by low carbon / technology	-	100%	95%	100%

Economic Assessment

The economic performance of all scheme options for the Fishponds candidate area is shown in Table 36 and Figure 69.

Table 36: Economic assessment – Fishponds without residential connections

	BAU	Individual ASHP	HCN	Ambient Network
Capital costs (including contingency), £	£40,679,935	£139,766,475	£115,433,655	£125,932,062
Discounted OPEX – 60 years, £	£71,646,511	£91,396,888	£81,096,457	£76,351,627
Discounted REPEX – 60 years, £	£28,389,991	£29,626,709	£8,165,293	£19,257,361
Net Present Cost – 60 years, £	£136,697,339	£259,653,241	£198,908,635	£220,296,049
Levelised cost of energy – 60 years, p/kWh	10.1	19.2	14.7	16.3
Total carbon saving against BAU, tCO_2e	-	483,249	458,849	485,292
Social NPC – 60 years	-	£183,648,762	£143,961,982	£127,991,253

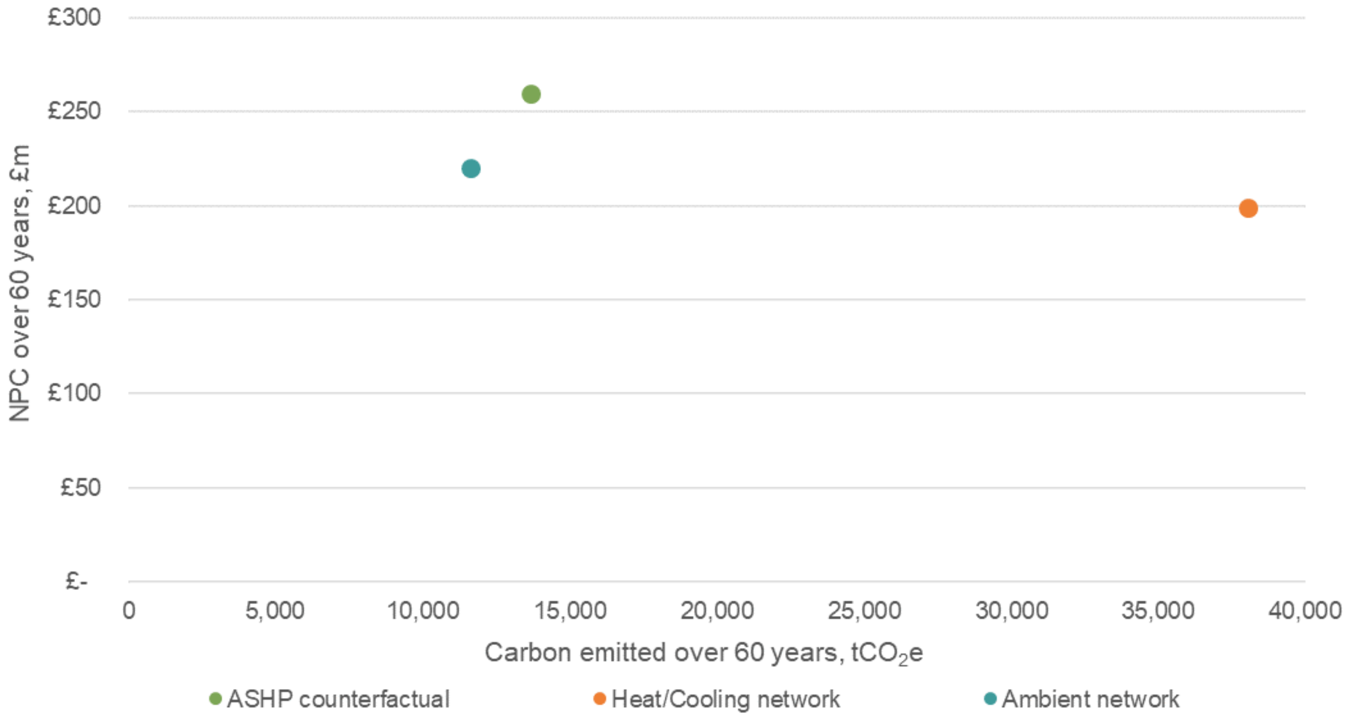


Figure 69: NPC vs Carbon emission – Fishponds without residential connections

CO_2e Assessment

The carbon performance of different network scheme options is shown in Figure 70 and Table 37.

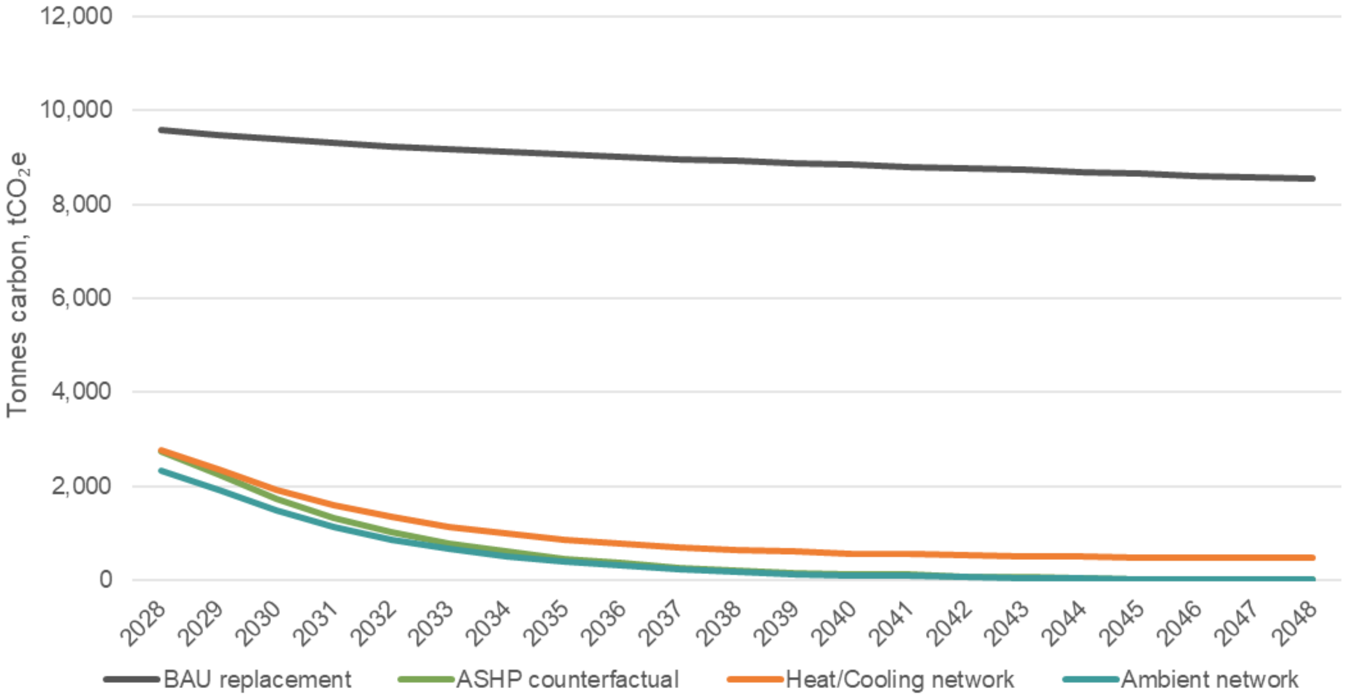


Figure 70: Scheme options lifetime carbon emissions over 20 years – Fishponds without residential connections

Table 37: Scheme options carbon emissions – Fishponds without residential connections

Scheme option carbon performance	BAU	Individual reversible ASHP	HCN	Ambient network
Carbon intensity of energy delivered in year 2030, gCO_2e/kWh	178.8	32.9	36.8	28.1
Carbon intensity of heat delivered in year 2030, gCO_2e/kWh	216.3	36.4	42.8	33.7
tCO_2e savings against BAU over 60 years	-	483,249	458,849	485,292
Total carbon emitted over 60 years, tCO_2e	496,918	13,670	38,069	11,626
First year CO_2e savings, tCO_2e	-	6,844	6,805	7,238

6.3.2.2 Candidate Area 2 –Summary

Similarly to the Lawrence hill area, adding the low-rise residential improves the case for ASHPs (see change from Figure 69 to Figure 67). In this candidate area, the proportion of low-rise residential is large enough that, if these are included, individual ASHPs are the lowest NPC option.

Without low-rise residential connections the HCN and ambient network have very similar NPCs (Figure 69), with the HCN yielding slightly lower NPC and the ambient network yielding more carbon savings.

6.3.3 Candidate Area 3 – Bristol and Bath Science Park

Network Summary

The heat and cooling demands shown are for 2020 and 2080, respectively. A summary of all the network scheme options for the Bristol and Bath Science Park candidate areas is shown in Table 38.

Table 38: Network summary – BBSP with residential connections

	BAU	Individual ASHP	MWSHP	Ambient Network
Total heat demand (excl. losses), kWh	60,030,150			
Total heat demand (incl. losses), kWh			62,629,895	
Total cooling demand (excl. losses), kWh	24,155,002			
Total cooling demand (incl. losses), kWh			25,121,203	
Network spine trench length - Heat, m			11,602	
Network spine trench length - Cooling, m			11,217	
Network spine trench length - Ambient, m				11,602
Low carbon heat capacity, kW	-	36,370	13,000	36,370
Low carbon cooling capacity, kW	23,160	23,160	15,100	23,160
Gas boiler capacity, kW	36,370	-	16,000	-
% heat demand met by low carbon / technology	-	100%	95%	100%

Economic Assessment

The economic performance of all scheme options for the BBSP candidate area is shown in Table 39 and Figure 71.

Table 39: Economic assessment – BBSP with residential connections

	BAU	Individual ASHP	HCN	Ambient Network
Capital costs (including contingency), £	£79,849,831	£145,286,157	£258,875,224	£200,446,639
Discounted OPEX – 60 years, £	£141,492,535	£161,320,028	£105,930,138	£128,154,358
Discounted REPEX – 60 years, £	£57,119,104	£50,241,315	£10,249,226	£36,698,105
Net Present Cost – 60 years, £	£271,371,961	£353,924,578	£357,648,898	£362,239,877
Levelised cost of energy – 60 years, p/kWh	14.5	18.9	19.1	19.4
Total carbon saving against BAU, tCO_2e	-	639,938	610,017	643,823
Social NPC – 60 years	-	£254,157,171	£261,438,247	£262,693,251

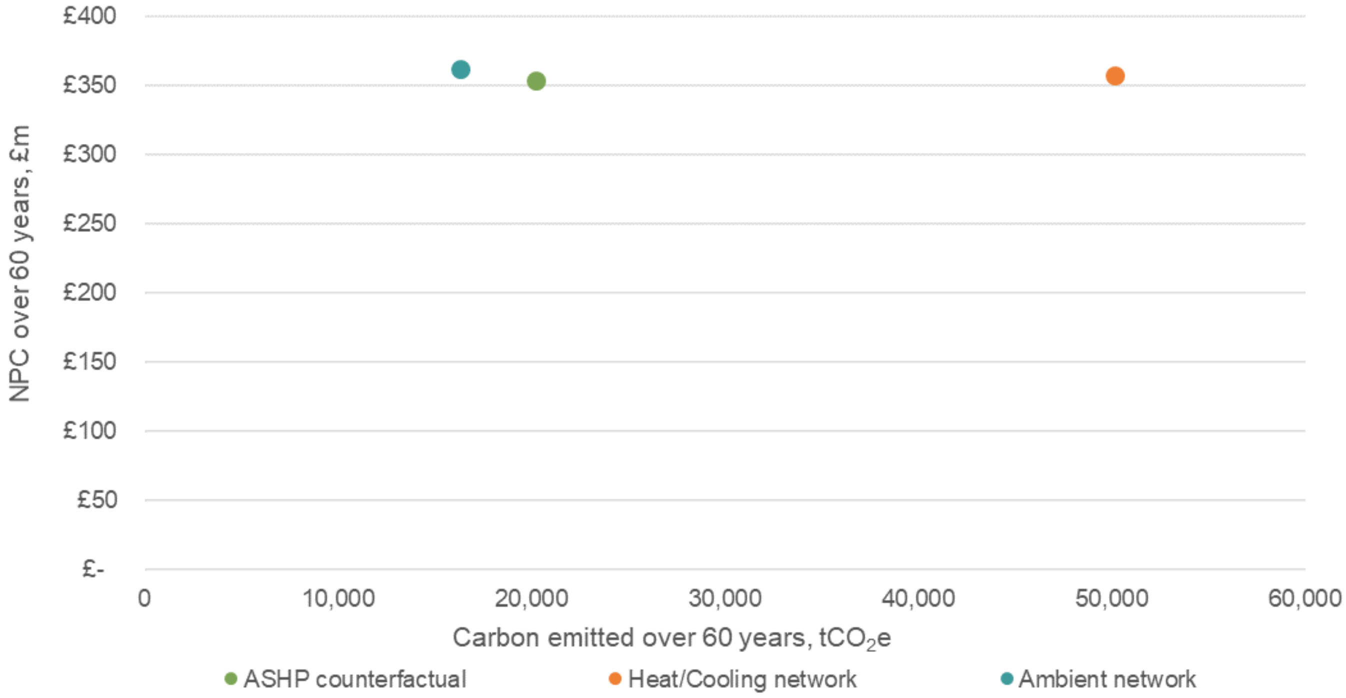


Figure 71: NPC vs Carbon emissions - BBSP with residential connections

CO_2e Assessment

The carbon performance of different network scheme options is shown in Figure 72 and Table 40.

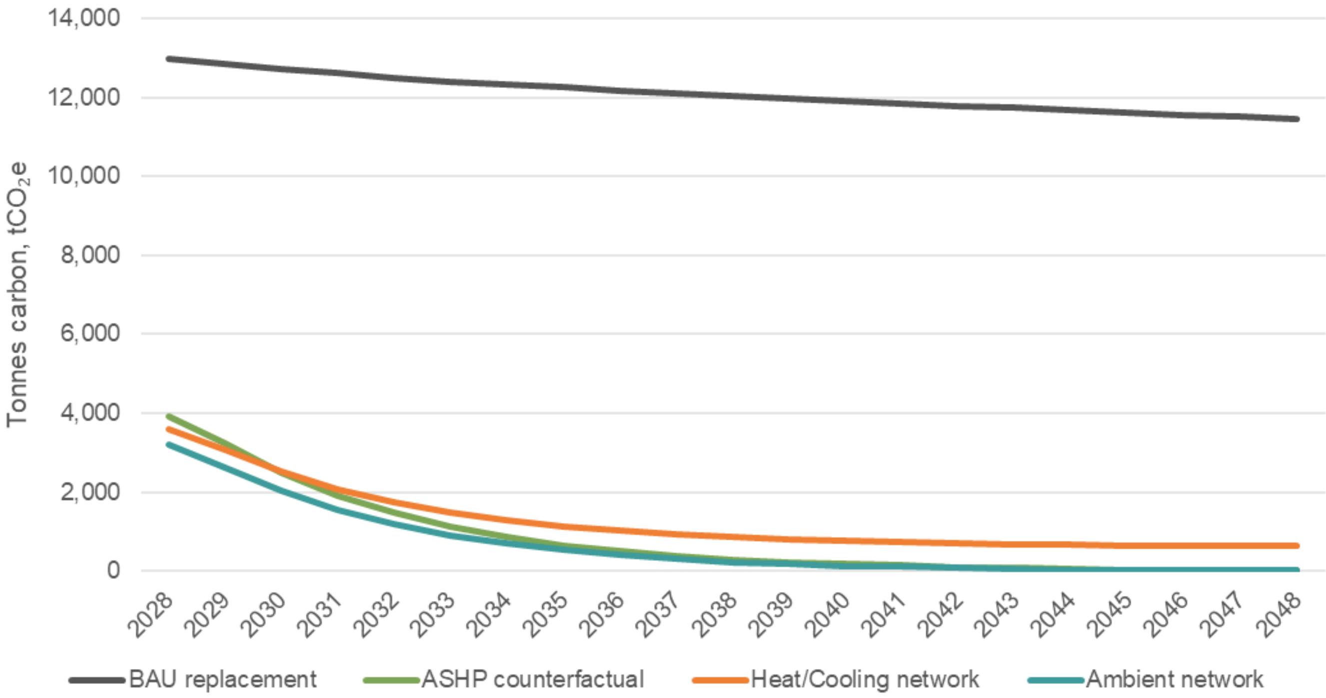


Figure 72: Scheme options lifetime carbon emissions over 20 years – BBSP with residential connections

Table 40: Scheme options carbon emissions - BBSP with residential connections

Scheme option carbon performance	HCN	Ambient network	Individual reversible ASHP	BAU
Carbon intensity of energy delivered in year 2030, gCO_2e/kWh	35.2	28.3	34.9	177.5
Carbon intensity of heat delivered in year 2030, gCO_2e/kWh	41.1	34.2	39.0	216.3
tCO_2e savings over 60 years	610,017	643,823	639,938	-
Total carbon emitted, tCO_2e	50,121	16,315	20,200	660,138
First year CO_2e savings, tCO_2e	9,381	9,788	9,051	-

6.3.3.1 Candidate Area 3 – Bristol and Bath Science Without Residential Connections

Network Summary

A summary of all the network scheme options for the Bristol and Bath Science Park candidate areas without residential connections is shown in Table 41.

Table 41: Network summary - BBSP without residential connections

	BAU	Individual ASHP	HCN	Ambient Network
Total heat demand (excl. losses), kWh	21,134,896			
Total heat demand (incl. losses), kWh			22,825,688	
Total cooling demand (excl. losses), kWh	21,943,091			
Total cooling demand (incl. losses), kWh			22,820,815	
Network spine trench length - Heat, m			9,460	
Network spine trench length - Cooling, m			9,070	
Network spine trench length - Ambient, m				9,460
Low carbon heat capacity, kW	-	14,090	5,040	14,090
Low carbon cooling capacity, kW	17,110	17,110	11,120	17,110
Gas boiler capacity, kW	14,090	-	6,180	-
% heat demand met by low carbon / technology	-	100%	95%	100%

Economic Assessment

The economic performance of all scheme options for the BBSP candidate area is shown in Table 42 and Figure 73.

Table 42: Economic assessment – BBSP without residential connections

	BAU	Individual ASHP	HCN	Ambient Network
Capital costs (including contingency), £	£37,622,581	£71,170,179	£81,664,172	£75,221,062
Discounted OPEX – 60 years, £	£49,841,051	£50,390,504	£42,256,203	£38,727,004
Discounted REPEX – 60 years, £	£26,032,565	£15,009,904	£3,971,596	£9,756,438
Net Present Cost – 60 years, £	£109,650,744	£135,482,874	£122,950,816	£122,550,286
Levelised cost of energy – 60 years, p/kWh	11.9	14.6	13.3	13.3
Total carbon saving against BAU, tCO_2e	-	219,044	209,485	220,878
Social NPC – 60 years	-	£100,646,299	£87,392,910	£90,132,410

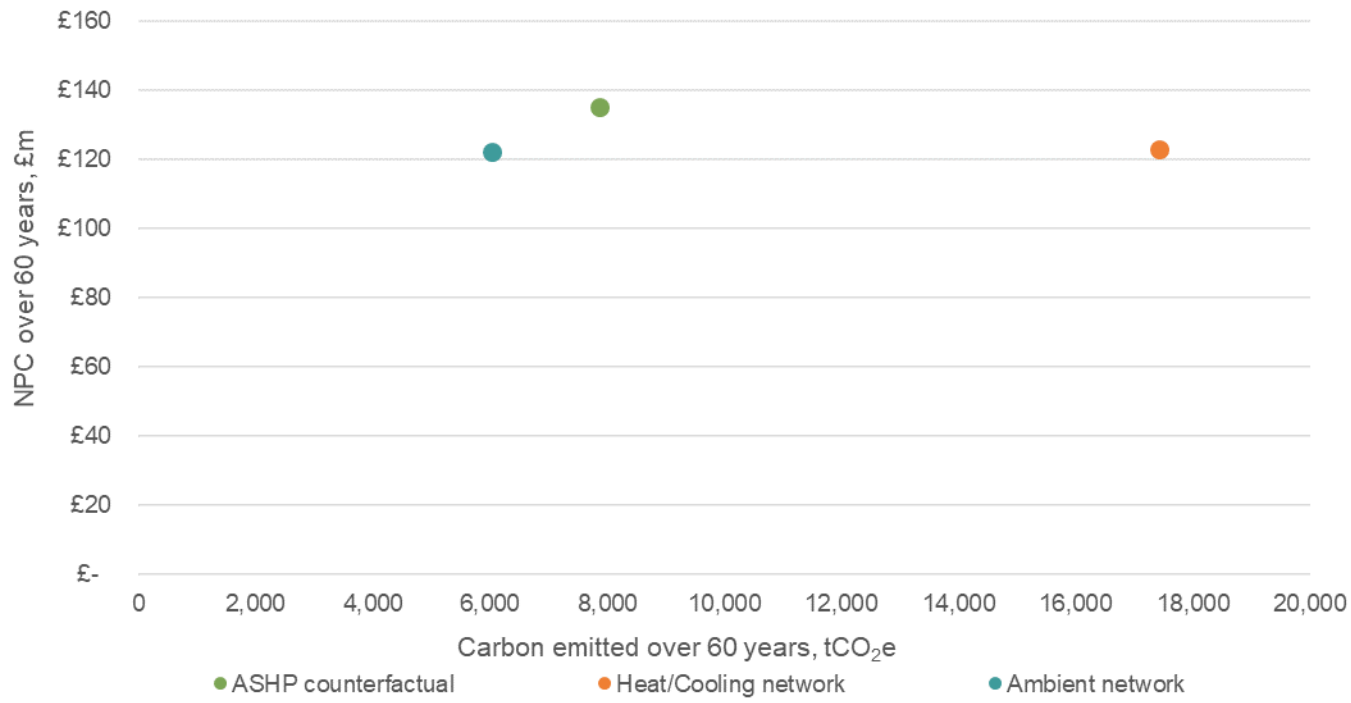


Figure 73: NPC vs carbon emission – BBSP without residential connections

CO_2e Assessment

The carbon performance of different network scheme options is shown in Figure 74 and Table 43.

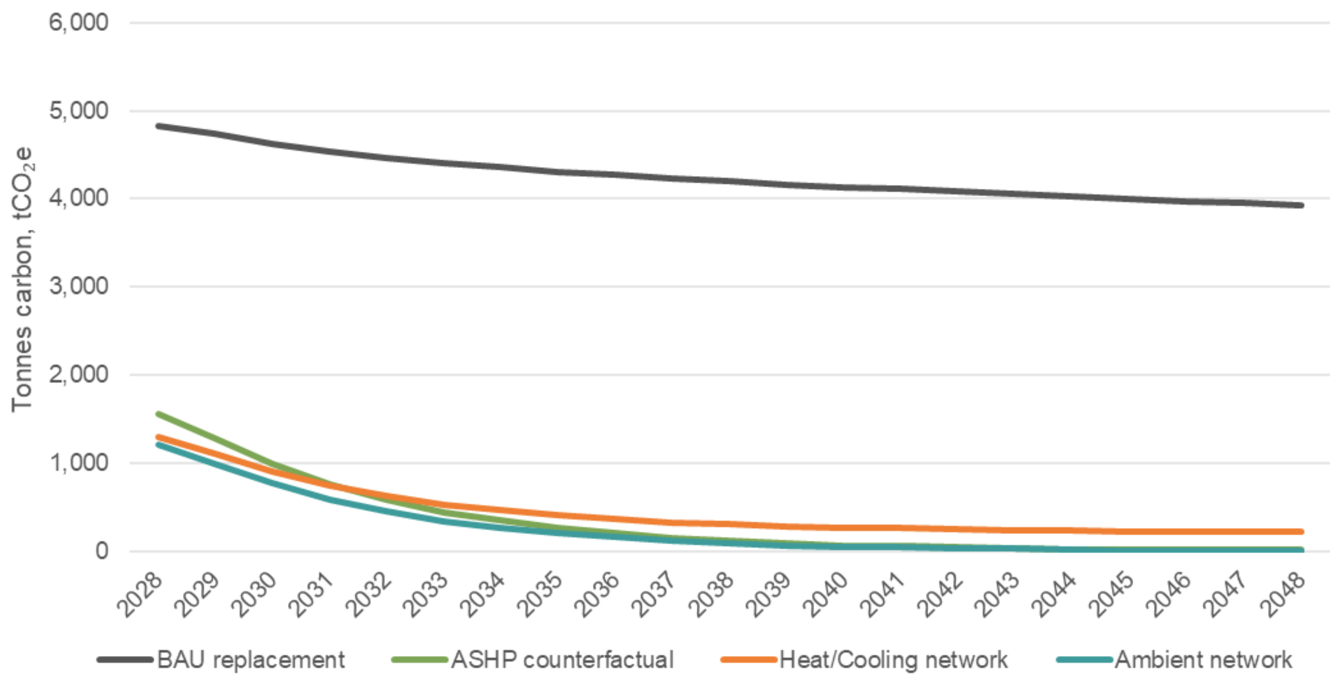


Figure 74: Scheme options lifetime carbon emissions over 20 years – BBSP without residential connections

Table 43: Scheme options carbon emissions – BBSP without residential connections

Scheme option carbon performance	BAU	Individual reversible ASHP	HCN	Ambient network
Carbon intensity of energy delivered in year 2030, gCO_2e/kWh	135.0	28.9	26.3	22.4
Carbon intensity of heat delivered in year 2030, gCO_2e/kWh	216.3	36.4	37.0	35.0
tCO_2e savings over 60 years	-	219,044	209,485	220,878
Total carbon emitted, tCO_2e	226,915	7,871	17,430	6,037
First year CO_2e savings, tCO_2e	-	3,271	3,538	3,615

6.3.3.2 Candidate Area 3 – Summary

This candidate area performs similarly to Fishponds, with the ASHP option yielding the lowest NPC option if the low-rise residential connections are included (see Figure 71). With fewer houses connected to the network, the cost of the individual ASHP solution would increase relative to networked options. Without any low-rise residential connections, the HCN and ambient network perform very similarly (see Figure 73), with the ASHP option being more expensive than both.

It has been assumed that a HCN or ambient network within the BBSP candidate area would benefit from a source of cheaper waste heat from a 5 MW supercomputer. Given the substantial heating and cooling load within the candidate area, utilising the mine seams for interseasonal storage would significantly enhance the network's efficiency of both the HNC and ambient options, although this is dependent on the mine’s ability to store surpluses of heat/coolth.

6.3.4 Candidate Area 4 – Douglas Road Industrial Park

Network Summary

The heat and cooling demands shown are for 2020 and 2080, respectively. A summary of all the network scheme options for the Douglas Road Industrial Park candidate areas is shown in Table 44.

Table 44: Network summary – Douglas Road Industrial Park with residential connections

	BAU	Individual ASHP	MWSHP	Ambient Network
Total heat demand (excl. losses), kWh	127,462,732			
Total heat demand (incl. losses), kWh			137,659,750	
Total cooling demand (excl. losses), kWh	24,392,238			
Total cooling demand (incl. losses), kWh			25,367,927	
Network spine trench length - Heat, m			16,170	
Network spine trench length - Cooling, m			15,638	
Network spine trench length - Ambient, m				16,170
Low carbon heat capacity, kW	-	76,220	27,250	76,220
Low carbon cooling capacity, kW	27,750	27,750	18,040	27,750
Gas boiler capacity, kW	76,220	-	33,440	-
% heat demand met by low carbon / technology	-	100%	95%	100%

Economic Assessment

The economic performance of all scheme options for the Douglas Road Industrial Park candidate area is shown in Table 45 and Figure 75.

Table 45: Economic assessment – Douglas Road Industrial Park with residential connections

	BAU	Individual ASHP	HCN	Ambient Network
Capital costs (including contingency), £	£138,902,562	£273,975,983	£569,194,077	£412,115,551
Discounted OPEX – 60 years, £	£301,650,263	£357,956,237	£222,863,124	£287,102,108
Discounted REPEX – 60 years, £	£101,247,255	£110,704,853	£21,479,733	£82,798,894
Net Present Cost – 60 years, £	£530,549,950	£736,993,399	£774,578,485	£776,100,039
Levelised cost of energy – 60 years, p/kWh	14.9	20.7	21.7	21.8
Total carbon saving against BAU, tCO_2e	-	1,424,050	1,355,410	1,431,512
Social NPC – 60 years	-	£518,135,081	£554,965,756	£565,982,941

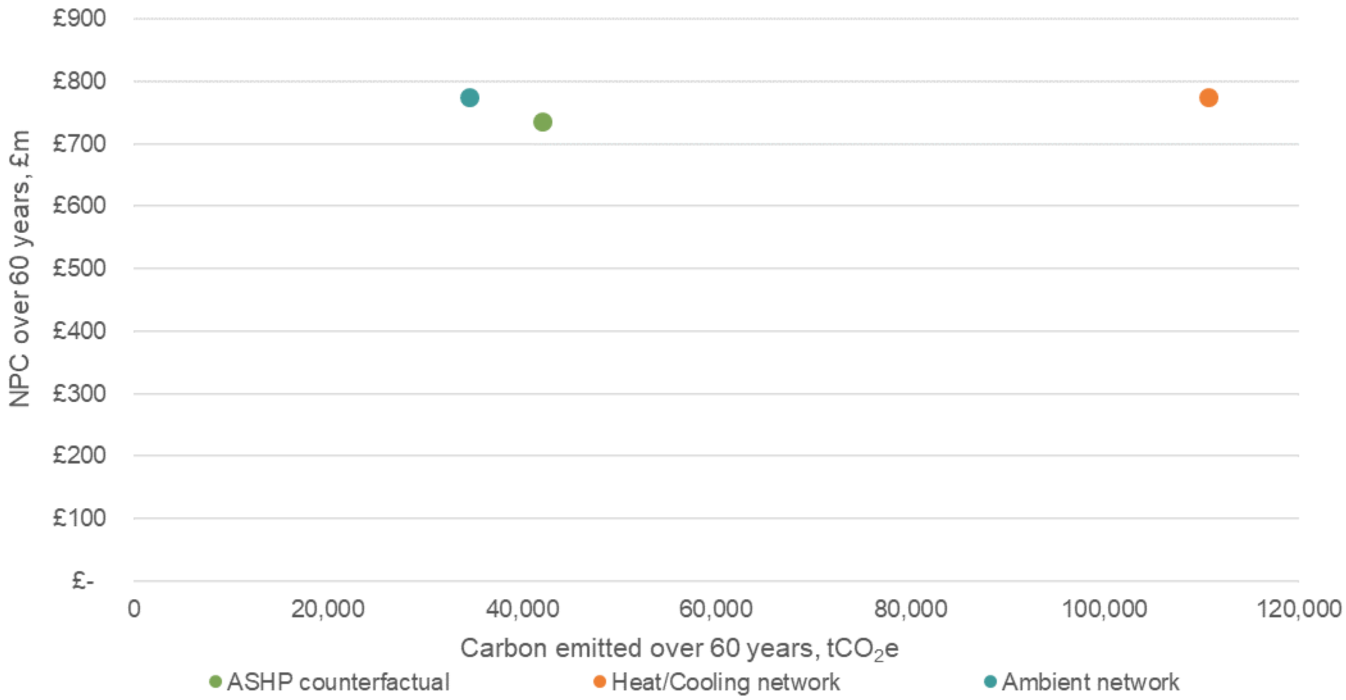


Figure 75: NPC vs carbon emission – Douglas Road Industrial Park with residential connections

CO_2e Assessment

The carbon performance of different network scheme options is shown in Figure 76 and

Scheme option carbon performance	HCN	Ambient network	Individual reversible ASHP	BAU
Carbon intensity of energy delivered in year 2030, gCO_2e/kWh	39.6	30.9	37.5	196.2
Carbon intensity of heat delivered in year 2030, gCO_2e/kWh	42.8	33.9	39.7	216.3
tCO_2e savings against BAU over 60 years	1,355,410	1,431,512	1,424,050	-
Total carbon emitted over 60 years, tCO_2e	110,649	34,547	42,009	1,466,059
First year CO_2e savings, tCO_2e	19,520	20,616	19,202	-

Table 46.

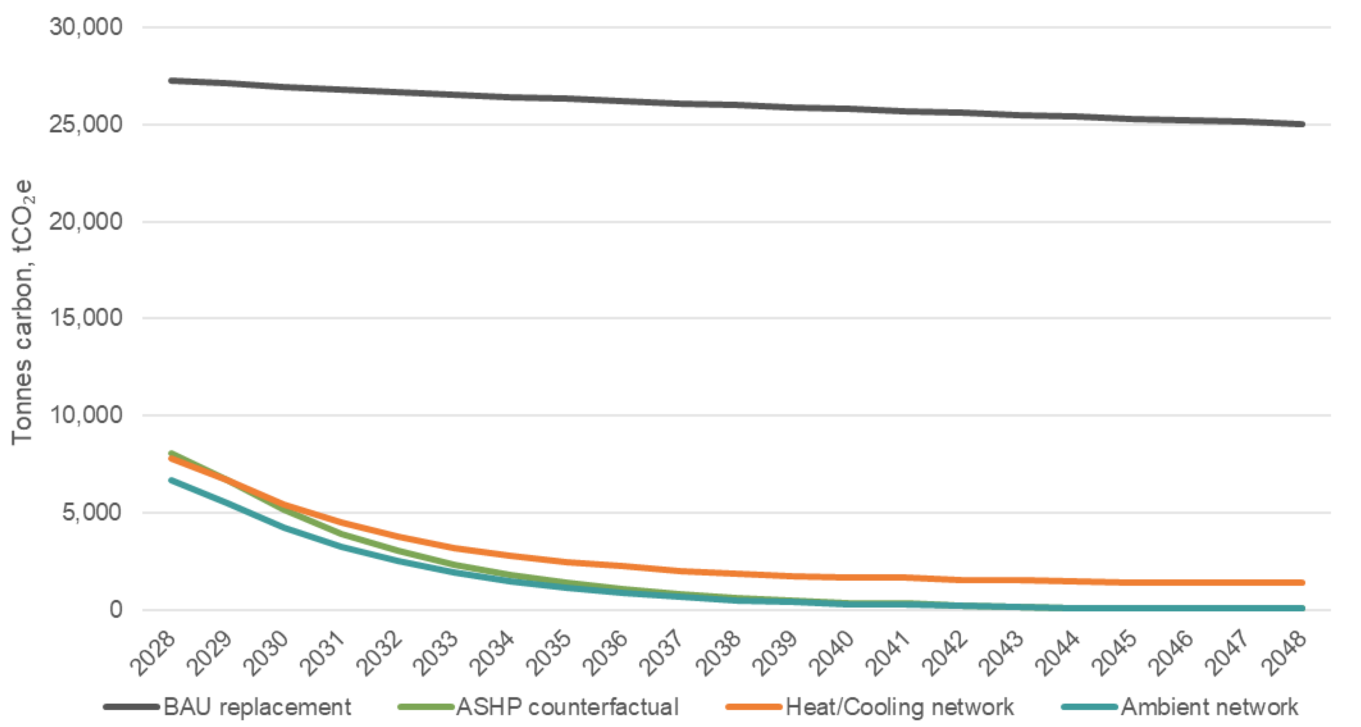


Figure 76: Scheme options lifetime carbon emissions over 20 years – Douglas Road Industrial Park with residential

Table 46: Scheme options carbon emissions – Douglas Road Industrial Park candidate area with residential

Scheme option carbon performance	HCN	Ambient network	Individual reversible ASHP	BAU
Carbon intensity of energy delivered in year 2030, gCO_2e/kWh	39.6	30.9	37.5	196.2
Carbon intensity of heat delivered in year 2030, gCO_2e/kWh	42.8	33.9	39.7	216.3
tCO_2e savings against BAU over 60 years	1,355,410	1,431,512	1,424,050	-
Total carbon emitted over 60 years, tCO_2e	110,649	34,547	42,009	1,466,059
First year CO_2e savings, tCO_2e	19,520	20,616	19,202	-

6.3.4.1 Douglas Road Industrial Park Without Residential Connections

Network Summary

A summary of all the network scheme options for the Douglas Road Industrial Park candidate areas without residential connections is shown in Table 47.

Table 47: Network summary – Douglas Road Industrial Park without residential connections

	BAU	Individual ASHP	HCN	Ambient Network
Total heat demand (excl. losses), kWh	23,645,238			
Total heat demand (incl. losses), kWh			25,536,857	
Total cooling demand (excl. losses), kWh	18,180,836			
Total cooling demand (incl. losses), kWh			18,908,069	
Network spine trench length - Heat, m			15,548	
Network spine trench length - Cooling, m			15,015	
Network spine trench length - Ambient, m				15,543
Low carbon heat capacity, kW	-	15,330	5,480	15,330
Low carbon cooling capacity, kW	11,340	11,340	7,370	11,340
Gas boiler capacity, kW	15,330	-	6,730	-

	BAU	Individual ASHP	HCN	Ambient Network
% heat demand met by low carbon / technology	-	100%	95%	100%

Economic Assessment

The economic performance of all scheme options for the Douglas Road Industrial Park candidate area without residential connections is shown in Table 48 and Figure 77.

Table 48: Economic assessment – Douglas Road Industrial Park without residential connections

	BAU	Individual ASHP	HCN	Ambient Network
Capital costs (including contingency), £	£25,627,062	£75,095,757	£102,752,358	£85,061,944
Discounted OPEX – 60 years, £	£51,928,640	£55,549,810	£50,023,496	£43,562,746
Discounted REPEX – 60 years, £	£17,856,951	£16,195,841	£4,319,467	£10,527,297
Net Present Cost – 60 years, £	£92,864,772	£146,120,721	£150,402,332	£138,372,919
Levelised cost of energy – 60 years, p/kWh	9.6	15.1	15.6	14.3
Total carbon saving against BAU, tCO_2e	-	257,893	245,374	259,763
Social NPC – 60 years	-	£105,551,031	£112,542,803	£97,474,439

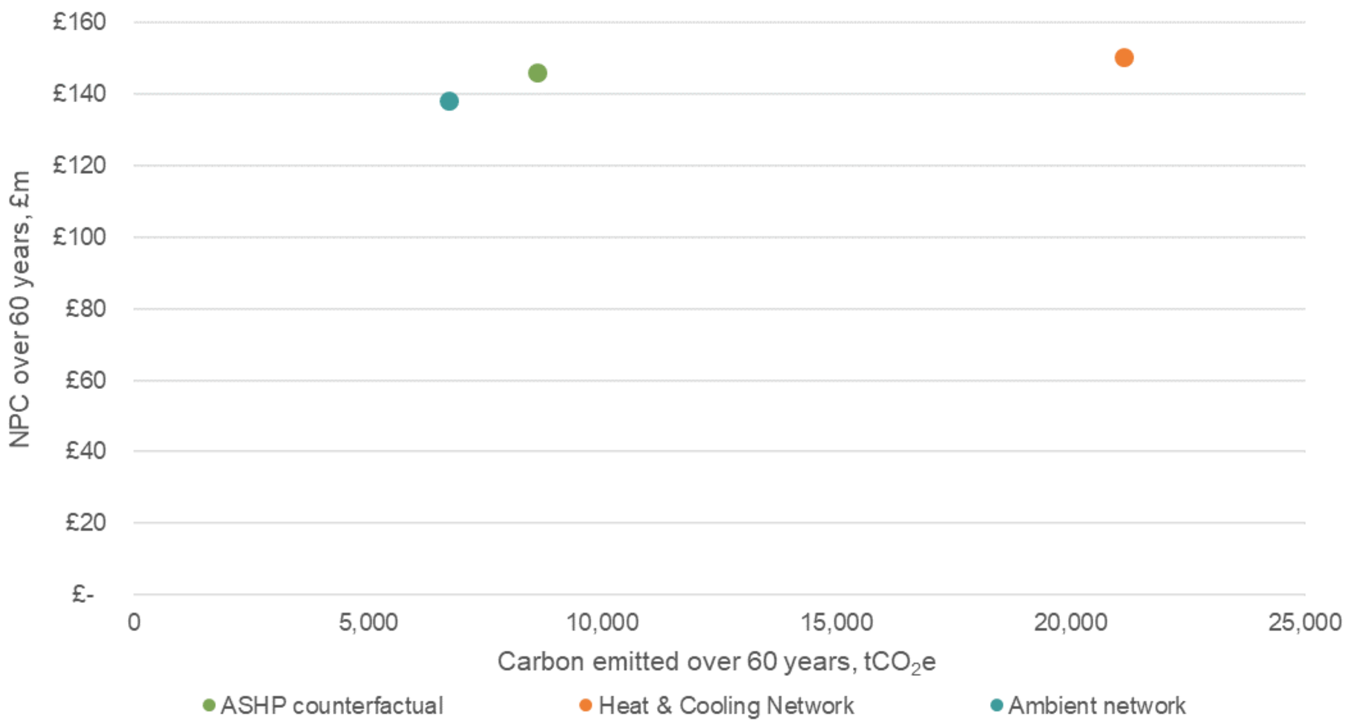


Figure 77: NPC vs carbon emission – Douglas Road Industrial Park without residential connections

CO_2e Assessment

The carbon performance of different network scheme options is shown in Figure 78 and Table 49.

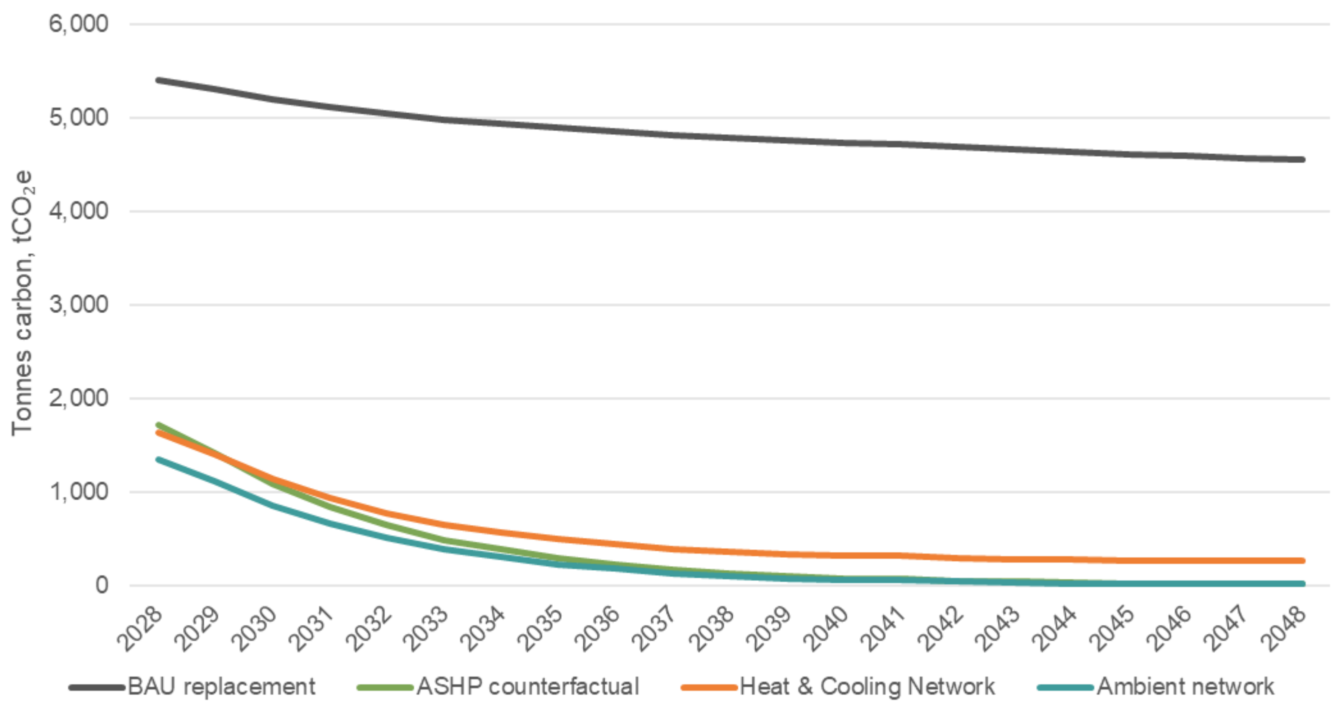


Figure 78: Scheme options lifetime carbon emissions over 20 years – Douglas Road Industrial Park without residential connections

Table 49: Scheme options carbon emissions – Douglas Road Industrial Park candidate area without residential

Scheme option carbon performance	BAU	Individual reversible ASHP	HCN	Ambient network
Carbon intensity of energy delivered in year 2030, gCO_2e/kWh	141.2	29.4	30.7	23.2
Carbon intensity of heat delivered in year 2030, gCO_2e/kWh	216.3	36.4	42.8	34.8
tCO_2e savings over 60 years	-	257,893	245,374	259,763
Total carbon emitted, tCO_2e	266,494	8,601	21,120	6,731
First year CO_2e savings, tCO_2e	-	3,687	3,761	4,047

6.3.4.2 Candidate Area 4 – Summary

Without low-rise residential, the ambient network option was identified to have the lowest NPC (see Figure 77), indicating that the commercial connections are more economical to be served by an ambient network in the Douglas Road Industrial candidate area.

Adding the low-rise residential connections, the individual ASHPs network is the low-carbon option with the lowest NPC (see Figure 75). This is due to the large proportion of residential connections, and the pipework costs to individual residential dwellings leading to a high CAPEX, especially for the HCN option with 4-pipe solutions.

In all cases, the ambient network provides the greatest carbon savings, but all three low-carbon options yield more than 90% carbon savings compared to the BAU.

6.3.5 Candidate Area 5 – Barrs Court Residential

Network Summary

The heat and cooling demands shown are for 2020 and 2080, respectively. A summary of all the network scheme options for the Barrs Court Residential candidate areas is shown in Table 50.

Table 50: Network summary – Barrs Court Residential candidate area

	BAU	Individual ASHP	MWSHP	Ambient Network
Total heat demand (excl. losses), kWh	53,809,818			
Total heat demand (incl. losses), kWh			58,114,603	
Total cooling demand (excl. losses), kWh	3,531,340			
Total cooling demand (incl. losses), kWh			3,672,594	
Network trench length - Heat, m			34,859	
Network trench length - Cooling, m			34,859	
Network trench length - Ambient, m				34,859
Low carbon heat capacity, kW	-	29,650	10,600	29,650
Low carbon cooling capacity, kW	7,850	7,850	5,100	7,850
Gas boiler capacity, kW	29,650	-	13,010	-
% heat demand met by low carbon / technology	-	100%	95%	100%

Economic Assessment

The economic performance of all scheme options for the residential candidate area is shown in Table 51 and Figure 79.

Table 51: Economic assessment – Barrs Court Residential candidate area

	BAU	Individual ASHP	HCN	Ambient Network
Capital costs (including contingency), £	£53,186,250	£93,438,622	£277,852,391	£189,709,767
Discounted OPEX – 60 years, £	£123,879,631	£150,470,141	£32,520,321	£120,601,014
Discounted REPEX – 60 years, £	£39,154,253	£44,374,820	£8,356,382	£33,933,686
Net Present Cost – 60 years, £	£212,134,166	£285,972,093	£300,015,786	£341,828,690
Levelised cost of energy – 60 years, p/kWh	16.1	21.7	22.7	25.9
Total carbon saving against BAU, tCO_2e	-	582,468	556,465	585,433
Social NPC – 60 years	-	£196,119,722	£250,963,612	£213,282,160

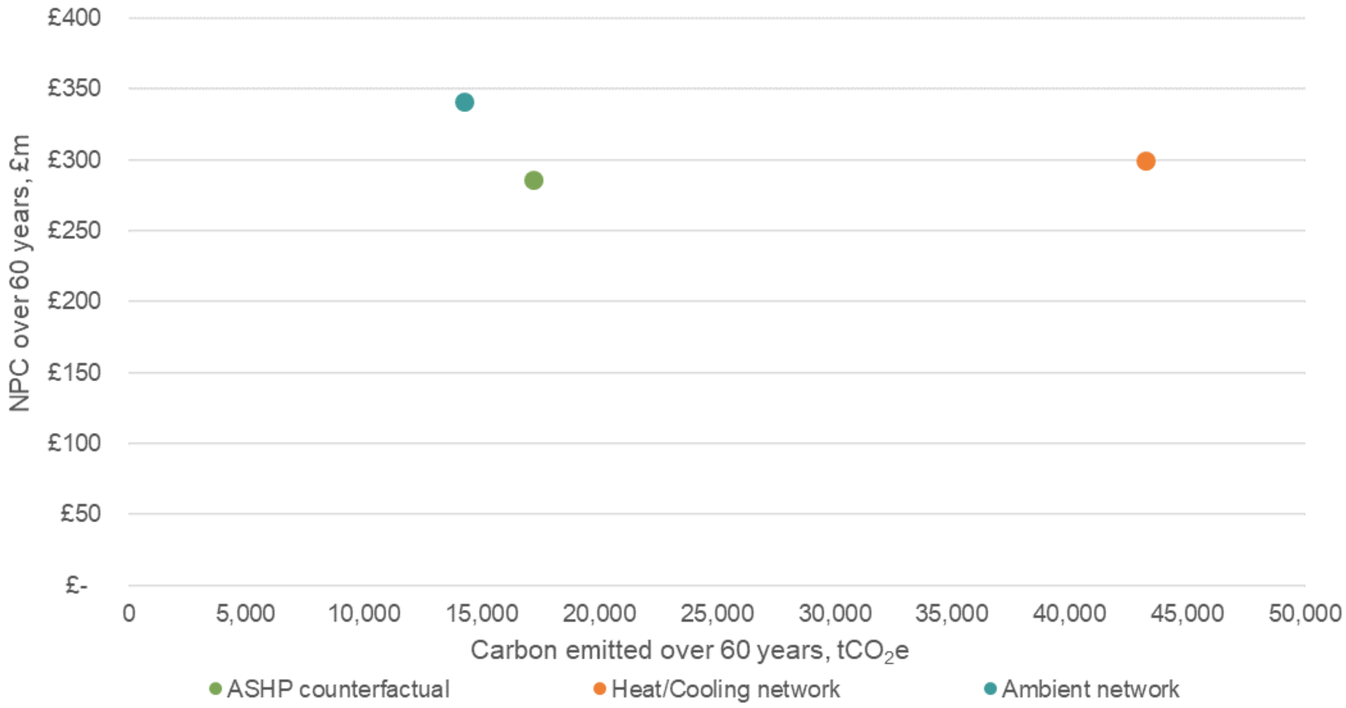


Figure 79: NPC vs carbon emission – Barrs Court Residential candidate area

CO_2e Assessment

The carbon performance of different network scheme options is shown in Figure 80 and Table 52.

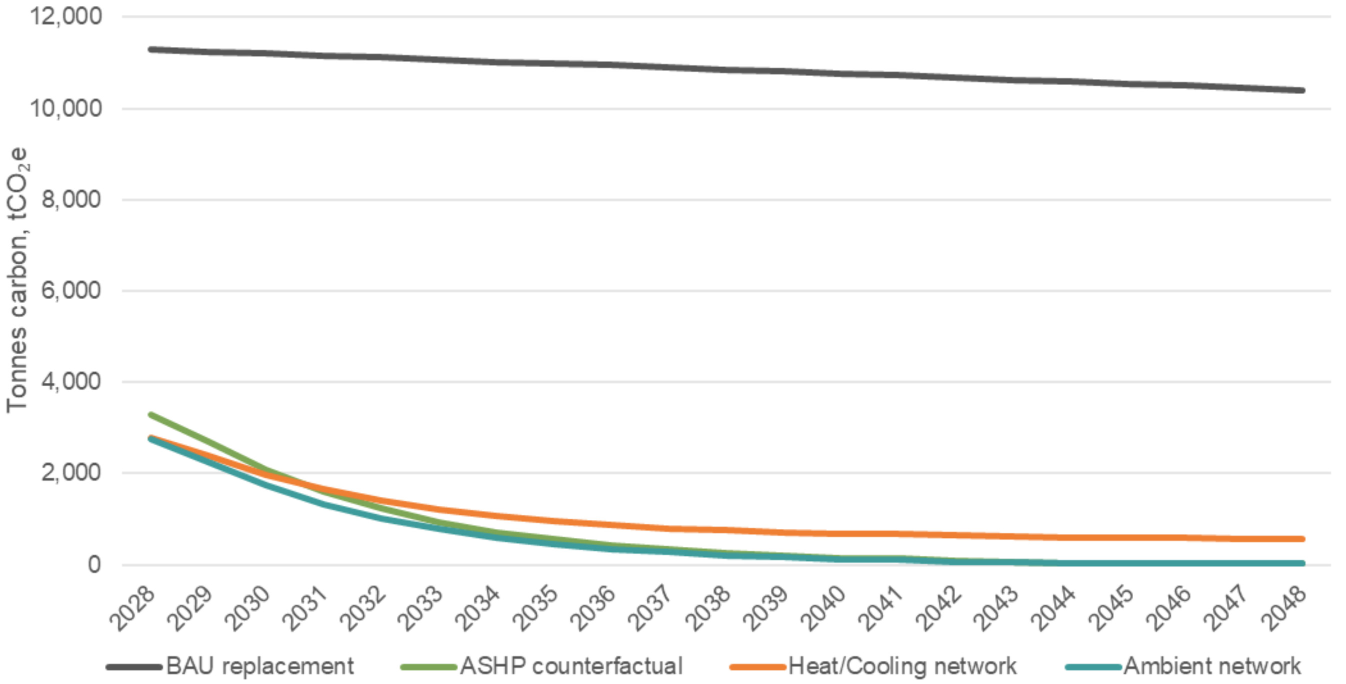


Figure 80: Scheme options lifetime carbon emissions over 20 years – Barrs Court Residential

Table 52: Scheme options carbon emissions - Barrs Court Residential

Scheme option carbon performance	BAU	Individual reversible ASHP	HCN	Ambient network
Carbon intensity of energy delivered in year 2030, gCO_2e/kWh	216.3	40.4	38.2	33.7
Carbon intensity of heat delivered in year 2030, gCO_2e/kWh	-	63.0	53.4	52.6
tCO_2e savings against BAU over 60 years	-	582,468	556,465	585,433
Total carbon emitted over 60 years, tCO_2e	599,665	17,197	43,199	14,231
First year CO_2e savings, tCO_2e	-	7,997	8,502	8,541

6.3.5.1 Candidate Area 5 - Summary

The Barrs Court Residential candidate area follows the trend seen in the other candidate areas, with ASHP yielding the lowest NPC. The low-density nature of this area leads to high network costs for both the heating/cooling and ambient network options. This cost is too great to be made up for in 60 years of higher efficiency.

7 SENSITIVITY ANALYSIS

Sensitivity analysis has been undertaken for the Network based on the key network risks and key parameters and variables. The following sensitivities were carried out for all candidate areas:

- Capital cost
- Heating/cooling demands
- Energy tariffs including fuel purchase tariffs and indexation of energy tariffs
- Inclusion of electric boilers rather than gas
- Heat pump SPF
- Impact of carbon price scenarios on NPC

The full results of all sensitivities are shown in Appendix 5: Sensitivity Results. This section describes key trends arising across all candidate areas. The sensitivity assessments conducted do not include the BAU scenario.

Interpreting Sensitivity Graphs

In the majority of the graphs presented below, the y-axis shows the NPC of the specific scheme option. To provide a clearer display, the y-axis displays a selected range of NPCs rather than starting at 0, as some network scheme options have relatively similar NPC values.

The base case is displayed in the centre of the graph, and the x-axis represents the variance applied to the selected parameter (usually -30%, -15%, +15% and +30%). The effect on the project NPC is then displayed. A lower NPC means lower costs to build and operate the scheme option, a lower NPC is preferred. If the line for a specific option is flat, this indicates that the NPC is not affected by the parameter being varied. If instead, the line is very steep, this indicates that the option is very sensitive to the parameter being varied, indicating a high risk.

7.1 Capital Costs

The capital costs sensitivity was split into two categories: total CAPEX and network CAPEX. The total network CAPEX was varied by 30% in either direction to determine the effect on the project NPC. The effect on the Lawrence Hill candidate area is shown in Figure 81 as an example. In all candidate areas, the HCN is the most sensitive to overall CAPEX, whereas the ASHP option is the least sensitive. This is reflective of the high CAPEX for the network options and the low efficiency of the ASHP option.

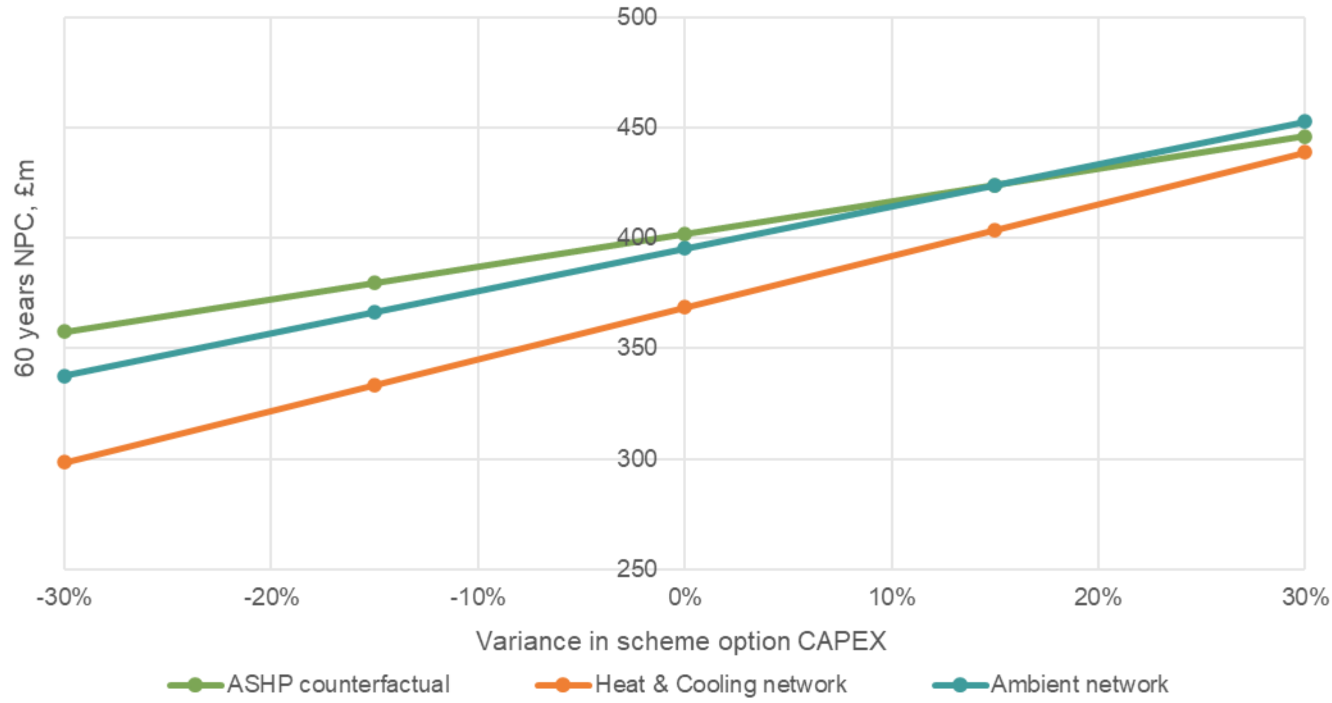


Figure 81: Variance in scheme option CAPEX – Lawrence Hill

Figure 82 shows the sensitivity of the Lawrence Hill candidate area to variances in the costs associated with the buried network only. There are no network costs in the ASHP scenario and therefore there is no effect on this option. In all candidate areas, the HCN is more sensitive than the ambient network option, and this is reflective of the proportionally higher costs of installing a 4-pipe system to serve heating and cooling, compared to the cost of a 2-pipe system in the ambient option.

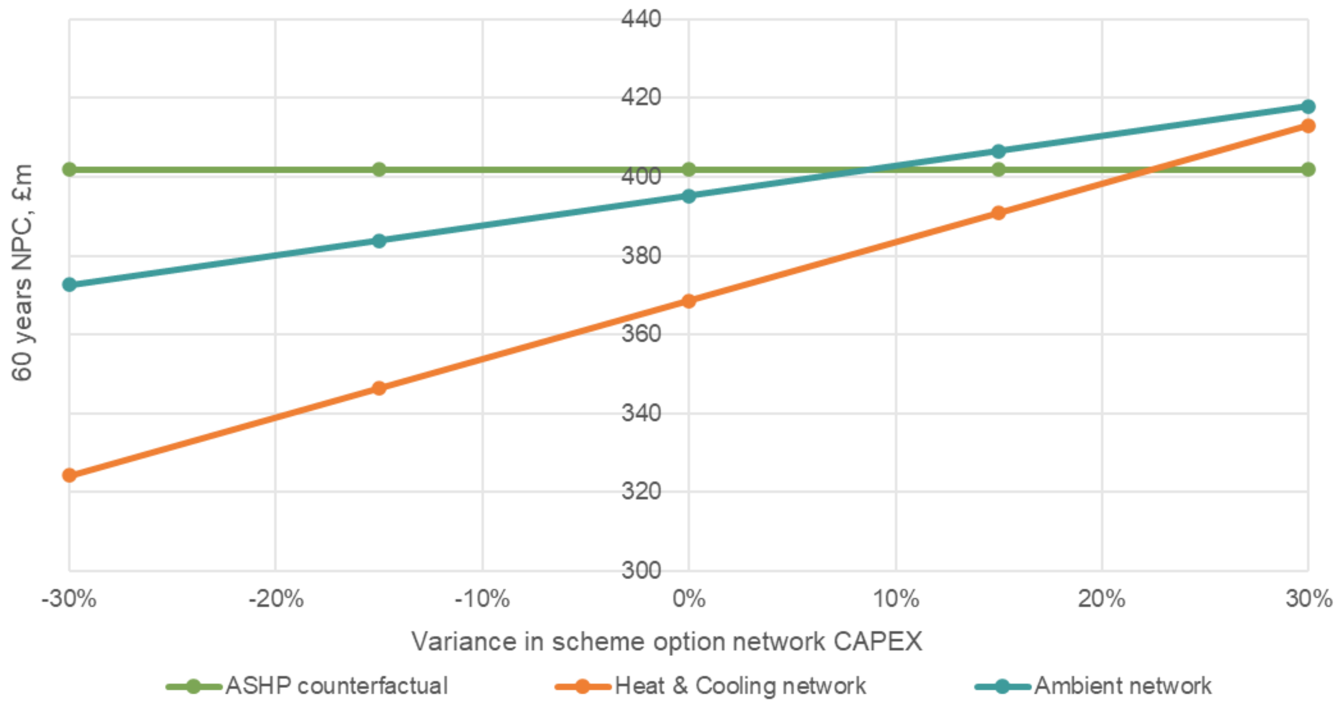


Figure 82: Variance in network CAPEX – Lawrence Hill

7.2 Heat and Cooling Demands

The heating and cooling demands were varied for each candidate area and the impact on the NPCs was recorded. Figure 83 shows this sensitivity for the Fishponds candidate area as an example. The ASHP option is the most sensitive to this variance, and this is reflective of the poorer efficiencies achieved by individual ASHP. Therefore, if the heating or cooling demand increases, the cost of meeting this additional demand is greatest in the ASHP option. The HCN and ambient network options are less sensitive to variations in energy demand.

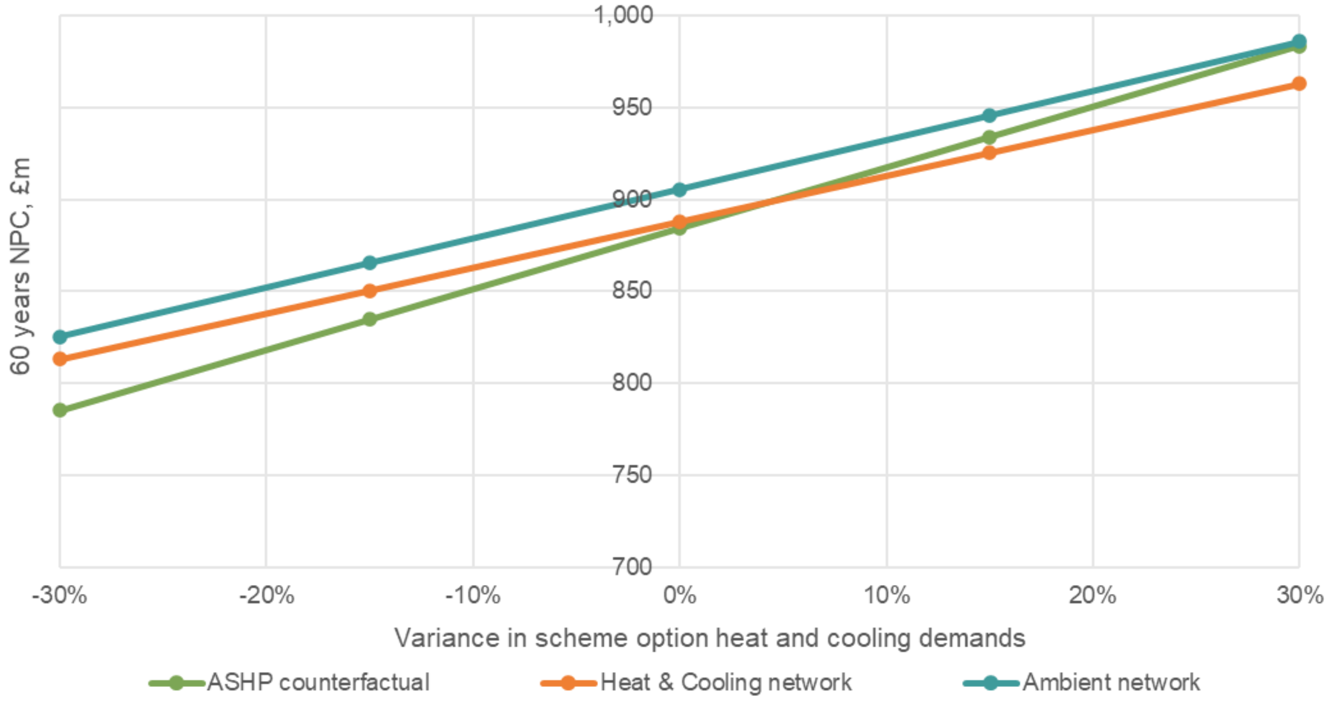


Figure 83: Variance in heat and cooling demands – Fishponds

7.3 Electricity Tariffs

Figure 84 shows the effect of variance in electricity costs on the NPCs of the BBSP candidate area as an example. In all candidate areas, the AHSP is the most sensitive to electricity tariffs as a larger portion of its costs are from electricity purchases. The ambient network has proportionally fewer costs in electricity purchases and is less sensitive. The HCN is the least sensitive, as it has the highest heat pump efficiency of all the options, as well as having peak and reserve gas boilers supplying 5% of the heat demand.

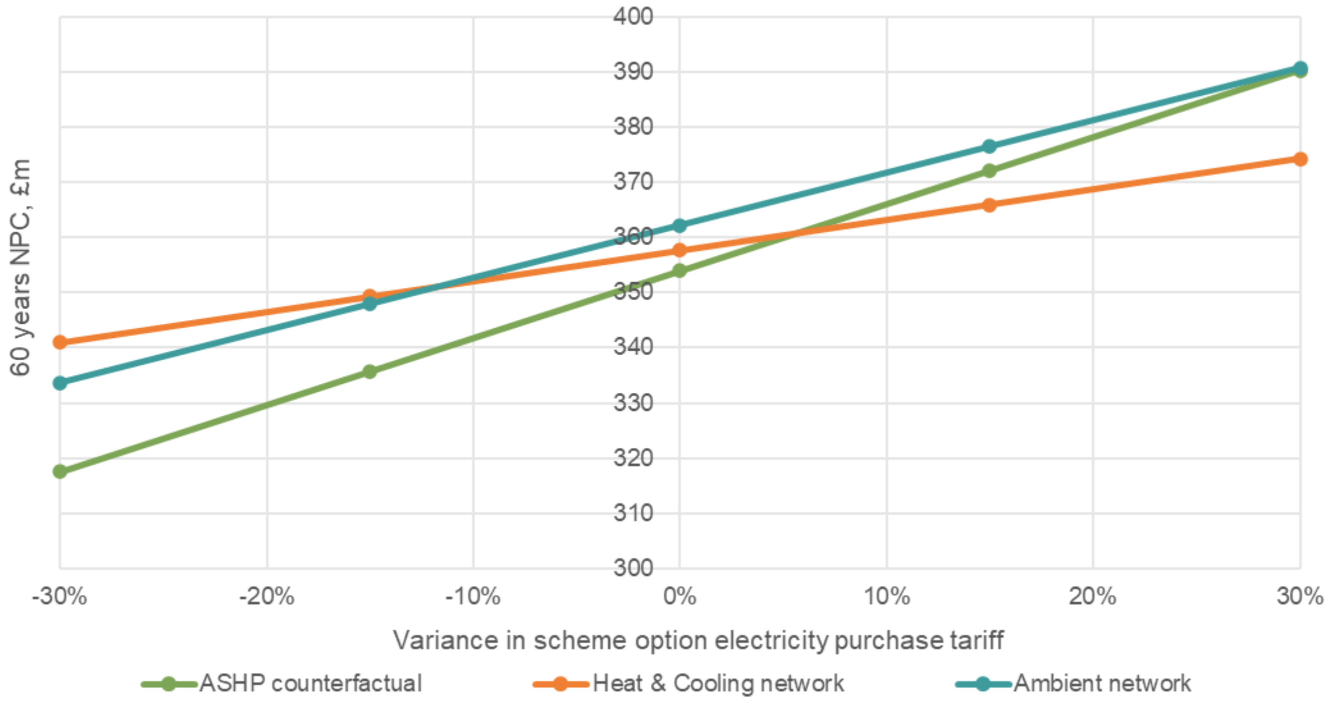


Figure 84: Variance in scheme options electricity purchase tariff – BBSP

7.4 Electric Peak and Reserve Boilers

The economic and socioeconomic performance of an HCN scheme option in each candidate area, using gas boilers and electric boilers as peak and reserve, were compared. For all of the candidate areas, the use of electric peak and reserve boilers increases network lifetime carbon savings compared to gas boilers. However, it also increases the NPC due to higher network OPEX from increased electricity consumption. This increase in network OPEX has a more significant impact compared to the savings from carbon emission reduction, resulting in a higher Social NPC when using electric peak and reserve boilers for most candidate areas.

The only candidate area where the electric boiler achieved a marginally lower Social NPC compared to the gas boiler is the BBSP candidate area. This is due to this candidate area having been assessed with a large portion of waste heat (28%) which has higher efficiency than the minewater heat pumps. Therefore, a larger portion of emissions are from the gas boilers, and implementing electric peak and reserve boilers saves more carbon proportionally compared to the base case.

An example of the comparison of network economics between the use of electric and gas boilers as peak and reserve boilers from the Douglas Road Industrial Park candidate area is shown in Table 53.

Table 53: Electric vs gas peak and reserve – Douglas Road Industrial Park

Scheme option carbon performance	HCN with gas boiler peak and reserve	HCN with electric boiler peak and reserve
NPC, £	£774,578,485	£790,457,049
Total carbon saving against BAU, tCO_2e	1,355,410	1,429,625
Social NPC, £	£565,982,941	£571,055,906

7.5 Heat Pump SPF

The heat pump seasonal performance factor (SPF) was varied for each candidate area and the impact on the NPCs was recorded. An example of the impact of variance in the SPF of heat pumps on the scheme options' Social NPC from the Barrs Court Residential candidate area is shown in Figure 85. SPF includes the electrical consumption related to the heat pumps and chillers. If the electricity consumption related to the heat pump/chiller increases, the project NPC will increase, as a significant portion of operational expenditures arises from electricity consumption. A variance in system SPFs will have a larger impact on the individual ASHP option in all candidate areas. This is because the individual ASHP scheme option starts from a lower system SPF in the base case compared to a HCN or ambient network scheme options.

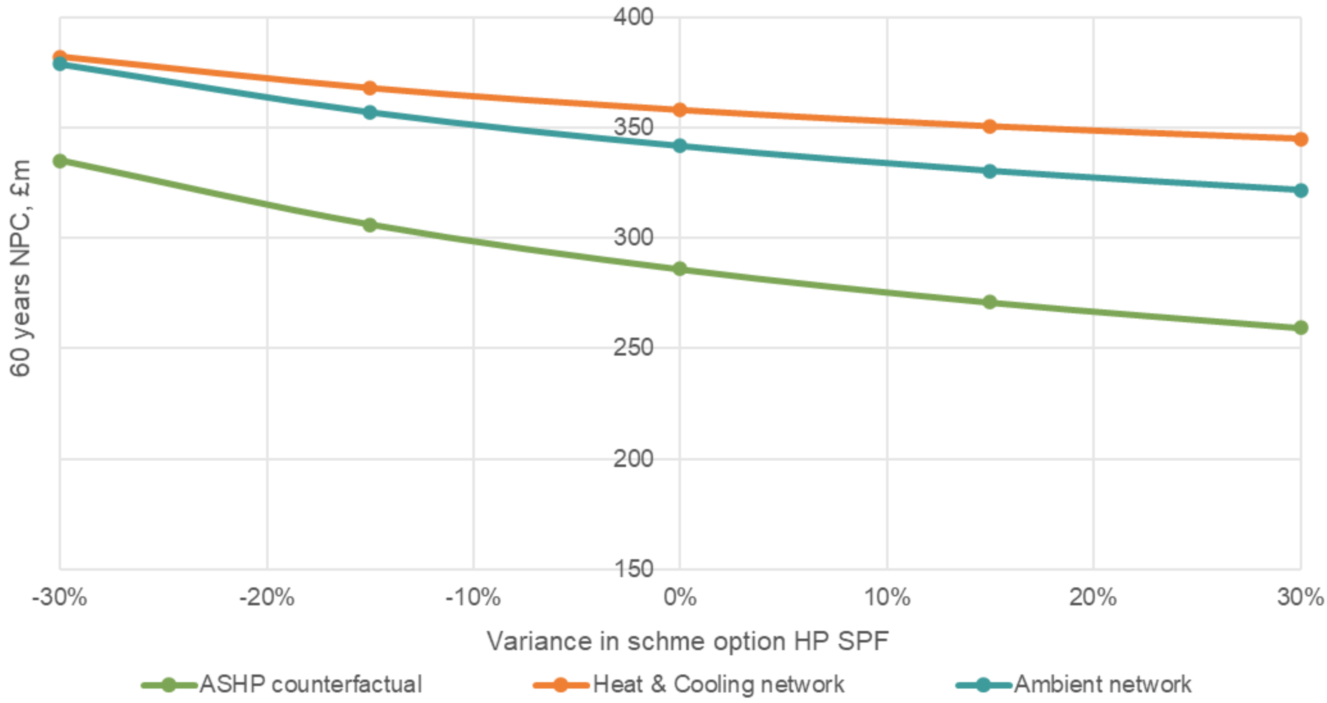


Figure 85: Impact of variance in heat pump SPF – Barrs Court Residential candidate area

7.6 Carbon Price Scenarios

The impact of the DESNZ carbon price scenarios—Low, Central (base case), and High on the Social NPC was assessed for each candidate area, and the outcome was recorded. An example of the impact of variance in the carbon price on the scheme options' Social NPC from the Lawrence Hill candidate area is shown in Figure 86. An increased carbon price from the High carbon price scenario will result in a decreased Social NPC due to increased savings per tCO_2e saved. For detailed DESNZ carbon price projections from low, central, and high scenarios, please see section 6.2.4.

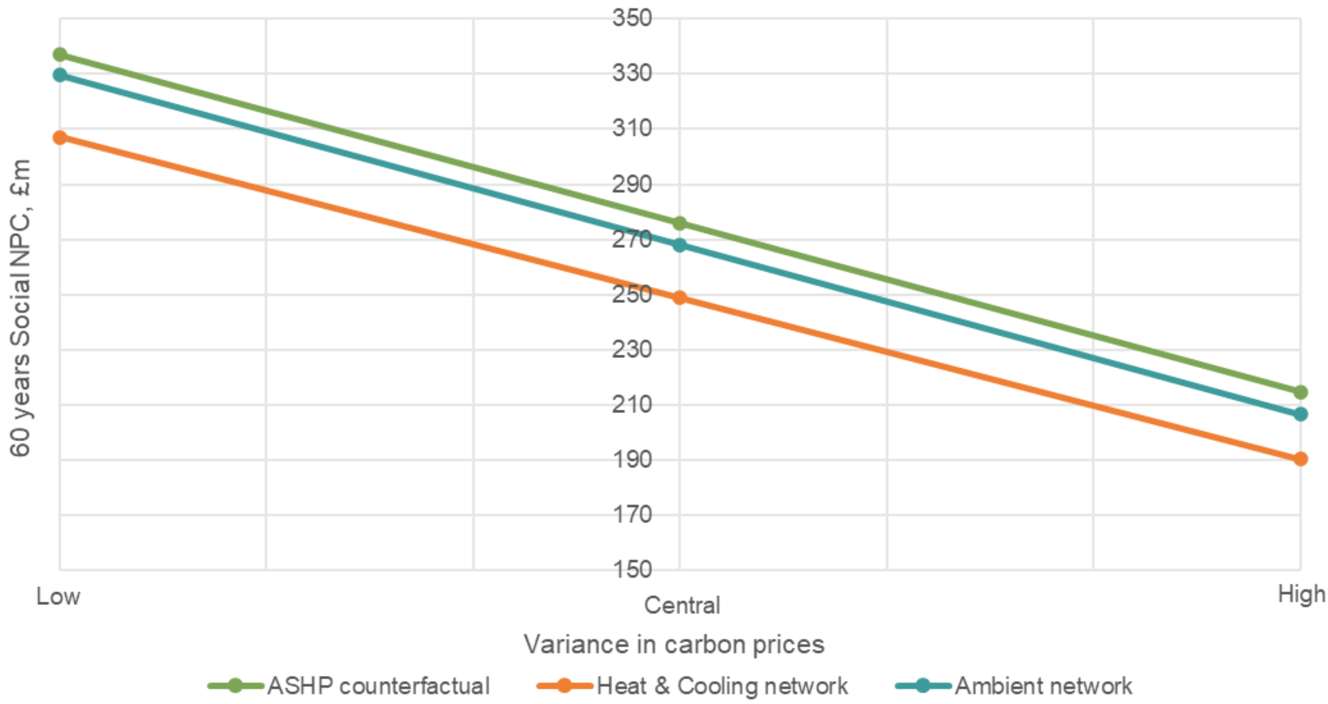


Figure 86: Variance in carbon prices – Lawrence Hill

8 RISKS AND ISSUES

Table 54: Risk level key

Impact	1	Insignificant
	2	Minor
	3	Moderate
	4	Major
	5	Catastrophic
Likelihood	1	Highly unlikely, but may occur in exceptional circumstances
	2	Not expected, but a slight possibility it may occur
	3	Might occur at some time
	4	There is a strong possibility of occurrence
	5	Very likely, expected to occur
Risk rating	0-5	Low risk
	6-14	Medium risk
	15-25	High risk

Table 55: Risk register

	Risk / issue	Risk rating			Rationale	Mitigating measure / action	Relevant options
		Impact	Likelihood	Rating			
Technical	**T1.1** Access to the mine water is not viable.	Risk rating: 4	5	**20**	The heat energy available from the mine seams is based on assumptions and the CA study done in the area. More detailed information should form the basis of detailed design.	When appropriate, a further study from the Coal Authority should be commissioned to determine the available resources, including potentially carrying out a trial borehole.	HCN, Ambient
		Mitigated risk rating: 3	5	**15**			
Technical	**T1.2** Securing suitable sites for energy centres.	Risk rating: 5	4	**20**	The HCN (and to a lesser extent the ambient network) is reliant on a suitable energy centre locations being secured with ease of access to the mine seams and utilities.	Several EC locations identified for the candidate areas are within privately owned land. These sites are either currently disused or reserved for future redevelopment (e.g. Bristol Ambulance Station and Filwood House). Engagement with the site owners should occur at the next stage of the project to discuss the potential for EC construction on-site.	HCN, Ambient
		Mitigated risk rating: 4	3	**12**			
Technical	**T1.3** Securing suitable sites for local ASHP or WSHP.	Risk rating: 4	5	**20**	The space allocated to heat generation plant within existing buildings is likely sized to accommodate gas boilers, whereas heat pumps will require more space. Most buildings will also not have any space currently allocated to cooling plant. In the case of ASHPs, space for the external units is also needed, potentially requiring structural upgrades.	Costs have been included for structural works for the external units of ASHPs. Buildings will need to be assessed on a case by case basis to determine if they can house a local heat pump, or if an external location is appropriate.	Ambient, ASHPs
		Mitigated risk rating: 4	5	**20**			
Technical	**T1.4** Building heat emitters are not compatible with local heat pumps	Risk rating: 4	5	**20**	Building heat emitters within existing buildings are likely to be designed to operate at the relatively higher temperatures generated by gas boilers, rather than the lower temperatures required for localised heat pumps. The HCN option has peak and reserve boilers, allowing it to raise temperatures when needed.	Replacement costs for building heat emitters have been included in the assessment for both the ambient and ASHP options.	Ambient, ASHPs
		Mitigated risk rating: 4	4	**16**			

	Risk / issue	Risk rating			Rationale	Mitigating measure / action	Relevant options
		Impact	Likelihood	Rating			
	T1.5 The visual and noise impact of the energy centre / pumping station.	Risk rating			The visual impact of the building may be deemed significant by planning officers. Should it be deemed significant, it may increase design costs, or limit the energy centre size.	Undertake engagement with the planning officers as part of the next stage of the project. An average energy centre cost (£3000/m²) has been included in the business case.	HCN
		4	3	12			
		Mitigated risk rating					
		4	3	12			
	T1.6 Air quality restrictions and considerations may restrict gas boiler options.	Risk rating			Emissions from the peak and reserve gas boilers will need to be considered and a more detailed assessment of the flue design and emissions dispersion may be required to assess the impact on neighbouring areas.	Low NOx boilers will be used in the network. During the further project stages an emissions dispersion model, air quality impact and flue height assessments should be undertaken. Assess the viability of including electric boilers as peak and reserve.	HCN
		5	4	20			
		Mitigated risk rating					
		5	3	15			
	T1.7 Utility connections to the energy centre/pumping station.	Risk rating			The required large utility connections pose a technical and economic risk. Electrical infrastructure reinforcement in the area of the energy centres will likely be required.	Costs for grid connections have been included in this study. Budget quotes for connection should be requested from the DNOs and included in future economic assessments.	HCN
		4	3	12			
		Mitigated risk rating					
		4	3	12			
	T1.8 Grid capacity	Risk rating			Individual HPs installed for both the ambient solution and individual HP solution must meet the building's peak/cooling demand. The peak electricity demand of local ASHP will be larger than local WSHP due to the poorer heat source (air). Local WSHPs will have a larger peak demand than the HCN, as the HCN has peak and reserve gas boilers, thermal storage and diversity.	Individual HP installations should consider the available local electrical capacity. More accurate costs for grid upgrades should be included in subsequent economic analyses.	Ambient, ASHP
		5	4	20			
		Mitigated risk rating					
		5	4	20			
Econom	**Ec1.1**	Risk rating			Sensitivity analysis indicates that the impact of increasing capital costs would be significant. If the TEM does	All project costs have been based on a combination of previous project experience, recent quotes for similar projects and soft market testing. The consultant team hold	HCN, Ambient, ASHPs
		5	4	20			

	Risk / issue	Risk rating			Rationale	Mitigating measure / action	Relevant options
		Impact	Likelihood	Rating			
	Capital costs are significantly higher than estimated.	Mitigated risk rating			not include robust project capital costs of the network, the conclusions may be inaccurate.	a broad knowledge of the actual costs of installing district energy schemes including costs for equipment supply and installation, distribution pipe work supply and installation, trench excavation and re-instatement. Sensitivity analysis has been undertaken to show the effect of a variance in capital costs. Contingency has been applied to all items of capital costs.	
		5	3	15			
	Ec1.3 Low-carbon schemes will require significant CAPEX to implement.	Risk rating			The HCN and ambient networks require significant upfront costs to construct the network and energy centres. If this funding cannot be secured then these options may not be viable.	Identify and target grant funding opportunities such as the Green Heat Network Fund. Ensure a robust grant funding bid is submitted for all potential low carbon schemes. Engagement with potential funding providers (including private investment) should take place as part of the next stage.	HCN, Ambient
		5	4	20			
		Mitigated risk rating					
		5	4	20			
	Ec1.4 Energy demands are not based on actual data.	Risk rating			The TEM's NPC is calculated based on the cost of heat and cooling generation. If these are incorrect, this could have an impact on the project economics. Sensitivity on the heating and cooling demands has been carried out in section 7.2	Both heat and cooling demand are estimated based on benchmarks obtained from in-house heat and cooling demand models. Actual data should be obtained where possible as the project progresses to ensure more accurate TEM output.	HCN, Ambient, ASHPs
		4	3	16			
		Mitigated risk rating					
		4	2	8			
Commercial	**C1.1** Senior decision-makers do not fully support the scheme, and / or the scheme is not linked to corporate priorities.	Risk rating			There is a risk that senior decision makers and elected members will not fully support the project. If this is the case, then viability will be affected. Engagement with senior decision makers and elected members is key to advance the project further, and create a base for local policies.	Engagement with senior members should be carried out to ensure key findings and opportunities from project work to date are understood.	HCN, Ambient, ASHPs
		5	3	15			
		Mitigated risk rating					
		5	3	15			

9 CONCLUSIONS

In most candidate areas identified, there is a case for either a HCN or an ambient network to serve the energy demands of the commercial and high-rise residential buildings. The ambient network tends to yield a slightly higher NPC but emits less carbon than the HCN. This is based on the HCN using gas boilers to meet 5% of the heat demand, and if this were replaced with electric boilers, the carbon emissions would reduce while the NPC would increase. This is discussed in further detail in the sensitivity section 7.

Extending to Low-rise Residential Properties

Adding low-rise residential connections always leads to an improvement in the case for individual ASHPs, even when the low-rise is at its densest such as in the area surrounding the Lawrence Hill candidate area. This indicates that ASHPs are the most economical way of heating and cooling these properties. In some cases however, if a HCN or ambient network is built to serve the commercial connection of a candidate area, this network could extend to a number of low-rise residential properties and still maintain a lower overall NPC than the individual ASHP option (as the residential option is a small enough portion of the overall demand). In essence, the high-density commercial demands would be subsidising the low-density residential. This would also allow the other benefits discussed in section 4.1 to be realised (e.g. less strain on the electrical grid and reduced amount of high-GWP refrigerant used).

Areas for further focus

In order to prioritise which areas should be explored in further detail, the NPCs of each candidate area have been compared against each other, using the ASHP as the benchmark (100%) as this is the most likely to occur without council intervention. The areas with the greatest reduction indicate the greatest potential for a viable network. This is displayed in Table 56. This table only includes the candidate areas without the low-rise residential, in order to identify core networks.

Table 56: Difference between NPCs for LZC solutions, using ASHP as the benchmark

Candidate area	ASHPs	HCN	Ambient	Rank
Lawrence Hill	100%	88%	89%	2
Fishponds	100%	77%	85%	1
Bristol and Bath Science Park	100%	91%	90%	3
Douglas Road	100%	103%	95%	4
Barrs Court Residential candidate area	100%	105%	120%	5

Based on this assessment, the Fishponds area should be the next area of focus, followed by Lawrence Hill, BBSP, and Douglas Road.

10 NEXT STEPS

The following next steps and recommendations should be considered to progress the scheme:

	Ref.	Action	Responsibility	Timing			Risk ref.
				Short term	Medium term	Long term	
General	AP1	Present the findings of the report to relevant stakeholders including SGC senior staff and elected members	Project team				
	AP2	Ensure the technical and economic work undertaken in this study will provide an evidence base for further work					
	AP3	Progress the identified schemes which offer a saving on ASHPs to feasibility stage, directing resource to those with the greatest savings (i.e. in order: Fishponds, Lawrence Hill, BBSP and Douglas Road)					
	AP4	Identify funding routes to support the next stages of the project in the required timescales					
Heat demand	AP5	Update energy assessment with more bespoke modelling of energy demands as the geographical scope of projects narrows, and for planned developments if further details are known or if development plans change					
EC / heat source	AP6	Further engage the Coal Authority to discuss the potential energy centre locations discussed in this study, and determine if further work is needed ahead of a Stage 2 Coal Authority report					
	AP7	Following on from engagement with the Coal Authority, determine whether to progress to trial boreholes. If so, engage with specialist drilling company, and identify potential funding for this activity (including the WECA Heat from Mines project)					
	AP8	Work with Local Authority planners to safeguard energy centre sites					
	AP9	Once project timeline is established, further investigate technology sizing and phasing strategy					
Heat network & connection	AP10	Engage with any developers in the candidate areas to ensure developments are compatible with the preferred solution					

APPENDIX 1: ENERGY DEMAND ASSESSMENT

Candidate Area 1 – Lawrence Hill

Table 57: Summary of all energy loads – Lawrence Hill

Site name	Ownership	Building use	Annual heat demand (2020), MWh	Source of heat data	Annual cooling demand (2080), MWh	Source of cooling data
First Group West of England Bus Depot	Private sector	Warehouse	46,573	Estimated using benchmark	0	Estimated using benchmark
City Academy Bristol	Public sector	Education	984,827	Estimated using DEC data	87,282	
We are Padel	Private sector	Leisure centre (Dry)	403,801	Estimated using benchmark	238,389	
City Academy Sports Centre	Public sector	Leisure centre (Dry)	274,480		228,973	
Barton Hill Academy	Public sector	Education	299,926	Estimated using DEC data	37,625	
Croydon House	Public sector	Residential	1,339,102	Estimated using benchmark	60,267	
Barton House	Public sector	Residential	1,268,607		57,094	
Lincoln Gardens Extra Care	Private sector	Nursing Home	842,466		34,689	
Oldland Aerospace	Private sector	Industrial	517,786		0	
Kingsmarsh House	Public sector	Residential	1,173,563		52,817	
Ashmead House	Public sector	Residential	1,068,126		48,071	
Redfield Lodge	Private sector	Nursing Home	416,933		17,167	
Princess Royal Gardens	Private sector	Residential	439,029		17,700	
Corbett House	Public sector	Residential	1,009,669		45,441	
Beaufort House	Public sector	Residential	933,052		41,992	
Longlands House	Public sector	Residential	932,848		41,983	
Eccleston House	Public sector	Residential	865,435		38,949	
Jubilee House	Public sector	Offices	367,249		242,977	
Harwood House	Public sector	Residential	861,521		38,773	
City View Apartments	Private sector	Residential	774,117		31,210	
Burdens & Fusion Utilities	Private sector	Warehouse	15,313		0	
Phoenix House	Public sector	Residential	755,924		34,021	
Mary Court	Private sector	Residential	302,805		12,208	

Site name	Ownership	Building use	Annual heat demand (2020), MWh	Source of heat data	Annual cooling demand (2080), MWh	Source of cooling data
Protyre Bristol	Private sector	Industrial	129,996		0	
Redfield Educate Together Primary Academy	Public sector	Education	169,581	Estimated using DEC data	17,197	
Lidl	Private sector	Retail	159,303		842,355	Actual chiller data
Dawkins Ales Brewery	Private sector	Industrial	109,556	Estimated using benchmark	0	
Baynton House	Public sector	Residential	597,873		26,907	
Berkeley House	Public sector	Offices	396,398	Estimated using DEC data	283,791	
Saint Patricks Catholic School	Public sector	Education	72,141		12,849	
Whitehall Printing	Private sector	Industrial	84,289	Estimated using benchmark	0	
Easton Community Childrens Centre	Public sector	Community Centre	130,860		78,462	Estimated using benchmark
Bristol Futures Academy	Public sector	Education	190,478	Estimated using DEC data	12,556	
Wellspring Healthy Living Centre	Private sector	Community Centre	260,186		156,004	
Cashmore House 1	Private sector	Residential	298,844		12,049	
Cashmore House 2	Private sector	Residential	269,547		10,867	
Cashmore House 3	Private sector	Residential	247,871		9,993	
Aldi	Private sector	Retail	200,146		1,102,890	Actual chiller data
Iceland	Private sector	Retail	141,669		46,659	
Moorfields House	Public sector	Residential	433,287	Estimated using benchmark	19,500	
Area 1	Private sector	Residential	6,350,400		387,926	
Area 2	Private sector	Residential	2,825,280		172,587	
Area 3	Private sector	Residential	2,937,600		179,449	Estimated using benchmark
Area 4	Private sector	Residential	3,300,480		201,616	
Area 5	Private sector	Residential	6,390,986		367,225	
Area 6	Private sector	Residential	23,863,680		1,457,756	
Area 7	Private sector	Residential	7,283,520		444,927	

Candidate Area 2 – Fishponds

Table 58: Summary of all energy loads – Fishponds

Site name	Ownership	Building use	Annual heat demand (2020), kWh	Source of heat data	Annual cooling demand (2080), kWh	Source of cooling data
UWE Glenside Campus	Private sector	Education	3,447,754	Estimated using DEC data	240,127	Estimated using benchmark
Lodge Causeway	Private sector	Warehouse	149,400	Estimated using benchmark	0	
Fromeside Unit	Public sector	Nursing Home	2,360,827		97,207	
TES Automotive	Private sector	Warehouse	173,063		0	
Bristol Metropolitan Academy	Public sector	Education	1,312,547	Estimated using DEC data	111,380	
Bristol Brunel Academy	Public sector	Education	2,046,495		139,894	
Booker Wholesale	Private sector	Warehouse	109,900	Estimated using benchmark	0	
Morrisons	Private sector	Retail	1,221,114		4,688,420	Actual chiller data
Absolutely Karting	Private sector	Warehouse	52,225		0	Estimated using benchmark
Captains House	Private sector	Residential	1,306,437		52,672	
Brunelcare	Private sector	Nursing Home	857,146		35,293	
Fulton	Private sector	Warehouse	82,986		0	
Panalex	Private sector	Industrial	374,088		0	
Bristol Uniforms	Private sector	Industrial	372,131		0	
B&M Bargains	Private sector	Retail	591,804		194,913	
MB Frames PVC	Private sector	Warehouse	29,079		0	
Wickham Unit	Private sector	Nursing Home	625,089		25,738	
Fishponds CE Academy	Public sector	Education	153,156	Estimated using DEC data	15,704	
Purdy Court	Private sector	Residential	898,734	Estimated using benchmark	36,235	
JD Gyms	Private sector	Leisure centre (Dry)	590,816		348,796	
Nelson House	Private sector	Residential	931,707		37,564	
Quarry House	Private sector	Nursing Home	1,037,120		42,704	
A City Carpets	Private sector	Industrial	200,941		0	
The Bed Superstore	Private sector	Warehouse	21,960		0	
Kirk House	Private sector	Residential	484,036		19,515	
Bristol Trasmissions	Private sector	Industrial	428,181		0	
Avanti Gardens School 1	Private sector	Education	338,171		21,522	
Parkway Mercedes	Private sector	Industrial	286,256		0	
Briarwood School 1	Public sector	Education	250,406	Estimated using DEC data	12,491	
Beechwood Medical Practice	Public sector	GP Surgery	276,470		198,292	
Acer Unit	Public sector	Hospital	381,269		119,924	

Site name	Ownership	Building use	Annual heat demand (2020), kWh	Source of heat data	Annual cooling demand (2080), kWh	Source of cooling data
Roegate House	Private sector	Residential	916,454	Estimated using benchmark	41,245	
Lidl	Private sector	Retail	206,486		1,201,605	Actual chiller data
B Block	Private sector	Education	288,960	Estimated using DEC data	20,125	Estimated using benchmark
St Joseph's Catholic	Public sector	Education	92,252		10,016	
SA Manufacturing	Private sector	Industrial	175,952	Estimated using benchmark	0	
Packaging People	Private sector	Warehouse	16,974		0	
Aldi	Private sector	Supermarket	200,349		1,028,896	Actual chiller data
Shrubbery Court	Private sector	Residential	752,403		30,335	Estimated using benchmark
Wolseley Plumb & Parts	Private sector	Retail	189,027		62,257	
Avanti Gardens School 2	Private sector	Education	154,761		9,849	
Pinnacle Brush	Private sector	Industrial	158,320		0	
Pleasant House	Private sector	Residential	445,490		17,961	
Glenside Student Centre	Private sector	Community centre	117,853	Estimated using DEC data	85,329	
Cedar House	Private sector	Residential	304,321	Estimated using benchmark	12,269	
C Block	Private sector	Education	213,548	Estimated using DEC data	14,873	
Berkeley House	Private sector	Residential	727,442	Estimated using benchmark	29,329	
Avanti Gardens School 3	Private sector	Education	212,311		13,512	
Broadway Engineering 1	Private sector	Industrial	242,832		0	
Lodge House	Public sector	Offices	463,903		306,924	
Iceland	Private sector	Retail	134,409		44,268	
Briarwood School 2	Public sector	Education	149,903	Estimated using DEC data	7,478	
Linden Homes	Private sector	Offices	85,968	Estimated using benchmark	56,878	
Fishponds Delivery Office	Private sector	Warehouse	19,581		0	
St Matthias Academy	Public sector	Education	83,536	Estimated using DEC data	10,279	
Woodland Court	Private sector	Residential	730,944	Estimated using benchmark	29,470	
Chester Park Junior	Public sector	Education	194,165	Estimated using DEC data	19,909	
Chester Park Infant	Public sector	Education	195,483		14,011	
Bed Maker	Private sector	Industrial	242,033	Estimated using benchmark	0	
Pendennis House	Private sector	Residential	196,207		7,911	

Site name	Ownership	Building use	Annual heat demand (2020), kWh	Source of heat data	Annual cooling demand (2080), kWh	Source of cooling data
Broadway Engineering 2	Private sector	Industrial	215,562	Estimated using DEC data	0	Actual chiller data
BIE Magnum	Private sector	Industrial	133,085		0	
HAG 1	Private sector	Industrial	130,716		0	
SFG Products	Private sector	Warehouse	22,428		0	
HAG 2	Private sector	Industrial	102,556		0	
Beacon Tower	Private sector	Offices	305,461		202,097	
A Block	Private sector	Education	65,535		4,564	
Rajani Superstore	Private sector	Retail	503,094	Estimated using benchmark	4,404,866	
Filwood Road	Planned development	Planned developments	3,646,100		209,585	Estimated using benchmark
Diamonite	Planned development	Planned developments	819,400		89,408	
Former Parnalls Works	Planned development	Planned developments	2,309,700		193,794	
The Vassall Centre	Planned development	Planned developments	626,400		40,175	
Churchill Retirement Living	Planned development	Planned developments	136,500		12,192	
Central Fishponds	Planned development	Planned developments	1,560,000		139,337	
Area 1	Private sector	Residential	15,137,280		924,688	
Area 2	Private sector	Residential	4,507,718		283,147	
Area 3	Private sector	Residential	16,256,463		1,021,130	
Area 4	Private sector	Residential	27,037,348		1,698,319	
Area 5	Private sector	Residential	10,207,338		641,162	
Area 6	Private sector	Residential	9,270,720		566,319	
Area 7	Private sector	Residential	26,920,847		1,691,001	

Candidate Area 3 – Bristol and Bath Science Park

Table 59: Summary of all energy loads – Bristol and Bath Science Park

Site name	Ownership	Building use	Annual heat demand (2020), kWh	Source of heat data	Annual cooling demand (2080), kWh	Source of cooling data
Prism	Private sector	Offices	273,505	Estimated using benchmark	180,954	Estimated using benchmark
Newlands Farm	Private sector	Offices	76,866		50,856	

Site name	Ownership	Building use	Annual heat demand (2020), kWh	Source of heat data	Annual cooling demand (2080), kWh	Source of cooling data
My Garage	Private sector	Industrial	161,249	Estimated using DEC data	0	Actual chiller data
Claranet	Private sector	Offices	73,493		48,624	
ALD	Private sector	Offices	374,752		247,941	
ITC Compliance	Private sector	Offices	87,387		57,816	
Emersons Green Library	Public sector	Library	17,947		35,227	
Emersons Green Retail Park	Private sector	Retail	761,581	Estimated using benchmark	763,967	
Chrysalis Supported Association Ltd	Private sector	Offices	89,209		59,022	Estimated using benchmark
UPS Bristol	Private sector	Industrial	236,024		0	
Just One Call Ltd	Private sector	Offices	257,439		170,325	
Danfloor UK Ltd	Private sector	Industrial	197,023		0	
Stannah Lifts	Private sector	Offices	115,983		76,736	
Leidos	Private sector	Offices	127,184		84,147	
Lidl	Private sector	Supermarket	132,642		43,686	
Lyde Green Community Centre	Public sector	Community centre	108,032		64,775	
David Lloyd	Private sector	Leisure centre (Dry)	333,958		197,157	
Folly	Private sector	Pub	102,528		30,361	
Toolstation Bristol Emersons Green	Private sector	Retail	369,642		121,743	
Emersons Green NHS Treatment Centre	NHS	Hospital	1,381,590	Estimated using DEC data	445,517	Estimated using benchmark
Knorr Bremse Syst	Private sector	Industrial	650,911	Estimated using benchmark	0	
Police station	Private sector	Police station	266,988		176,643	
Emerson Way	Private sector	Retail	223,628		73,653	
Sainsbury's	Private sector	Supermarket	1,358,793		447,523	
Costa Drive Thru	Private sector	Retail	26,923		8,867	
TRG Solutions	Private sector	Offices	113,841		75,319	
Travelodge Bristol Emersons Green	Private sector	Hotel	499,098		111,537	
ALD Automotive	Private sector	Offices	507,720		335,914	
Iceland	Private sector	Supermarket	95,150		31,338	
DPD Parcel Distribution Centre	Private sector	Warehouse	70,431		0	

Site name	Ownership	Building use	Annual heat demand (2020), kWh	Source of heat data	Annual cooling demand (2080), kWh	Source of cooling data
The Cobden Centre	Private sector	Warehouse	76,508	Previous project data	0	Previous project data
Emerald Park East	Private sector	Offices	362,433		239,791	
Premier Inn Bristol East (Emersons Green)	Private sector	Hotel	346,716		77,483	
National Composites Centre	Private sector	Offices	882,811		3,779,477	
Emersons Green Village Hall	Private sector	Community Centre	164,561	Estimated using benchmark	98,669	
Office 2	Private sector	Offices	93,355		61,765	
Bristol and Bath Science Park	Private sector	Offices	1,573,726	Previous project data	1,178,941	Previous project data
Sainsbury's Distribution Depot	Private sector	Warehouse	383,283	Estimated using benchmark	4,571,186	
Expleo	Private sector	Offices	233,752		154,654	Estimated using benchmark
Hft	Private sector	Offices	157,925		104,485	
Sainsbury's Local	Private sector	Retail	46,472		15,306	
Busy Bees	Other public sector	Education	98,110		6,244	
S J Cook & Sons Accident Repair Centre	Private sector	Industrial	411,274		0	
Boots	Private sector	Retail	188,364		62,038	
Lyde Green Primary School	Other public sector	Education	132,711	Estimated using DEC data	22,561	Estimated using benchmark
Sungard Availablity Services	Private sector	Industrial	233,783	Estimated using benchmark	0	
Leidos Europe Ltd	Private sector	Offices	166,021		109,841	
Office 1	Private sector	Offices	107,045		70,822	
ERIKS	Private sector	Industrial	144,287		0	
IAAPS ltd	Private sector	Offices	418,021	Previous project data	1,484,323	Previous project data
Emersons Green Beefeater	Private sector	Pub	183,839	Estimated using benchmark	54,438	Estimated using benchmark
Emersons Green Medical Centre	Private sector	GP Surgery	128,229		65,173	
Huboo	Private sector	Warehouse	29,146		0	
Procentia Ltd	Private sector	Offices	181,300		119,951	
DHL Exel Supply Chain Ltd	Private sector	Warehouse	97,881		0	

Site name	Ownership	Building use	Annual heat demand (2020), kWh	Source of heat data	Annual cooling demand (2080), kWh	Source of cooling data
Countryside Partnerships South West	Private sector	Offices	169,716	Previous project data	112,286	Previous project data
NHS Blood & Transplant	Private sector	Industrial	139,561		0	
Office	Private sector	Offices	93,276		61,713	
The Mill House	Private sector	Pub	168,400		49,866	
Blackcore Technologies	Private sector	Industrial	290,613		0	
Office 3	Private sector	Offices	109,101		72,183	
AMX Solutions	Private sector	Offices	122,342		80,943	
Vectura	Planned development	Planned developments	696,960		759,475	
Plot K1	Planned development	Planned developments	374,374		407,955	
Plot B	Planned development	Planned developments	959,504		1,045,568	
Plot C	Planned development	Planned developments	465,471		1,992,768	
Plot D	Planned development	Planned developments	155,216	Previous project data	551,145	Previous project data
Plot J	Planned development	Planned developments	482,482		525,759	
BBSP residential	Private sector	Residential	24,589,057	Estimated using benchmark	1,398,341	Estimated using benchmark
Lyde green north	Planned development	Residential	10,776,796		612,859	
Lyde green south	Planned development	Residential	3,529,401		200,711	
New Lyde Green Secondary School	Other public sector	Education	974,808		66,636	

Candidate Area 4 – Douglas Road Industrial Park

Table 60: Summary of all energy loads – Douglas Road Industrial Park

Site name	Ownership	Building use	Annual heat demand (2020), kWh	Source of heat data	Annual cooling demand (2080), kWh	Source of cooling data
John Cabot Academy	Public sector	Education	879,598	Estimated using DEC Data	70,760	Estimated using benchmark
Vue	Private sector	Theatre	1,722,518	Estimated using benchmark	100,111	
Douglas Road Industrial Park	Private sector	Industrial	549,277		-	

Site name	Ownership	Building use	Annual heat demand (2020), kWh	Source of heat data	Annual cooling demand (2080), kWh	Source of cooling data
Ministry of Fitness	Private sector	Leisure centre (Dry)	888,111		347,843	
King's Oak Academy 1	Public sector	Education	598,904	Estimated DEC benchmark	43,137	
Kingswood Estate	Private sector	Industrial	671,472	Estimated using DEC Data	-	
Kingswood Civic Centre	Public sector	Community centre	567,417	Estimated DEC benchmark	291,827	
Lidl (North)	Private sector	Supermarket	352,963	Estimated using benchmark	1,575,321	
Hollywood Bowl	Private sector	Leisure centre (Dry)	733,331		287,221	
Longwell Green Leisure Centre	Private sector	Leisure centre (Dry)	340,172		133,234	
The Park Centre Kingswood	Public sector	Community centre	253,908		101,001	
Springly Court	Private sector	Residential (Low-rise)	827,900		33,379	
Magpie Court	Private sector	Nursing Home	1,007,855	Estimated using benchmark	41,499	Estimated using benchmark
Falcon Court	Private sector	Residential (Low-rise)	706,489		28,484	
Sainsbury's	Private sector	Supermarket	379,094		99,100	
King's Oak Academy 2	Public sector	Education	163,350	Estimated using DEC data	11,766	
Kings Chase Shopping Centre 1	Private sector	Retail	412,819	Estimated using benchmark	107,917	
Avon Valley Care Home	Private sector	Nursing Home	713,339		29,372	
Kings Chase Shopping Centre 2	Private sector	Retail	456,350		119,296	
New Horizons Learning Cente 1	Public sector	Education	301,784		16,115	
Kings Chase Shopping Centre 3	Private sector	Retail	389,844		101,911	
Courtney Primary School	Public sector	Education	188,192		10,049	
The Park Primary School	Public sector	Education	143,398	Estimated using DEC data	15,055	
Two Mile Hill Primary School 1	Public sector	Education	206,830		18,045	
The Kingswood Centre	Public sector	Education	117,396	Estimated using benchmark	6,733	
Lidl (South)	Private sector	Supermarket	151,652		773,754	
Kingswood Community Centre	Public sector	Community centre	129,973		51,702	
Studio 2 Display Graphics	Private sector	Industrial	118,014		-	

Site name	Ownership	Building use	Annual heat demand (2020), kWh	Source of heat data	Annual cooling demand (2080), kWh	Source of cooling data
King's Oak Academy 3	Public sector	Education	179,597	Estimated using DEC data	12,936	
Kingswood Delivery Office	Private sector	Warehouse	23,522	Estimated using benchmark	-	
Avon Fire & Rescue Service	Public sector	Fire Station	155,476	Estimated using DEC data	54,841	
Oatley Trading Centre	Private sector	Warehouse	10,708	Estimated using benchmark	-	Estimated using benchmark
Oakfield Business Park	Private sector	Industrial	110,808		-	
New Horizons Learning Centre 2	Public sector	Education	109,506	Estimated using DEC data	5,606	
Fairview Court Care Home 1	Private sector	Nursing Home	350,720	Estimated using benchmark	14,441	
Avon Lodge Care Home	Private sector	Nursing Home	342,035		14,083	
Mortimer House Nursing Home	Private sector	Nursing Home	244,550		10,069	
Elmtree Way 1	Private sector	Residential (Low-rise)	233,660		13,985	
Kings Gate House	Private sector	Residential (Low-rise)	169,324		6,827	
Its Leisure	Private sector	Leisure centre (Dry)	238,070		93,244	
Kingswood House	Private sector	Offices	86,925		38,154	
Kingswood Hub	Public sector	Community centre	134,811	Estimated using DEC data	124,802	
Our Lady of Lourdes Catholic Primary School	Public sector	Education	99,258		7,882	
Minestry of Fitness	Private sector	Leisure centre (Dry)	101,409	Estimated using benchmark	39,718	
Beacon Rise Primary School 1	Public sector	Education	128,131	Estimated using DEC data	7,150	
Cecil House	Private sector	Residential (Low-rise)	372,025	Estimated using benchmark	14,999	
Elmtree Way 2	Private sector	Residential (Low-rise)	187,530		11,224	
Beacon Rise Primary School 2	Public sector	Education	120,398	Estimated using DEC data	6,719	
Co-op Food	Private sector	Supermarket	78,369	Estimated using benchmark	20,487	
Iceland	Private sector	Supermarket	124,098		32,441	
The Orchard Medical Centre	Public sector	GP Surgery	199,689		67,334	
Bendix Social Club	Public sector	Community centre	86,611		34,452	
Beacon Rise Primary School 3	Public sector	Education	110,695	Estimated using DEC data	6,177	

Site name	Ownership	Building use	Annual heat demand (2020), kWh	Source of heat data	Annual cooling demand (2080), kWh	Source of cooling data
Two Mile Hill Primary School 2	Public sector	Education	72,665	Estimated using DEC data	6,340	Estimated using benchmark
The Edge	Private sector	Residential (Low-rise)	315,016	Estimated using benchmark	12,701	
Kenver House	Private sector	Nursing Home	160,008		6,588	
Ultimate FIIT PT & Group	Private sector	Leisure centre (Dry)	131,824		51,631	
Fairview Court Care Home 2	Private sector	Nursing Home	138,288		5,694	
Kingswood Health Centre	Public sector	GP Surgery	59,347	Estimated using DEC data	43,307	
Link House	Private sector	Offices	165,456	Estimated using benchmark	72,625	
John Cabot Academy 2	Public sector	Education	72,935	Estimated using DEC data	5,867	
Courtney Ladybirds Pre School	Public sector	Education	38,259	Estimated using benchmark	2,043	
Beacon Rise Primary School 4	Public sector	Education	83,031	Estimated using DEC data	4,634	
Asda	Private sector	Supermarket	1,738,395	Estimated using benchmark	12,754,874	
Former Douglas Motorcycle	Public sector	Planned developments	1,358,640		73,036	
Anstey's Road	Private sector	Planned developments	1,341,500		89,292	
Area 1	Private sector	Residential (Terraced)	12,098,250		725,705	
Area 2	Private sector	Residential (Terraced)	10,512,035		630,557	
Area 3	Private sector	Residential (Terraced)	5,995,355		359,627	
Area 4	Private sector	Residential (Terraced)	6,452,400		387,043	
Area 5	Private sector	Residential (Terraced)	36,841,412		2,209,907	
Area 6	Private sector	Residential (Terraced)	9,615,868		576,801	
Area 7	Private sector	Residential (Terraced)	4,561,920	Estimated using benchmark	264,549	Estimated using benchmark
Area 8	Private sector	Residential (Terraced)	3,701,168		222,012	
Area 9	Private sector	Residential (Terraced)	10,565,805		633,783	
Area 10	Private sector	Residential (Terraced)	3,473,280		201,418	

Candidate Area 5 – Barrs Court Residential

Table 61: Summary of all energy loads – Barrs Court Residential

Site name	Assumed floor area, m^2	Annual heat demand (2020), kWh	Annual cooling demand (2080), kWh	Source of energy data
Detached house	120	16,080	852	Estimated using benchmark
Semi-detached house	95	8,962	656	
Terraced house	80	8,640	584	
Flats	65	3,699	404	

APPENDIX 2: KEY PARAMETERS AND ASSUMPTIONS

Energy Tariffs

The energy tariff used in the scheme options Techno-Economic Modelling assessment are shown in Table 62.

Table 62: Scheme option import tariff

Energy tariffs	
Scheme options commercial electricity tariff, p/kWh	12.68
Scheme options residential electricity tariff, p/kWh	20.75
Scheme options commercial gas tariff, p/kWh	3.12
Scheme options residential gas tariff, p/kWh	4.92
Energy centre electricity tariff (excl. CCL), p/kWh	12.68
Energy centre gas tariff (excl. CCL), p/kWh	3.09

Key Technology Parameters

Key technology parameters for the network are shown in Table 63.

Table 63: Technical inputs

Parameter	Value	Source of data / assumption
SPF for heat pump	Various	Varies for each network phase derived from manufacturers' performance curves based on the selected heat pump, assumed water conditions for the site and required network temperatures.
Peak and reserve boiler efficiency	85% gas 100% electric	Expected efficiency of new gas boilers based on the experience of the operating plant.

Technology replacement costs have been calculated on an annualised basis and take into account the expected lifetime of the technology, fractional repairs and the length of the business term. Plant/equipment lifetimes are shown in Table 64.

Table 64: Plant and equipment lifetime

Plant / equipment	Lifetime	Fractional repairs
Heat pumps	20 years	50%
Peak and reserve boilers	30 years	100%
Heat network customer-building connections	20 years	100%

Table 65: Energy centre building costs

Candidate areas	Energy Centre, m^2	Energy Centre cost, £/m^2	Pumping station (Ambient network), m^2	Pumping station cost, £/m^2
Lawrence Hill	3,037	3,000	737	3,000
Fishponds	7,144		1,678	
Bristol and Batch Science Park	3,408		655	
Douglas Road Industrial Park	5,778		1,372	
Barrs Court Residential	2,055		534	

DESNZ Energy Price Projection

The DESNZ fossil fuel price projections (central scenario) are shown in Table 66.

Table 66: DESNZ fossil fuel price projections

	Sector	Units	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
El	Industrial	p/kWh	28.1	26.8	20.9	11.9	11.3	11.2	10.9	11.1	11.1	11.2	11.1	11.2	11.6	11.7	11.7	11.7

	Sector	Units	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
	Residential	p/kWh	30.7	41.7	40.3	34.8	22.3	21.3	20.8	20.7	20.6	19.8	19.8	20.1	20.4	20.2	20.2	19.6
	Services	p/kWh	30.1	29.0	23.0	13.8	13.2	13.0	12.7	12.8	12.7	12.7	12.6	12.6	13.0	13.1	13.1	12.9
Natural gas	Industrial	p/kWh	8.2	8.2	5.6	2.5	2.2	2.3	2.3	2.3	2.4	2.4	2.5	2.5	2.5	2.6	2.6	2.6
	Residential	p/kWh	7.4	11.3	11.3	8.6	5.2	4.9	4.9	4.9	4.9	5.0	5.0	5.0	5.0	5.1	5.1	5.1
	Services	p/kWh	8.9	8.9	6.4	3.3	3.0	3.1	3.1	3.2	3.2	3.2	3.3	3.3	3.3	3.4	3.4	3.4

CO_2e Emissions Factors

The electricity grid CO_2e emissions figures used in assessments are shown in Table 67.

Table 67: Electricity grid CO_2e emissions

Year	Electricity grid CO_2e emissions, gCO_2e/kWh			Year	Electricity grid CO_2e emissions, gCO_2e/kWh	
	long run marginal figures (commercial)	long run marginal figures (Residential)			long run marginal figures (commercial)	long run marginal figures (Residential)
2023	243	248		2037	14	15
2024	226	230		2038	11	11
2025	207	211		2039	8	9
2026	187	191		2040	6	7
2027	166	169		2041	6	6
2028	143	145		2042	4	4
2029	118	120		2043	3	3
2030	91	93		2044	2	2
2031	70	71		2045	1	1
2032	54	55		2046	1	1
2033	41	42		2047	1	1
2034	32	32		2048	1	2
2035	24	25		2049	2	2
2036	19	19		2050	1	1

Table 68: Natural gas CO_2e emissions

Parameter	Value
Natural gas CO_2e emissions factor, gCO_2e/kWh	183.9
Average efficiency for BAU gas boilers	90%

Capital Cost

Capital costs for the schemes are based on a combination of previous project experience and quotations for recent similar works.

Candidate Area 1 – Lawrence Hill

A summary of scheme options capital costs for the Lawrence Hill candidate area is shown in Table 69.

Table 69: Capital costs include contingency – Lawrence Hill

	BAU replacement	Individual ASHPs	HCN	Ambient network
Further project development (e.g. professional fees, legal, design, surveys, etc.)	-	-	£14,788,400	£6,226,000
Contractor costs for preliminaries, project management and design	-	-	£10,563,300	£4,447,300

	BAU replacement	Individual ASHPs	HCN	Ambient network
Construction insurance	-	-	£2,113,100	£889,900
Cost of land purchase/lost land value	-	-	-	-
Energy centre building	-	-	£10,477,927	£2,543,794
Heat pump	-	£68,230,794	£16,108,650	£50,810,756
Other HP technology	-	-	-	-
Cost of accessing the heat source (e.g. boreholes, abstraction platform etc…)	-	-	£4,592,962	£4,592,962
Heat pump M&E	-	-	£5,591,432	-
Peak and reserve gas boilers	£17,748,405	-	£1,581,577	-
Initial ASHP install (civils, screening and local electrical upgrades)	-	£25,953,760	-	-
Pressurisation & Water treatment	-	-	£848,100	£429,465
Peak and reserve boiler flues	-	-	£949,200	-
Main district heat network pumps	-	-	£467,500	£693,000
Commercial chillers & AC units for residential	£42,489,893	-	-	-
Chiller M&E	£11,588,153	-	-	-
Main district cooling network pumps	-	-	£237,600	-
Controls	-	-	£1,620,000	£405,000
Other energy centre M&E	-	-	£1,372,800	£1,364,000
Secondary side upgrade - cooling (FCU)	-	£13,611,941	-	£13,611,941
Heat emitter upgrade - (Rads, AHUs, FCUs)	-	£40,274,171	-	£40,274,171
Thermal store(s)	-	-	-	-
Gas grid connection	-	-	-	-
Electricity grid connection	-	£2,252,958	£483,259	£1,351,775
Additional feed connection cost to residential - heat and cooling network	-	-	£112,108,309	-
Additional feed connection cost to residential - Ambient network	-	-	-	£49,336,037
Heat network spines	-	-	£18,526,023	-
Cooling network spines	-	-	£14,479,103	-
Ambient network spines	-	-		£17,873,298
Cost of substations at building connections	-	-	£32,138,446	-
Total	**£71,826,451**	**£150,323,623**	**£249,047,687**	**£194,849,399**

A summary of the network spine size, length, and associated cost for the Lawrence Hill candidate area is shown in Table 70.

Table 70: Network spine summary for Lawrence Hill candidate area

Pipe size	Heat network	£/m for heat network	Cooling network	£/m for cooling network	Ambient network	£/m for ambient network
20	51	£618	-	£494	-	£477
25	97	£971	-	£767	51	£747
32	221	£1,229	33	£854	-	£832
40	405	£1,774	265	£1,266	97	£1,233
50	912	£1,835	335	£1,312	66	£1,280
65	1853	£1,919	1490	£1,368	154	£1,336
80	505	£1,998	570	£1,470	772	£1,438
100	261	£2,165	113	£1,647	1089	£1,513
125	580	£2,175	1173	£1,828	1368	£1,790
150	561	£2,305	849	£1,999	450	£1,961
200	660	£2,742	820	£2,206	752	£2,140
250	800	£3,157	373	£2,432	516	£2,363
300	348	£3,419	775	£2,681	785	£2,608
350	-	£3,722	-	£2,955	-	£2,879
400	28	£4,055	28	£3,258	443	£3,178
450	-	£4,389	-	£3,592	360	£3,508
500	-	£4,722	-	£3,960	348	£3,872
600	-	£5,389	-	£4,365	25	£4,274
700	-	£6,055	-	£4,812	-	£4,718

Candidate Area 2 – Fishponds

A summary of scheme options capital costs for the Fishponds candidate area is shown in Table 69.

Table 71: Capital costs include contingency – Fishponds

	BAU replacement	Individual ASHPs	HCN	Ambient network
Further project development (e.g. professional fees, legal, design, surveys, etc.)	-	-	£38,141,400	£16,519,800
Contractor costs for preliminaries, project management and design	-	-	£27,243,700	£11,799,700
Construction insurance	-	-	£5,449,400	£2,360,600
Cost of land purchase/lost land value	-	-	£0	£0
Energy centre building	-	-	£24,645,865	£5,789,741
Heat pump	-	£149,076,527	£36,663,697	£110,093,637
Other HP technology	-	-	£0	£0
Cost of accessing the heat source (e.g. boreholes, abstraction platform etc…)	-	-	£10,453,699	£10,453,699
Heat pump M&E	-	-	£12,726,242	-
Peak and reserve gas boilers	£36,950,360	-	£3,599,708	-
Initial ASHP install (civils, screening and local electrical upgrades)	-	£68,108,576	-	-
Pressurisation & Water treatment	-	-	£1,985,500	£2,825,548
Peak and reserve boiler flues	-	-	£2,158,800	-

	BAU replacement	Individual ASHPs	HCN	Ambient network
Main district heat network pumps	-	-	£1,062,600	£1,631,850
Commercial chillers & AC units for residential	£97,172,488	-	-	-
Chiller M&E	£26,501,588	-	-	-
Main district cooling network pumps	-	-	£600,600	-
Controls	-	-	£3,792,000	£948,000
Other energy centre M&E	-	-	£3,175,700	£3,125,100
Secondary side upgrade - cooling (FCU)	-	£29,670,028	-	£29,670,028
Heat emitter upgrade - (Rads, AHUs, FCUs)	-	£98,360,328	-	£98,360,328
Thermal store(s)	-	-	-	-
Gas grid connection	-	-	-	-
Electricity grid connection	-	£5,127,790	£1,099,911	£3,076,674
Additional feed connection cost to residential - heat and cooling network	-	-	£341,089,206	-
Additional feed connection cost to residential - Ambient network	-	-	-	£147,786,291
Heat network spines	-	-	£39,683,229	-
Cooling network spines	-	-	£29,370,414	-
Ambient network spines	-	-		£39,611,284
Cost of substations at building connections	-	-	£58,550,418	-
Total	**160,624,435**	**350,343,249**	**641,492,089**	**484,052,280**

A summary of the network spine size, length, and associated cost for the Fishponds candidate area is shown in Table 72.

Table 72: Network spine summary for Fishponds candidate area

Pipe size	Heat network	£/m for heat network	Cooling network	£/m for cooling network	Ambient network	£/m for ambient network
20	558	£618	-	£494	-	£477
25	22	£971	-	£767	398	£747
32	229	£1,229	43	£854	61	£832
40	904	£1,774	172	£1,266	121	£1,233
50	885	£1,835	1,235	£1,312	153	£1,280
65	3,883	£1,919	885	£1,368	417	£1,336
80	841	£1,998	2,104	£1,470	1,061	£1,438
100	1,702	£2,165	997	£1,647	2,757	£1,513
125	1,129	£2,175	1,891	£1,828	1,570	£1,790
150	716	£2,305	424	£1,999	1,015	£1,961
200	1,712	£2,742	1,844	£2,206	1,995	£2,140
250	1,118	£3,157	1,994	£2,432	578	£2,363
300	904	£3,419	824	£2,681	764	£2,608
350	-	£3,722	-	£2,955	-	£2,879

Pipe size	Heat network	£/m for heat network	Cooling network	£/m for cooling network	Ambient network	£/m for ambient network
400	582	£4,055	388	£3,258	2,561	£3,178
450	9	£4,389	274	£3,592	203	£3,508
500	-	£4,722	0	£3,960	904	£3,872
600	-	£5,389	9	£4,365	526	£4,274
700	-	£6,055	-	£4,812	99	£4,718

Candidate Area 3 – BBSP

A summary of scheme options capital costs for the BBSP candidate area is shown in Table 73.

Table 73: Capital costs include contingency– BBSP

	BAU replacement	Individual ASHPs	HCN	Ambient network
Further project development (e.g. professional fees, legal, design, surveys, etc.)	-	-	£15,385,700	£7,003,700
Contractor costs for preliminaries, project management and design	-	-	£10,990,100	£5,002,800
Construction insurance	-	-	£2,198,900	£1,001,000
Cost of land purchase/lost land value	-	-		
Energy centre building	-	-	£11,758,150	£2,258,646
Heat pump	-	£57,747,177	£6,969,606	£42,180,663
Other HP technology	-	-	£7,333,333	-
Cost of accessing the heat source (e.g. boreholes, abstraction platform etc…)	-	-	£2,928,111	£4,078,111
Heat pump M&E	-	-	£4,664,657	-
Peak and reserve gas boilers	£13,595,534	-	£1,404,289	-
Initial ASHP install (civils, screening and local electrical upgrades)	-	£30,401,051	-	-
Pressurisation & Water treatment	-	-	£920,700	£1,254,118
Peak and reserve boiler flues	-	-	£842,400	£0
Main district heat network pumps	-	-	£414,700	£790,350
Commercial chillers & AC units for residential	£52,056,948	-	-	-
Chiller M&E	£14,197,349	-	-	-
Main district cooling network pumps	-	-	£396,000	-
Controls	-	-	£1,759,200	£439,800
Other energy centre M&E	-	-	£1,380,500	£1,273,800
Secondary side upgrade - cooling (FCU)	-	£13,657,941	-	£13,657,941
Heat emitter upgrade - (Rads, AHUs, FCUs)	-	£41,479,577	-	£41,479,577
Thermal store(s)	-	-	-	-
Gas grid connection	-	-	-	-
Electricity grid connection	-	£2,000,411	£429,088	£1,200,247

	BAU replacement	Individual ASHPs	HCN	Ambient network
Additional feed connection cost to residential - heat and cooling network	-	-	£104,196,690	-
Additional feed connection cost to residential - Ambient network	-	-	-	£45,046,892
Heat network spines	-	-	£30,005,390	-
Cooling network spines	-	-	£28,542,965	-
Ambient network spines	-	-	-	£33,778,995
Cost of substations at building connections	-	-	£26,354,744	-
Total	**79,849,831**	**145,286,157**	**258,875,224**	**200,446,639**

A summary of the network spine size, length, and associated cost for the BBSP candidate area is shown in Table 74.

Table 74: Network spine summary for BBSP candidate area

Pipe size	Heat network	£/m for heat network	Cooling network	£/m for cooling network	Ambient network	£/m for ambient network
20	53	£618	-	£494	-	£477
25	201	£971	34	£767	-	£747
32	441	£1,229	-	£854	39	£832
40	594	£1,774	93	£1,266	9	£1,233
50	1,502	£1,835	156	£1,312	109	£1,280
65	1,099	£1,919	443	£1,368	148	£1,336
80	644	£1,998	797	£1,470	699	£1,438
100	1,323	£2,165	546	£1,647	937	£1,513
125	795	£2,175	1,090	£1,828	857	£1,790
150	1,046	£2,305	1,962	£1,999	638	£1,961
200	3,009	£2,742	2,106	£2,206	2,165	£2,140
250	853	£3,157	1,785	£2,432	617	£2,363
300	-	£3,419	753	£2,681	760	£2,608
350	-	£3,722	-	£2,955	-	£2,879
400	41	£4,055	1,063	£3,258	3,361	£3,178
450	-	£4,389	348	£3,592	86	£3,508
500	-	£4,722	41	£3,960	787	£3,872
600	-	£5,389	-	£4,365	348	£4,274
700	-	£6,055	-	£4,812	41	£4,718

Candidate Area 4 – Douglas Road Industrial Park

A summary of scheme options capital costs for the Douglas Road Industrial Park candidate area is shown in Table 75.

Table 75: Capital costs include contingency – Douglas Road Industrial Park

	BAU replacement	Individual ASHPs	HCN	Ambient network
Further project development (e.g. professional fees, legal, design, surveys, etc.)	-	-	33,826,100	£14,698,200

	BAU replacement	Individual ASHPs	HCN	Ambient network
Contractor costs for preliminaries, project management and design	-	-	24,161,500	£10,498,400
Construction insurance	-	-	4,832,300	£2,099,900
Cost of land purchase/lost land value	-	-	-	-
Energy centre building	-	-	19,935,130	£4,733,539
Heat pump	-	127,243,738	29,975,272	£95,168,735
Other HP technology	-	-	-	-
Cost of accessing the heat source (e.g. boreholes, abstraction platform etc…)	-	-	8,546,668	£8,546,668
Heat pump M&E	-	-	10,404,640	-
Peak and reserve gas boilers	33,765,591	-	2,943,027	-
Initial ASHP install (civils, screening and local electrical upgrades)	-	44,461,494	-	-
Pressurisation & Water treatment	-	-	1,608,200	£2,285,434
Peak and reserve boiler flues	-	-	1,765,200	
Main district heat network pumps	-	-	869,000	£1,320,000
Commercial chillers & AC units for residential	82,607,620	-	-	-
Chiller M&E	22,529,351	-	-	-
Main district cooling network pumps	-	-	475,200	-
Controls	-	-	3,072,000	£768,000
Other energy centre M&E	-	-	2,582,800	£2,549,800
Secondary side upgrade - cooling (FCU)	-	£26,371,192	-	£26,371,192
Heat emitter upgrade - (Rads, AHUs, FCUs)	-	£71,707,214	-	£71,707,214
Thermal store(s)	-	-	-	-
Gas grid connection	-	-	-	-
Electricity grid connection	-	£4,192,346	£899,258	£2,515,407
Additional feed connection cost to residential - heat and cooling network	-	-	£293,022,787	-
Additional feed connection cost to residential - Ambient network	-	-	-	£126,285,889
Heat network spines	-	-	£39,840,953	-
Cooling network spines	-	-	£34,238,343	-
Ambient network spines	-	-	-	£42,567,173
Cost of substations at building connections	-	-	£56,195,700	-
Total	**138,902,562**	**273,975,983**	**569,194,077**	**412,115,551**

A summary of the network spine size, length, and associated cost for the Doulas Road In candidate area is shown in Table 76.

Table 76: Network spine summary for Douglas Road Industrial Park candidate area

Pipe size	Heat network	£/m for heat network	Cooling network	£/m for cooling network	Ambient network	£/m for ambient network
20	296	£618	-	£494	16	£477
25	112	£971	4	£767	125	£747
32	1,107	£1,229	925	£854	74	£832
40	1,420	£1,774	271	£1,266	90	£1,233
50	2,483	£1,835	695	£1,312	148	£1,280
65	1,909	£1,919	1,657	£1,368	991	£1,336
80	639	£1,998	2,376	£1,470	1,100	£1,438
100	1,193	£2,165	719	£1,647	1,415	£1,513
125	2,225	£2,175	1,146	£1,828	981	£1,790
150	658	£2,305	1,195	£1,999	1,248	£1,961
200	2,879	£2,742	2,169	£2,206	3,267	£2,140
250	859	£3,157	2,926	£2,432	1,525	£2,363
300	235	£3,419	1,166	£2,681	1,343	£2,608
350	-	£3,722	-	£2,955	-	£2,879
400	146	£4,055	381	£3,258	2,344	£3,178
450	7	£4,389	-	£3,592	527	£3,508
500	-	£4,722	7	£3,960	588	£3,872
600	-	£5,389	-	£4,365	381	£4,274
700	-	£6,055	-	£4,812	-	£4,718

Candidate Area 5 – Barrs Court Residential

A summary of scheme options capital costs for Barrs Court Residential candidate area is shown in Table 77.

Table 77: Capital costs include contingency – Barrs Court Residential

	BAU replacement	Individual ASHPs	HCN	Ambient network
Further project development (e.g. professional fees, legal, design, surveys, etc.)			£16,658,400	£7,761,600
Contractor costs for preliminaries, project management and design	-	-	£11,899,800	£5,544,000
Construction insurance	-	-	£2,380,400	£1,108,800
Cost of land purchase/lost land value	-	-	-	-
Energy centre building	-	-	£7,088,574	£1,841,516
Heat pump	-	£51,004,250	£11,661,450	£39,003,250
Other HP technology	-	-	-	-
Cost of accessing the heat source (e.g. boreholes, abstraction platform etc…)	-	-	£3,324,959	£3,324,959
Heat pump M&E	-	-	£4,047,776	-
Peak and reserve gas boilers	£15,001,250	-	£1,144,942	-

	BAU replacement	Individual ASHPs	HCN	Ambient network
Initial ASHP install (civils, screening and local electrical upgrades)	-	£9,000,750	-	-
Pressurisation & Water treatment	-	-	£580,800	£527,538
Peak and reserve boiler flues	-	-	£687,600	-
Main district heat network pumps	-	-	£338,800	£465,300
Commercial chillers & AC units for residential	£30,002,500	-	-	-
Chiller M&E	£8,182,500	-	-	-
Main district cooling network pumps	-	-	£135,300	-
Controls	-	-	£1,108,800	£277,200
Other energy centre M&E	-	-	£961,400	£974,600
Secondary side upgrade - cooling (FCU)	-	£10,800,900	-	£10,800,900
Heat emitter upgrade - (Rads, AHUs, FCUs)	-	£21,001,750	-	£21,001,750
Thermal store(s)	-	-	-	-
Gas grid connection	-	-	-	-
Electricity grid connection	-	£1,630,972	£349,843	£978,583
Additional feed connection cost to residential - heat and cooling network	-	-	£80,643,865	-
Additional feed connection cost to residential - Ambient network	-	-	-	£34,651,345
Heat network spines	-	-	£63,016,873	-
Cooling network spines	-	-	£46,639,038	-
Ambient network spines	-	-	-	£61,448,426
Cost of substations at building connections	-	-	£27,774,456	-
Total	**53,186,250**	**93,438,622**	**280,443,077**	**189,709,767**

A summary of the network spine size, length, and associated cost for the Barrs Court Residential candidate area is shown in Table 78.

Table 78: Network spine summary for the Barrs Court Residential candidate area

Pipe size	Heat network	£/m for heat network	Cooling network	£/m for cooling network	Ambient network	£/m for ambient network
20	11,658	£618	-	£494	-	£477
25	5,634	£971	4,176	£767	5,406	£747
32	3,764	£1,229	3,433	£854	4,915	£832
40	3,134	£1,774	2,275	£1,266	5,075	£1,233
50	2,988	£1,835	3,317	£1,312	5,065	£1,280
65	1,344	£1,919	-	£1,368	2,623	£1,336
80	2,074	£1,998	793	£1,470	2,643	£1,438
100	1,375	£2,165	1,734	£1,647	1,842	£1,513
125	691	£2,175	-	£1,828	1,203	£1,790
150	1,220	£2,305	1,884	£1,999	2,404	£1,961

Pipe size	Heat network	£/m for heat network	Cooling network	£/m for cooling network	Ambient network	£/m for ambient network
200	169	£2,742	1,745	£2,206	675	£2,140
250	807	£3,157	-	£2,432	1,039	£2,363
300	-	£3,419	1,986	£2,681	-	£2,608
350	-	£3,722	1,392	£2,955	1,277	£2,879
400	-	£4,055	-	£3,258	-	£3,178
450	-	£4,389	464	£3,592	691	£3,508
500	-	£4,722	-	£3,960	-	£3,872
600	-	£5,389	-	£4,365	-	£4,274
700	-	£6,055	-	£4,812	-	£4,718

APPENDIX 3: SITE SURVEY REPORT

Please see the separate document “Site Survey Report” for further details.

APPENDIX 4: HEAT PUMP REFRIGERANT

There are advantages and disadvantages associated with different refrigerants and the choice of refrigerant in heat pumps can depend on a number of criteria including efficiency, required water temperatures and scale.

Most domestic scale heat pumps use synthetic refrigerants (HFCs) that have a high GWP meaning they have a considerable environmental impact when they leak. This impact can be two to three thousand times higher than CO_2. For this reason, the UK has committed to the Kigali amendment of the Montreal Protocol in January 2019 where we commit to cutting the production and consumption of HFCs by more than 80% over the next 30 years and replacing them with less damaging, ideally natural, alternatives.

The European Commission F-gas phase down states that by 2021-2023 the average GWP of refrigerants should be less than 900, and by 2030 the average GWP should be 400. The lifetime of a chilling or heating plant is approximately 15-20 years. Therefore, the plant installed now will require a GWP of less than 400, as otherwise by 2030, it will exceed the Kilgali Amendment phase down targets. Net zero CO_2e targets will also be affected by plants and equipment installed in buildings that contain powerful greenhouse gases. All new buildings should consider the lifetime impacts of the refrigerant as well as its efficiency in reducing overall emissions of greenhouse gases. The main refrigerants used in commercially available heat pumps are summarised in Table 79.

Table 79: Refrigerants used in heat pump systems

Refrigerant	GWP	Type	Application	Considerations
R134a	1,430	HFC	Medium and large heat pump systems	• Higher efficiency than R410a but lower than ammonia • Low pressure and high volume requirements which result in higher CAPEX • Mainly used in split heating and cooling units
R410a	2,088	HFC	Domestic heat pumps and heat and cooling installations	• Can be used in low temperature systems • Lower volume requirements and resultant CAPEX than R134a • Lower efficiency than R134a
R32	675	HFC	Domestic heat pumps	• Relatively new refrigerant often used as a substitute for R410a • Mildly flammable and non-toxic • More efficient than R410a
R454c	146	Hydro -fluoro-olefin	Commercial and industrial refrigeration systems and domestic	• Suitable for low and medium temperature refrigeration systems • Mildly flammable
R600a/R600 (iso/butane	3	Natural refrigerant	Large heat pump and refrigerant installations	• Can provide temperatures higher than 80°C • Subject to strict safety requirements due to fire and explosion hazard
R290 (propane)	3	Natural refrigerant	Large heat pump systems and more recently a limited choice of domestic heat pumps	• Due to its low environmental impact and thermodynamic properties has started to be used in domestic heat pumps • Domestic heat pump systems higher cost than those utilising HFCs • Lower efficiency than R32 at higher temperatures in domestic models
R717 (ammonia)	0	Natural refrigerant	Large heat pump and refrigerant installations in industrial environments	• High efficiency • Can provide temperatures of up to 80°C

Refrigerant	GWP	Type	Application	Considerations
				• Although non-flammable, it is subject to strict safety requirements as it is toxic and carries a strong odour
R744 (CO_2)	1	Natural refrigerant	Large heat pump and refrigerant installations	• Requires a maximum return temperature of 30°C, which limits its suitability in domestic heat pumps

APPENDIX 5: SENSITIVITY RESULTS

10.1 Candidate Area 1 – Lawrence Hill

Capital Costs

Figure 87 shows the effect of a variance of network CAPEX on scheme option NPCs. The reduction in CAPEX has a more significant impact on the HCN and ambient network NPC compared to the individual HPs option. This suggests that a distribution network scenario is more CAPEX-sensitive compared to individual HP solutions.

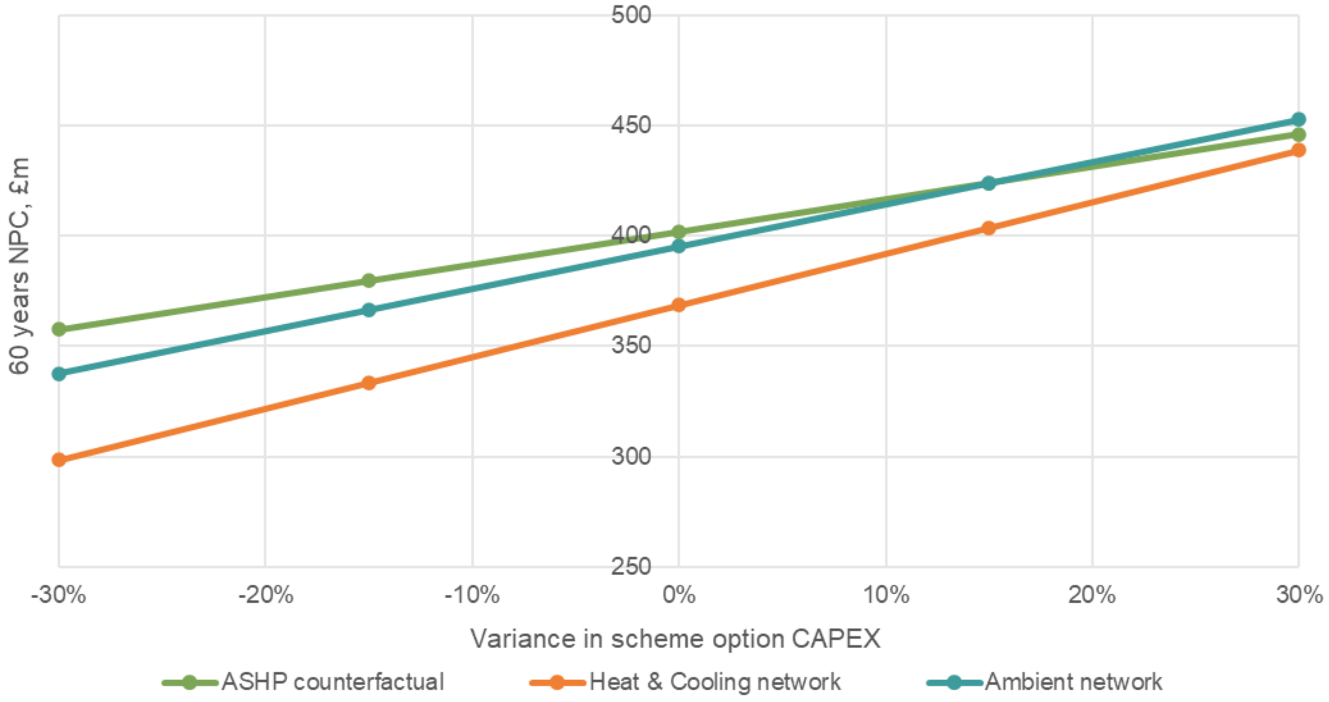


Figure 87: Variance in scheme option CAPEX – Lawrence Hill

Figure 88 shows the effect of a variance of network CAPEX on scheme option NPCs. The HCN and ambient network options are more CAPEX sensitive, and therefore, a reduced network CAPEX would result in a significant reduction in NPCs.

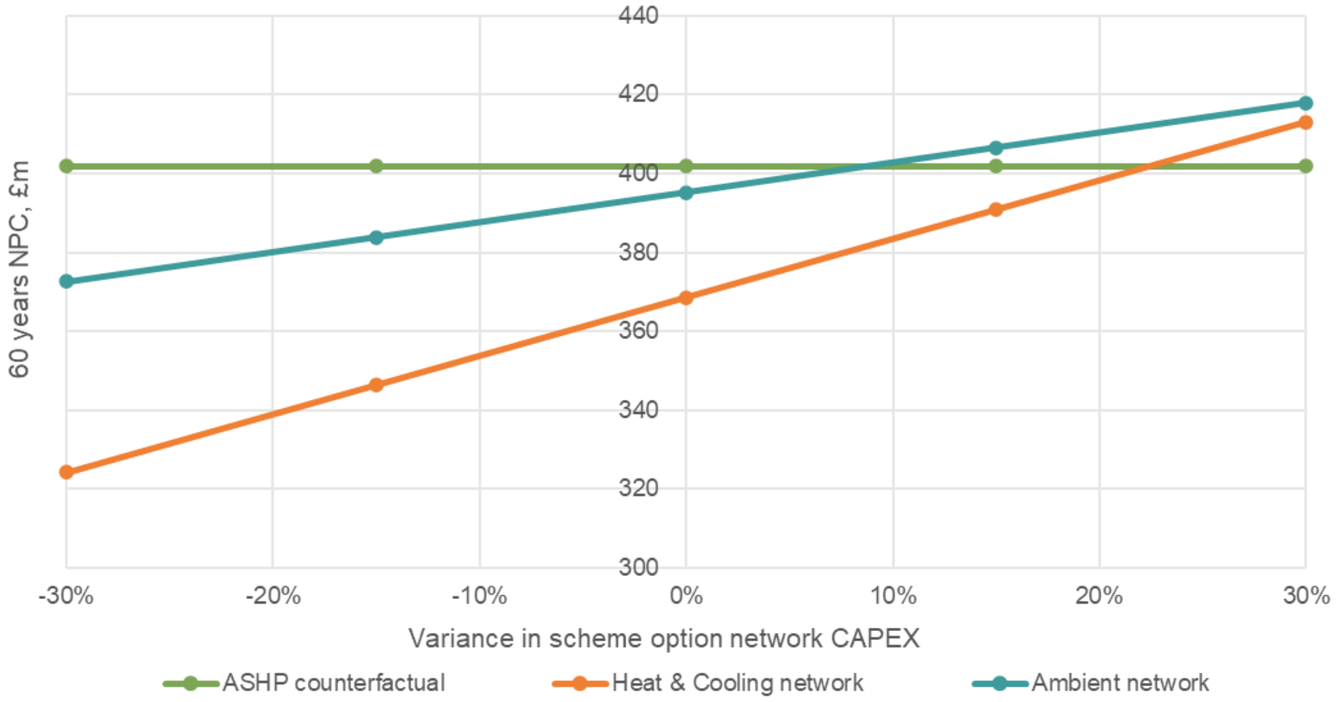


Figure 88: Variance in network CAPEX – Lawrence Hill

Heat and Cooling Demands

Figure 89 shows the effect of a variance in the total network heat and cooling demand, with all other parameters remaining constant. An increase in heat and cooling demand results in higher NPCs across all scheme options due to increased fuel consumption. The heat and cooling network scheme option remains the lowest-cost option because of its higher system efficiency. The analysis does not consider the installation of additional or larger-capacity heat pumps.

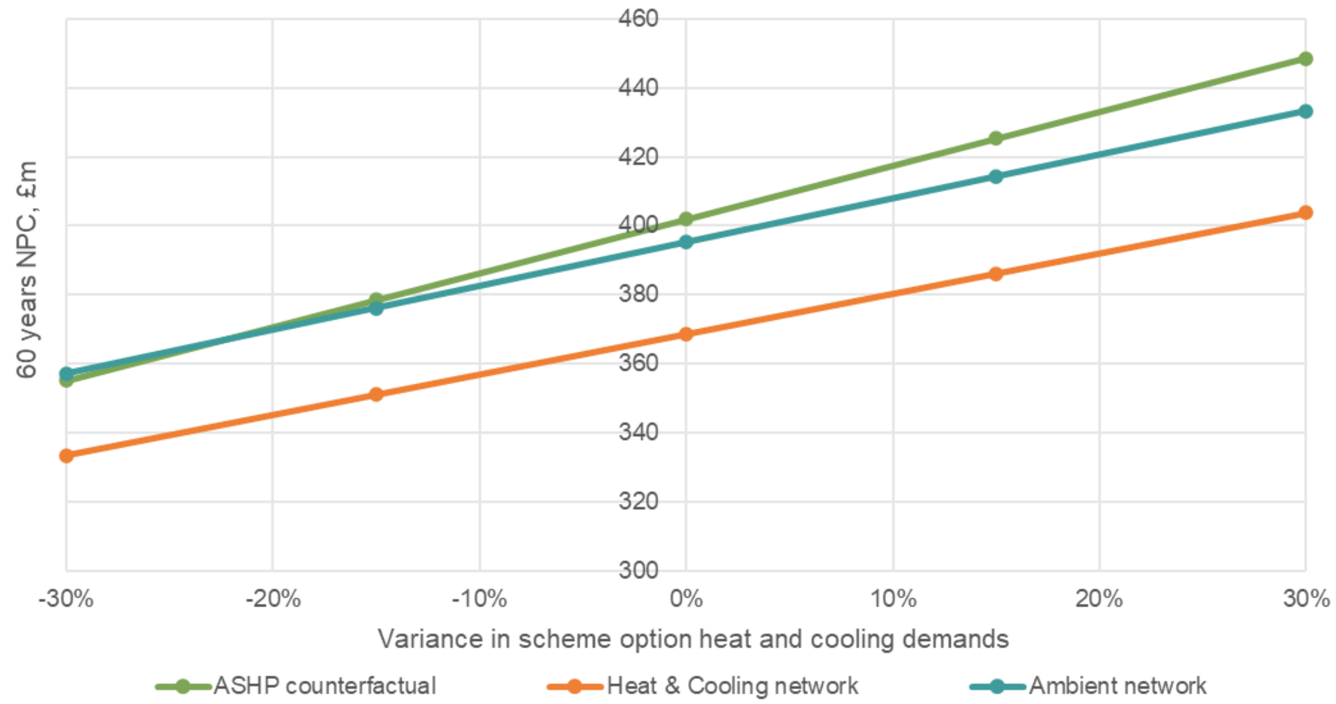


Figure 89: Variance in heat and cooling demands – Lawrence Hill

Electricity Tariffs

Figure 90 shows the effect of a variance in electricity purchase tariff for different scheme options. For the base case assessment, an electricity purchase tariff of 12.68 p/kWh has been used for HCN energy centres and commercial buildings, while an electricity tariff of 20.75 p/kWh has been used for residential dwellings. This has a significant effect on the 60-year NPC for all scheme options, as a significant portion of the operational costs comes from electricity purchases.

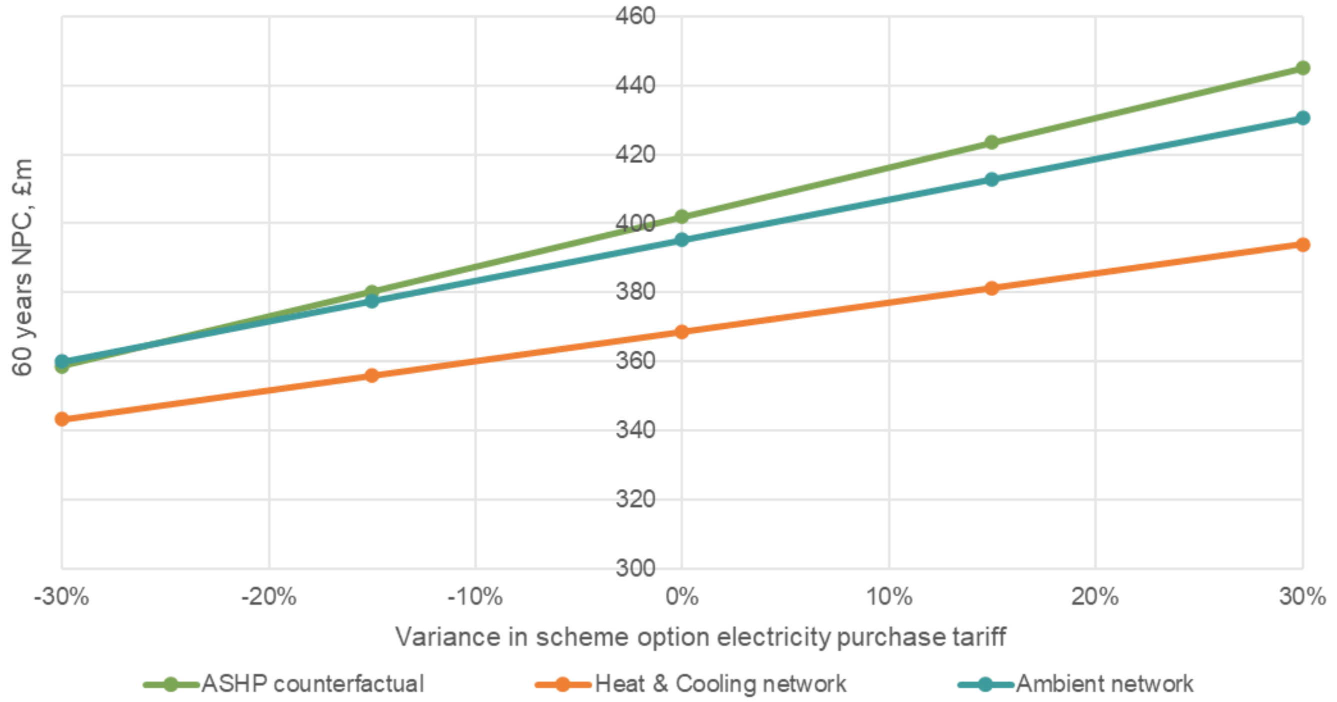


Figure 90: Variance in scheme options electricity purchase tariff – Lawrence Hill

The impact of price indexing on all energy tariffs is shown in Table 80. The NPCs remain relatively constant across different DESNZ scenarios, suggesting that the scheme options are resilient against changes in energy prices.

Table 80: Impact of indexing of all energy tariffs – Lawrence Hill

	BAU	Individual ASHPs	HCN	Ambient network
DESNZ central scenario	£275,618,099	£401,883,433	£368,625,978	£395,245,943
DESNZ low scenario	£256,476,681	£393,816,751	£364,014,554	£388,783,991
DESNZ high scenario	£298,102,980	£411,051,533	£376,468,014	£402,854,523
Fixed rate: 0%	£272,339,653	£406,472,693	£366,313,660	£398,497,023
Fixed rate: 2.5%	£275,024,777	£410,043,490	£368,394,587	£401,397,392

Electric Peak and Reserve Boilers – HCN only

The use of electric peak and reserve boilers increases network lifetime carbon savings compared to gas boilers. However, it also increases the NPC due to higher network OPEX from increased electricity consumption. This increase in network OPEX has a more significant impact compared to the savings from carbon emission reduction, resulting in a higher Social NPC when using electric peak and reserve boilers. The comparison of the network economics between the use of electric and gas boilers is shown in Table 81.

Table 81: Electric vs gas peak and reserve – Lawrence Hill

Scheme option carbon performance	HCN with gas boiler peak and reserve	HCN with electric boiler peak and reserve
NPC, £	£368,625,978	£377,746,785
Discounted OPEX – 60 years, £	£123,276,777	£132,397,584
Carbon intensity of heat delivered in year 2030, gCO_2e/kWh	42.8	36.1
Total carbon saving against BAU, tCO_2e	777,995	820,618
Social NPC, £	£248,837,129	£251,750,865

Heat Pump SPF

The impact of variance in the SPF of the heat pumps is shown in Figure 91. SPF includes the electrical consumption related to the heat pumps and chillers. If the electricity consumption related to the heat pump/chiller increases, the project NPC will increase.

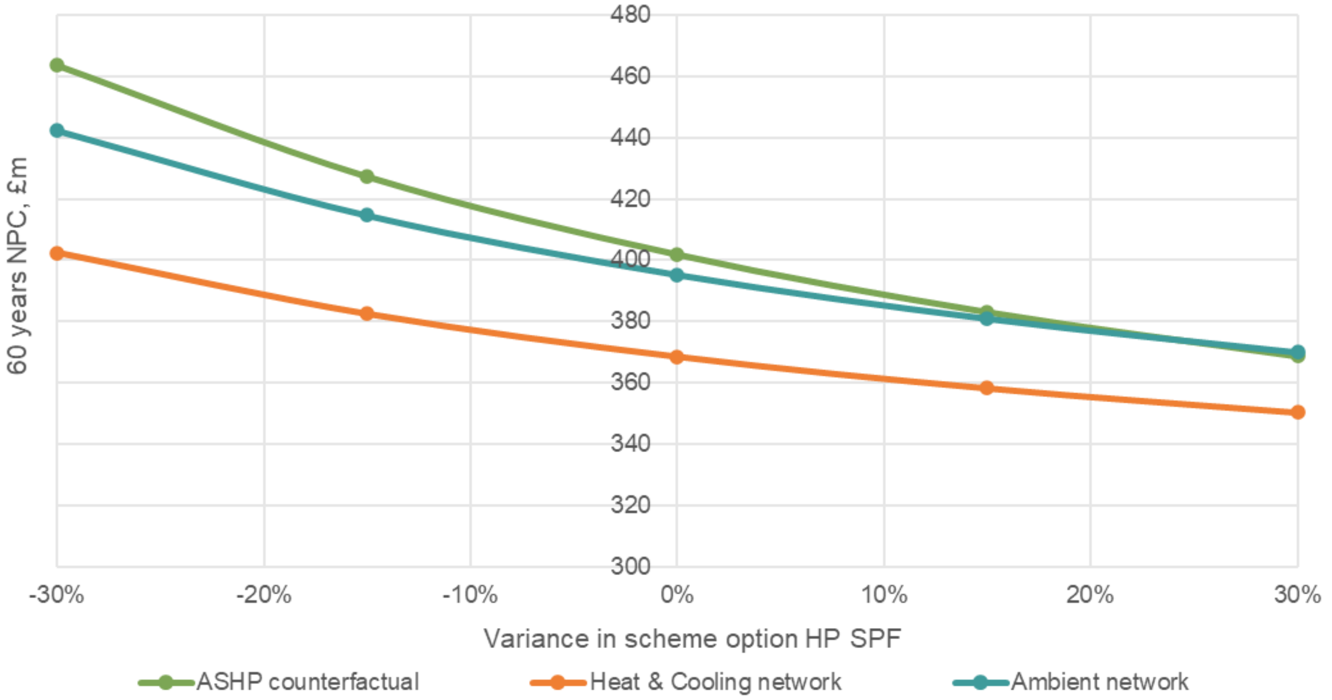


Figure 91: Impact of variance in heat pump SPF – Lawrence Hill

Carbon Price Scenarios

The effect of carbon prices on scheme option economics is shown in Figure 92. An increased carbon price in the High scenario will result in a decreased Social NPC due to increased savings per tCO_2e saved. For detailed DESNZ carbon price projections from low, central, and high scenarios, please see section 6.2.4.

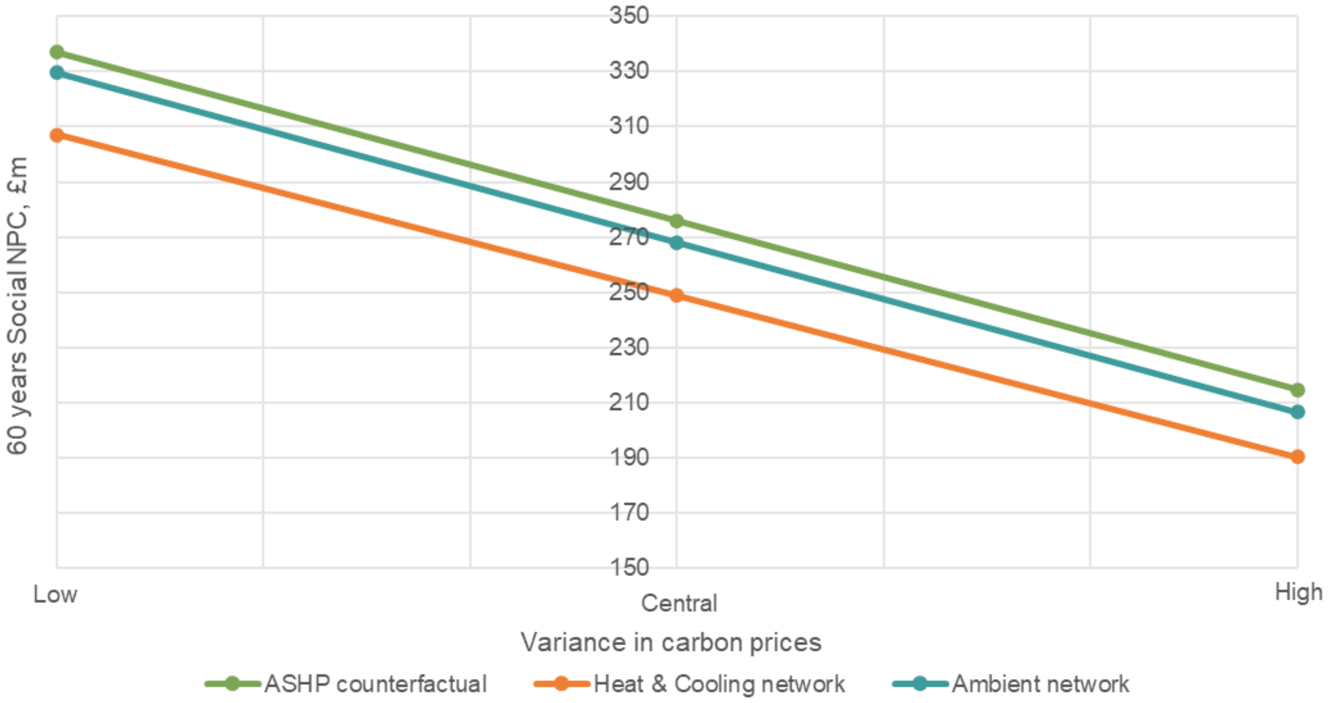


Figure 92: Variance in carbon prices – Lawrence Hill

10.2 Candidate Area 2 – Fishponds

Capital Costs

Figure 93 shows the effect of a variance of network CAPEX on scheme option NPCs. The reduction in CAPEX has a more significant impact on the HCN and ambient network NPC compared to the individual HPs option. This suggests that a distribution network scenario is more CAPEX-sensitive compared to individual HP solutions.

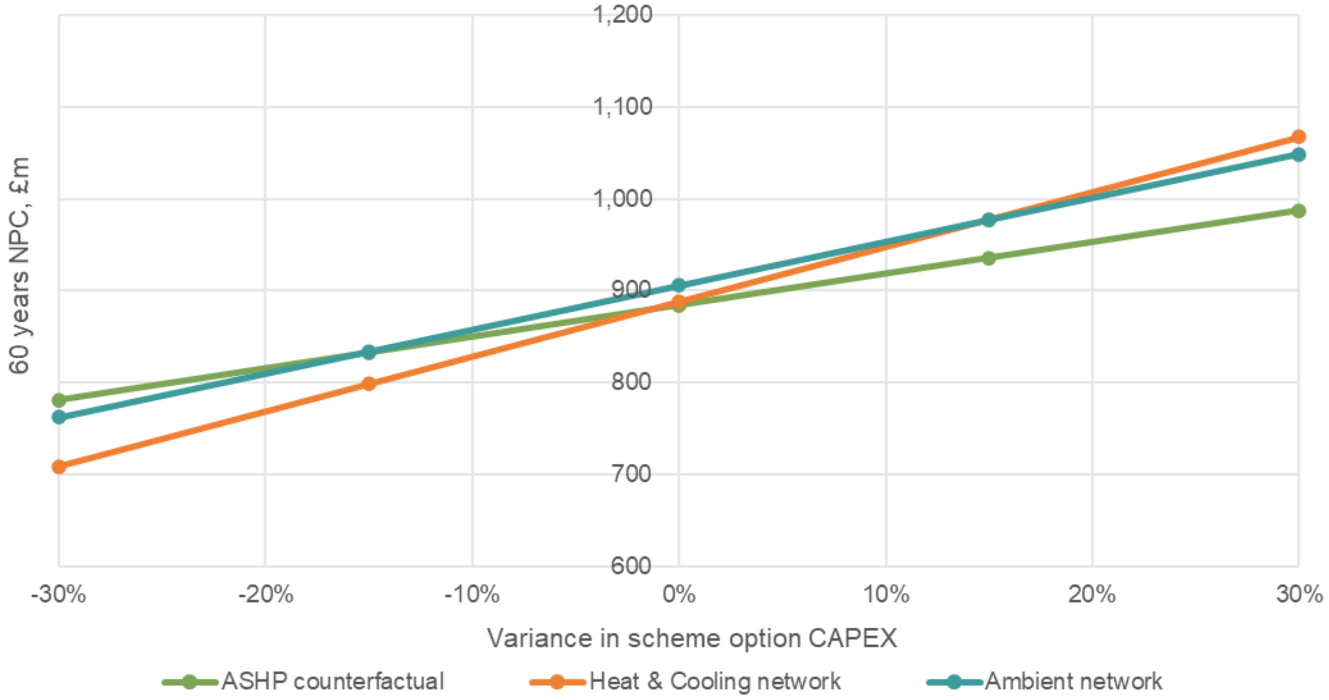


Figure 93: Variance in scheme option CAPEX – Fishponds

Figure 94 shows the effect of a variance of network CAPEX on scheme option NPCs. The HCN and ambient network options are more CAPEX sensitive, and therefore, a reduced network CAPEX would result in a significant reduction in NPCs.

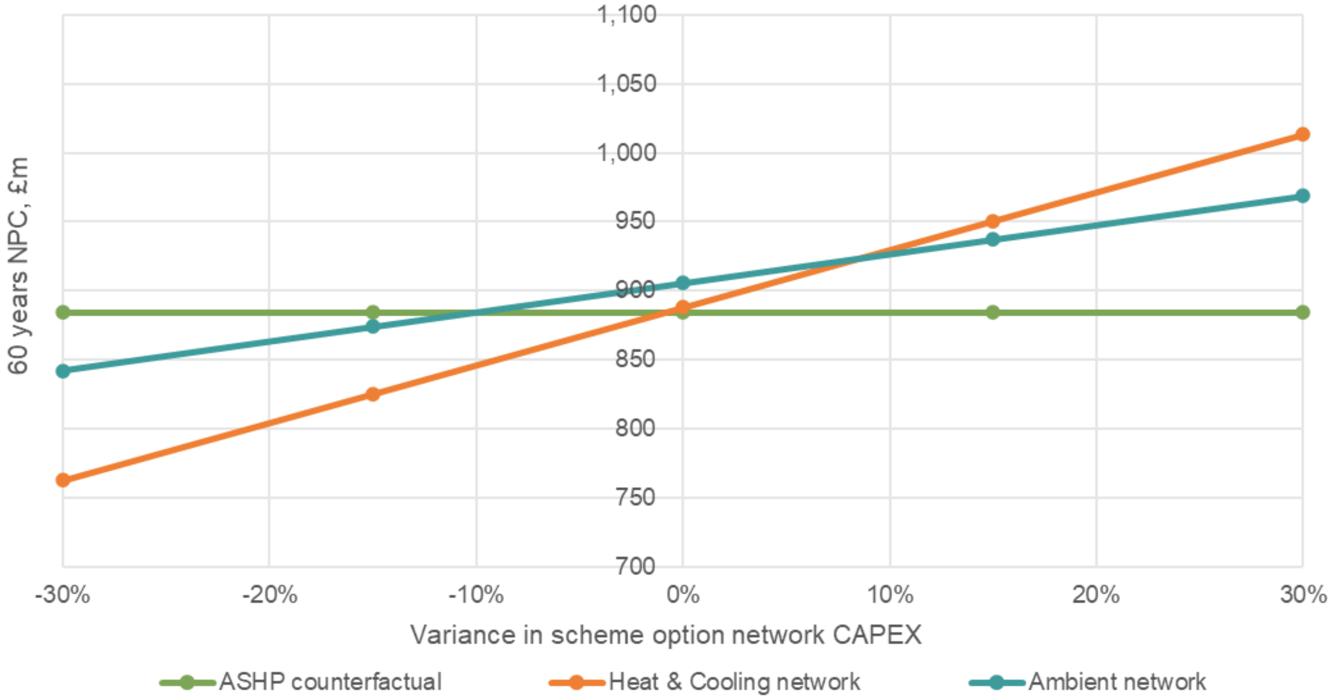


Figure 94: Variance in network CAPEX – Fishponds

Heat and Cooling Demands

Figure 95 shows the effect of a variance in the total network heat and cooling demand, with all other parameters remaining constant. An increase in heat and cooling demand results in higher NPCs across all scheme options due to increased fuel consumption. The increase in energy demand has more impact on the individual HP solutions, as the individual systems have lower heating and cooling efficiency, resulting in more electricity consumed compared to the distribution network scheme options. The analysis does not consider the installation of additional or larger-capacity heat pumps.

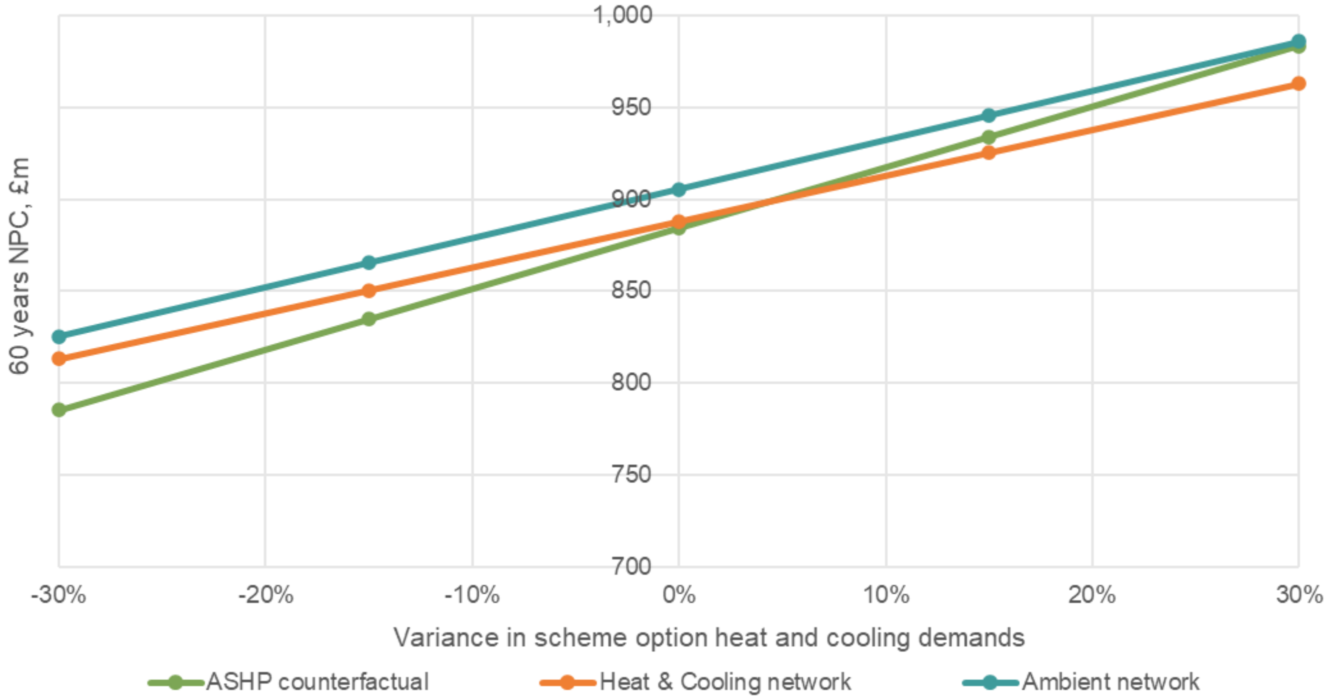


Figure 95: Variance in heat and cooling demands – Fishponds

Electricity Tariffs

Figure 96 shows the effect of a variance in electricity purchase tariff for different scheme options. For the base case assessment, an electricity purchase tariff of 12.68 p/kWh has been used for HCN energy centres and commercial buildings, while an electricity tariff of 20.75 p/kWh has been used for residential dwellings. This has a significant effect on the 60-year NPC for all scheme options, as a significant portion of the operational costs comes from electricity purchases.

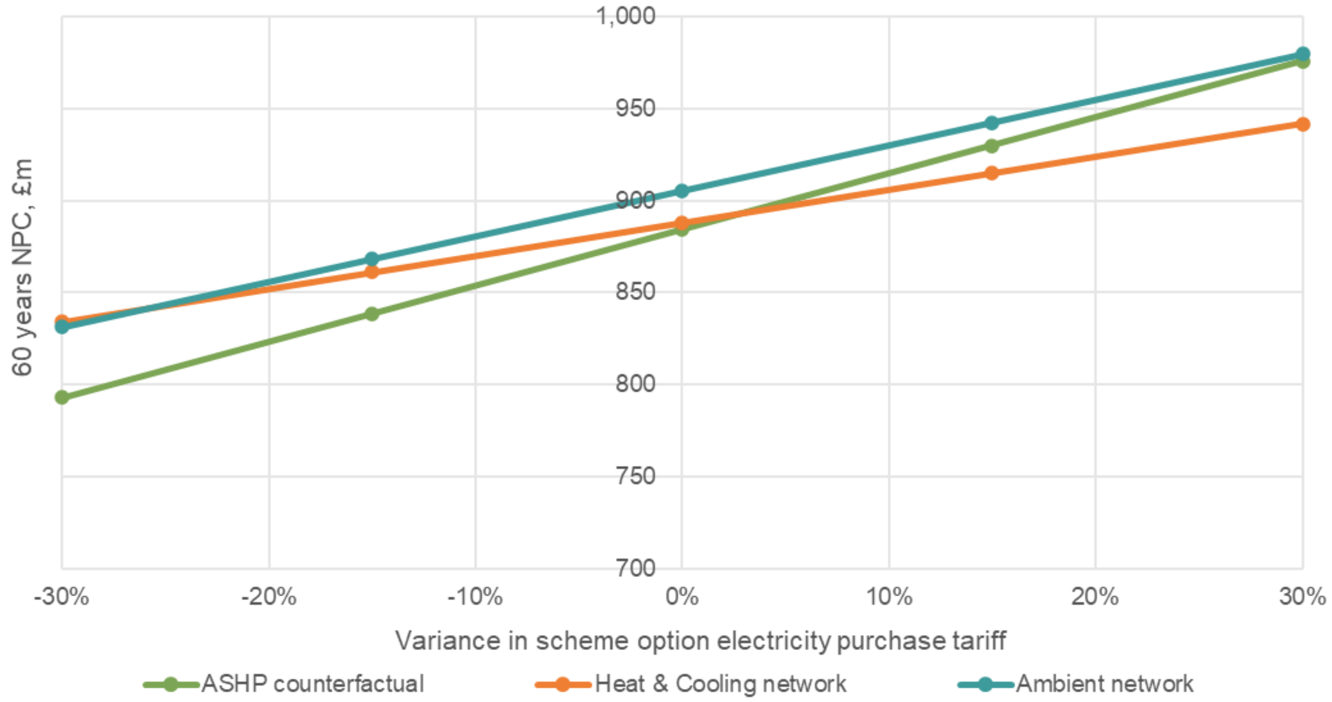


Figure 96: Variance in scheme options electricity purchase tariff – Fishponds

The impact of price indexing on all energy tariffs is shown in Table 82. The NPCs remain relatively constant across different DESNZ scenarios, suggesting that the scheme options are resilient against changes in energy prices.

Table 82: Impact of indexing of all energy tariffs – Fishponds

	BAU	Individual ASHPs	HCN	Ambient network
DESNZ central scenario	£599,422,808	£884,271,488	£887,945,149	£905,457,680
DESNZ low scenario	£559,109,041	£867,313,251	£878,173,922	£891,939,338
DESNZ high scenario	£646,919,972	£903,772,259	£904,579,875	£921,505,935
Fixed rate: 0%	£592,366,927	£893,559,502	£883,038,852	£912,050,602
Fixed rate: 2.5%	£598,085,249	£901,102,153	£887,460,426	£918,138,678

Electric Peak and Reserve Boilers – HCN only

The use of electric peak and reserve boilers increases network lifetime carbon savings compared to gas boilers. However, it also increases the NPC due to higher network OPEX from increased electricity consumption. This increase in network OPEX has a more significant impact compared to the savings from carbon emission reduction, resulting in a higher Social NPC when using electric peak and reserve boilers. The comparison of the network economics between the use of electric and gas boilers is shown in Table 83.

Table 83: Electric vs gas peak and reserve – Fishponds

Scheme option carbon performance	HCN with gas boiler peak and reserve	HCN with electric boiler peak and reserve
NPC, £	£887,945,149	£907,041,567
Discounted OPEX – 60 years, £	£263,303,957	£282,400,376
Carbon intensity of heat delivered in year 2030, gCO_2e/kWh	42.8	36.1
Total carbon saving against BAU, tCO_2e	1,628,466	1,717,654
Social NPC, £	£637,150,178	£643,253,574

Heat Pump SPF

The impact of variance in the SPF of the heat pumps is shown in Figure 97. SPF includes the electrical consumption related to the heat pumps and chillers. If the electricity consumption related to the heat pump/chiller increases, the project NPC will increase. A variance in system SPFs will have a greater impact on the individual HPs option because a large portion of operational expenditures arises from electricity consumption due to lower system SPF when compared with a distribution network option.

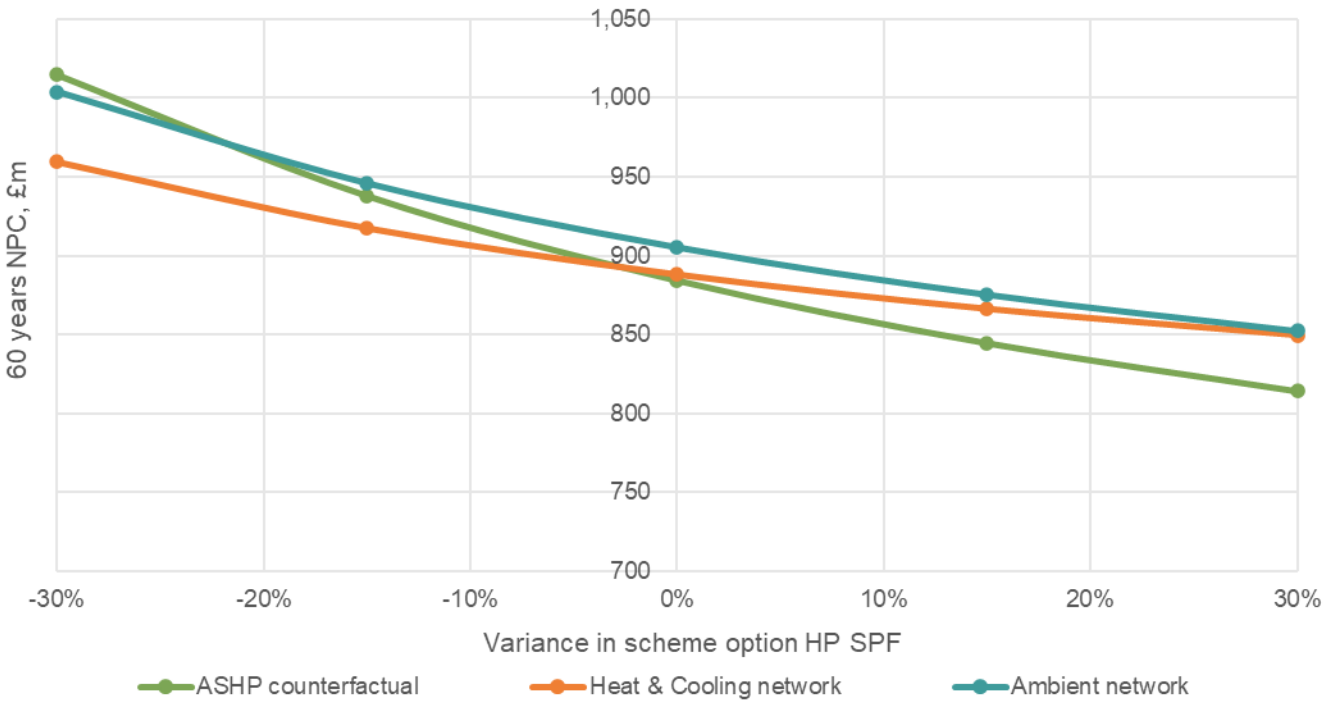


Figure 97: Impact of variance in heat pump SPF – Fishponds

Carbon Price Scenarios

The effect of carbon prices on scheme option economics is shown in Figure 98. An increased carbon price in the High scenario will result in a decreased Social NPC due to increased savings per tCO_2e saved. For detailed DESNZ carbon price projections from low, central, and high scenarios, please see section 6.2.4.

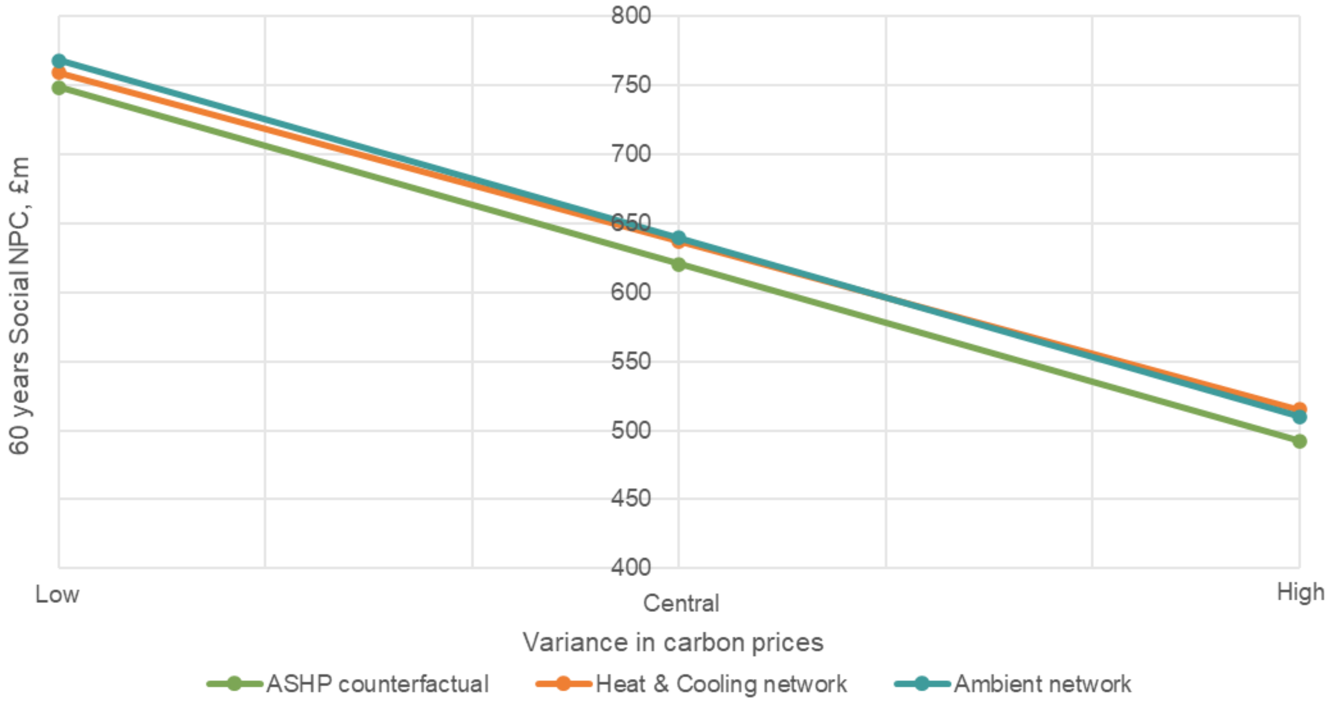


Figure 98: Variance in carbon prices – Fishponds

10.3 Candidate Area 3 – Bristol and Bath Science Park

Capital Costs

Figure 93 shows the effect of a variance of network CAPEX on scheme option NPCs. The reduction in CAPEX has a more significant impact on the HCN and ambient network NPC compared to the individual HPs option. This suggests that a distribution network scenario is more CAPEX-sensitive compared to individual HP solutions.

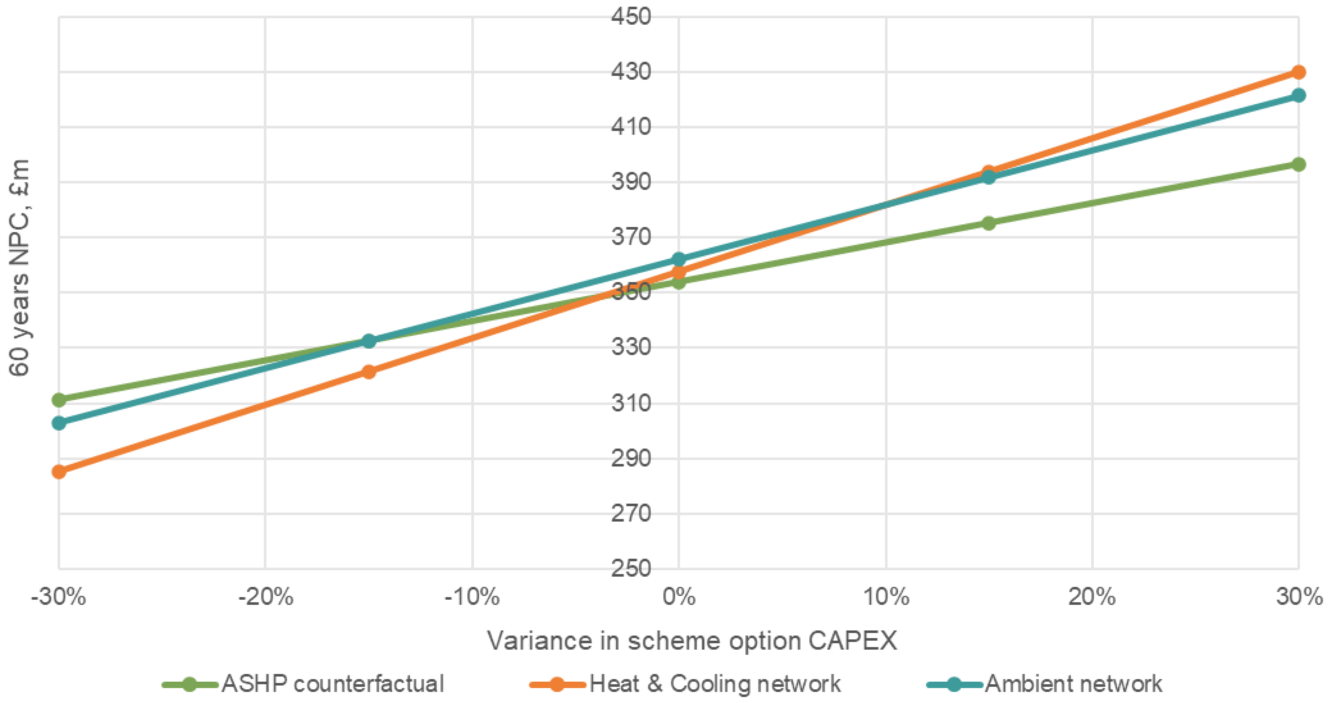


Figure 99: Variance in scheme option CAPEX – BBSP

Figure 100 shows the effect of a variance of network CAPEX on scheme option NPCs. The HCN and ambient network options are more CAPEX sensitive, and therefore, a reduced network CAPEX would result in a significant reduction in NPCs.

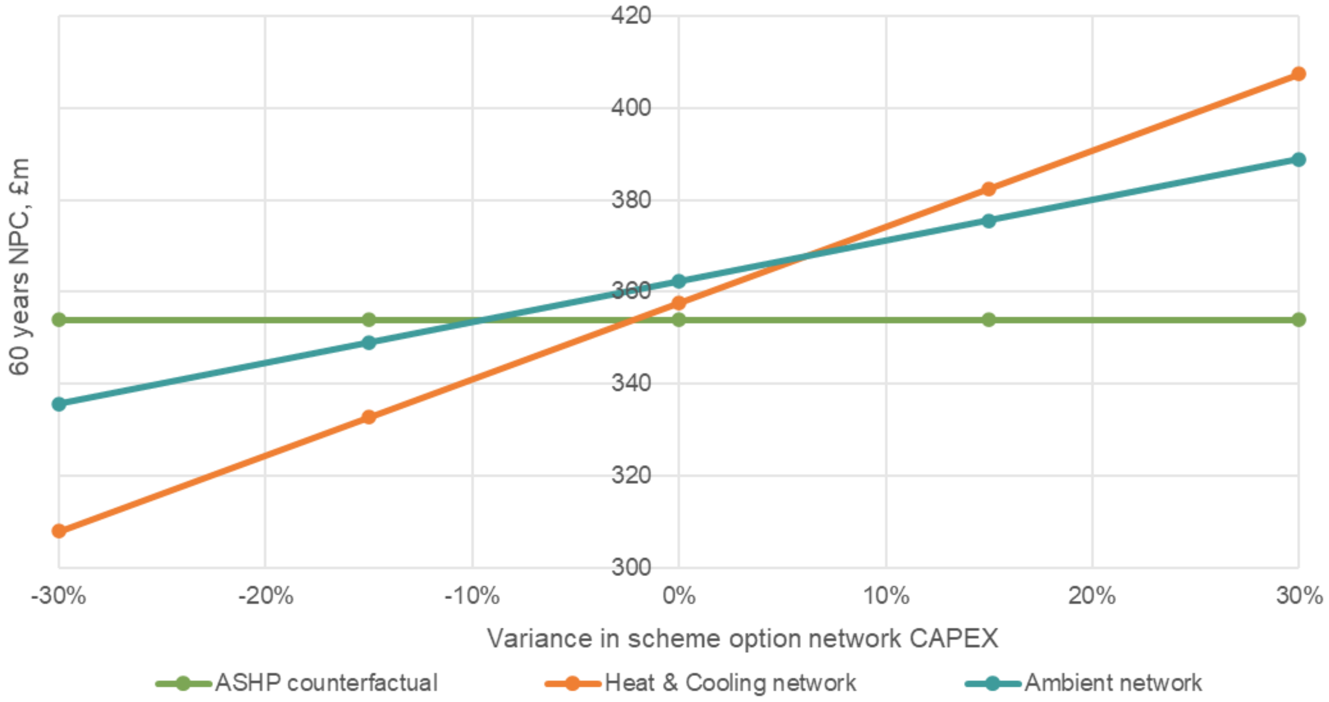


Figure 100: Variance in network CAPEX – BBSP

Heat and Cooling Demands

Figure 101 shows the effect of a variance in the total network heat and cooling demand, with all other parameters remaining constant. An increase in heat and cooling demand results in higher NPCs across all scheme options due to increased fuel consumption. The increase in energy demand has more impact on the individual HP solutions, as the individual systems have lower heating and cooling efficiency, resulting in more electricity consumed compared to the distribution network scheme options. The analysis does not consider the installation of additional or larger-capacity heat pumps.

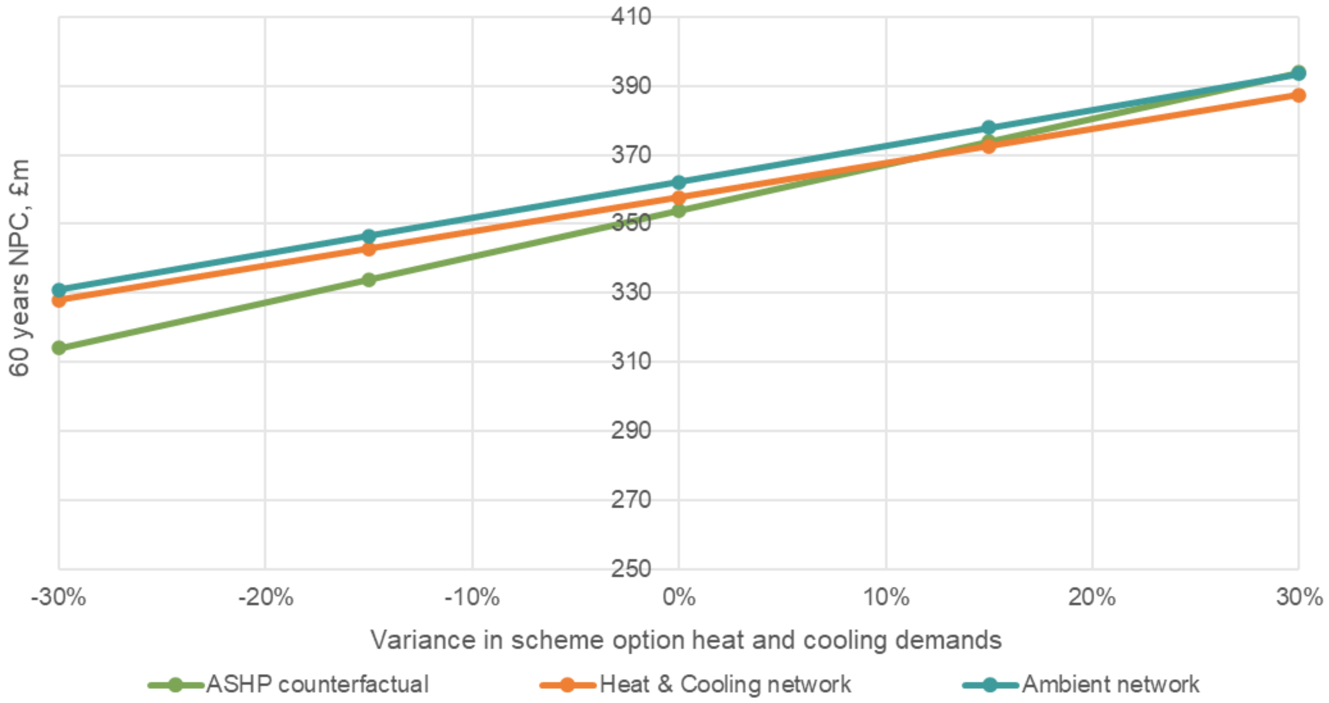


Figure 101: Variance in heat and cooling demands – BBSP

Electricity Tariffs

Figure 102 shows the effect of a variance in electricity purchase tariff for different scheme options. For the base case assessment, an electricity purchase tariff of 12.68 p/kWh has been used for HCN energy centres and commercial buildings, while an electricity tariff of 20.75 p/kWh has been used for residential dwellings. This has a significant effect on the 60-year NPC for all scheme options, as a significant portion of the operational costs comes from electricity purchases.

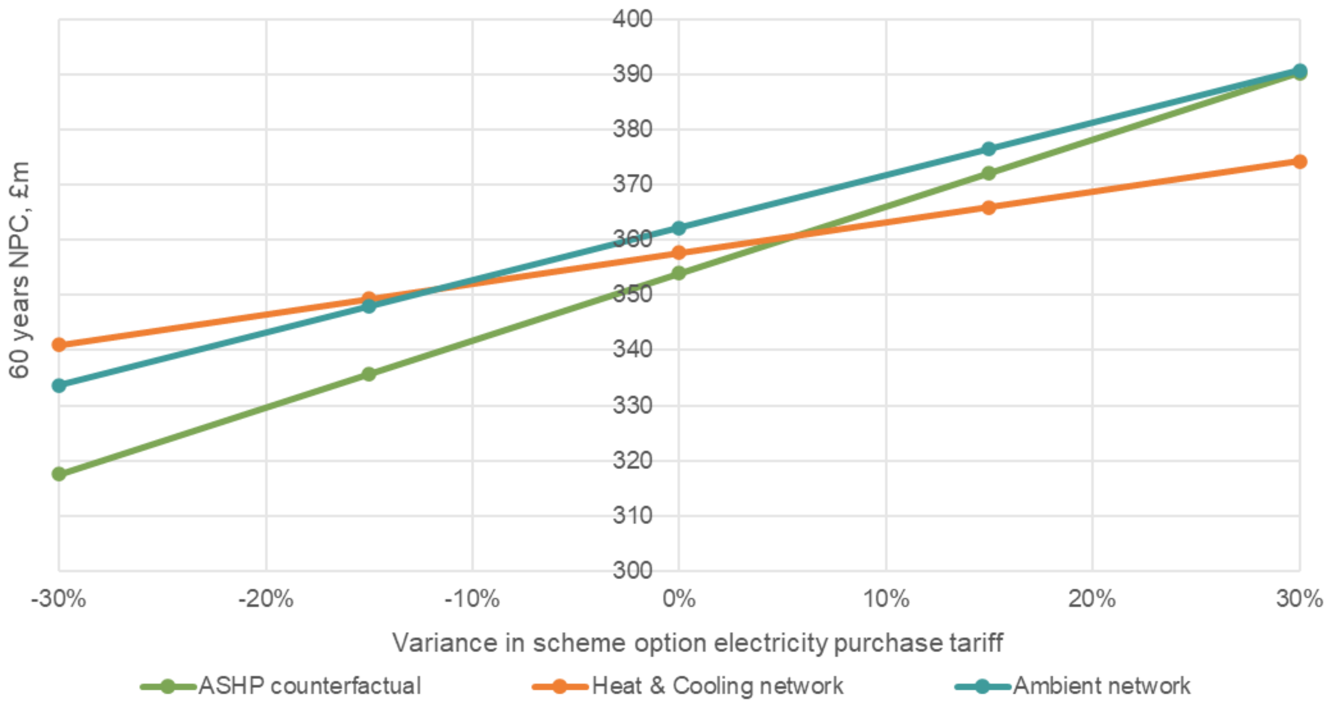


Figure 102: Variance in scheme options electricity purchase tariff – BBSP

The impact of price indexing on all energy tariffs is shown in Figure 84. The NPCs remain relatively constant across different DESNZ scenarios, suggesting that the scheme options are resilient against changes in energy prices.

Table 84: Impact of indexing of all energy tariffs – BBSP

	BAU	Individual ASHPs	HCN	Ambient network
DESNZ central scenario	£271,371,961	£353,924,578	£357,648,898	£362,239,877
DESNZ low scenario	£255,657,286	£347,388,376	£353,873,390	£357,152,243
DESNZ high scenario	£290,190,194	£361,912,649	£364,088,519	£368,549,887
Fixed rate: 0%	£268,276,008	£356,737,158	£355,751,125	£364,282,006
Fixed rate: 2.5%	£270,626,294	£359,717,312	£357,467,293	£366,614,101

Electric Peak and Reserve Boilers – HCN Only

The use of electric peak and reserve boilers increases network lifetime carbon savings compared to gas boilers. However, it also increases the NPC due to higher network OPEX from increased electricity consumption. For the BBSP candidate area, there is additional heat supply from a waste heat energy centre, which has a higher system efficiency compared to MWSHP. Therefore, a larger portion of emissions are from the gas boilers, and implementing electric peak and reserve boilers saves more carbon proportionally compared to the base case. This result in achieving a similar Social NPC when compared with gas boilers for peak and reserves. The comparison of the network economics between the use of electric and gas boilers is shown in Table 85.

Table 85: Electric vs gas peak and reserve – BBSP

Scheme option carbon performance	HCN with gas boiler peak and reserve	HCN with electric boiler peak and reserve
NPC, £	£357,648,898	£364,876,687
Discounted OPEX – 60 years, £	£105,930,138	£113,157,927
Carbon intensity of heat delivered in year 2030, gCO_2e/kWh	41.1	34.4
Total carbon saving against BAU, tCO_2e	610,017	643,299
Social NPC, £	£216,383,230	£216,250,541

Heat Pump SPF

The impact of variance in the SPF of the heat pumps is shown in Figure 103. SPF includes the electrical consumption related to the heat pumps and chillers. If the electricity consumption related to the heat pump/chiller increases, the project NPC will increase. A variance in system SPFs will have a greater impact on the individual HPs option because a large portion of operational expenditures arises from electricity consumption due to lower system SPF when compared with a distribution network option.

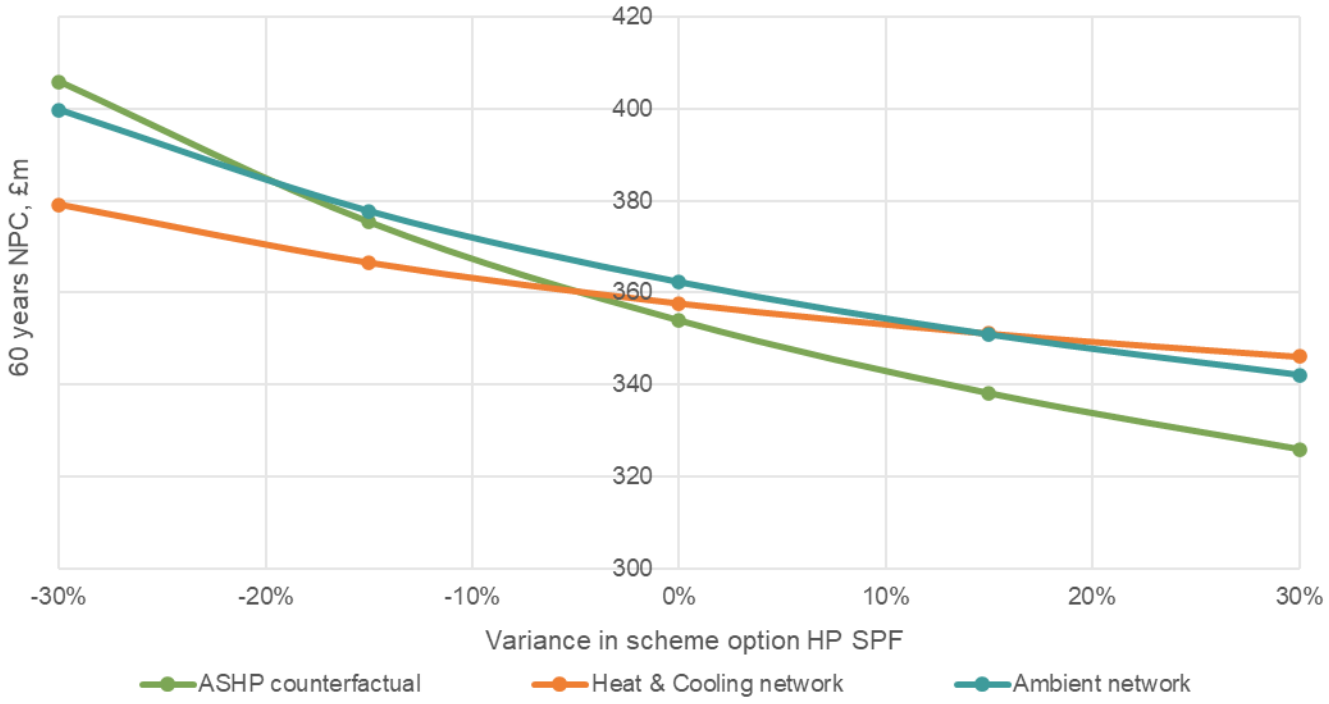


Figure 103: Impact of variance in heat pump SPF – BBSP

Carbon Price Scenarios

The effect of carbon prices on scheme option economics is shown in Figure 104. An increased carbon price in the High scenario will result in a decreased Social NPC due to increased savings per tCO_2e saved. For detailed DESNZ carbon price projections from low, central, and high scenarios, please see section 6.2.4.

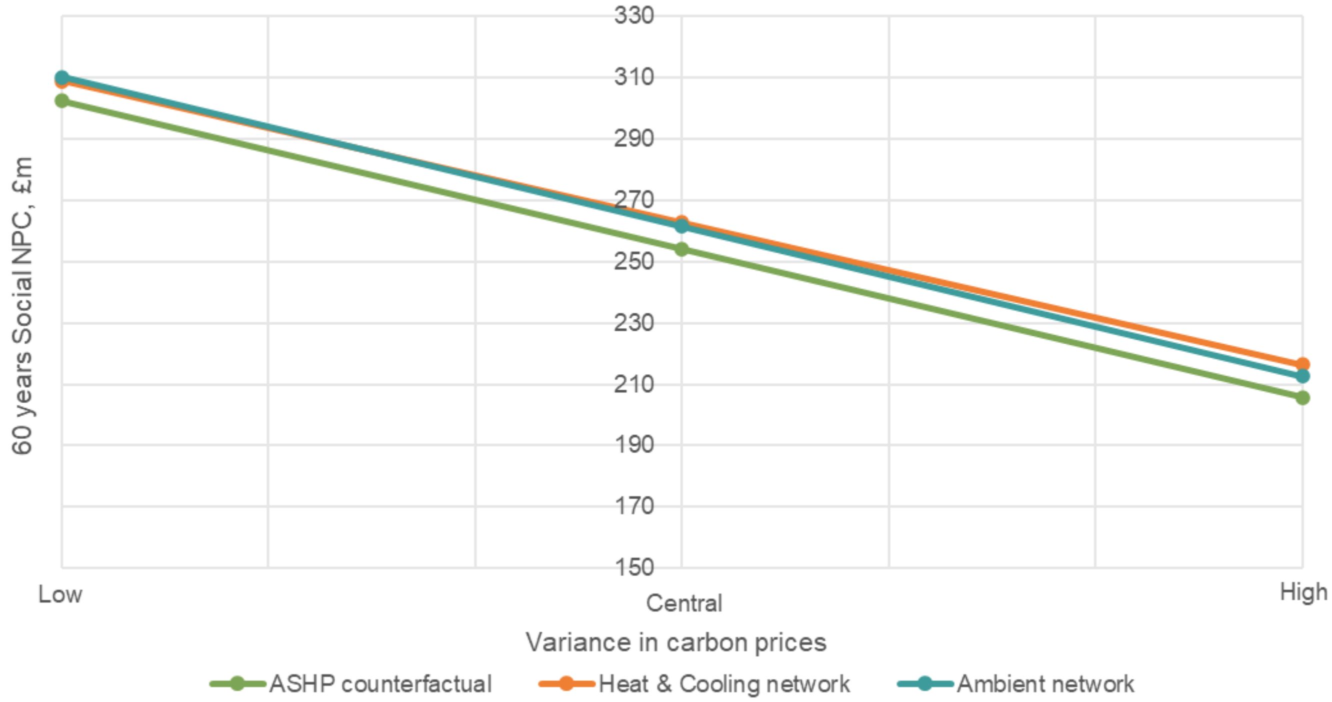


Figure 104: Variance in carbon prices – BBSP

10.4 Candidate Area 4 – Douglas Road Industrial Park

Capital Costs

Figure 105 shows the effect of a variance of network CAPEX on scheme option NPCs The reduction in CAPEX has a more significant impact on the HCN and ambient network NPC compared to the individual HPs option. This suggests that a distribution network scenario is more CAPEX-sensitive compared to individual HP solutions.

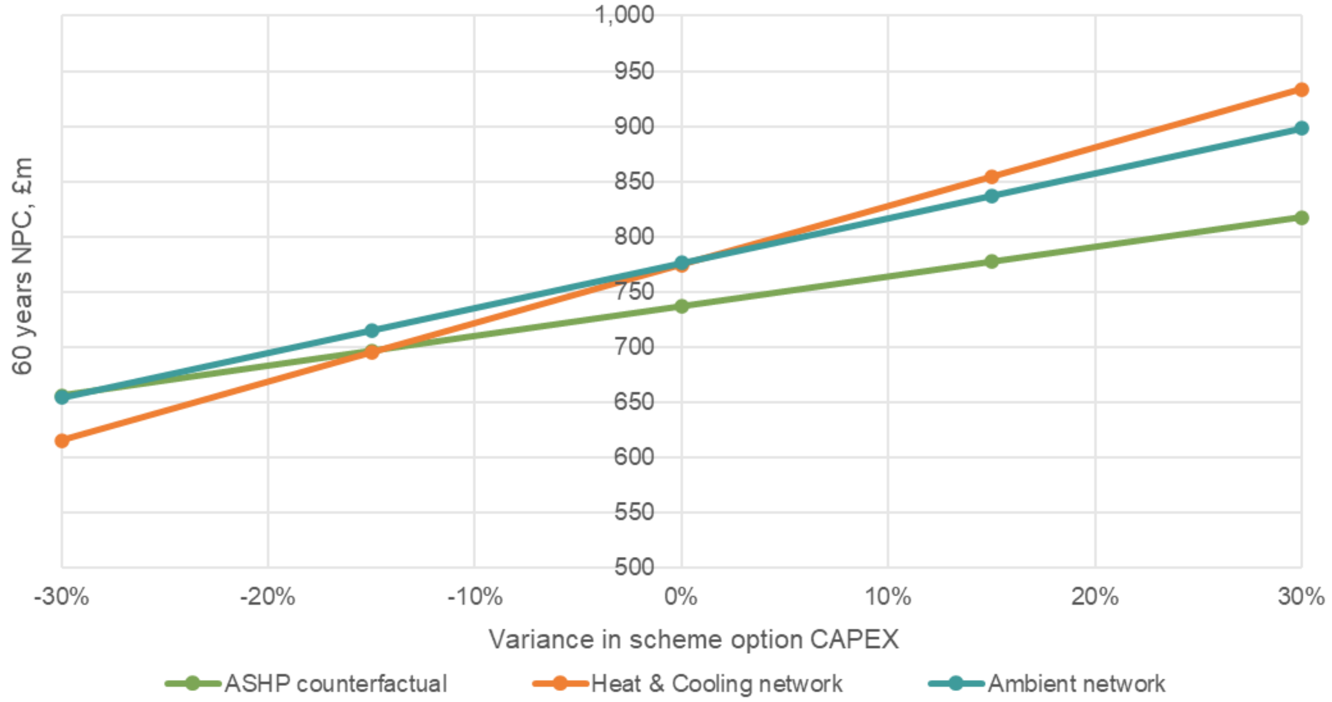


Figure 105: Variance in scheme option CAPEX – Douglas Road Industrial Park

Figure 106 shows the effect of a variance of network CAPEX on scheme option NPCs. The HCN and ambient network options are more CAPEX sensitive, and therefore, a reduced network CAPEX would result in a significant reduction in NPCs.

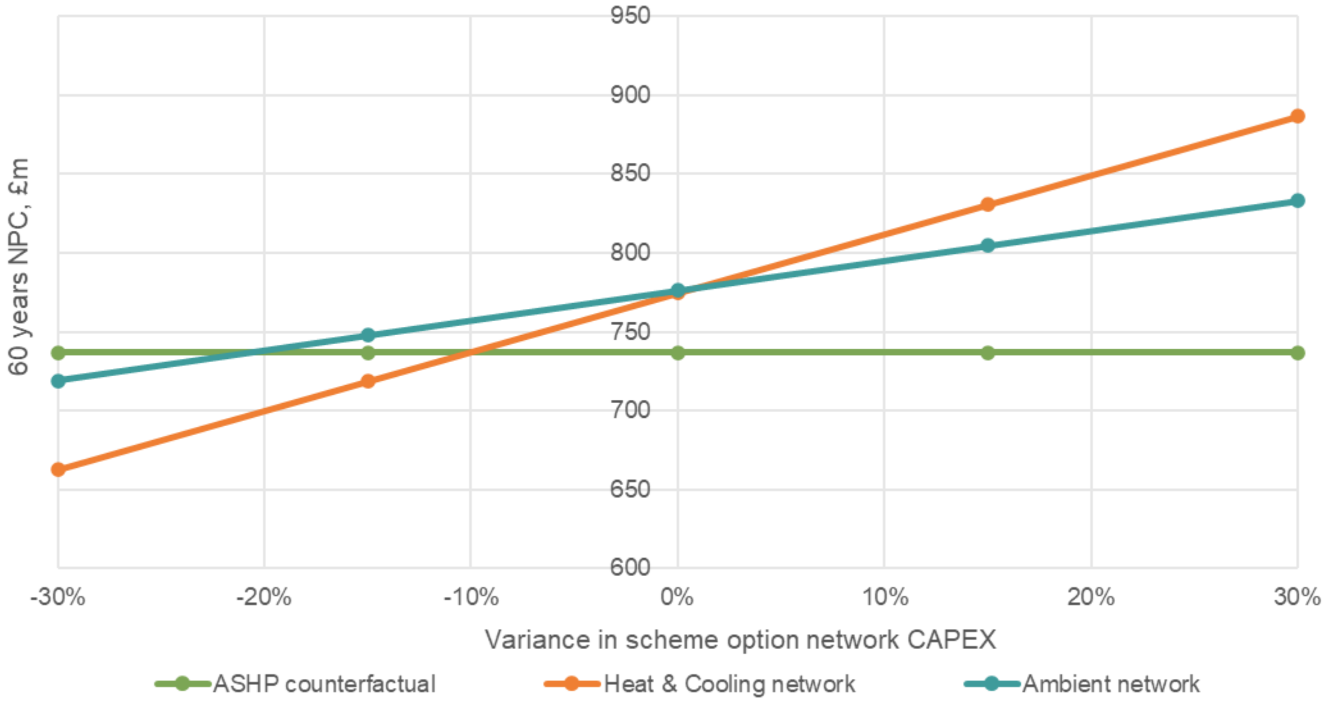


Figure 106: Variance in network CAPEX – Douglas Road Industrial Park

Heat and Cooling Demands

Figure 107 shows the effect of a variance in the total network heat and cooling demand, with all other parameters remaining constant. An increase in heat and cooling demand results in higher NPCs across all scheme options due to increased fuel consumption. The increase in energy demand has more impact on the individual HP solutions, as the individual systems have lower heating and cooling efficiency, resulting in more electricity consumed compared to the distribution network scheme options. The analysis does not consider the installation of additional or larger-capacity heat pumps.

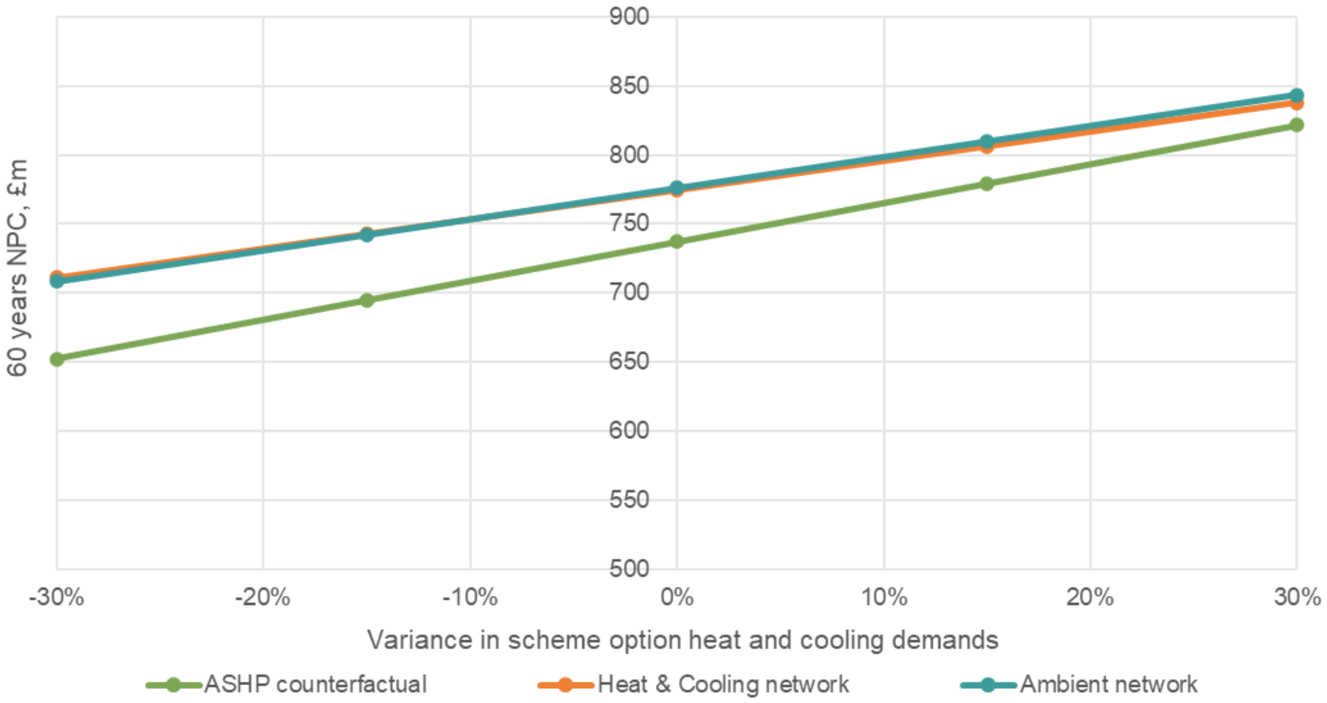


Figure 107: Variance in heat and cooling demands – Douglas Road Industrial Park

Electricity Tariffs

Figure 108 shows the effect of a variance in electricity purchase tariff for different scheme options. For the base case assessment, an electricity purchase tariff of 12.68 p/kWh has been used for HCN energy centres and commercial buildings, while an electricity tariff of 20.75 p/kWh has been used for residential dwellings. This has a significant effect on the 60-year NPC for all scheme options, as a significant portion of the operational costs comes from electricity purchases.

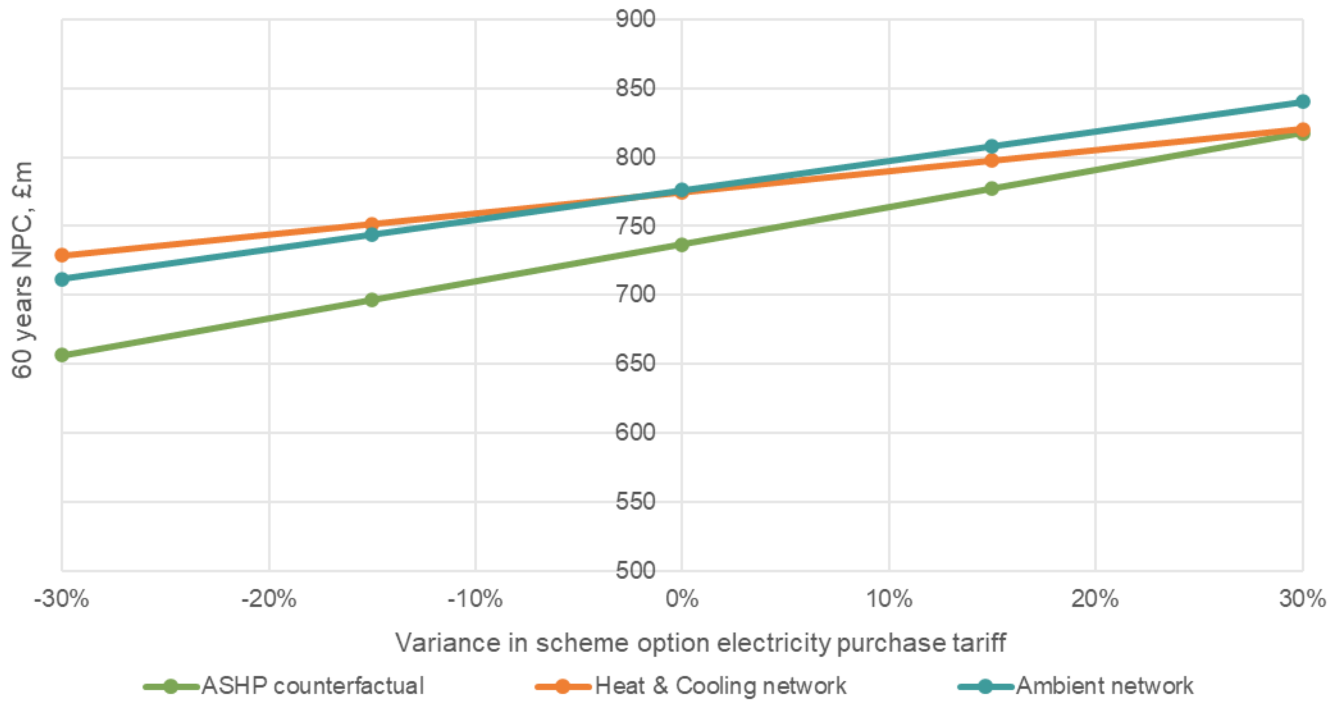


Figure 108: Variance in scheme options electricity purchase tariff – Douglas Road Industrial Park

The impact of price indexing on all energy tariffs is shown in Table 86. The NPCs remain relatively constant across different DESNZ scenarios, suggesting that the scheme options are resilient against changes in energy prices.

Table 86: Impact of indexing of all energy tariffs – Douglas Road Industrial Park

	BAU	Individual ASHPs	HCN	Ambient network
DESNZ central scenario	£530,549,950	£736,993,399	£774,578,485	£776,100,039
DESNZ low scenario	£496,998,213	£721,771,377	£766,337,086	£764,123,659
DESNZ high scenario	£570,191,851	£753,888,758	£788,626,697	£789,747,726
Fixed rate: 0%	£525,218,843	£746,279,674	£770,431,422	£782,830,273
Fixed rate: 2.5%	£530,251,596	£752,954,274	£774,173,251	£788,134,106

Electric Peak and Reserve Boilers – HCN Only

The use of electric peak and reserve boilers increases network lifetime carbon savings compared to gas boilers. However, it also increases the NPC due to higher network OPEX from increased electricity consumption. This increase in network OPEX has a more significant impact compared to the savings from carbon emission reduction, resulting in a higher Social NPC when using electric peak and reserve boilers. The comparison of the network economics between the use of electric and gas boilers is shown in Table 87.

Table 87: Electric vs gas peak and reserve – Douglas Road Industrial Park

Scheme option carbon performance	HCN with gas boiler peak and reserve	HCN with electric boiler peak and reserve
NPC, £	£774,578,485	£790,457,049
Discounted OPEX – 60 years, £	£222,863,124	£238,741,688
Carbon intensity of heat delivered in year 2030, gCO_2e/kWh	42.8	36.1
Total carbon saving against BAU, tCO_2e	1,355,410	1,429,625
Social NPC, £	£565,982,941	£571,055,906

Heat Pump SPF

The impact of variance in the SPF of the heat pumps is shown in Figure 109. SPF includes the electrical consumption related to the heat pumps and chillers. If the electricity consumption related to the heat pump/chiller increases, the project NPC will increase. A variance in system SPFs will have a greater impact on the individual HPs option because a large portion of operational expenditures arises from electricity consumption due to lower system SPF when compared with a distribution network option.

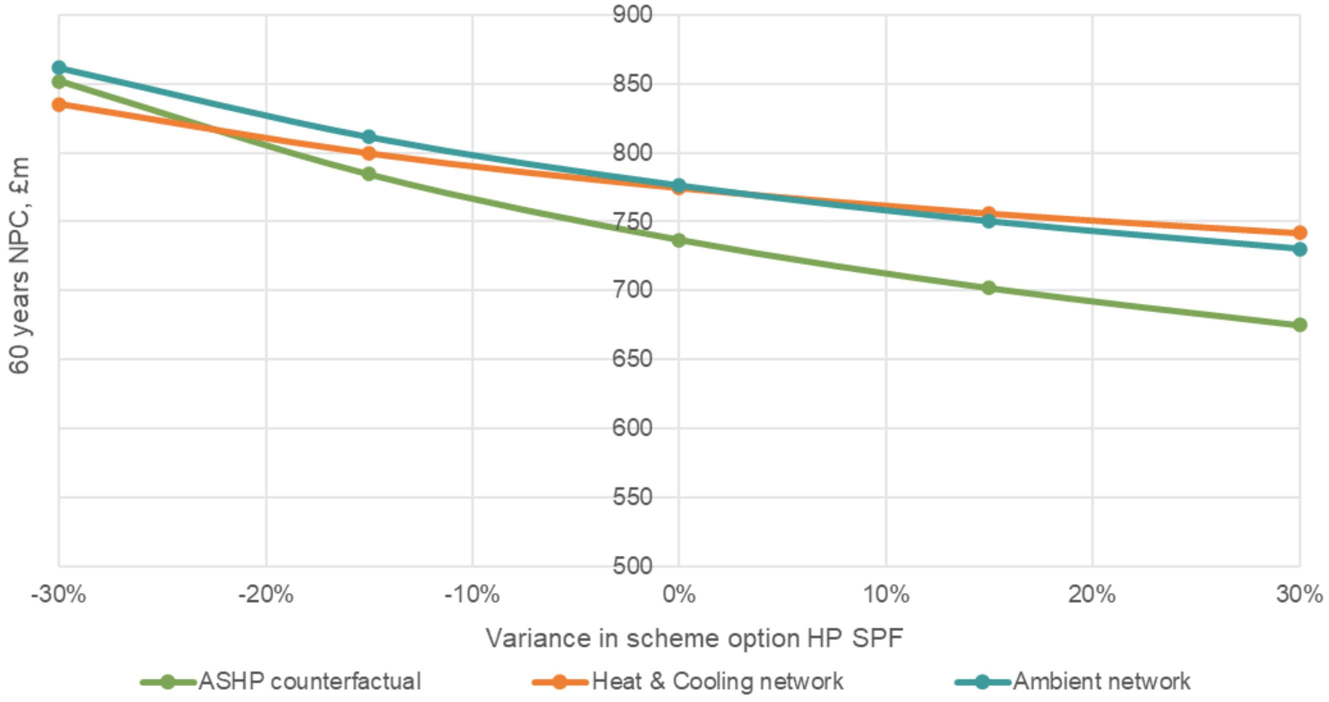


Figure 109: Impact of variance in heat pump SPF – Douglas Road Industrial Park

Carbon Price Scenarios

The effect of carbon prices on scheme option economics is shown in Figure 110. An increased carbon price in the High scenario will result in a decreased Social NPC due to increased savings per tCO_2e saved. For detailed DESNZ carbon price projections from low, central, and high scenarios, please see section 6.2.4.

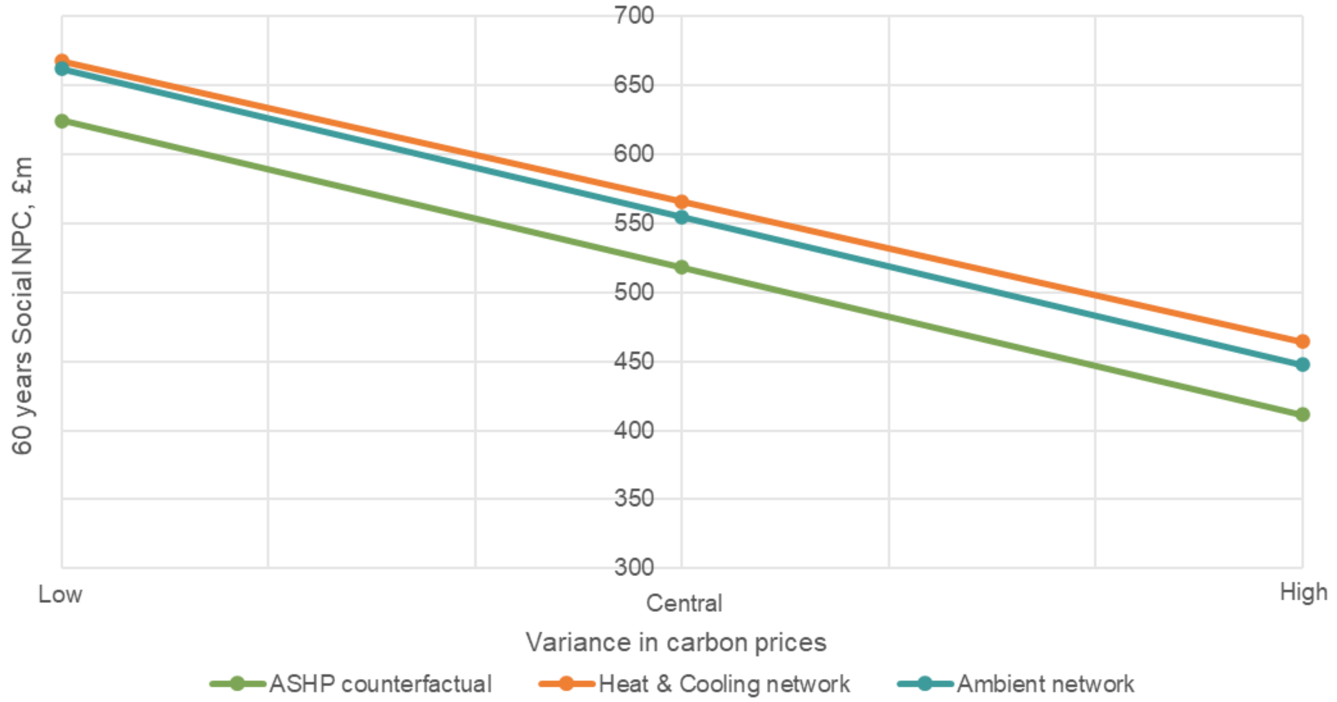


Figure 110: Variance in carbon prices – Douglas Road Industrial Park

10.5 Candidate Area 5 – Barrs Court Residential

Capital Costs

Figure 111 shows the effect of a variance of network CAPEX on scheme option NPCs. The reduction in CAPEX has a more significant impact on the HCN and ambient network NPC compared to the individual HPs option. This suggests that a distribution network scenario is more CAPEX-sensitive compared to individual HP solutions. However, due to the number of connections and pipe length required for the Barrs Court Residential candidate area, the capital cost associated with pipe works is significantly greater than the cost of the heating and cooling generation system, resulting in individual ASHPs being the most optimal option for the area even with a 30% reduction in overall CAPEX or 30% reduction in pipework CAPEX as shown in Figure 111.

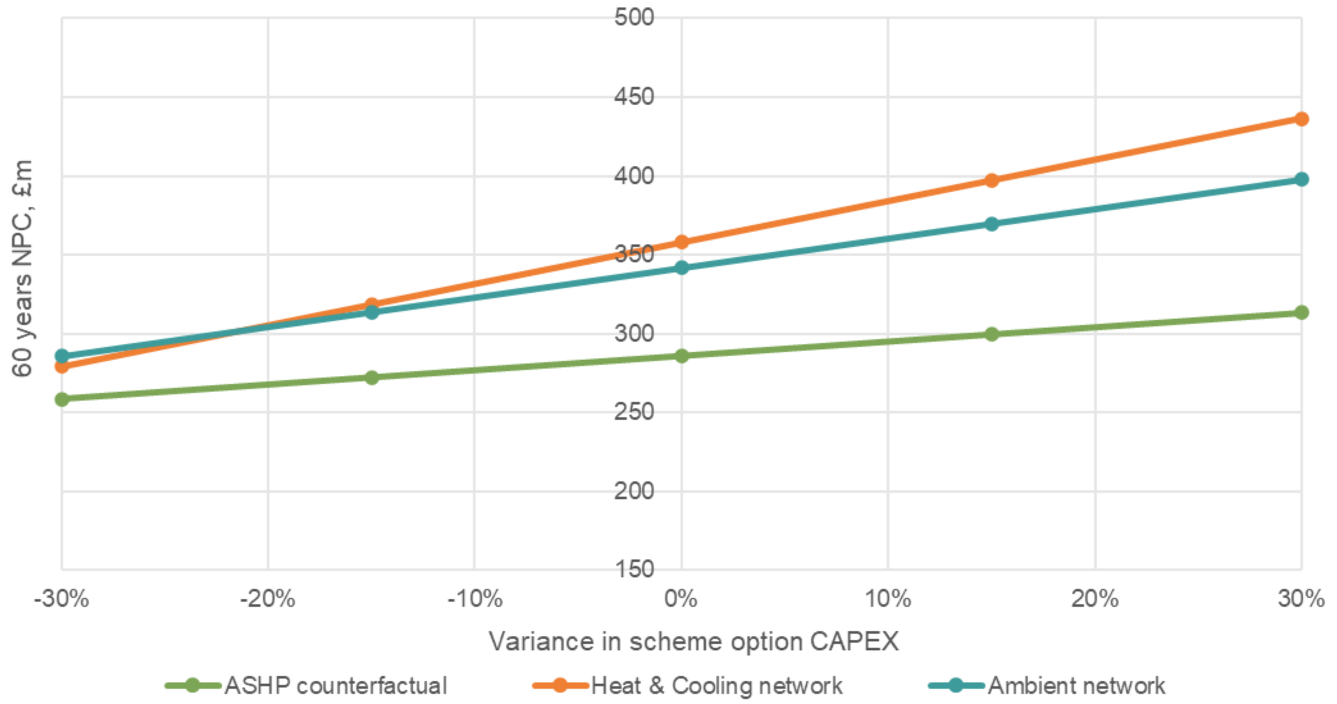


Figure 111: Variance in scheme option CAPEX – Barrs Court Residential

Figure 112 shows the effect of a variance of network CAPEX on scheme option NPCs.

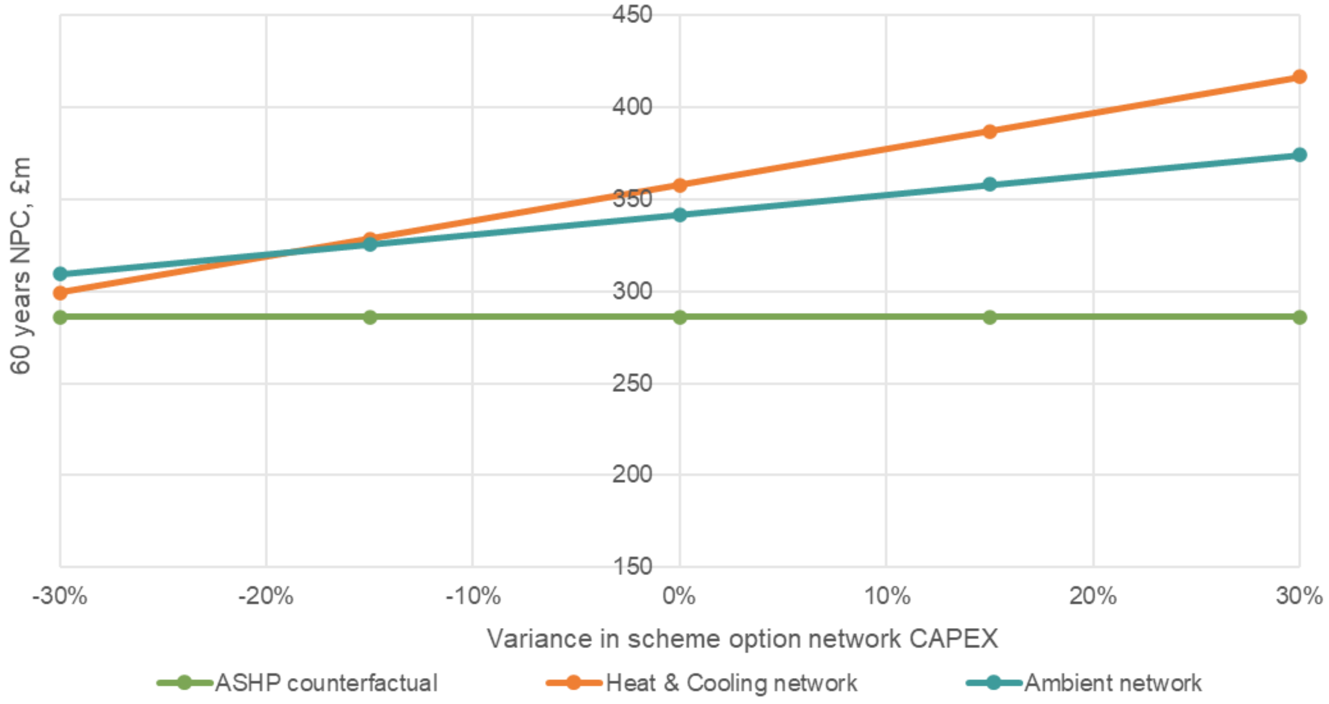


Figure 112: Variance in network CAPEX – Barrs Court Residential

Heat and Cooling Demands

Figure 113 shows the effect of a variance in the total network heat and cooling demand, with all other parameters remaining constant. An increase in heat and cooling demand results in higher NPCs across all scheme options due to increased fuel consumption. The increase in energy demand has more impact on the individual HP solutions, as the individual systems have lower heating and cooling efficiency, resulting in more electricity consumed compared to the distribution network scheme options. The analysis does not consider the installation of additional or larger-capacity heat pumps.

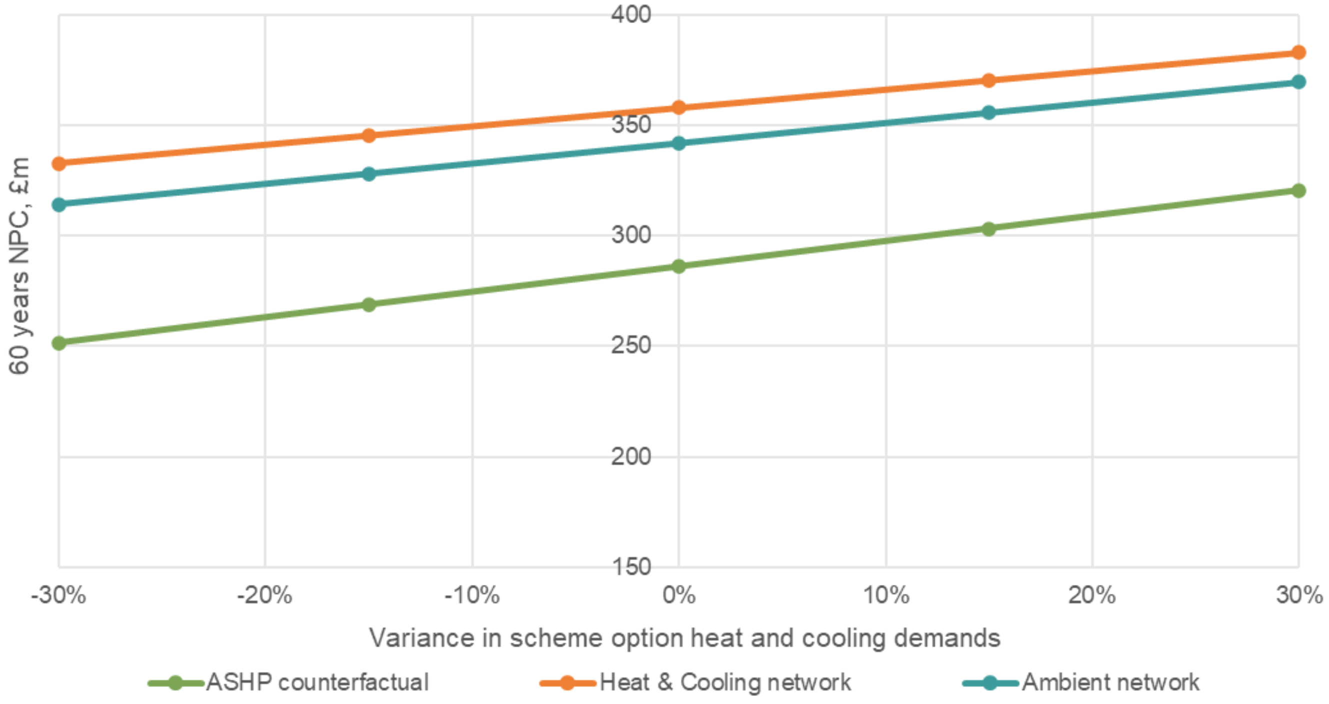


Figure 113: Variance in heat and cooling demands – Barrs Court Residential

Electricity Tariffs

Figure 114 shows the effect of a variance in electricity purchase tariff for different scheme options. For the base case assessment, an electricity purchase tariff of 12.68 p/kWh has been used for HCN energy centres and commercial buildings, while an electricity tariff of 20.75 p/kWh has been used for residential dwellings. This has a significant effect on the 60-year NPC for all scheme options, as a significant portion of the operational costs comes from electricity purchases.

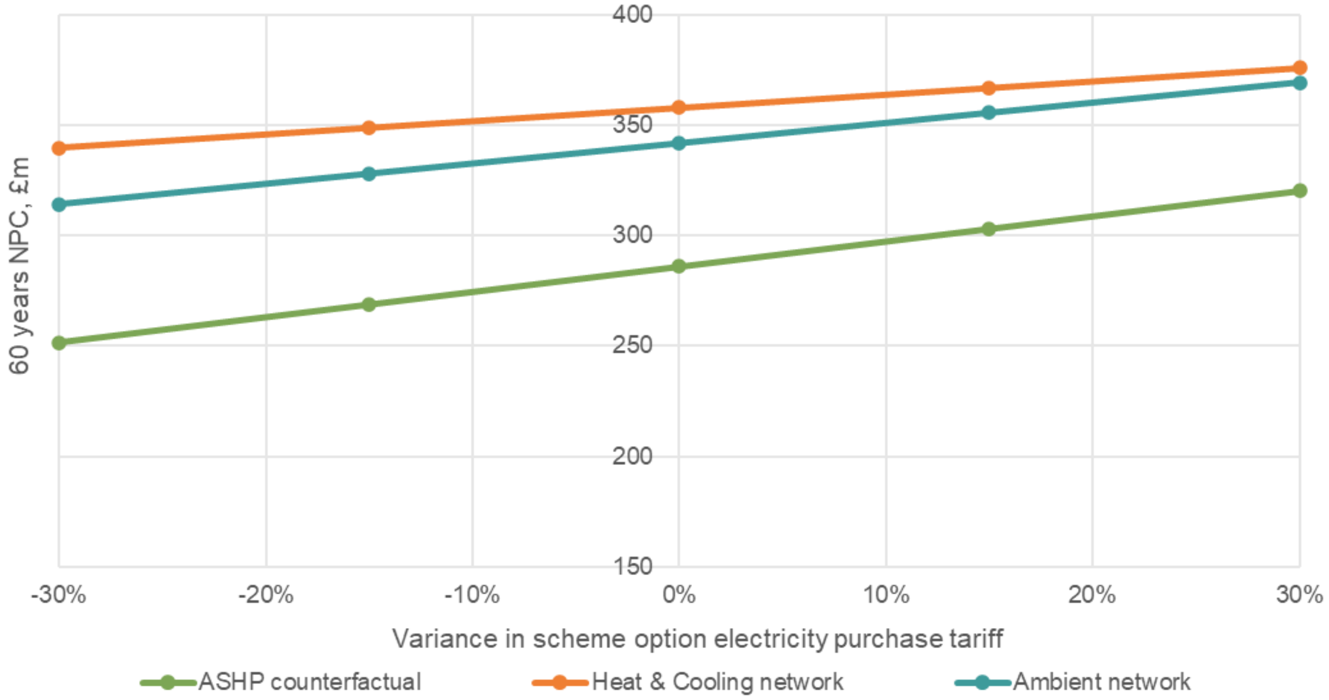


Figure 114: Variance in scheme options electricity purchase tariff – Barrs Court Residential

The impact of price indexing on all energy tariffs is shown in Table 88. The NPCs remain relatively constant across different DESNZ scenarios, suggesting that the scheme options are resilient against changes in energy prices.

Table 88: Impact of indexing of all energy tariffs – Barrs Court Residential

	BAU	Individual ASHPs	HCN	Ambient network
DESNZ central scenario	£212,134,166	£285,972,093	£357,889,891	£341,828,690
DESNZ low scenario	£198,577,503	£279,149,078	£354,592,562	£336,453,227
DESNZ high scenario	£227,986,522	£292,878,451	£363,494,001	£347,464,101
Fixed rate: 0%	£210,567,665	£291,157,067	£356,241,386	£345,595,934
Fixed rate: 2.5%	£212,661,142	£294,040,628	£357,726,178	£347,896,717

Electric Peak and Reserve Boilers – HCN Only

The use of electric peak and reserve boilers increases network lifetime carbon savings compared to gas boilers. However, it also increases the NPC due to higher network OPEX from increased electricity consumption. This increase in network OPEX has a more significant impact compared to the savings from carbon emission reduction, resulting in a higher Social NPC when using electric peak and reserve boilers. The comparison of the network economics between the use of electric and gas boilers is shown in Table 89.

Table 89: Electric vs gas peak and reserve – Barrs Court Residential

Scheme option carbon performance	HCN with gas boiler peak and reserve	HCN with electric boiler peak and reserve
NPC, £	£357,889,891	£364,455,296
Discounted OPEX – 60 years, £	£87,803,739	£94,369,144
Carbon intensity of heat delivered in year 2030, gCO_2e/kWh	42.8	36.1
Total carbon saving against BAU, tCO_2e	554,599	584,961
Social NPC, £	£271,815,374	£273,925,560

Heat Pump SPF

The impact of variance in the SPF of the heat pumps is shown in Figure 115. SPF includes the electrical consumption related to the heat pumps and chillers. If the electricity consumption related to the heat pump/chiller increases, the project NPC will increase. A variance in system SPFs will have a greater impact on the individual HPs option because a large portion of operational expenditures arises from electricity consumption due to lower system SPF when compared with a distribution network option.

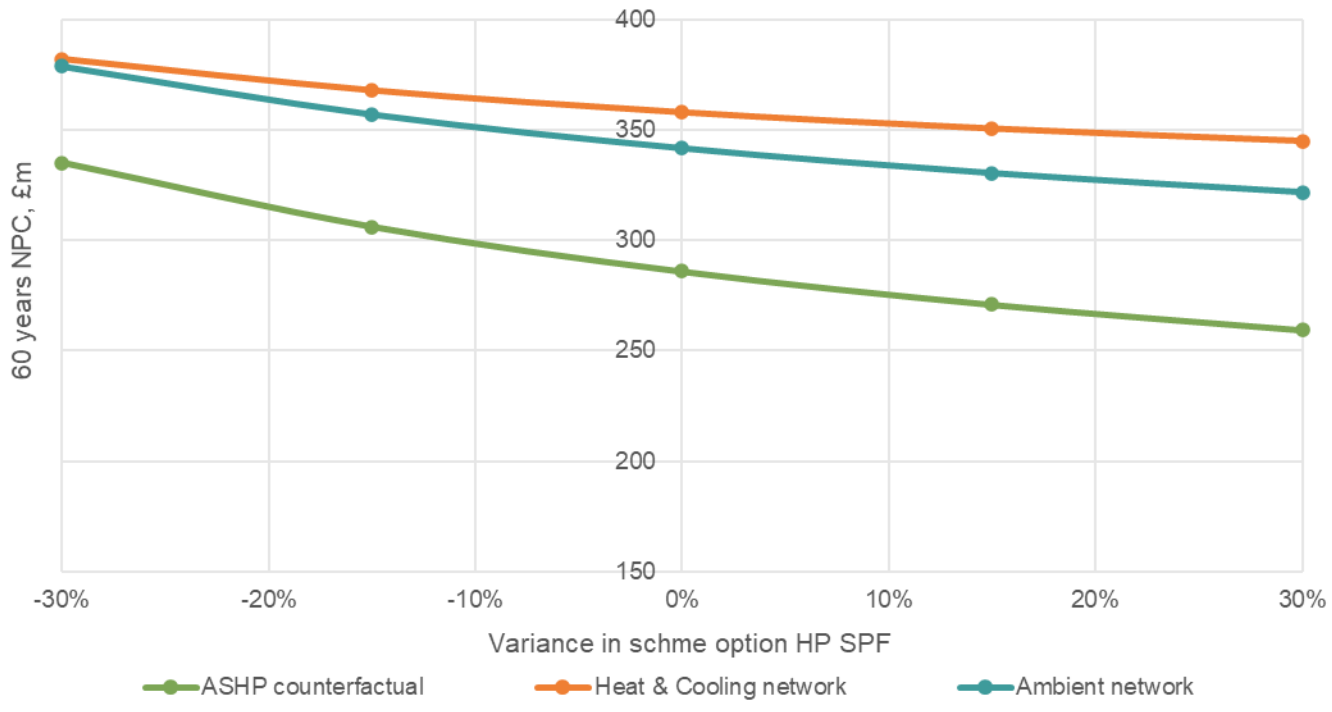


Figure 115: Impact of variance in heat pump SPF – Barrs Court Residential

Carbon Price Scenarios

The effect of carbon prices on scheme option economics is shown in Figure 116. An increased carbon price in the High scenario will result in a decreased Social NPC due to increased savings per tCO_2e saved. For detailed DESNZ carbon price projections from low, central, and high scenarios, please see section 6.2.4.

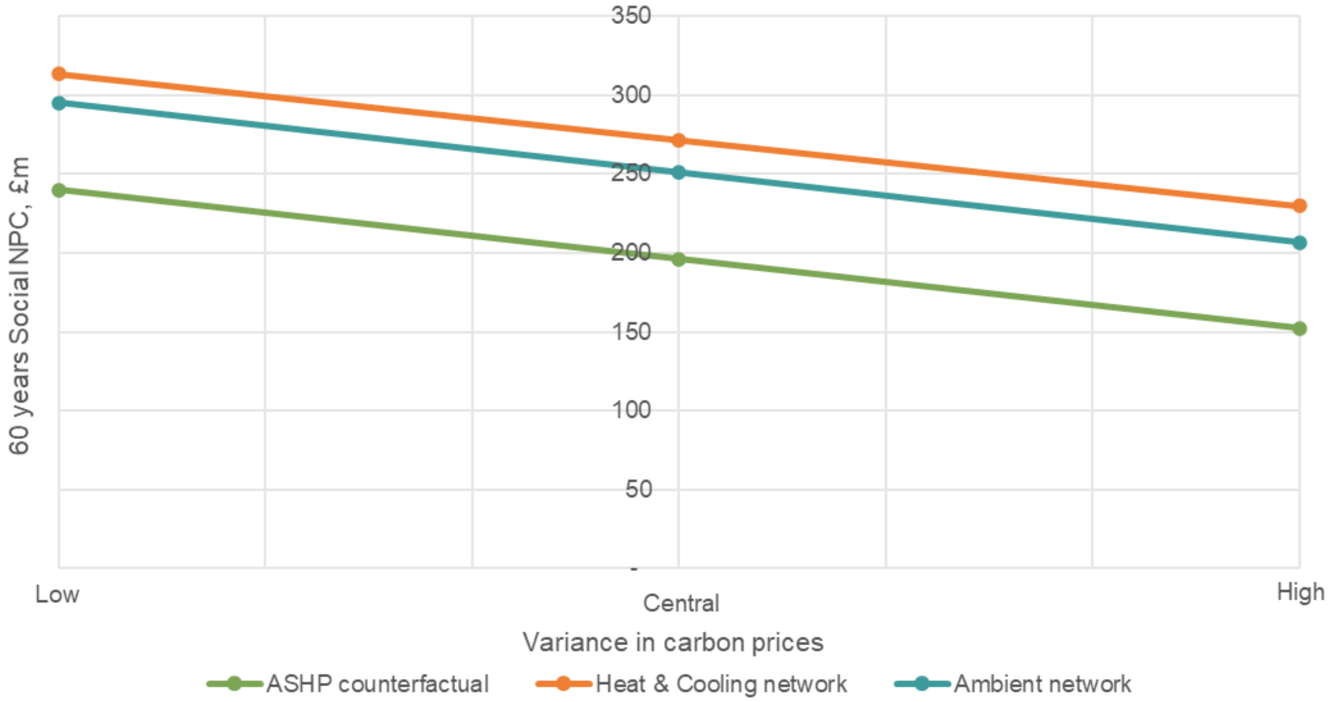
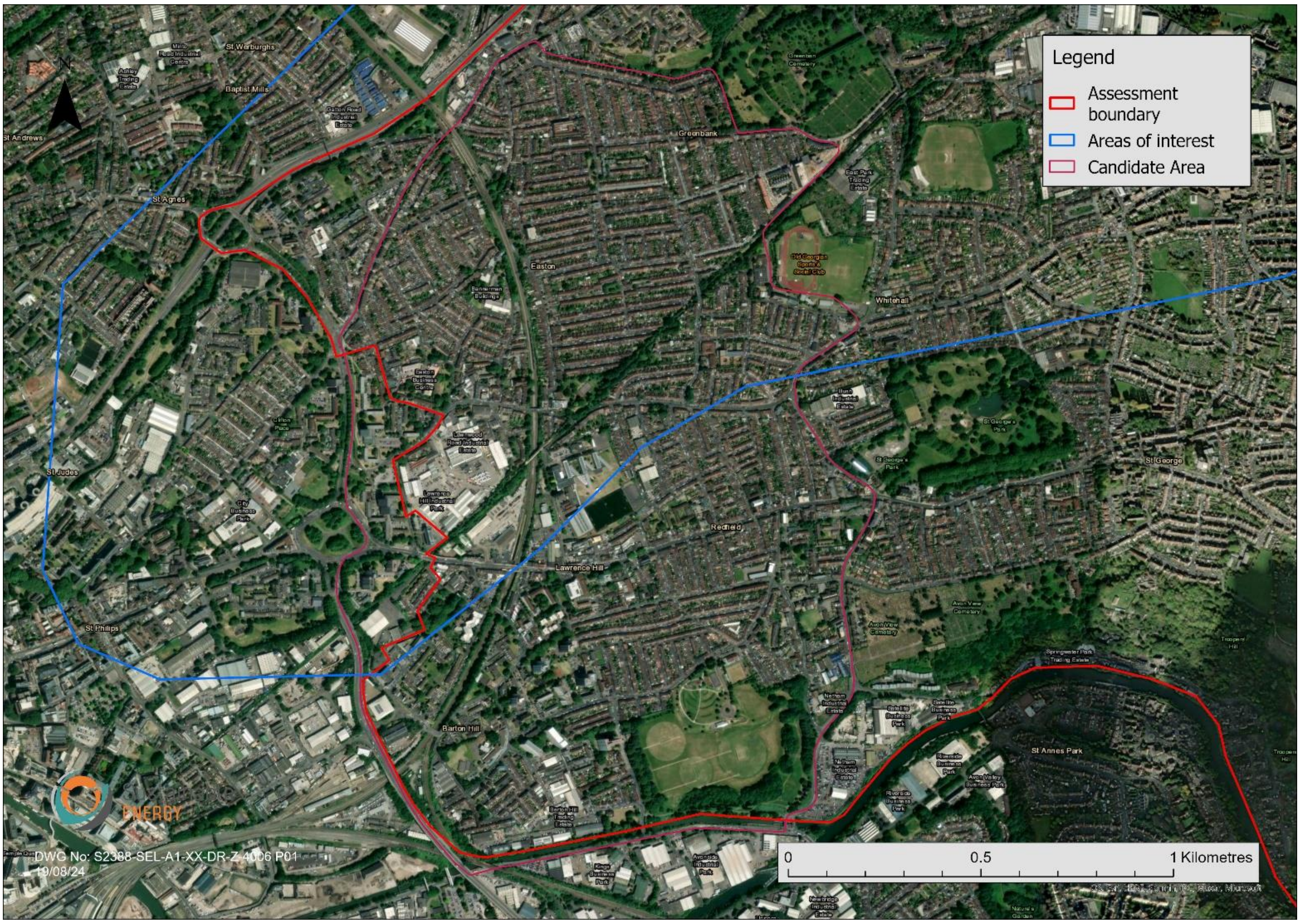


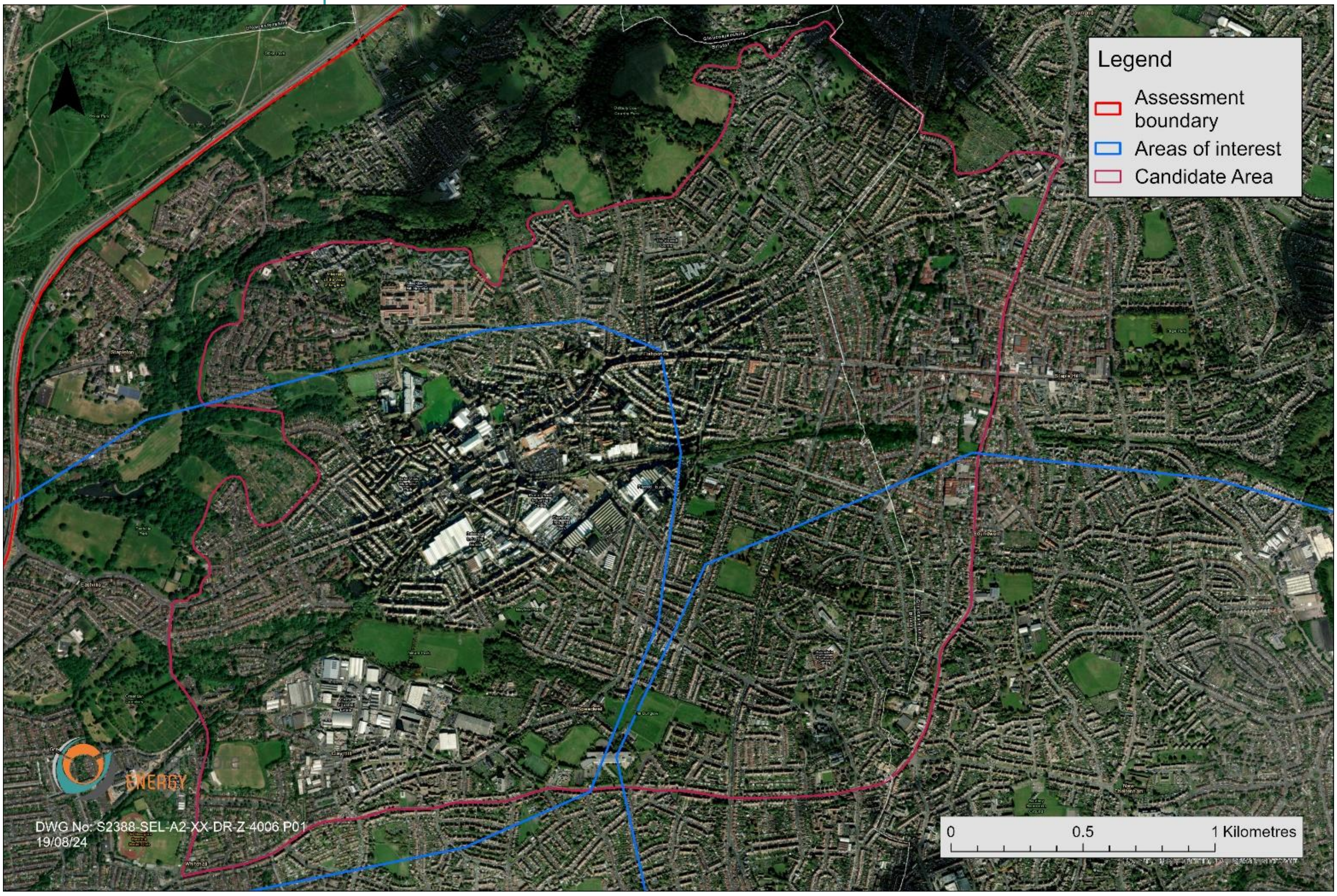
Figure 116: Variance in carbon prices – Barrs Court Residential

APPENDIX 6: AERIAL VIEW OF CANDIDATE AREAS

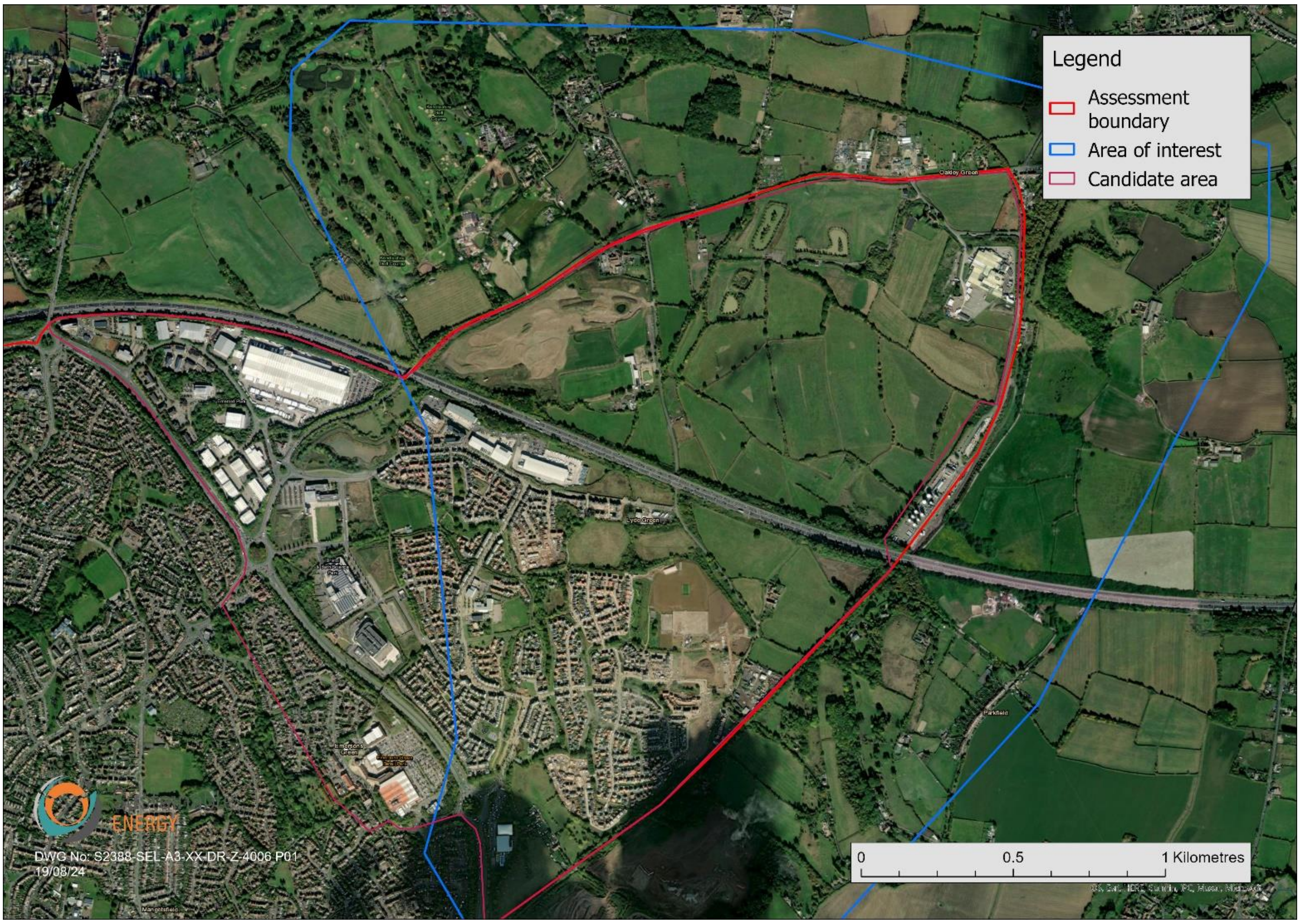
Candidate Area 1 – Lawrence Hill



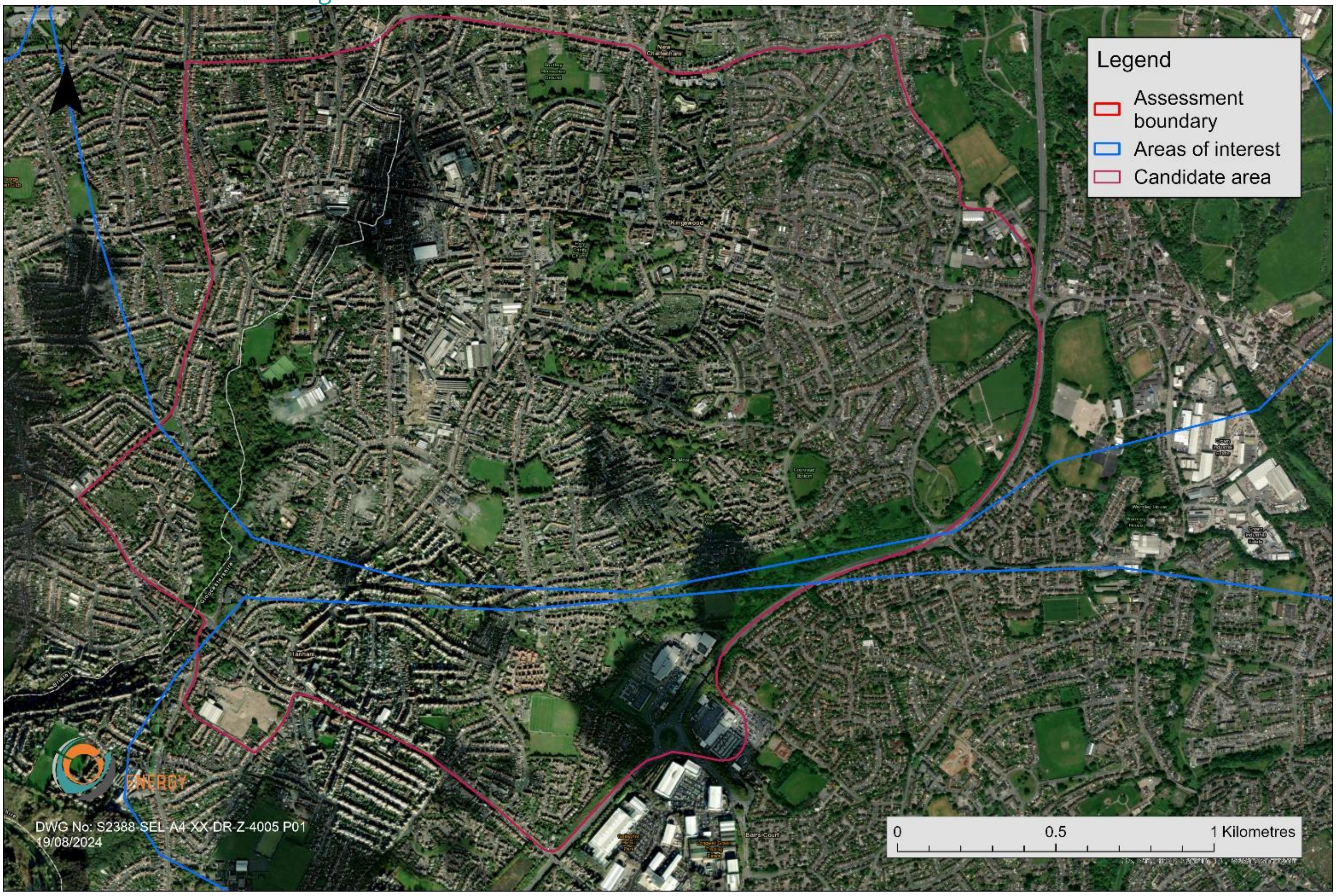
Candidate Area 2 – Fishponds



Candidate Area 3 – Bristol and Bath Science Park



Candidate Area 4 – Douglas Road Industrial Park



Candidate Area 5 – Barrs Court Residential