Killingworth Heat Network Feasibility Study

Document Number: S2064-SEL-ZZ-XX-RP-Y-001

Version: V01

Checked by: MC

Date of issue: 11/11/22

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Sustainable ENERGY

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List of Abbreviations

ASHP	Air source heat pump
AQMA	Air Quality Management Area
BAU	Business As Usual
BEIS	Department for Business, Energy and Industrial Strategy
BGS	British Geological Survey
CAPEX	Capital expenditure
CHP	Combined heat and power
CoP	Coefficient of Performance
CO_2e	Carbon dioxide equivalent
DEFRA	Department for Environment, Food and Rural Affairs
DHN	District heating network
DHW	Domestic hot water
Dph	Dwellings per hectare
EA	Environment Agency
EC	Energy centre
ESCo	Energy service company
FHS	Future Homes Standard
GA	General Arrangement drawing
GIS	Geographic Information System
GHNF	Green Heat Network Fund
GSHP	Ground source heat pump
HIU	Heat interface unit
HNCoP	Heat Networks Code of Practice
HNDU	Heat Network Delivery Unit
IAG	Interdepartmental Analysts Group
IRR	Internal Rate of Return
kWh	Kilowatt hour
LHD	Linear heat density
LTHW	Low temperature hot water
Mbus	Meter bus
MTHW	Medium temperature hot water
MWh	Megawatt hour
MWSHP	Mine water source heat pump
NOx	Nitrogen oxides
NTC	North Tyneside Council
NPV	Net Present Value
OPEX	Operational expenditure
PFD	Process flow diagram
PV	Photovoltaics
RFI	Request for information
SPF	Seasonal performance factor
SPV	Special purpose vehicle
TEM	Techno-economic model
WSHP	Water source heat pump

Glossary

Distribution Network	The circulation pipework (with flow and return) between the Energy Centre and the Substations
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 in 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
HNDU	The Heat Network Delivery Unit within BEIS
Internal Rate of Return	Defined as the interest rate at which the net present value of all the cash flows (both positive and negative) from a project or investment equal zero, and 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
NPV	Net present value, the value of investment discounted back to the present day using a determined discount rate (typically 3.5% as per Green Book guidance)
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)
Phases	Construction phases in which it is proposed the Heat Network will be delivered

Project IRR	Internal rate of return (IRR) of a project
Services Provider	Party who will deliver the operational and maintenance services including metering and billing
Social IRR	Internal rate of return of a project, including the additional social benefits of CO_2e savings and improvements in air quality
Social NPV	Social net present value
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

EXECUTIVE SUMMARY

This report presents the findings of the Killingworth Heat Network Feasibility Study. The study is funded by the department for Business, Energy, and Industrial Strategy (BEIS) and North Tyneside Council. This study should form a key part of the overall CO_2e reduction and heating strategy for the Killingworth area.

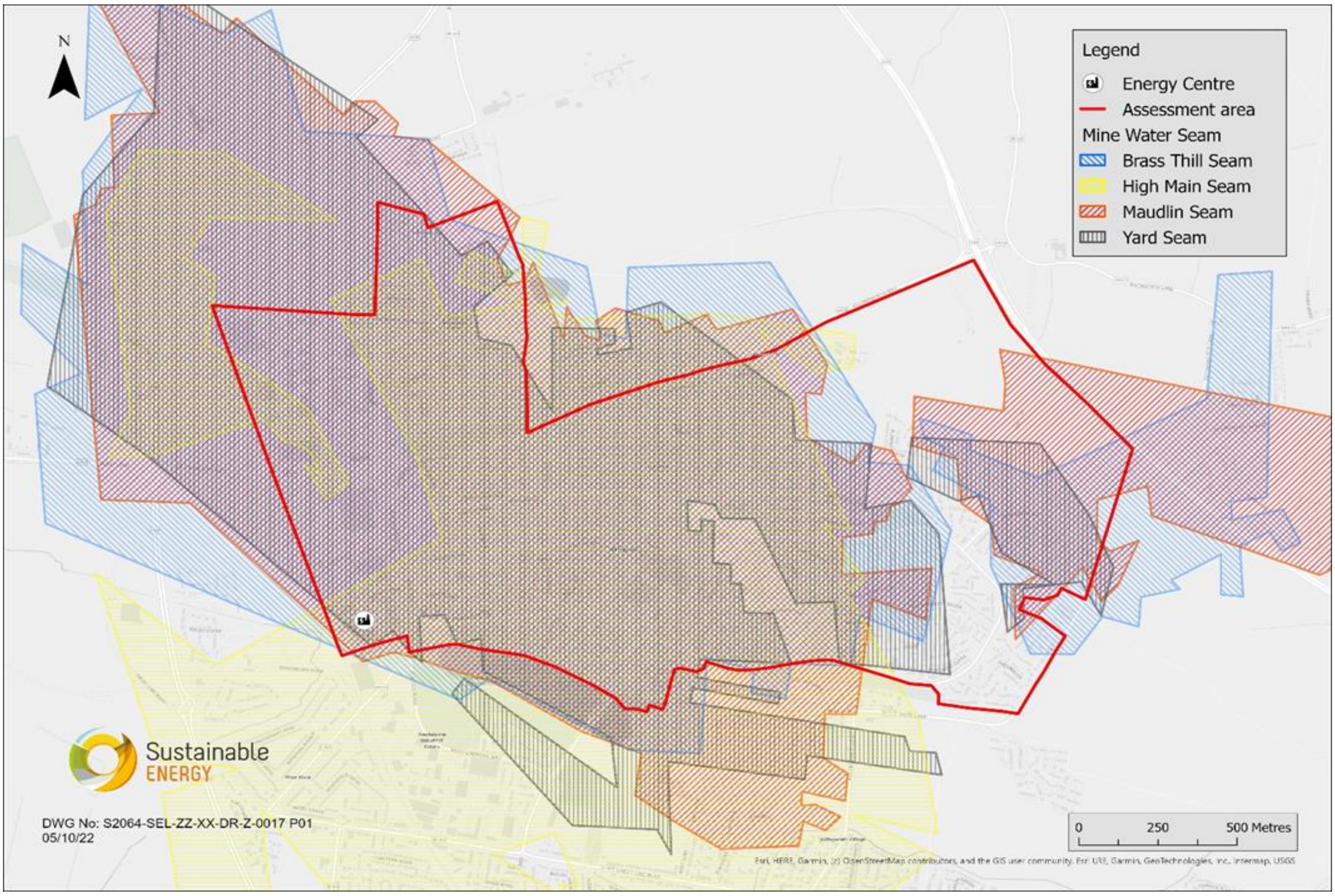
Energy Demand and Supply

The Killingworth area heat demand was assessed and calculated as 70.4 GWh. Of this demand an estimated 27.4 GWh would be viable for connection to a district heating network. Key heat demands come from the council buildings, specifically the NTC Killingworth Site, 6 local schools and community centres. As well as high density social housing sites near the main network route. Key private heat demands include Morrisons and Matalan/Home Bargains in the main shopping area. One large development was identified as a key connection as the network is built out.

The majority of the heat demand is made up of existing buildings, and their owners/operators will be exploring options to decarbonise their heating systems over the next 10 years. Delivering a reliable operational district heat network will be crucial to enable these stakeholders to decarbonise their heating supply.

Heat pumps, waste heat, biomass and CHP technologies were assessed as options to supply potential heat networks. Key potential source of renewable heat identified is water source heat pumps (WSHPs) using local coal mines as the water supply.

The network is reliant on suitable energy centre locations being secured. In discussion with North Tyneside Council officers, the preferred energy centre location is the Killingworth Depot site. The site is ideally located as it sits directly above 4 potential mine seams. Following consultation from the Coal Authority the energy centre site is likely to be a suitable location to abstract and re-inject mine water. However, the available flow rate and temperatures from the mines require further investigation.

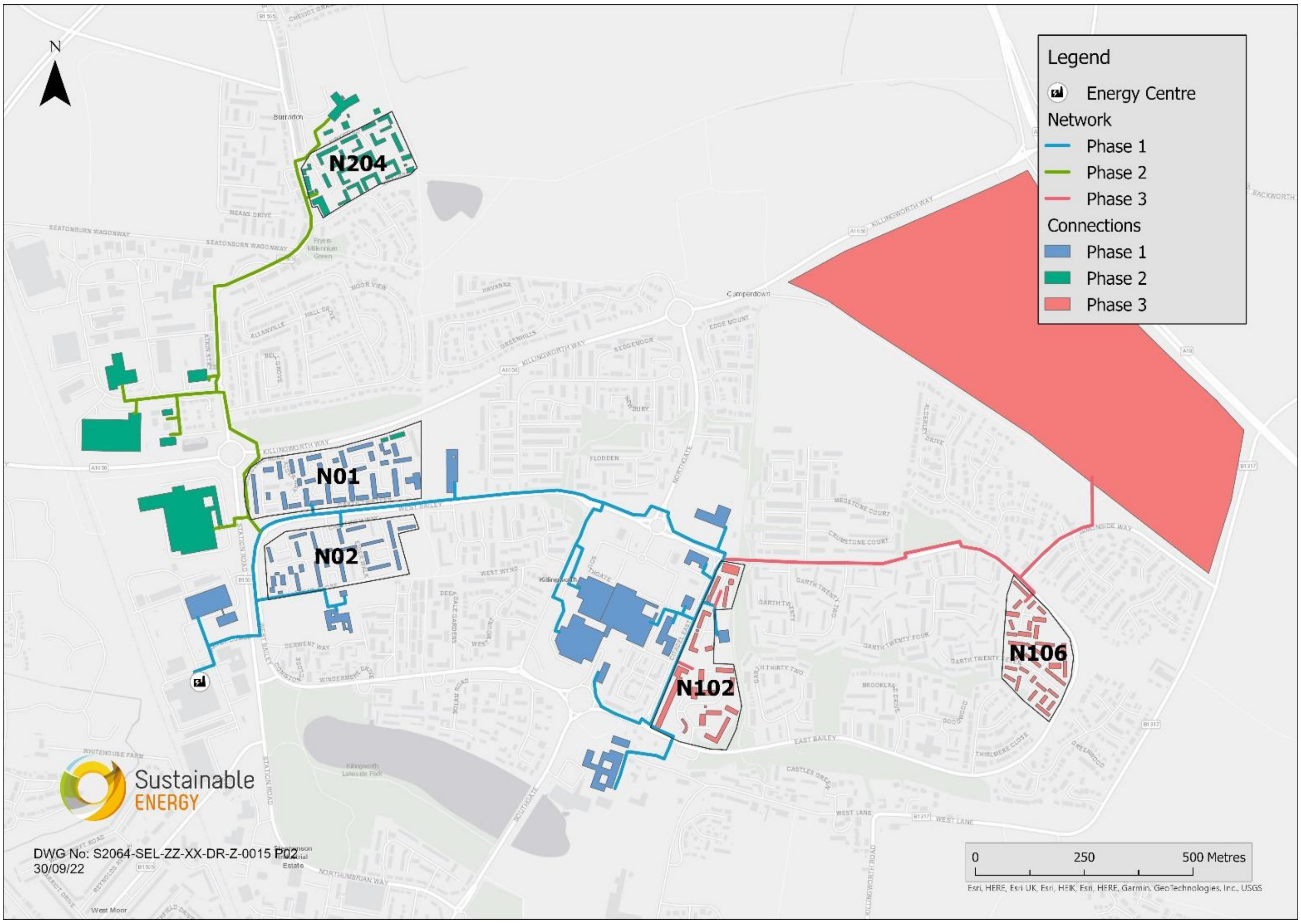


Network Assessment

The network was assessed over three phases. Phase 1 connections have been assessed as low risk connections, they include existing council buildings, social housing clusters located close to the main network spine and large commercial connections in Killingworth town centre. Phase 2 extends to connect larger connections in the northern industrial site as well as Burradon School and the adjacent social housing cluster. Phase 3 includes long term planned housing development at Killingworth Lane and the high density social housing clusters near to this development.

The DH network will be developed over three phases (see below):

	Phase 1	Phase 2	Phase 3	Total
Heat network spine length	2,572 m	1,206 m	1,103 m	4,880 m
Total heat demand (including losses)	11,803 MWh	3,473 MWh	6,096 MWh	21,372 MWh
Peak heat demand	4.6 MW	6.0 MW	7.4 MW	7.4 MW
Proposed phase start year	2024	2026	2028	-
No. of heat connections / stakeholders	16	8	3	27
Network average linear heat density	4.6 MWh/m	2.9 MWh/m	5.5 MWh/m	4.4 MWh/m



Economics

A techno-economic model (TEM) was developed to assess the viability of the proposed network. The key parameters for the TEM include:

- Annual heat demand, kWh
- Peak heat demand, kW
- Energy centre tariffs
- Heat sales tariffs
- Scheme capital costs

- Operational and replacement costs
- Carbon savings /emissions vs a BAU case
- Grant funding

The 40-year economics and carbon savings for each phase of the network are summarised below:

	Phase 1	Phase 2	Phase 3
Capital costs (incl. 20 % contingency)	£15,054.434	£5,071,053	£5,958,336
Total capital costs (including previous phases)		£20,125,487	£26,803,823
Lifetime carbon savings (40 years)	82,449 tCO_2e	104,618 tCO_2e	111,764 tCO_2e
Without grant funding			
IRR	1.47%	1.22%	3.02%
Social IRR	6.76%	6.51%	8.21%
NPV	-£4,406,989	-£6,343,057	-£1,667,671
Social NPV	£9,578,615	£11,342,662	£21,319,552
Simple payback	31 years	32 years	24 years
With 49% grant funding for Phase 1 (maximum available grant funding)			
IRR	5.80%	4.04%	5.83%
Social IRR	13.15%	10.76%	12.41%
NPV	£2,969,684	£1,033,616	£5,709,002
Social NPV	£16,955,288	£18,719,335	£28,696,225
Simple payback	16 years	21 years	17 years

The economics of the Phase 1 heat network return a low IRR and therefore would require grant funding to be viable from a local authority's perspective, which is available through the planned Green Heat Network Fund (GHNF).

Grant funding

Green Heat Network Fund is a £288m fund available to support heat network project with capital grants available to up to but not including 50% of the project capex.

The grant funding core requirements are shown below with the results from the preferred option:

Metric	Minimum score	Preferred option
Carbon gate	100 gCO_2e/kWh thermal energy delivered	91 gCO_2e/kWh reached in year 1 of operation
Customer detriment	Domestic and micro-businesses must not be offered a price of heat greater than a low carbon counterfactual for new buildings and a gas/oil counterfactual for existing buildings	Commercial customers and planned development sale tariffs have been calculated using an ASHP counterfactual. Social housing customers heat sale tariffs have been calculated using gas boiler counterfactual.
Social IRR	Projects must demonstrate a Social IRR of 3.5% or greater over a 40-year period	The 40-year social IRR is 6.8% for Phase 1
Minimum demand	For urban networks, a minimum end customer demand of 2GWh/year. For rural networks, a minimum number of 100 dwellings connected	End customer demand is 10.6 GWh/year for Phase 1 and 18.6 GWh/year for the fully built network
Maximum capex	Grant award requested up to but not including 50% of the combined total capex + commercialisation costs (with an upper limit of £1 million for commercialisation)	For Phase 3 to achieve a 5% 40-year IRR, £5,844,391 of grant funding is required, which equates to 22% of project total CAPEX. To achieve a Phase 3 10% 40-year IRR, £12,433,655 of grant funding is required, which equates to 47.7% of total project CAPEX

Metric	Minimum score	Preferred option
Capped award	The total 15-year kWh of heat/cooling forecast to be delivered will not exceed 4.5 pence of grant per kWh delivered (subject to review by GHNF)	The maximum grant funding available according to this metric is £11.4m. The Phase 1, 2 and 3 CAPEX is £26.7m, therefore this limit is will likely be the limiting metric.
Non-heat/cooling cost inclusion	For projects including wider energy infrastructure in their application, the value of income generated/costs saved/wider subsidy obtained should be greater than or equal to the costs included.	No non-heat/cooling infrastructure included

Key Sensitivities and Risks

Key sensitivity parameters for the prioritised network areas include:

- Capital costs
- Network heat demand and key sites not connecting
- Energy tariffs including heat sales tariffs, energy centre fuel purchase tariffs and indexation of energy tariffs
- Grant funding

The key risks for the project are:

- Confirming the water availability from the mines below the identified energy centre site
- Achieving grant funding for the Phase 1 heat network

Commercial and Governance Issues

The primary objectives for the project are to maximise CO_2e savings, provide affordable heat to residents and businesses. The overall return on the investment is low, therefore the schemes will need to be either public sector led or led by companies who can take a longer-term view. If grant funding is secured then there is the possibility that the network will meet the investment criteria of more private sector companies.

Next Steps

If the project is to be progressed, the next steps include:

- Securing commitment to the project from North Tyneside Council members
- Safeguard land at Killingworth Site for energy centre
- Continued engagement with the Coal Authority to develop:
  - Technical viability of utilising mine water from the proposed energy centre location
  - Available flowrates and temperatures
  - Confirm abstraction and reinjection locations
  - Commercial structure of heat supply
- Engagement with potential network connections and re-assess proposed network phasing
- Engagement with Northumberland Estates about development at Land Off Killingworth Lane
- Liaise with planning department to gather more detail on future planned developments
- Further engagement with Northern PowerGrid to determine cost of connection and available capacity
- Engagement with GHNF team to fully understand requirements and ensure a robust grant funding bid is submitted

1 INTRODUCTION

1.1 General

This report presents the findings of the Killingworth Heat Network Feasibility study. The project is supported by Heat Networks Delivery Unit (HNDU) from the Department for Business, Energy, and Industrial Strategy (BEIS). The work has been conducted by Sustainable Energy (SEL).

1.2 Project Scope

We were commissioned to undertake a feasibility study for Killingworth Township. The scope of the feasibility study included:

- Update predicted annual energy demands and profiles for heat and, if required, electricity and cooling
- Compile an energy demand database that includes building type, peak demand, annual demand and hourly profiles for all existing and planned buildings
- Identify potential energy centre / substation locations, considering locations of low and zero carbon plant and / or peak and reserve boilers and present the risks and benefits associated with each
- Compile energy demand and supply and risk assessments in line with latest information from development plans, planning applications, energy centre land availability assessment update, site surveys and any other relevant sources (including achieving sufficient accuracy of peak heat demands and annual heat consumptions)
- Identify electricity and gas capacity requirements for energy centres and decentralised options and provide budget connection costs
- Determine plant requirements and sizing (in line with likely grant funding requirements) including arrangements for peak and reserve boilers, thermal and electrical storage and potential for power supply
- Confirm feasible routes for heating/cooling pipes and power cables and suitable locations for building connections (liaising with local Highways, Structural and Planning teams to obtain critical feedback on proposed routes)
- Assess network temperatures including low temperature hot water and ambient network options
- Provide energy and mass balances (within the techno-economic model) using tried and tested in-house software to dynamically model hourly energy supply in response to hourly demand
- Provide a phased approach that includes detailed futureproofing considerations
- Provide heat demand sensitivity assessment that considers relevant and specific factors such as likely changes to planned developments and changes in occupancy for existing buildings (in light of C-19 or anything else) as opposed to a nominal percentage variation
- Review heat and power supply technology selection considering factors including, but not limited to, changes to energy price, CO_2e, CAPEX and OPEX forecasts
- Compare net present cost of all potential centralised and decentralised options to provide an appropriate economic comparison that assesses whole life costs
- Develop network hydraulic models using specialist design software
- Confirm demand assessment assumptions
- Confirm energy centre location options
- Assess connection risk
- Assess risk associated with energy centre location and identify mitigation measures and information required for energy centre planning application
- Complete optimisation and a concept design for preferred option:
- Energy centre plant (RIBA stage 2)

- Network spine and branches (RIBA stage 2)
- Domestic and commercial (design of HIUs and substations to RIBA stage 2)
- Undertake techno-economic modelling to assess and optimise options
- Compare potential options to business-as-usual case or counterfactual to determine the economics and compare risks, issues, benefits and disbenefits
- Develop an investment timeline delivery plan to confirm the network delivery strategy to include a long-term phased delivery strategy (to be agreed with Client) which outlines phasing of network development, timeline for connection of buildings / clusters and integration of future heat supply sources
- Identify funding gaps that could be supported through Green Heat Network Fund
- Assess the annual and lifetime carbon impact of all network options
- Assess how parameters such as development costs, CAPEX, OPEX, connection charges, developers' contributions, economic value of CO2e savings impact scheme viability
- Undertake meetings and workshops with Client to establish project priorities, critical success factors, hurdle rates and appetite for risk
- Identify next steps and implementation requirements for the recommended scheme

All work is compliant with the HNCoP, and we considered UK and international best practice.

1.3 Project Background

The council recognise a number of potential opportunities associated with the provision of lower cost, lower carbon energy which could arise from a district heat network in the Killingworth area and wishes to further explore such opportunities. This specific piece of work progresses initial heat mapping and master planning results for the area of Killingworth the council has undertaken in 2015. The heat mapping exercise identified six heat clusters across the North Tyneside, Killingworth Town Centre was one of those clusters and therefore Council applied for HNDU funding to conduct techno-economic feasibility study.

In 2019 NTC declared climate emergency and set a plan to be carbon net zero emission by 2030. Decarbonisation of heat is a key challenge in achieving net zero carbon.

The North East Local Partnership (NELEP) Energy Accelerator programme was designed to support Local Authorities like North Tyneside Council and help low carbon and energy efficient projects become a reality. NELEP offers expertise, capacity and funding to NTC associated with this study.

1.4 Project Drivers

The councils' key drivers for investigating heat networks include:

- Reducing carbon emissions
- Stimulating economic development
- Reducing Council operating costs using its operational buildings as anchor loads
- Addressing domestic fuel poverty
- Improving energy security

2 DATA COLLECTION

This section describes the potential customer and stakeholder engagement that has taken place. Stakeholder engagement is critical to developing successful energy networks and the engagement work carried out to date will need to continue if the project progresses through to subsequent HNDU stages of development.

A data collection exercise was undertaken to enable the revision of energy mapping of existing and future energy demands as well as potential energy sources, barriers and constraints. As part of this process, the energy demand assessment area was reviewed and amended to include land off Killingworth Lane which extends to the northeast of the Killingworth Town area.

Key stakeholders were consulted to inform the data collection exercise including representatives from the NTC, HDNU, and NELEP, as discussed in section 2.2.3

2.1 Network Assessment Area

The Killingworth network assessment area was reviewed to identify areas where it could be extended.

Following consultation with the project team, planned developments to the northeast of Killingworth shall be included in the assessment and the boundary has been expanded further, as shown in Figure 1.

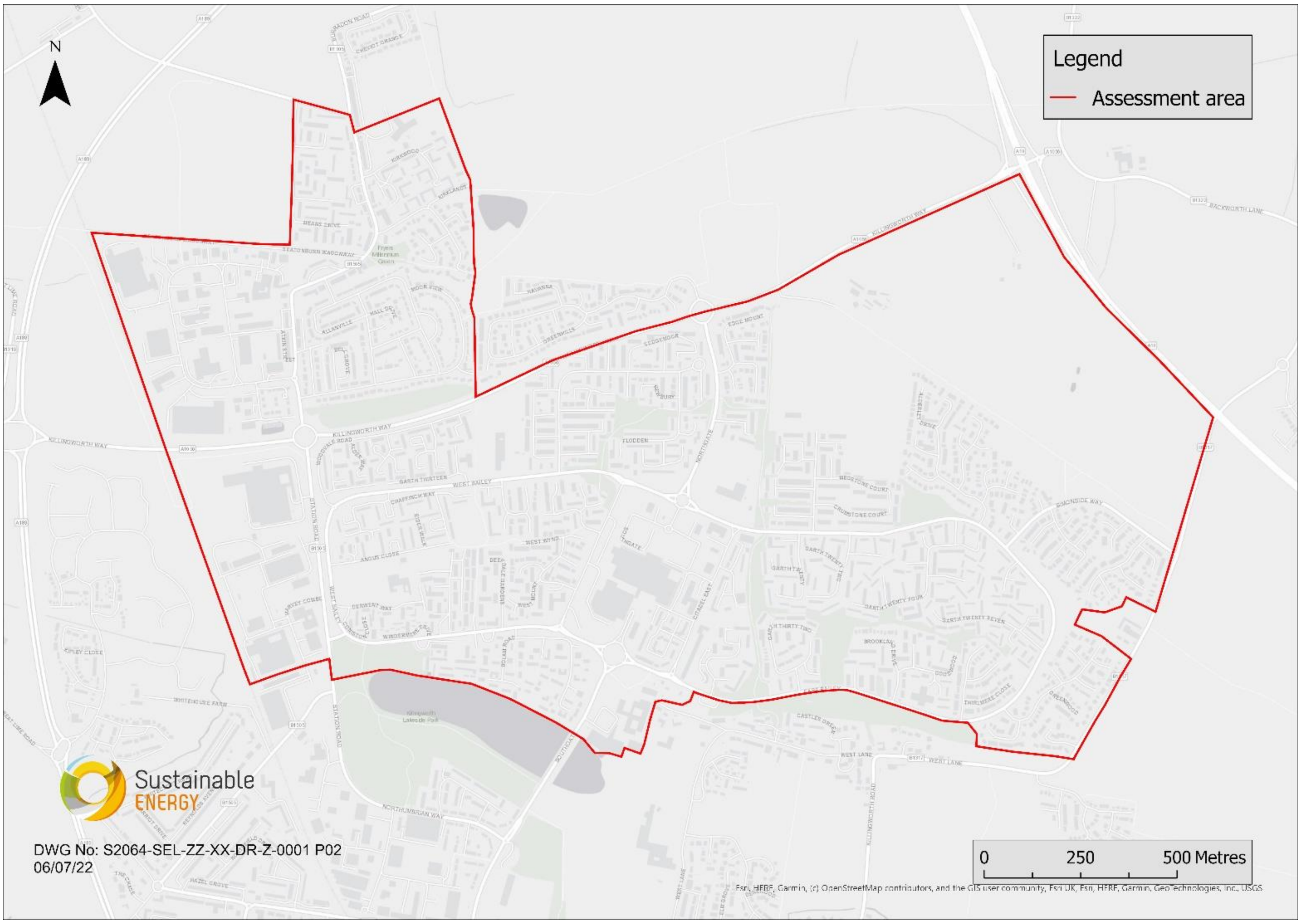


Figure 1: Network Assessment Area

2.2 Identification of Potential Customers

2.2.1 Planned Developments

Planned developments may provide significant energy demands and potentially lower risk of connecting than privately owned existing sites. However, there are risks associated with energy mapping and basing network assumptions around planned developments, these include:

- Permitted developments not being built
- Changes to the density, scale and timing of planned developments

Conversely, there may be potential for the density of developments to increase, meaning that higher heat density could improve the viability of networks. Figure 2 shows planned developments identified within the Killingworth area. Further details of these are in Table 1. Risks are considered further in section 10.3.

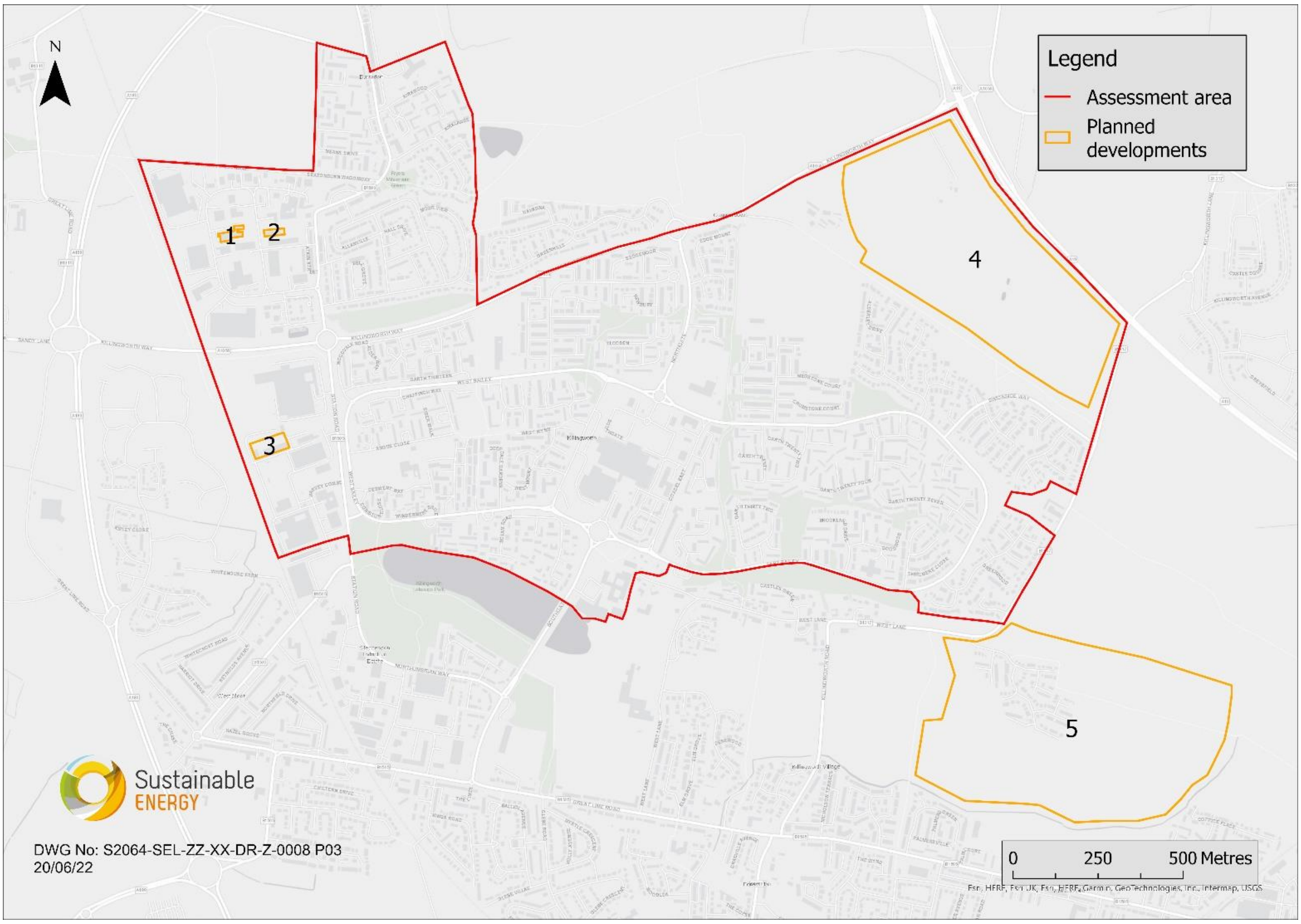


Figure 2: Killingworth planned developments

Table 1: Current information for planned developments

Map ref.	Name	Revised Name	Details of development	Timing	Assessed further
1	Site 7C Mylord Crescent Camperdown Industrial Estate	Aqua Leisure Developments Ltd	• Change of use of an industrial building (B2/B8) to a mixed-use scheme comprising office (B1),	-	Yes

Map ref.	Name	Revised Name	Details of development	Timing	Assessed further
			private swimming pool (D2) and ancillary cafe (A3)		
2	Unit 1 Locomotion Way Camperdown Industrial Estate	Locomotion Business Park Ltd.	• Demolition of an existing industrial building, to make way for a new multi-unit commercial/light industrial building	-	Yes
3	The Killingworth Site Station Industrial Estate	Killingworth Depot	• Demolition of blocks F, K, L and M and erection of a new replacement vehicle maintenance unit. Reconfiguration of vehicle access routes and parking • Partial retention of Block F, solar canopies, photovoltaic provision and amended site access	-	Yes
4	Land Off Killingworth Lane	Northumberland Estates	• Full planning permission for the change of use of agricultural land and development of 439no. residential dwellings	-	Yes, full planning application has been submitted this year
5	Land At Killingworth Moor	Bellways Homes Ltd (North East) And Banks Property Ltd	• Construction of 565no residential dwellings	-	No, outside of the assessment area and significant extra pipe work required to connect

The heating strategy for the planned developments is currently unknown. It is unlikely that these developments will be built before the proposed Future Homes Standard comes into effect which will not allow new builds to install gas boilers. If the Killingworth heat network can offer a credible alternative to installing ASHPs then there is a good possibility that they will connect. Planning policy can be used to promote and facilitate the development of district heat networks and the NTC planning team has an important role to play in developing and supporting guidance and working with developers.

2.2.2 Existing Sites

Existing sites within the assessment area were identified and their energy demands assessed. The following sites have been included in the energy demand assessment but may not connect to the network:

- Sites with annual demands below 50 MWh, unless of strategic importance
- 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.

2.2.3 Engagement with Potential Key Stakeholders

Key stakeholders were identified and contact established where possible. We contacted potential stakeholders to obtain information such as development plans, energy data and tariffs, building use and occupancy levels and patterns. Information requests were presented to stakeholders by email and, where possible, via video calls.

A summary of information received from the data collection exercise for potential key network customers can be seen in Table 2.

Table 2: Summary of engagement with key stakeholders

Contact	Site/Organisation	Role/interest
Michael Keenlyside	North Tyneside Council	• Environmental Sustainability Officer
Marissa Granath	North East Local Enterprise Partnership	• Programme Manager – Energy Accelerator
Bobo Ng	North East Local Enterprise Partnership	• Energy Programme Manager
Donna Skordili	Heat Network Delivery Unit at BEIS	• Low Carbon Heat Projects Manager
Victoria Brockley	WestRock Multi Packaging Solutions	• No response
Jeremy Groves	Entek International Ltd.	• Site manager • Meeting held on the 4/11/22 to discuss heat network opportunity
Carla Maley	Percy Hedley School	• School Business Manager • No response
Karen Dracou	Fenwick Warehouse	• No response
Pippa Wicks	John Lewis and Partners Delivery Hub	• No response
Guy Robinson	Killingworth shopping centre	• Asset Manager
Gill Wallis	Killingworth shopping centre	• Site Manager • Contact established
Victoria McDermott	Morrisons	• Property Specialist – Energy • Contact established
Matthew Fox	Coal Authority	• Principal Manager - Mine Energy Advisory
Charlotte Adams	Coal Authority	• Principal Manager Mine Water Heat

3 ENERGY DEMAND ASSESMENT

3.1 Energy Demand Profiles

Energy demands for potential network connections have been assessed (this included the issue of Requests for Information (RFIs) to all stakeholders). The energy demands and profiles for the panned development were modelled to consider Objective 2.1 of the CIBSE / ADE Heat Networks Code of Practice (to achieve sufficient accuracy of peak heat demands and annual heat consumptions) and comply with Future Home Standard Part L of the Building Regulations. In line with best practice hourly annual energy demand profiles were generated using in-house modelling software which apportions demands to hourly loads over the year, considering degree day data[1], building use and occupancy. All energy loads were then identified, categorised, and mapped.

For planned development we modelled hourly profiles of heating and domestic hot water demand, normalised against degree day data from the nearest monitoring station (Newcastle). Profiles were developed using in-house software and considered building plans, site measurements, building construction and operating parameters. Peak, base load, seasonal and annual heat demands were identified.

For existing domestic dwellings, information for the house size and age of the properties was supplied by NTC. Using this data, a heat demand was calculated for each property. More information on the methodology can be found in Appendix 2: Heat Demand Modelling Methodology.

Where no building data was available, data derived from hundreds of in-house data collection exercises for similar buildings was utilised and a demand profile for the building was constructed using in-house software or selected from our profile database as appropriate. Relevant Building Regulations were considered for planned developments. Electricity profiles for key electricity loads were identified from half hourly data or modelled where this was not available.

For each building and network phase, the hourly heat demand model was used to identify the average, maximum and minimum hourly demand throughout the year.

3.2 Energy Demand Assessment Results

Geographic Information System (GIS) software was used to map the key heat, electricity, and cooling demands for the Killingworth 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 greater the energy demand. Appendix 1: Energy Demand Assessment shows demands for all network connections in detail, Appendix 2: Heat Demand Modelling Methodology shows heat demand model methodology and assumptions.

3.2.1 Heat Demand

The heat demands for all potential network connections are shown in Figure 3. The largest commercial heat demand arises from the NTC Killingworth site. Table 3 shows details of top 5 heat demands for single sites. The total heat demand for both commercial and residential sites identified within the energy demand assessment area is approximately 70,249 MWh.

[1] Degree days are a type of weather data calculated from outside air temperature readings. Heating degree days and cooling degree days are used extensively in calculations relating to building energy consumption. They are used to determine the heating requirements of buildings, representing a fall of one degree below a specified average outdoor temperature (15.5°C) for one day.

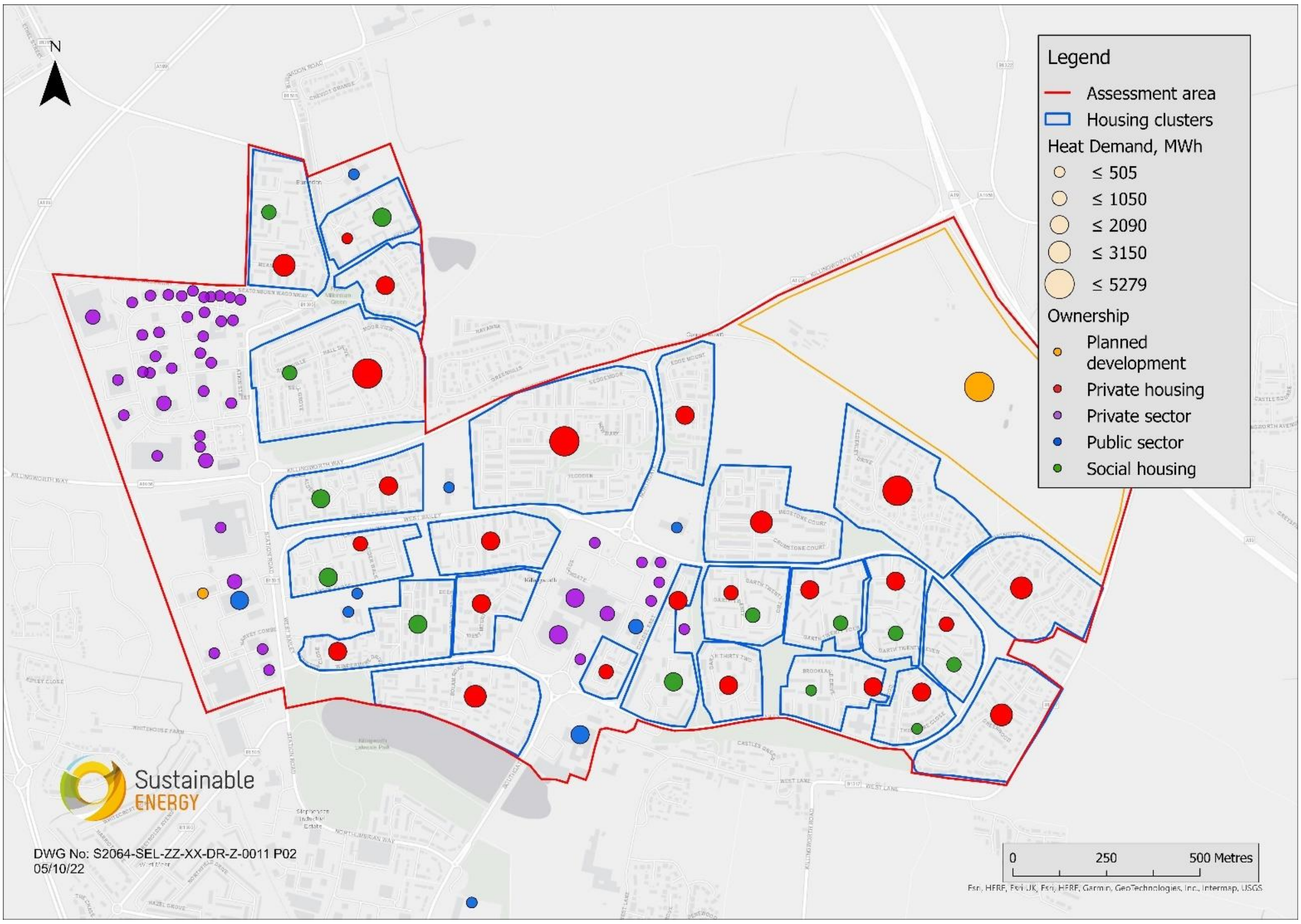


Figure 3: Heat Demands

Table 3: Top 5 commercial heat demands within assessment area

Rank	Name	Ownership	Building use	Annual heat demand, MWh	Source of data
1	Killingworth Site	Public Sector	Office	1,522	Actual data (metered)
2	Matalan/Home Bargains	Private Sector	Retail	1,277	Estimated using data for similar sites
3	Morrisons	Private Sector	Retail	1,212	
4	George Stephenson High School	Public Sector	Education	985	Actual data (metered)
5	White Swan Centre	Public Sector	Education	858	

Figure 4 shows the proportion of heat demand from the site apportioned to each ownership.

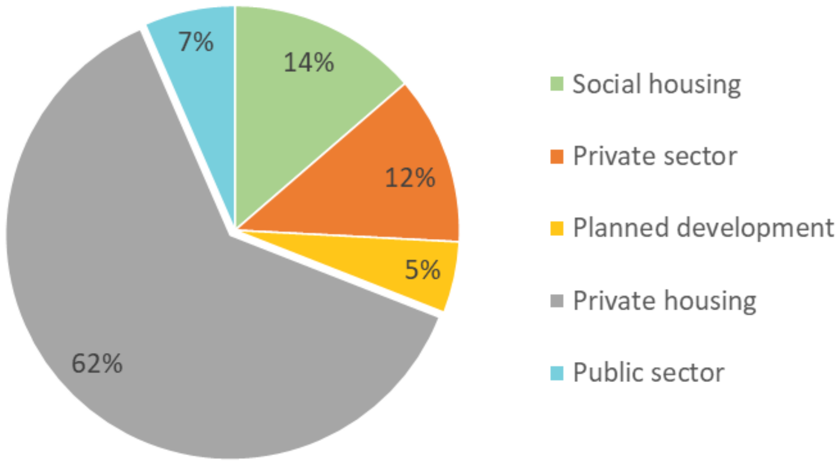


Figure 4: Heat demand split by ownership

Figure 5 shows further breakdown of the heat demand by building use.

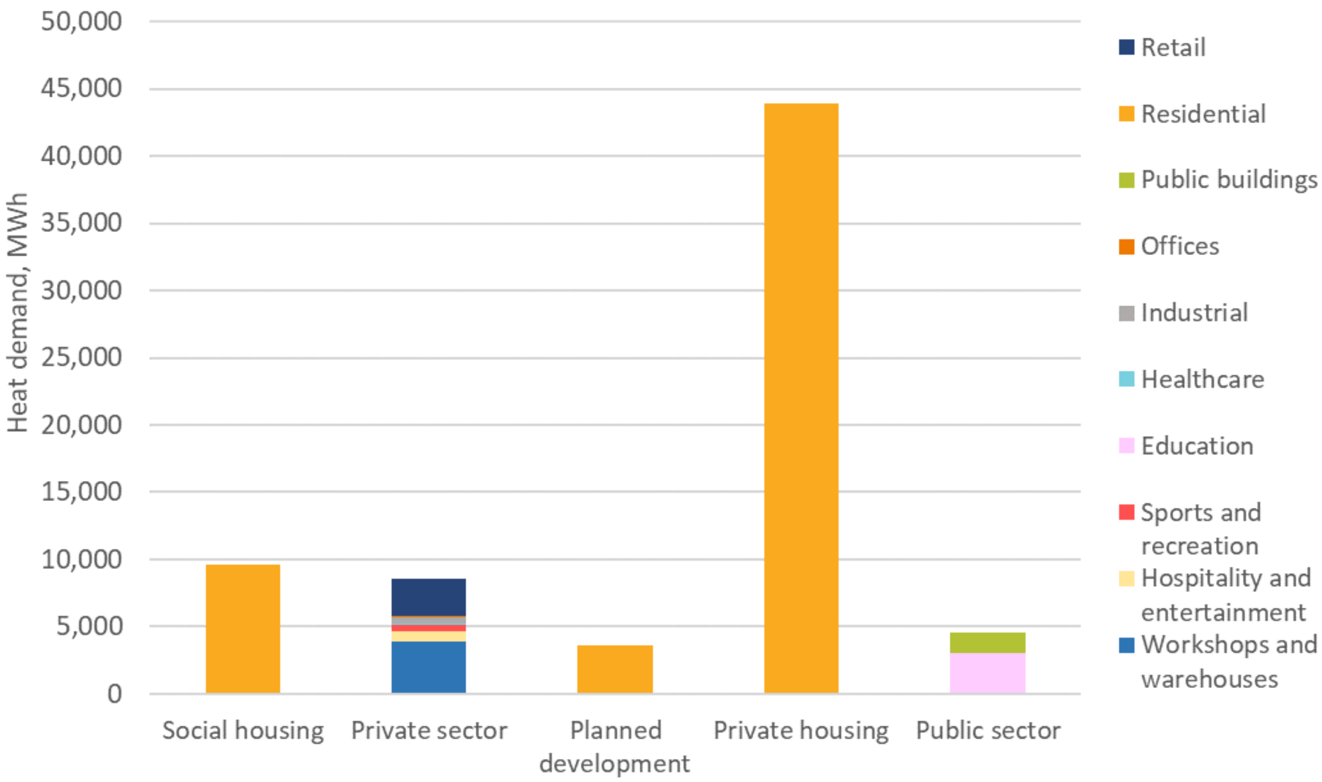


Figure 5: Categorisation of heat demand

From Figure 4 and Figure 5 the majority of heat demand (62%) is associated with low rise private housing within the social housing clusters identified in WP1. From previous project experience it is very difficult to get engagement at scale from private sector housing and will be unlikely connect to a heat network. Therefore, the heat demand breakdown without existing private housing is shown in Figure 6 and Figure 7.

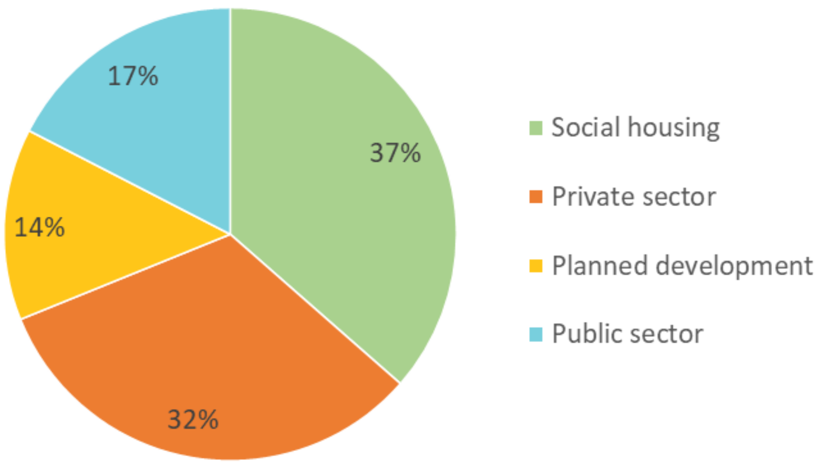


Figure 6: Heat demand split by ownership (excluding private housing)

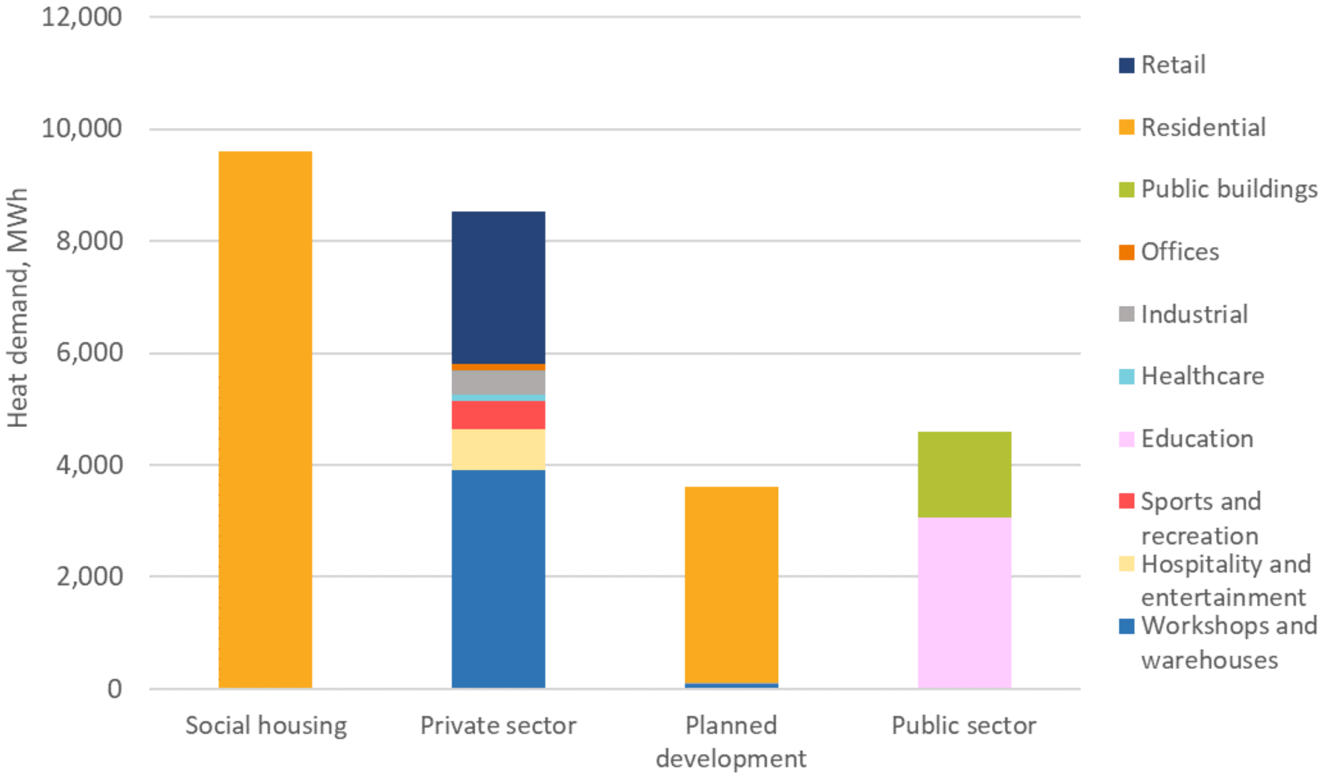


Figure 7: Categorisation of heat demand (excluding private housing)

3.2.2 Electricity Demands

The electricity demands have been assessed to analyse the potential for private wire connections. The total electricity demand for all identified key non-domestic electricity demands within the energy demand assessment area is approximately 19,116 MWh. The electricity demand for potential network connections are shown in Figure 8.

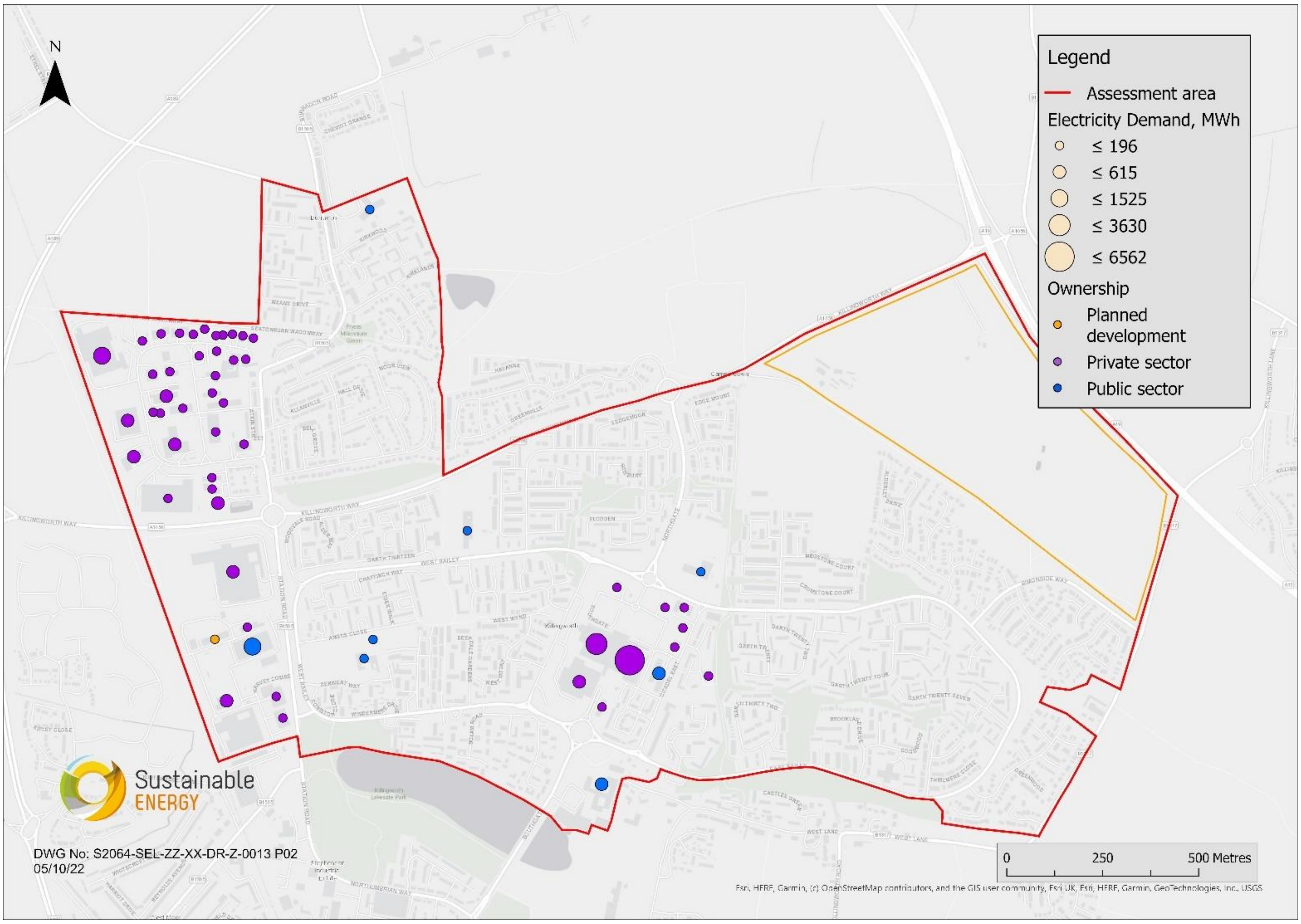


Figure 8: Electricity demands

The largest electricity demands are shown in Table 4.

Table 4: Top 5 electricity demands

Rank	Name	Ownership	Building use	Annual electricity demand, MWh	Source of data
1	Killingworth Shopping centre	Private sector	Retail	6,562	Estimated using data for similar sites
2	Morrisons	Private sector	Retail	3,630	
3	Killingworth site	Public sector	Public buildings	1,524	Actual data (metered)
4	Entek International	Private sector	Workshops and warehouses	1,244	Estimated using data for similar sites
5	Tyne Pressure Testing	Private sector	Workshops and warehouses	613	

Figure 9 shows the proportion of electricity demand from the site apportioned to each ownership.

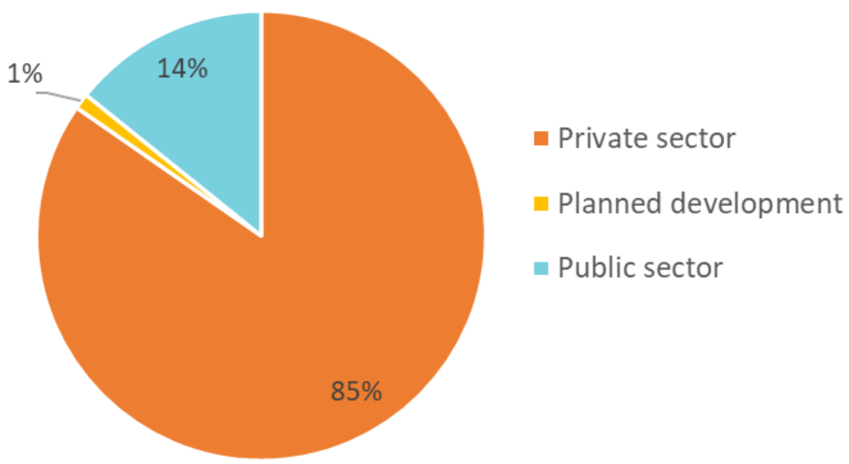


Figure 9: Commercial electricity demand split by ownership

Figure 10 shows further breakdown of the electricity demand by building use.

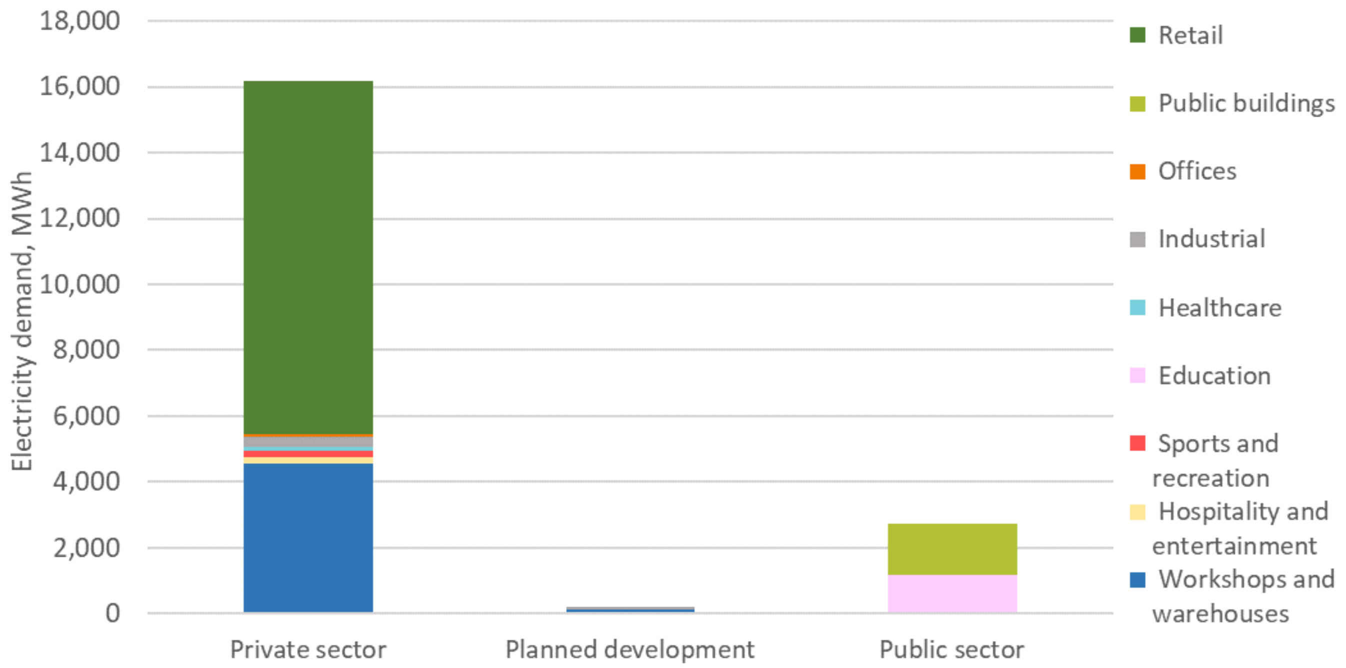


Figure 10: Commercial electricity demand split by building usage

3.2.3 Cooling Demands

Cooling demands are only assessed for connections that are likely to have or could be designed to have wet cooling systems. Within the assessment area no significant cooling loads were found.

3.2.4 Sources of Data for Energy Demand Assessment

Half hourly gas and electric data was available for all council sites in the assessment area. We attempted to establish contact with the largest potential heat demand customers in the area. However, no data was forthcoming from any of the private connections. For each of these sites the heat demand was based on similar sites and proportioned to the area of the buildings.

For residential connections a heat demand model was created as discussed in 3.1. Table 5 summarises the sources of the energy demand assessment.

Table 5: Summary of energy demand data sources

	Total demand	% from actual data	% based on heat demand model	% based on data for similar sites
Heat demand	70,249 MWh	6.2	81.2	12.6
Heat (excluding private housing)	26,340 MWh	16.6	49.7	33.7
Electricity demand	19,116 MWh	13.8	-	86.2

3.3 Summary

A significant proportion of the energy demands within the Killingworth area arise from low density, private sector housing (62%). Due to the difficulty in predicting uptake of a heat network connection for existing private housing, this assessment will only consider social housing connections. In the later phases of the network there is a significant planned development that could benefit the heat network. Therefore, engagement with the planners and site developers should be made a priority.

When excluding private housing, there is a significant heat demand from public sector buildings (17.4%) and social housing (36.5%).

Key potential heat network demands include NTC's Killingworth Site, Morrisons and public sector schools.

4 ENERGY CENTRE ASSESSMENT

4.1 Potential Energy Centre Locations

Figure 11 and Table 6 provide details of the potential energy centre locations identified.

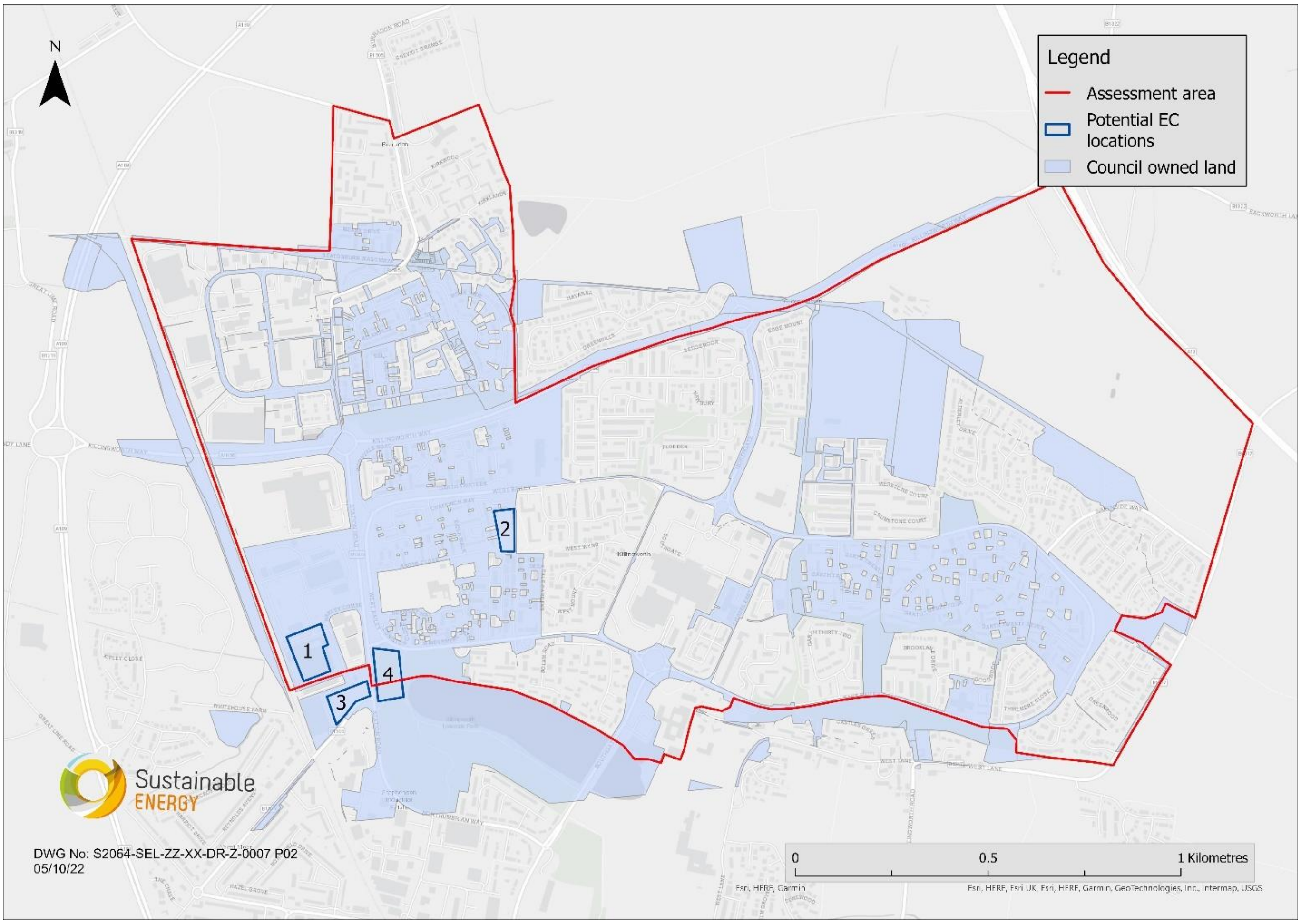


Figure 11:Potential energy centre locations

Table 6: Potential Energy Centre locations

Map ref	Location	Land ownership	Current use	Comments
1	Killingworth Depot	North Tyneside Council	Council buildings	• Close to key council heat demand • Within assessment area • Existing building has planning permission to be partially demolished with no current plans for future development • Within industrial area with no residents nearby • Easy vehicle access
2	Keegan Park	North Tyneside Council	Park	• Close to heat demands • Within assessment area • Surrounded by low rise residential dwellings • Possible opposition from local residents • Large vehicle access may not be possible
3	Land adjacent to station road	North Tyneside Council	N/A	• Large grass area off main road • Just outside assessment area

Map ref	Location	Land ownership	Current use	Comments
				• Easy vehicle access
4	Lakeside Park	North Tyneside Council	Park	• Large space available • Surrounded by large trees that may restrict building network • Local opposition to using park land

The preferred energy centre location was determined to be the Killingworth Depot site. This site has planning permission to demolish some of the existing buildings and would provide a substantial plot for locating an energy centre. The site is within an industrial area where large vehicle access would not be restricted. The site would also be in close proximity to one of the largest network demands, the Killingworth site.

4.2 Existing and Planned Energy Sources

Potential low carbon or renewable energy sources within or near the network assessment area were assessed to identify any energy sources that may have potential to supply a heat network.

Existing borehole records, mine entries and large water sources were assessed, and the findings are presented in Figure 12.

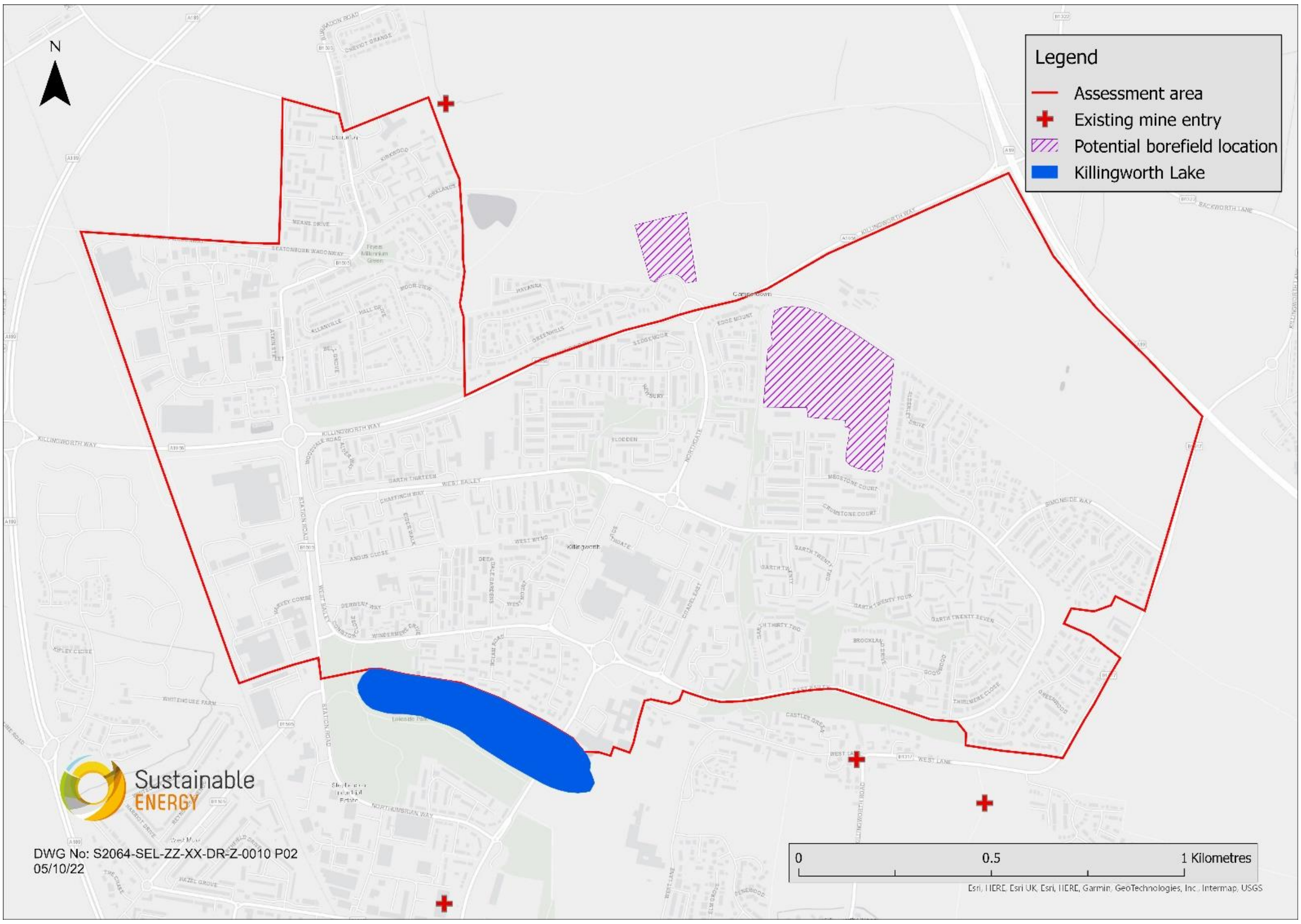


Figure 12: Potential heat sources

There were no borehole records[2] found in the area that yielded any water. However, several mine workings have been identified that suggested there could be potential for mine water to be used as a heat source.

Mine Water Assessment

Mine water was assessed as potential energy source. Figure 13 shows seam data provided by Coal Authority. For mine water to be a suitable heat source the abstraction and reinjection boreholes need to be sufficiently separated to prevent cooling of the abstracted water. This can either be from having a long surface pipeline to increase separation or by abstracting and injecting into different interconnecting seams.

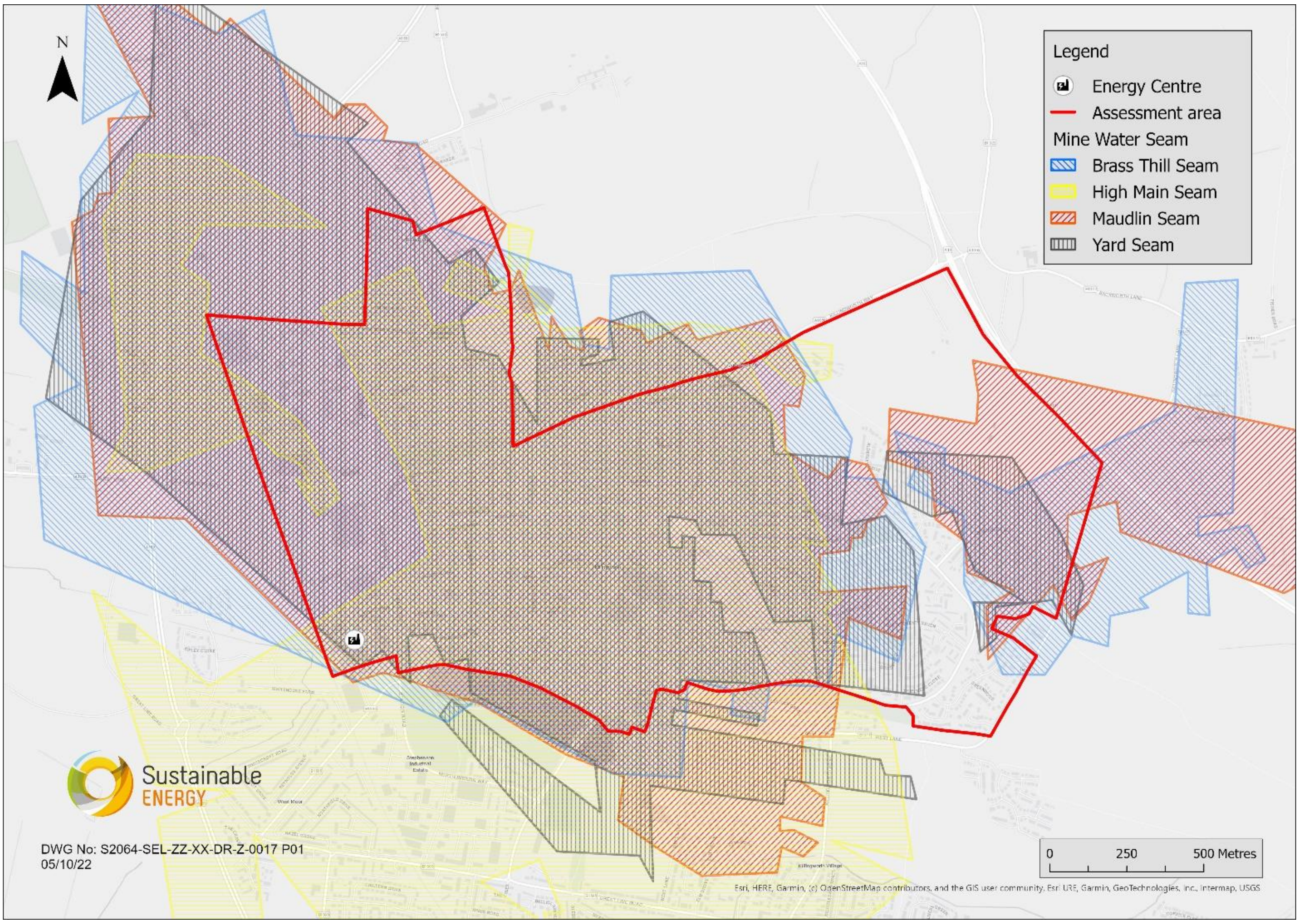


Figure 13: Mine water seams across assessment area

The preferred energy centre location sits above 4 potential seams. This would enable a minimum amount of abstraction and discharge pipework. The approximate depths of the 4 seams below the energy centre are shown in Figure 14. The interconnectivity of the seams would need to be assessed with a further study from the Coal Authority.

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[2] British Geological Survey: [GeoIndex - British Geological Survey (bgs.ac.uk)](https://www.bgs.ac.uk)

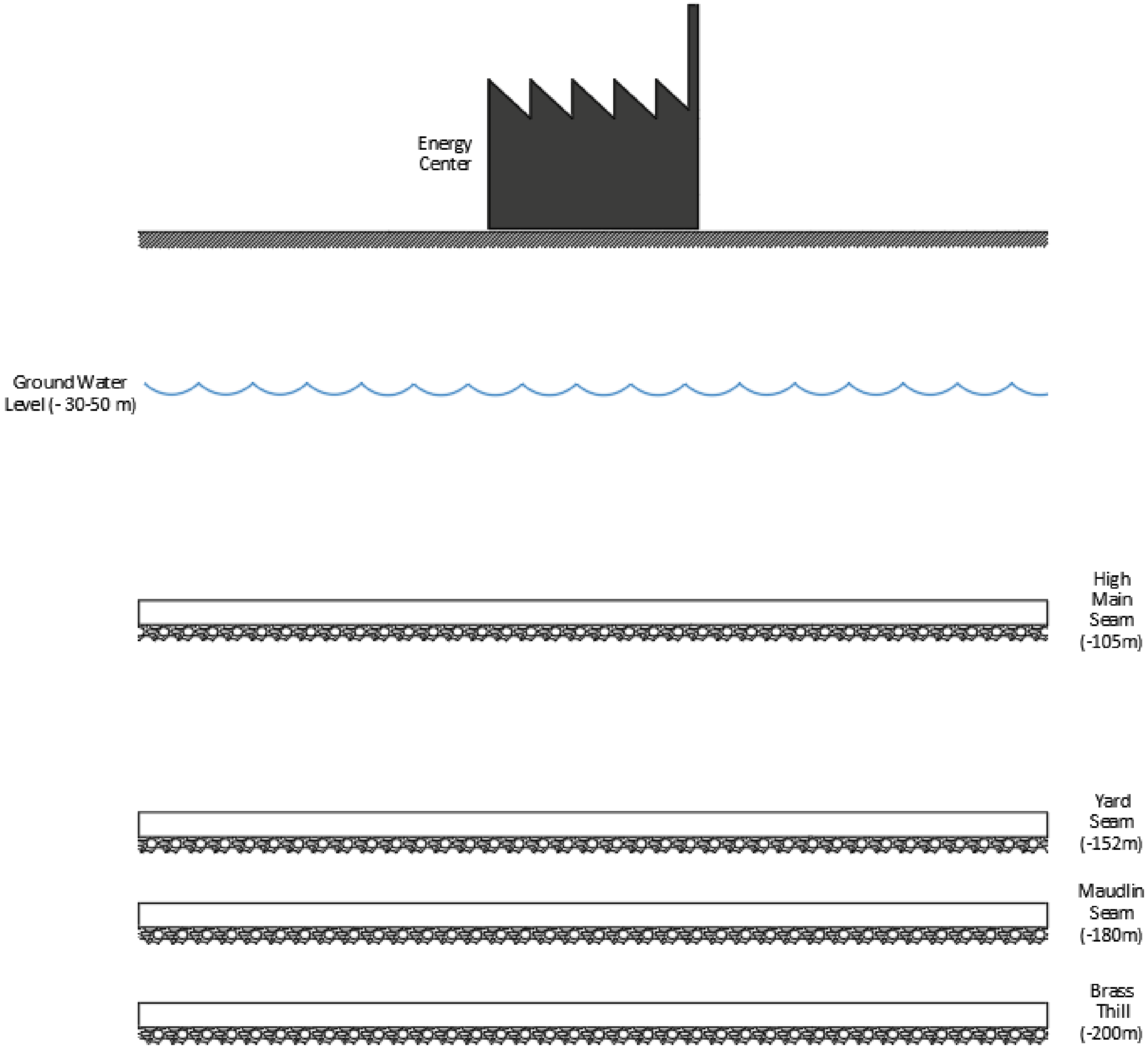

Figure 14: Approx. seam depths below energy centre

Planned energy sources

No planned energy sources were identified within or near by the assessment area.

4.3 Domestic Counterfactual

Counterfactual solution is an alternative to the current heating system and would be considered as a future solution e.g., low carbon counterfactual would be individual ASHPs.

Table 7: Potential counterfactual solution

	ASHPs in individual buildings	Electric heating	Gas boilers (BAU)
Efficiency	Range of 200 -250 %	100%	Range of 80-90%
Average cost	£10,000 (Estimate from NTC Housing Officer for an upgrade in social housing)	£2,000 (average price from previous quotes based on 8kW of electric heating)	£2,000 (average price for replacement of combi gas boiler)

	ASHPs in individual buildings	Electric heating	Gas boilers (BAU)
Risks	• Higher capacity of heat pumps required and therefore increase to the electricity grid connection and distribution capacity requirement which may result in significant additional CAPEX • May not be operated and maintained in most efficient manner	• Electricity grid connection capacity and distribution capacity will be even greater than individual ASHPs requirements, which may require grid reinforcement and hence incur significant additional CAPEX	• As the government phases out the use of gas boilers as a heating system, an alternative will eventually be required to be installed
Benefits	• Higher CO_2e savings • Lower cost of heat to customer in comparison to electric heating due to higher efficiency	• Simple ease of use	• Current BAU therefore it would not require an upgrade
Disbenefits	• High CAPEX in comparison to other counterfactual solutions • Additional space required at each dwelling (external and internal for heat pump, DHW cylinder, buffer vessel and controls)	• Every dwelling and building must have a wet system converted to a wire network, which requires decommissioning the current wet system, which may cause significant disruptions to residents and result in significant additional CAPEX • Higher cost per kWh in comparison to other counterfactual options and DHN	• Will have negative impact on the environment and the quality of the air due to higher carbon content

For the purpose of this study, gas boilers have been assumed as business as usual (BAU) for every connection. Counterfactual for social housing is assumed to be gas boilers to prevent customer detriment and for commercial connections and planned development individual ASHPs have been assumed as counterfactual.

4.4 Renewable/ Low Carbon Heat Source

Table 8 shows potential heat sources and network options.

Table 8: Long list options for potential heat sources

Technology		High level technical viability considerations	Considered further?
Open loop heat pump	Boreholes utilising aquifer	• Geo-environmental reports do not state pumping rates or water resting levels, which may indicate limited amounts of water • Test well required	No
	Deep geothermal	• Killingworth has a relatively low geothermal potential of rock (approximately 30-50 mW/m²) • Significant space requirements Potentially economic against low carbon counterfactual • Potentially the highest temperatures of water source available • Ground temperature at 1km deep is <30°C • High CAPEX associated with deep drilling	No
	Mine WSHP	• Abstraction and discharge connections into mines may involve high CAPEX • Lower operating cost due to higher COP than ASHP • Potentially higher temperatures available than other water source heat pump options • Third party negotiations that may impact the cost of heat required • Further assessment and discussion with the Coal Authority required on the heat resource • Potentially constant temperature ~12-20°C	Yes
	WSHP Killingworth lake	• About 1m deep therefore volume is likely too low • Low incoming and outflowing water rate • Space requirements for abstraction platform • EA requirements	No
Closed loop bore field		• Requires a large area of land • Significant CAPEX associated with bore field • May have a cooling effect on local ground condition if not designed correctly	No
Centralised Air Source Heat Pump (ASHP)		• Lower initial CAPEX than GSHP or MWSHP, however higher operating costs due to lower CoP • ASHP at large scale may have cooling effect on local environment • Potential noise restrictions close to residential developments • Not dependant on accessing ground water	Yes
Individual Air Source Heat Pumps (ASHP)		• No losses from heat network • Space required at each building • Visual and noise impacts for residents • Lower SPF for smaller heat pumps • Heat demand is not diversified, and significantly greater heat pump capacity required	Yes, as counterfactual
Gas CHP		• Higher carbon emissions compared to other technologies • Private wire revenue is usually critical to project economics • Not eligible for grant funding	No

Technology	High level technical viability considerations	Considered further?
Electric Boilers	• Expensive if used during peak electricity usage times • Possible price reduction /kWh in future	Yes, only as peak and reserve
Gas Boilers	• High CO_2e • Potentially lower OPEX than electric boilers	Yes, only as peak and reserve
Biomass CHP/ Biomass boiler	• Lowest carbon in earlier years (better than heat pumps until predictions of grid decarbonisation) • Air quality considerations for biomass • Fuel costs may be equal or lower than gas and electricity • Requires space for solid fuel delivery and storage • Haulage of fuel may have small environmental impact due to frequency of fuel deliveries • Sustainability of biomass needs further consideration • May provide energy source resilience as part of larger energy system • Council has considered biomass before and is not the preferred solution	No
Hydrogen Fuel Cell CHP	• Economics of hydrogen-based CHP very uncertain • Security of fuel supply issues • Requires significant space for fuel cell • No local hydrogen generation • Fuel will need d to be transported by road • Economic and regulatory issues relating to private wire • Fuel cell market not developed	No
EfW	• At the time of this study there are no planned energy from waste sites planned within a feasible distance • Additional back-up energy centres required • Changing public perception of EfW as 'green' technology option • Significant negotiations required with plant operator or network operator accessing heat for existing planned network	No
Industrial waste heat	• No industrial waste heat sources identified near or within the assessment area large enough to support DHN at scale required • Significant third-party negotiations that may impact the cost of heat required	No
Solar thermal	• Significant initial capital costs • Significant land required for collector arrays	No

4.4.1 Short list assessment

The options from the long list assessment have been assessed and have been condensed to a short list, which considers possible risks, benefits and disbenefits of the selected options. The following options have been shortlisted:

LTHW Network Options

- MWSHP DHN (see Figure 15 and Table 9)
- ASHP DHN (see Figure 16 and Table 10)

Counterfactual

- ASHPs in each building (see Figure 17 and Table 11)

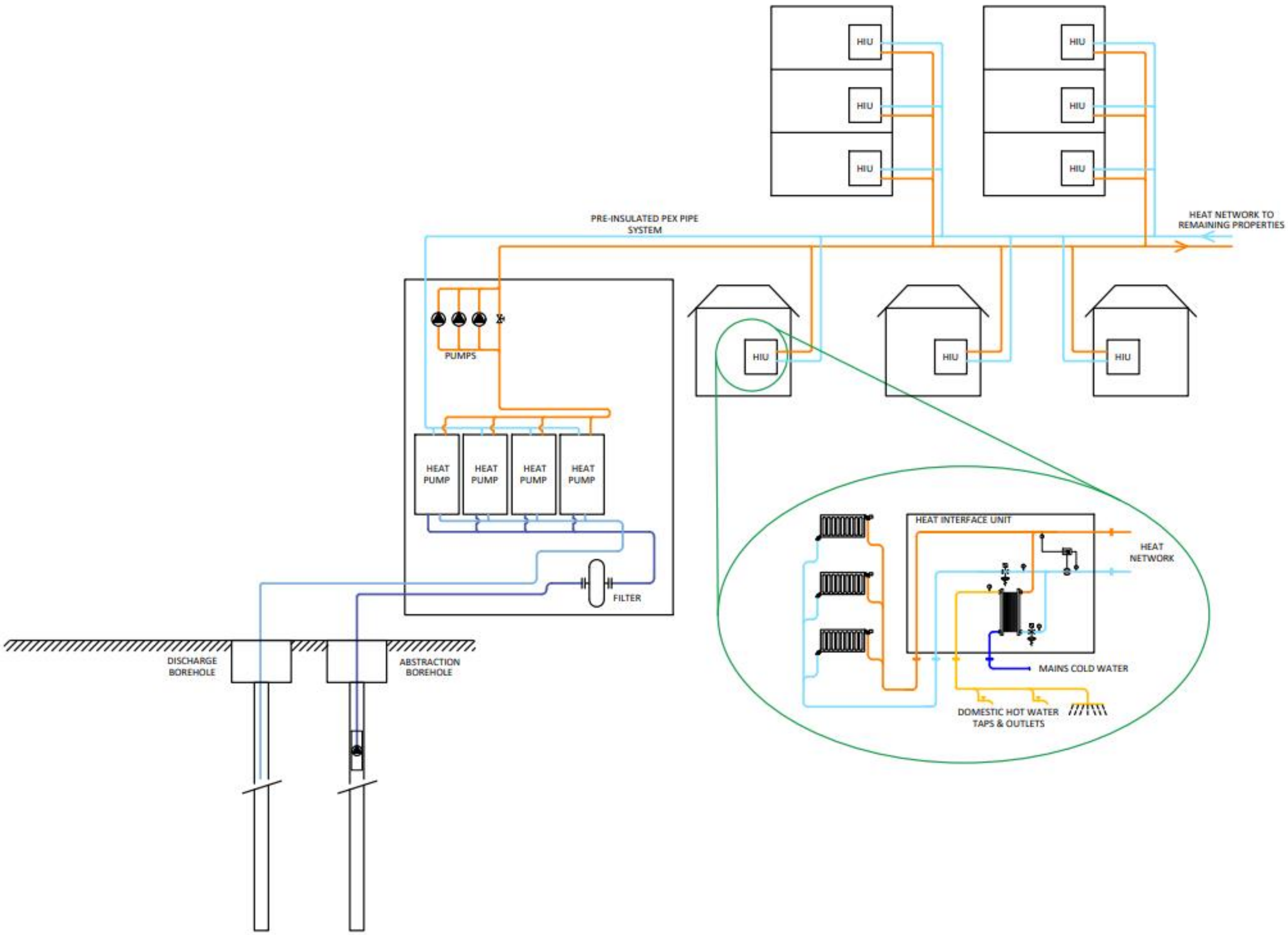

Figure 15: Schematic of Open Loop Mine Water Heat Network

Table 9: Specific issues, risks, benefits and disbenefits for open loop MWSHP using mine water DHN

Short list option	Viability consideration		Risks	Benefits	Disbenefits
Mine WSHP DHN	Technology selection	• Open loop • Potentially high CAPEX	Long term performance of boreholes		
	Heat resource	• Engagement with Coal Authority will be important to understand possible abstraction / reinjection locations, flow temperatures and flow rates • Potentially the highest available source temperature	Availability of heat in mines Multiple attempts required to hits heat source, increased CAPEX	If correctly designed and modelled, temperature of heat resource likely to be stable and sustainable	Dependant on accessing mine water
	Plant operation	• Heat generated from the MWSHP will be prioritised with gas boilers only supplying peak demands and in times of maintenance / failure		~90% of network heat demand will be from renewable technology	
	Energy Centre design	• A large building would be developed		Will require smaller EC in comparison to ASHP DHN option	
	Commercial	• Continued Engagement with the Coal Authority is required • Eligible for GHNF	High charge for using resources might have negative impact on the project economics		Third party negotiations that may impact the cost of heat required

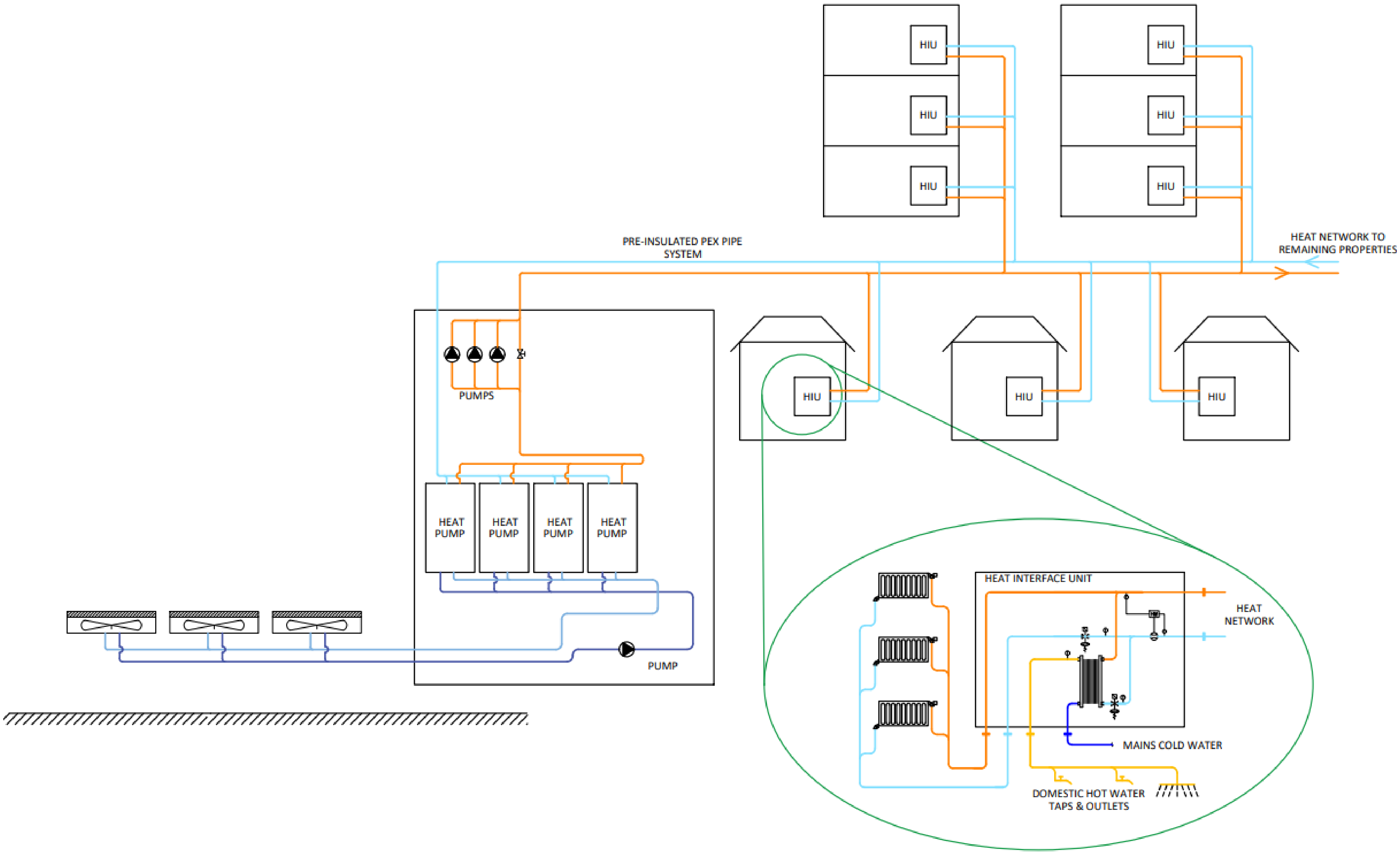

Figure 16: Schematic of ASHP Heat Network

Table 10: Specific issues, risks, benefits and disbenefits for ASHP DHN

Short list option	Viability consideration		Risks	Benefits	Disbenefits
ASHP DHN	Technology selection	• Potentially low CAPEX option • ASHPs will be less efficient than the GSHPs; operating temperatures will be important and, as efficiency will vary with external air temperature	Lower CoP will impact project economics, CO_2e savings and renewable heat availability during cold periods	No disruption caused by drilling borefield	
	Heat resource	• Heat output and project economics will be negatively impacted by external air temperature in cold winter periods		Not dependant on accessing ground water and so reduced project CAPEX and disruption	ASHP will be less efficient in winter and have a lower output
	Plant operation	• Heat generated from the ASHP will be prioritised with gas boilers only supplying peak demands and in times of ASHP maintenance / failure		~90% of network heat demand will be from renewable technology	
	Energy centre design	• Additional space required for air heat exchangers	Acoustic attenuation will impact cost and efficiency		Will require larger EC which could have significant visual impact
	Commercial	• Eligible for GHNF		Lower licencing implications and agreements for heat supply	

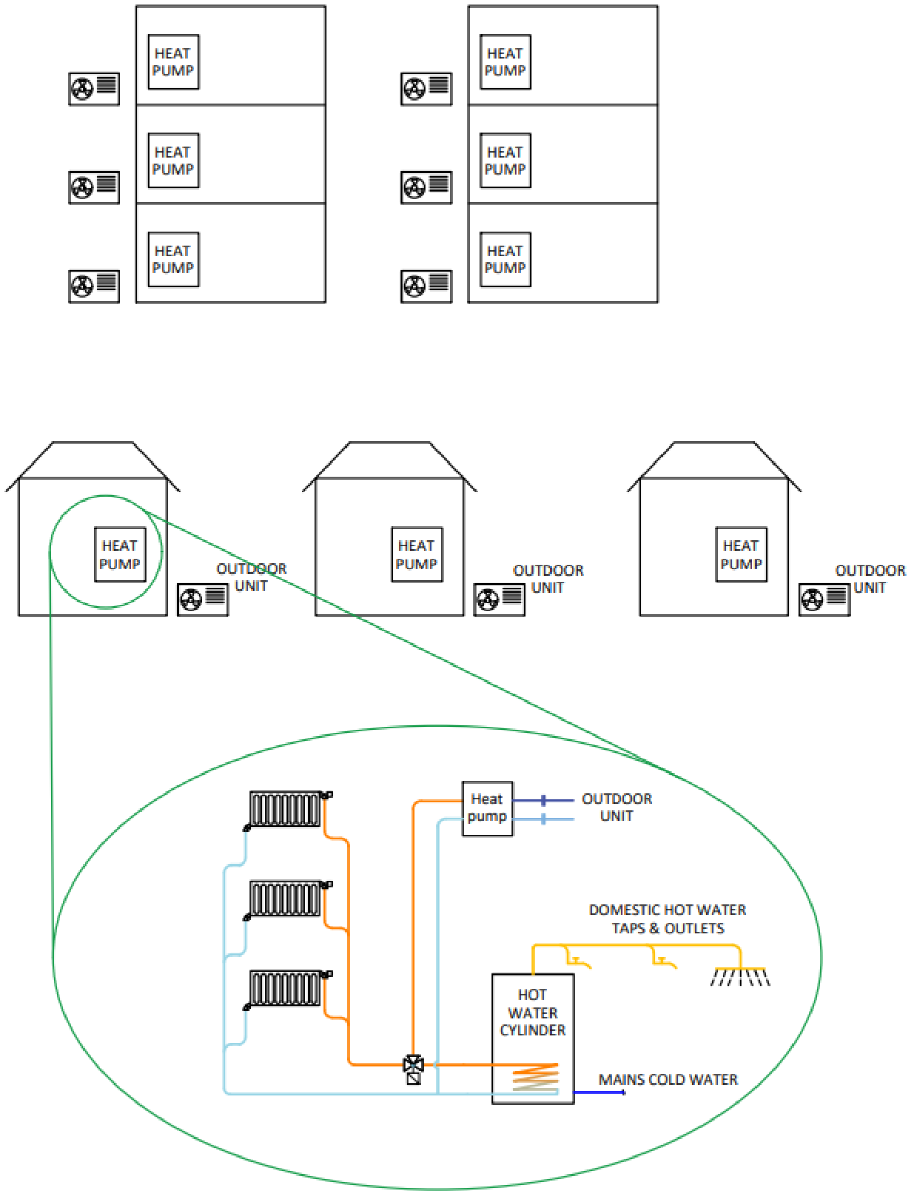

Figure 17: Schematic of Individual ASHPs

Table 11: Specific issues, risks, benefits and disbenefits for individual ASHP

Short list option	Viability consideration		Risks	Benefits	Disbenefits
ASHPs in each building	Technology selection	• Counterfactual • Potentially low risk option • ASHPs efficiency will vary with external air temperature	Lower CoP will impact project economics, CO_2e savings and renewable heat availability during cold periods	No disruption or CAPEX implications associated with heat network installation	ASHP will be less efficient in winter and have a lower output
	Heat Source	• Heat output and project economics will be negatively impacted by external air temperature in cold winter periods		Not dependant on accessing ground water and so reduced project CAPEX and disruption	
	Plant Operation	• Higher GWP refrigerants may be used in smaller heat pumps	May not be operated and maintained in most efficient manner	Potentially higher CO_2e savings if operated and maintained efficiently	
	Design	• Internal and external space required • Heat demand is not diversified, and significantly greater heat pump capacity required		No visual impact from energy centre Not impacted by changes to development plans	Visual and noise impacts for residents Additional space required at each building (internal for heat pump and cylinder, external for evaporator)
	Commercial	• Unlikely to be eligible for grant funding • Possibly higher heat cost to customers			

4.5 Summary

The preferred energy centre location was determined to be the Killingworth Depot site, which would utilise the mine water seams. This location was considered to be the most suited as it is on council owned land, located in close proximity to council buildings, and situated above several mine water seams. The heat source capacity would need to be determined with further analysis from the Coal Authority on available flow rates to ensure that it could supply enough heat for all identified potential connections. If the mine water capacity could not supply the full energy demand, then ASHPs could be used in conjunction with a mine water connection. The Killingworth site should have enough free space to accommodate these if required.

For this study it has been assumed that the mine water capacity will be sufficient due to the four seams located directly under the energy centre. Peak and back-up boilers would be located within the same energy centre.

5 NETWORK ROUTE ASSESSMENT

The key assumptions used for network route assessment can be found in Appendix 4: Network assessment. Further details on network sizing and costing can be found under the heading Network costs in Appendix 6: Techno Economic Modelling – Key Parameters. The results of the economic assessment are shown in section 8.6.

5.1 Heat Network Route Identification

Site terrain and land ownership, as well as any potential natural and infrastructure constraints have been assessed. The proposed network route is shown in Figure 18.

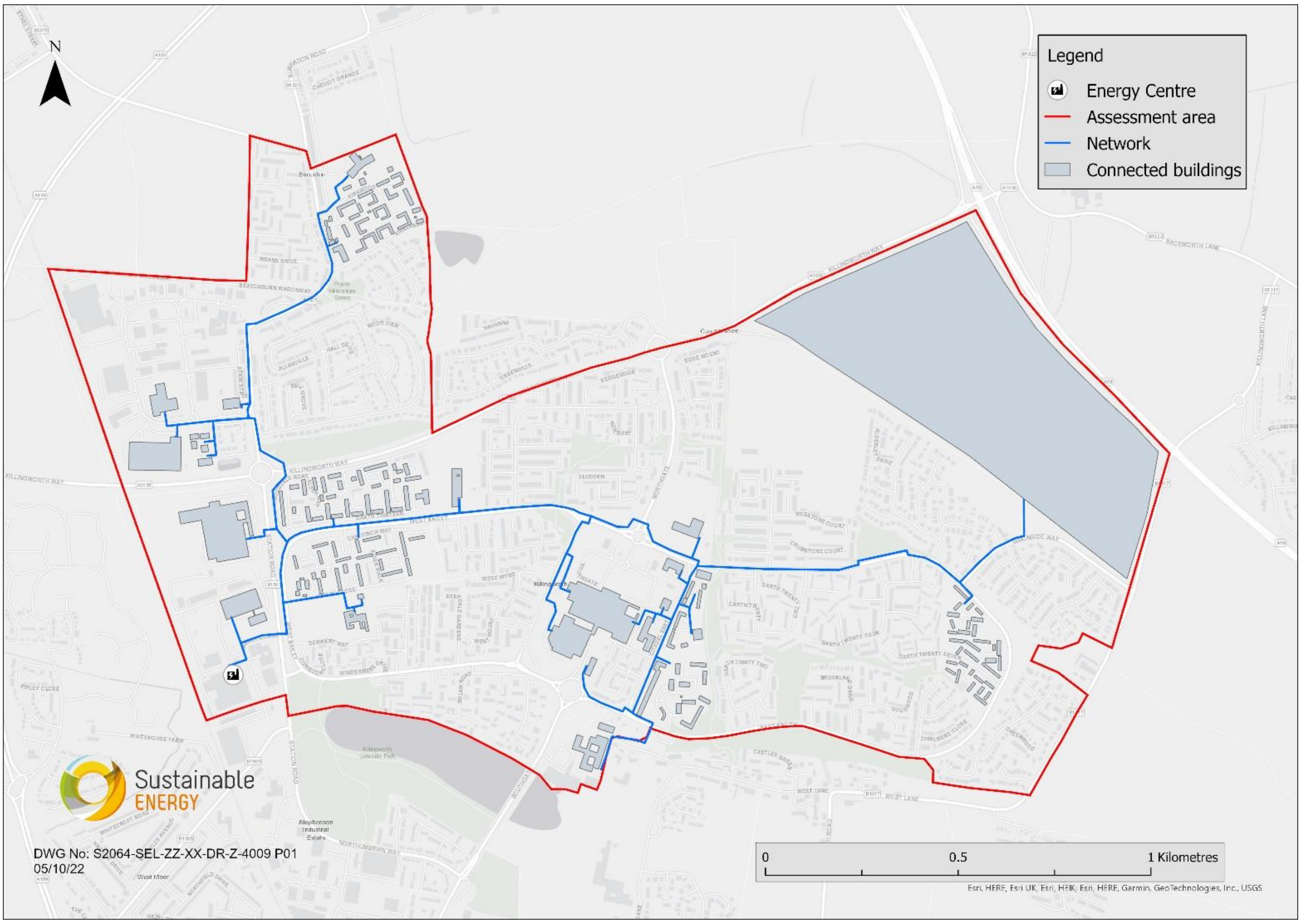

Figure 18: Proposed network route

5.1.1 Linear Heat Density

The linear heat density of the network has been assessed to identify sections with a low linear heat density that are likely to significantly reduce the economics of the network. Route sections with a linear heat density below 3 MWh/m have been classed as low. The results of the linear heat density assessment are shown in Figure 19.

In the assessment area several network sections have been identified to have linear heat density of < 3 MWh/m. These are all feeds to key council buildings such as schools and areas of make up a small proportion of the network. The rest of the assessment area indicates that the network has a high potential for viability.

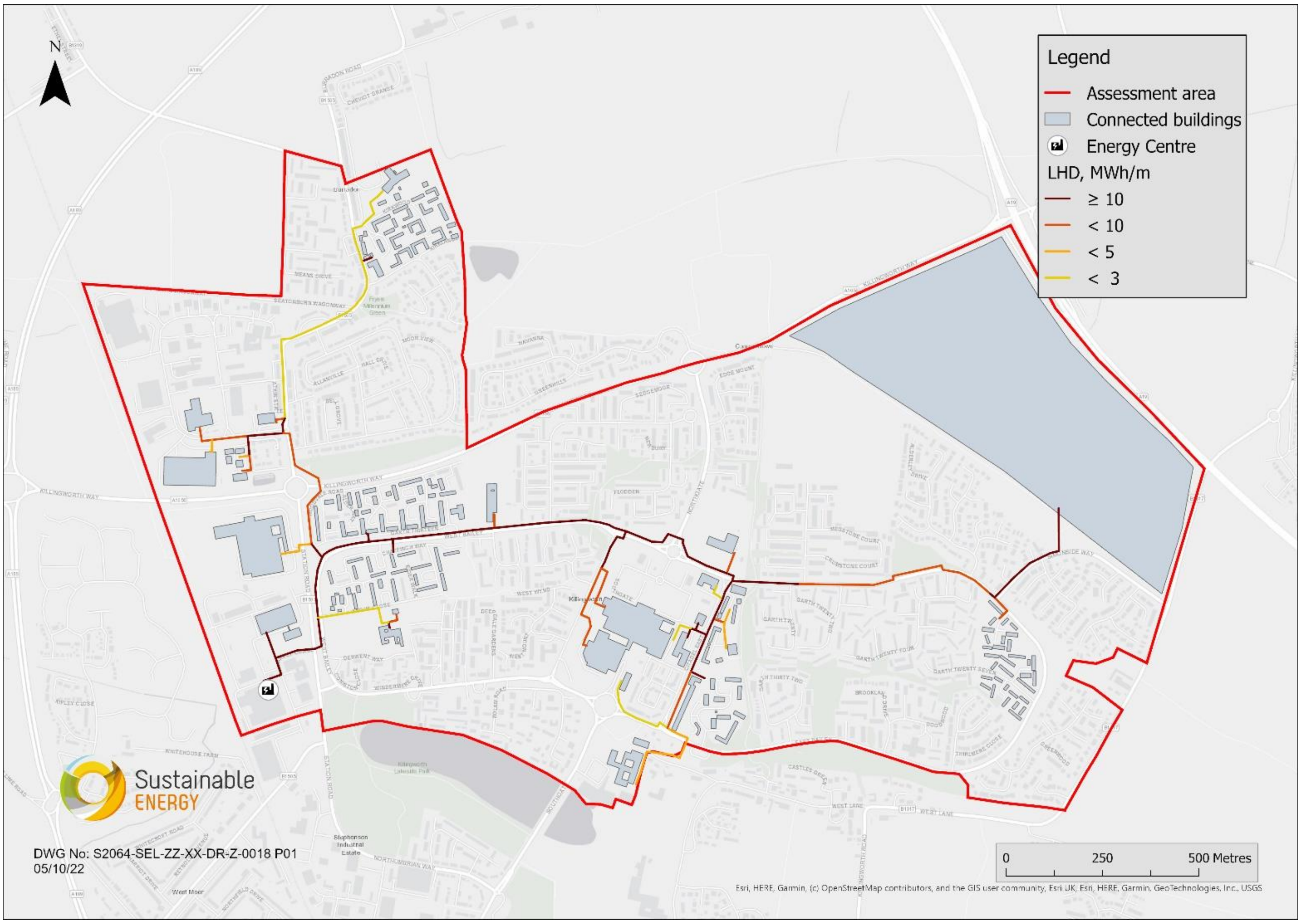

Figure 19: Linear Heat Density assessment

The linear heat density was assessed for the buried DHN; therefore, it does not consider the additional lengths of pipe required within parcels or development site or internally within the buildings.

Connections at the industrial park, north of Killingworth Depot were identified to have low linear heat density or higher temperature requirements therefore, the network has been optimised to include only the largest feasible connections.

5.2 Key Potential Constraints

A desktop study for the proposed network route has been undertaken and key potential network constraints were identified as shown in Figure 20. Major natural and infrastructure constraints were found to be outside of the assessment area.

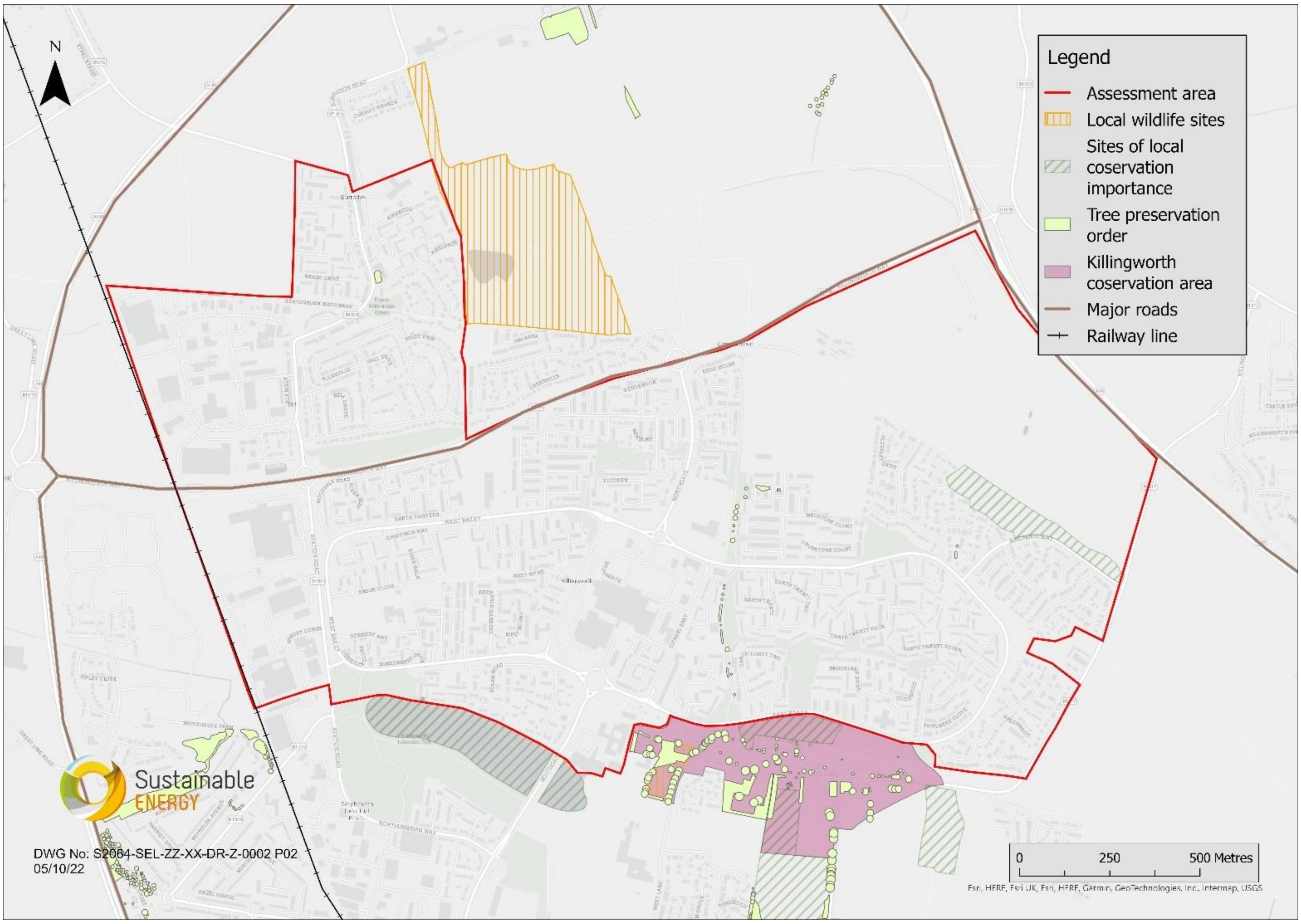

Figure 20: Key network constraints

5.2.1 Terrain

Figure 21 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 heat network or the location of the energy centre and the changes in elevation present no significant technical challenge to the pumping requirements of a district heat network.

Figure 21: Terrain constrains

5.3 Housing clusters

A large portion of the heat demand in the Killingworth area relates to residential dwellings. Details of the assessed clusters are shown in Figure 22 and Table 12.

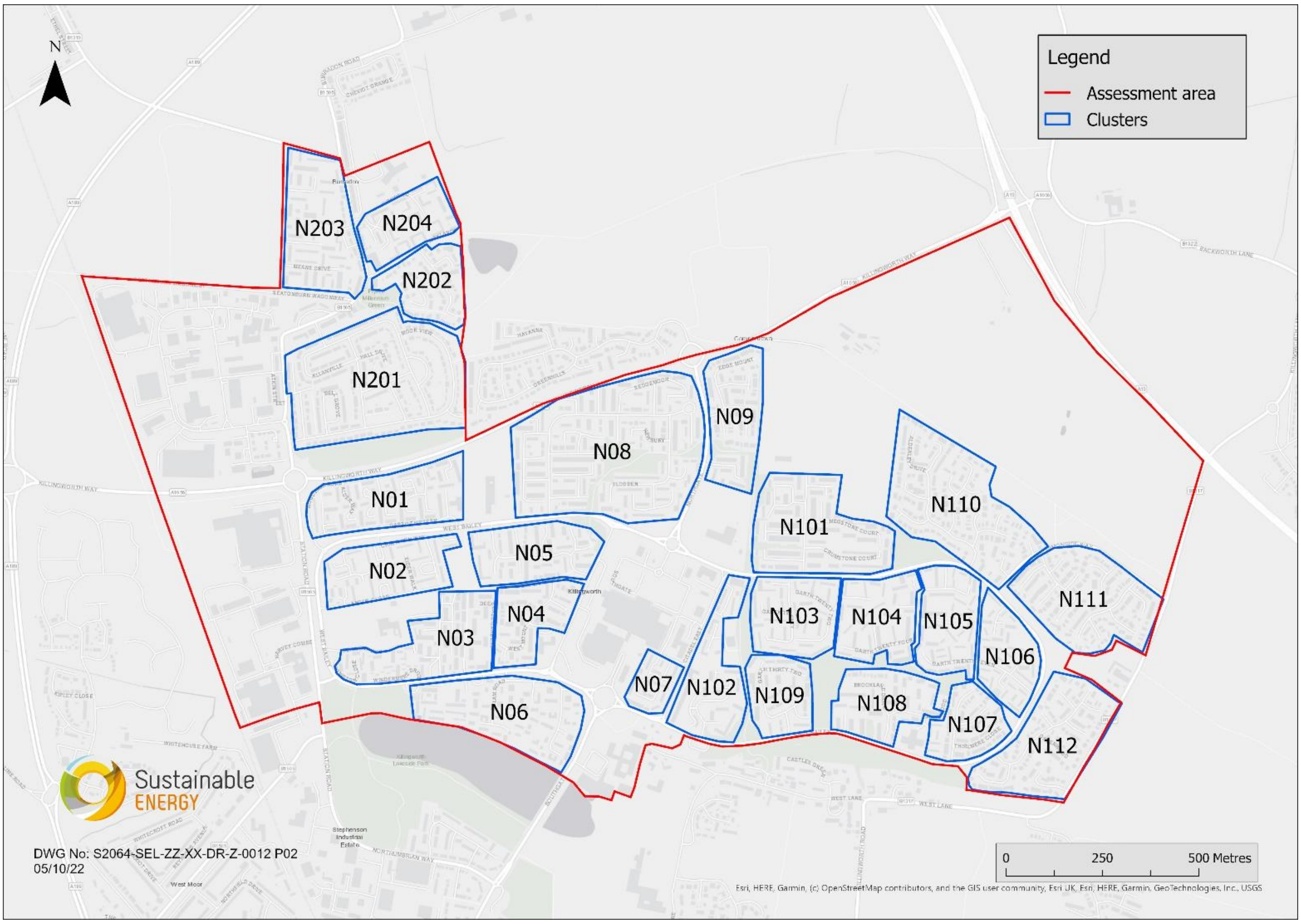

Figure 22: Housing clusters

Table 12: Housing cluster details

Cluster	Density	Social housing	Private	% of social housing	Cluster	Density	Social housing	Private	% of social housing
N01	high	127	96	57%	N105	medium	48	119	29%
N02	high	97	77	56%	N106	high	59	73	45%
N03	medium	93	134	41%	N107	medium	15	93	14%
N04	low	-	81	-	N108	medium	24	142	14%
N05	low	-	132	-	N109	medium	-	125	-
N06	medium	-	257	-	N110	low	-	232	-
N07	high	-	88	-	N111	low	-	171	-
N08	low	-	481	-	N112	low	-	132	-
N09	low	-	130	-	N201	low	60	387	13%
N101	low	-	204	-	N202	medium	-	123	-
N102	high	150	121	55%	N203	high	54	211	20%
N103	low	51	83	38%	N204	high	150	19	89%
N104	low	59	95	38%	**Total**		**987**	**3806**	**21%**

To assess which housing clusters should be connected to the network a cost benefit analysis was used to determine the network viability versus individual ASHPs.

The internal network route within the clusters depends on the housing density. If all houses in a cluster were to connect, then the network lengths per property for the different densities are:

- High = 16.3 m/dwelling
- Medium = 20.1 m/dwelling
- Low = 26.5 m/dwelling

The average cost of the cluster pipework is £381/m assuming that that PEX pipework is used. The steel equivalent would be more expensive, as it only comes in 12m sections which require welding. Therefore, if all houses are connected within a cluster, then the cost per dwelling will be:

- High £6,236 /dwelling
- Medium = £8,449 /dwelling
- Low = £10,109 /dwelling

In the high-density clusters, we have assumed that all of the social housing within that cluster will connect but only 10% of private housing will connect. This will increase the cost per dwelling as the spine and branches (green and blue in Figure 23) will not reduce but the number of feeds (in red) will.

Figure 23: Cluster costing example

Therefore, the cost per dwelling for each individual cluster can be calculated based on the % split between social and private housing. The counterfactual cost of an ASHP is ~£10,000 (see section 4.3), therefore it is more cost effective to install individual ASHPs within all, but the clusters highlighted in green below in Table 13.

Table 13: Cluster network costing

Cluster	Density	Dwellings	no. of social	no. of private	Total connecting	Overall % connecting	m/dwelling	£/dwelling
N01	high	223	127	96	137	61%	21.97243	8,371
N02	high	174	97	77	105	60%	22.21187	8,463
N03	medium	227	93	134	106	47%	29.30465	11,165
N04	low	81	0	81	8	10%	139.9332	53,315
N05	low	138	0	138	14	10%	139.9332	53,315
N06	medium	257	0	257	26	10%	92.25161	35,148
N07	high	88	0	88	9	10%	95.24217	36,287
N08	low	483	0	483	48	10%	139.9332	53,315
N09	low	138	0	138	14	10%	139.9332	53,315
N101	low	211	0	211	21	10%	139.9332	53,315
N102	high	271	150	121	162	60%	22.21187	8,463
N103	low	134	51	83	59	44%	42.56957	16,219
N104	low	154	59	95	69	45%	41.93321	15,977
N105	medium	167	48	119	60	36%	34.40119	13,107
N106	high	132	59	73	66	50%	25.13308	9,576
N107	medium	108	15	93	24	22%	48.56039	18,502
N108	medium	166	24	142	38	23%	46.97737	17,898
N109	medium	125	0	125	13	10%	92.25161	35,148
N110	low	242	0	242	24	10%	139.9332	53,315
N111	low	171	0	171	17	10%	139.9332	53,315
N112	low	132	0	132	13	10%	139.9332	53,315
N201	low	447	60	387	99	22%	71.20594	27,129
N202	medium	123	0	123	12	10%	92.25161	35,148
N203	high	265	54	211	75	28%	38.90451	14,823
N204	high	169	150	19	152	90%	17.34318	6,608

From this analysis the only cost-effective clusters to connect are where the social housing dwellings make up at least 50% of the total dwellings. Only clusters N01, N02, N102, N106 and N204 will be considered for connection to the heat network.

5.4 Summary

The selected network route considers:

- Minimising pipe length
- Routing through publicly owned land and service areas of connected buildings as much as possible
- Trench excavation, backfilling and reinstatement costs for different ground conditions
- Physical constraints and site barriers
- The outputs of hydraulic modelling exercises (including pipe lengths, diameter, insulation, and materials)
- Calculated heat distribution losses throughout the network
- CIBSE / ADE Heat Networks Code of Practice (specifically Objective 2.5)
- Linear heat density
- Critical feedback from planners
- Planned infrastructure projects
- Liaison with DNOs, scrutiny of historical OS maps, consideration of land ownership and future developments

6 RECOMMENDED SCHEME OPTIONS ASSESSMENT

The key assumptions used in the network assessment are discussed in. Appendix 3: Key Parameters and Assumptions. The results of the economic assessment for the preferred network option are shown in section 8.

6.1 Phasing

A detailed sizing exercise has been undertaken using SEL's heat pump and thermal sizing tool. The tool analyses the hourly network heat demand, network losses, water source temperature, heat pump capacity and modulation and thermal store size on an hourly basis for a full year taking into account hourly, daily and seasonal variation as well as peak and off-peak electricity tariffs. Further details of SEL's heat pump and thermal sizing tool are included in Appendix 5: Technology Sizing.

The proposed network is assessed over three phases:

- Phase 1: Key existing Council owned buildings, shopping centre and social housing clusters N01 and N02
- Phase 2: Larger loads from industrial estate, social housing cluster N204 and council owned Burradon School.
- Phase 3: Long term planned developments and social housing clusters N102 and N106.

The network phases, shown in following section, have been chosen based on technical issues, economics, timing of developments and risks. The network phasing and timing has been estimated based on high level information from the North Tyneside Council to coincide with the desire to achieve Green Heat Network Funding for Phase 1 network. The timings of further phases are based on experience for the development of heat networks within city/town centres. The phasing and timing of network should be further assessed if additional details for the area become available.

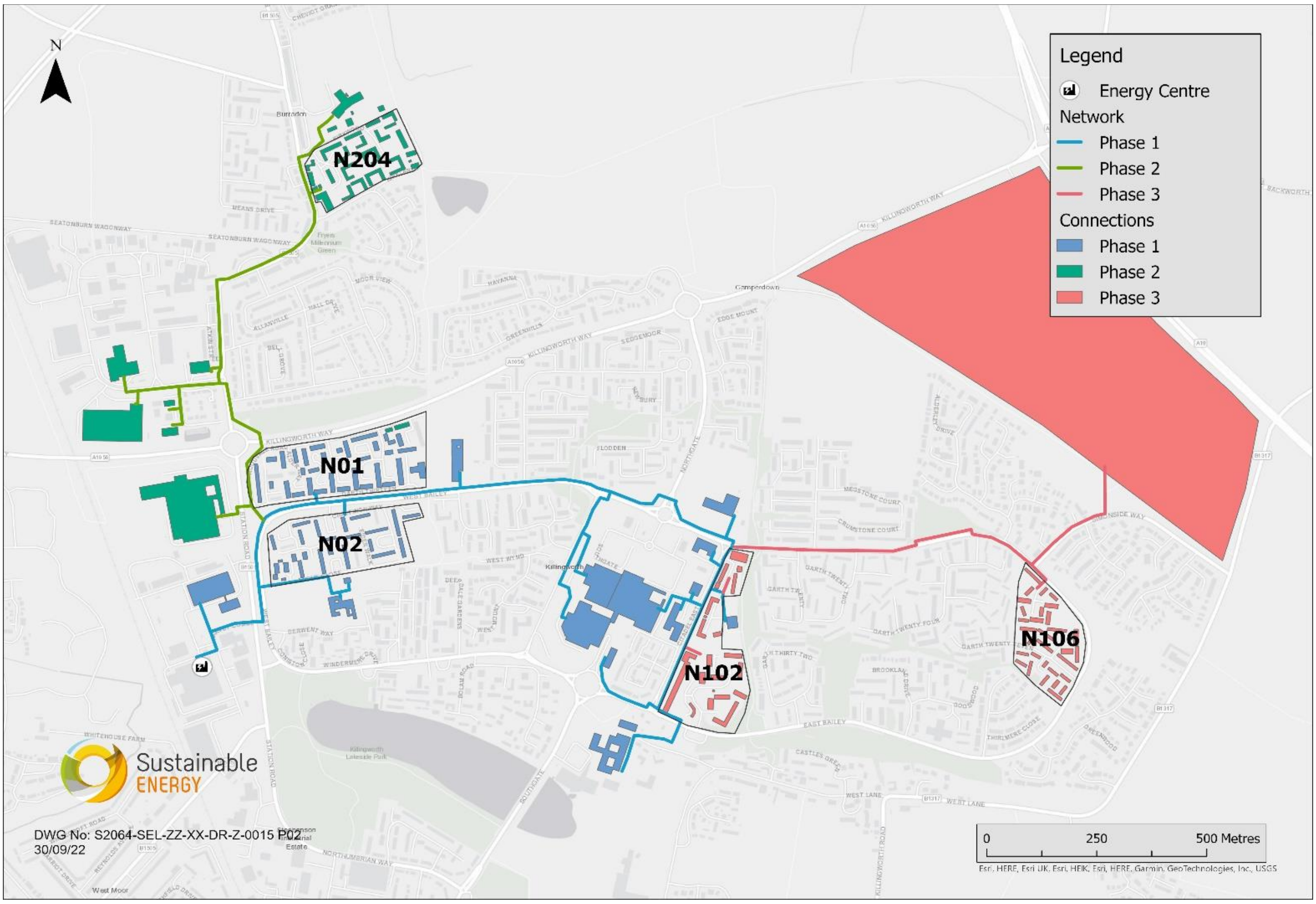

Figure 24: Phased network route

6.1.1 Phase 1

Phase 1 has identified seventeen potential connections. The key Phase 1 connections include North Tyneside Council buildings, including council schools, Killingworth shopping centre including Morrisons and Matalan/Home bargains. The network route and connected buildings are shown in Figure 25, further details on connected buildings are shown in Table 14.

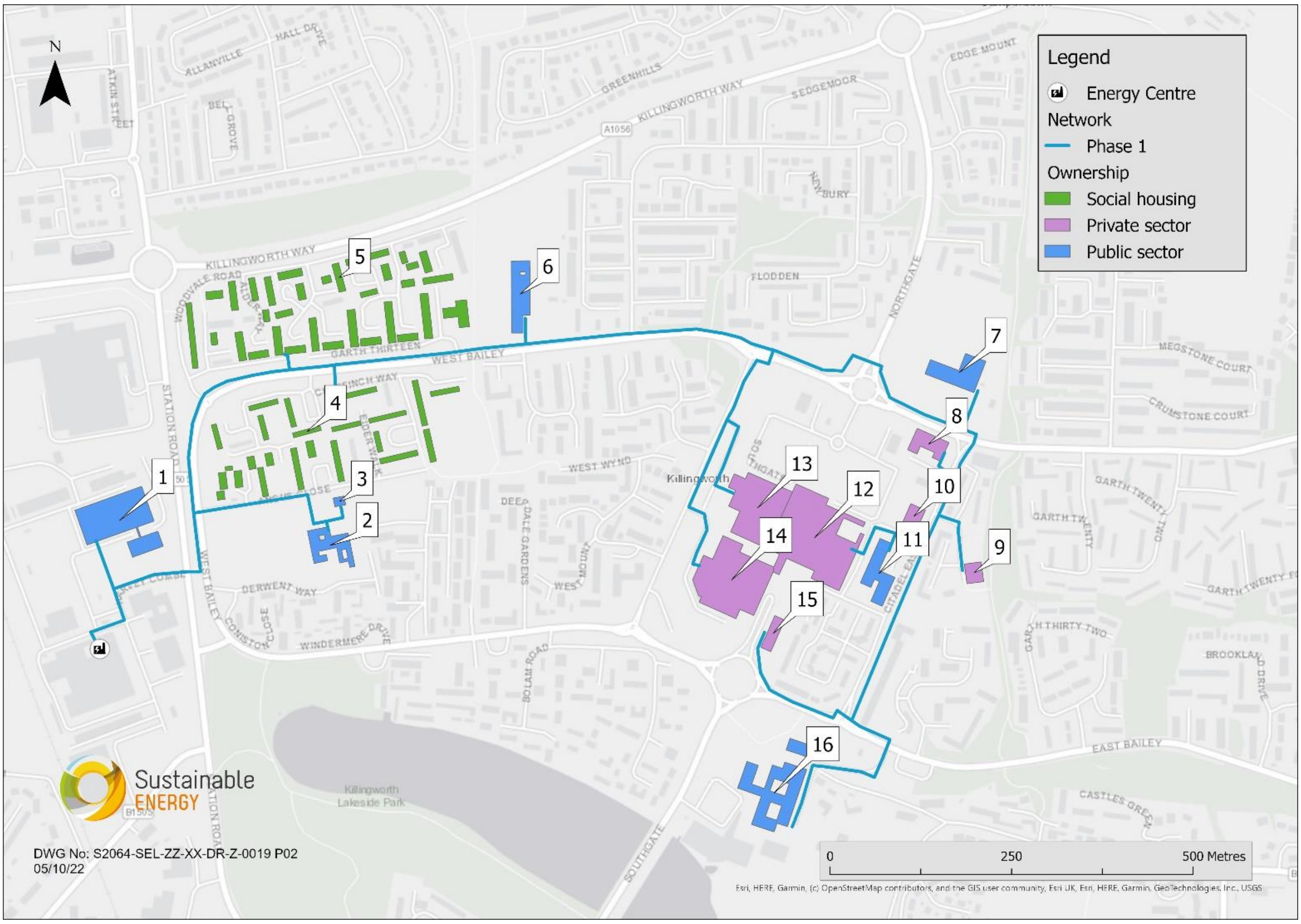

Figure 25: Phase 1 Heat Network Layout

Table 14: Phase 1 network connections

Map ref	Site name	Site ownership	Annual heat demand, MWh	Connection capacity, kW
1	Killingworth Site	Public sector	1,521.5	1,100
2	Grasmere Primary		211.5	340
3	Silverdale Primary		292.3	190
4	N02 social housing	Social housing	1,762.0	710
5	N01 social housing		1,193.4	470
6	Bailey Green Primary	Public sector	203.3	310
7	Amberley Primary		295.0	380
8	Wellspring Medical Practice	Private sector	122.9	130

Map ref	Site name	Site ownership	Annual heat demand, MWh	Connection capacity, kW
9	Killingworth Social Club	Private sector	244.0	210
10	Kings Arms		231.0	180
11	White Swan Centre	Public sector	858.4	400
12	Killingworth Shopping centre	Private sector	169.2	100
13	Morrisons		1,212.4	670
14	Matalan / Home bargains		1,277.2	710
15	Telephone Exchange building		104.8	50
16	George Stephenson	Public sector	985.3	1,720

The profiles for each phase have been created based on the identified heat demands for each connection. The heat demand profile for a year from January to December is shown in Figure 26. Figure 27 displays the Phase 1 average, minimum, and maximum heat demand over 24 hours.

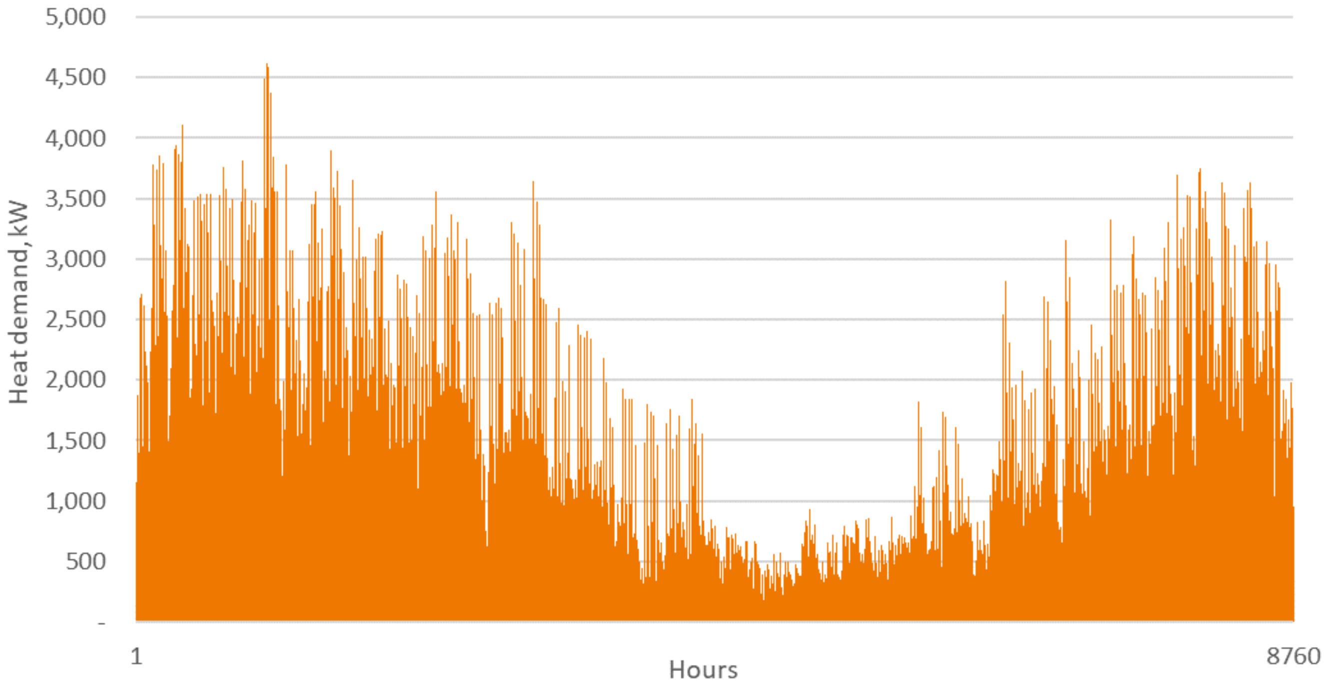

Figure 26: Annual heat demand profile for Phase 1

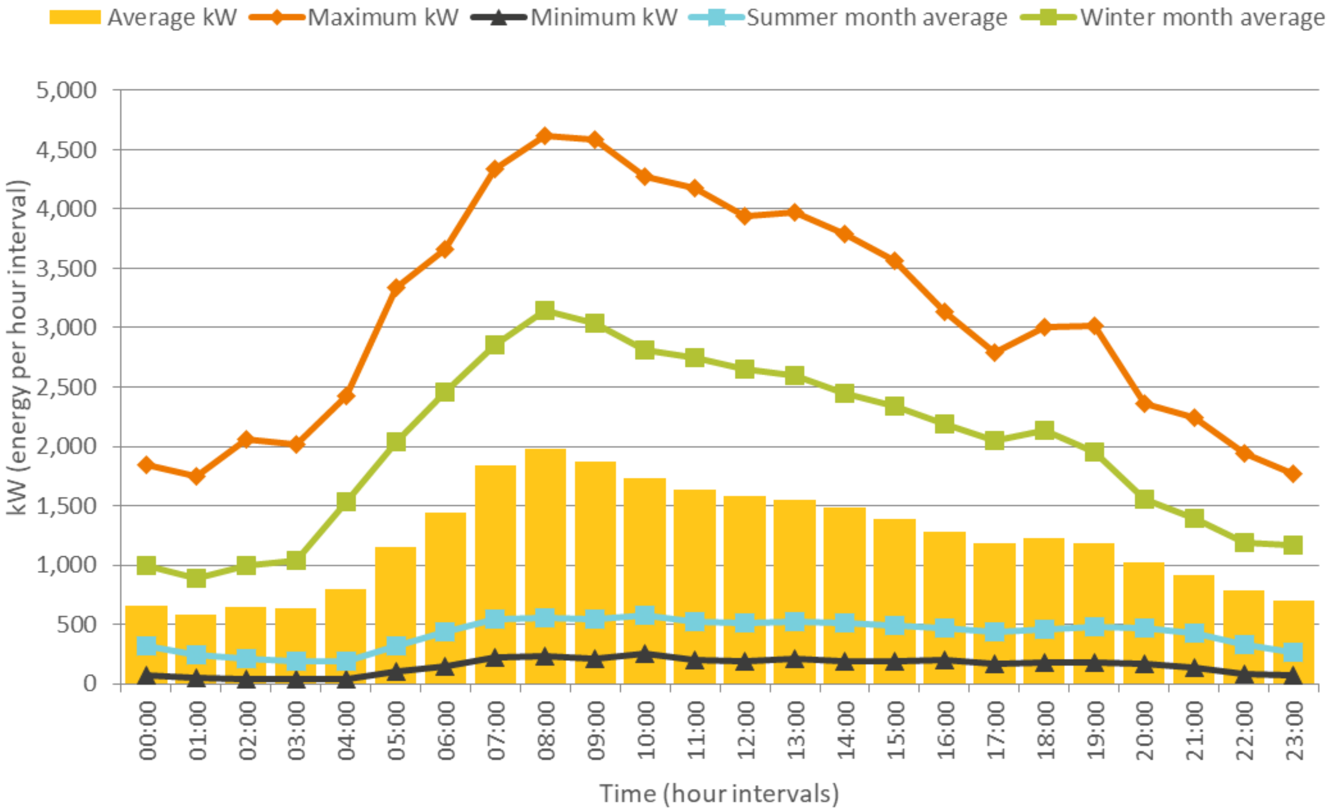

Figure 27: Average, maximum and minimum hourly heat demand for Phase 1

Furthermore, Figure 28 shows load duration curve (sorted heat demand in descending order) which highlights the phase's peak

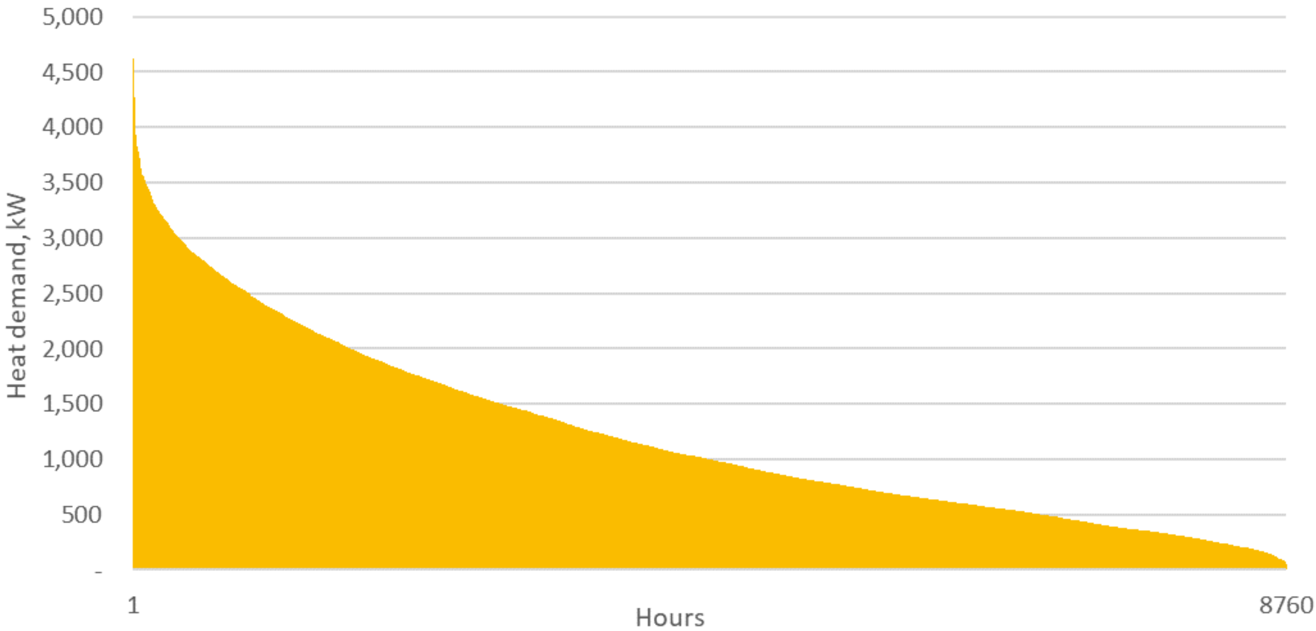

Figure 28: Load duration curve for Phase 1

A summary of the Phase 1 network is shown in Table 15.

Table 15: Phase 1 summary

	Phase 1
Total heat demand (excluding losses)	10,684 MWh
Network length	8,824 m
Peak heat demand	4.6 MW
No. of heat connections / customers	16

6.1.2 Phase 2

Additional to Phase 1 connections, seven potential connections have been identified as a Phase 2 heat network. The key Phase 2 connections include private sector buildings withing the Industrial Estate, social housing cluster and council owned school. The network route and connected buildings are shown in Figure 29.

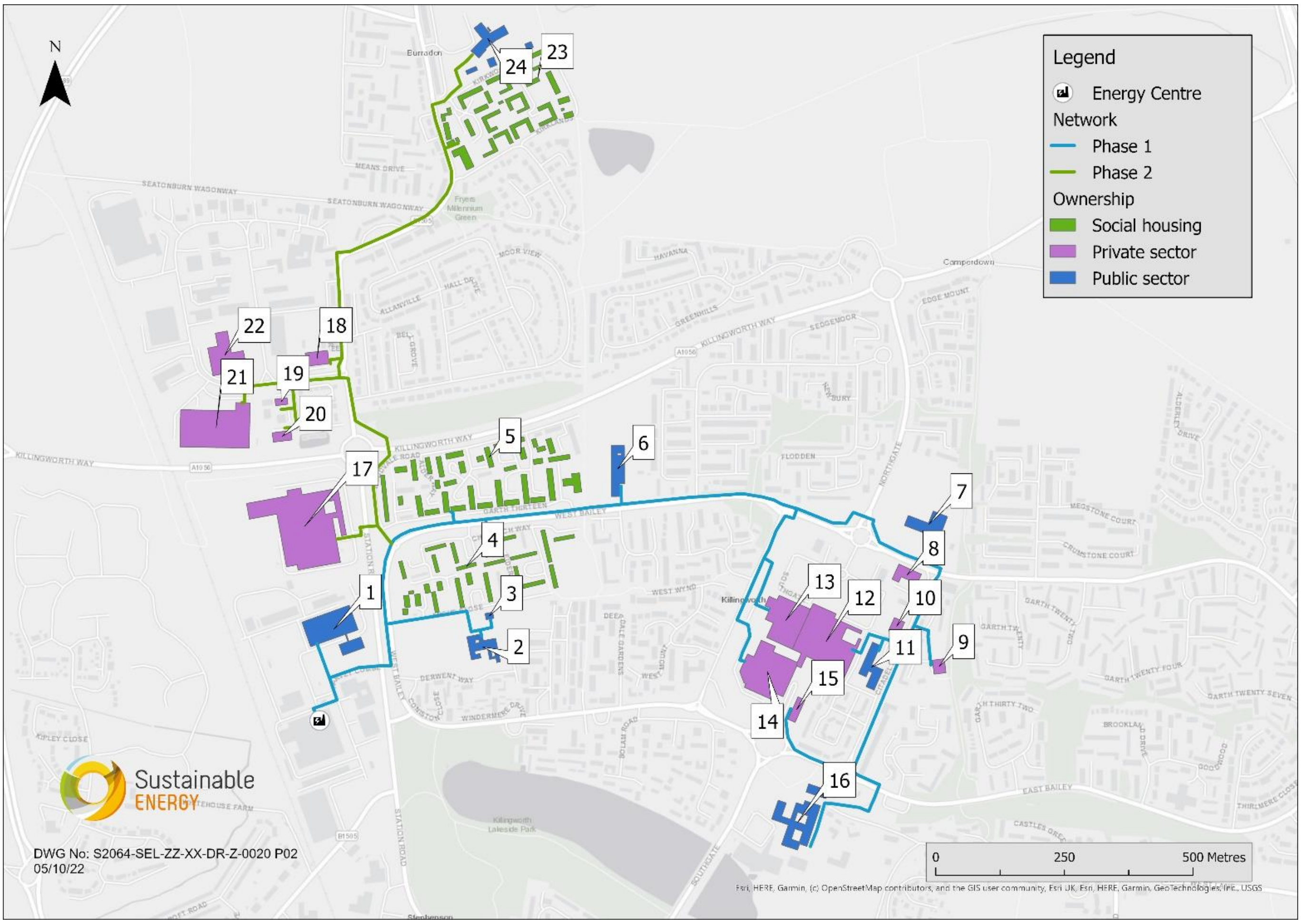

Figure 29: Phase 2 network layout

Table 16: Phase 2 network connections

Map ref	Site name	Site ownership	Annual heat demand, MWh	Connection capacity, kW
17	West Rock Newcastle	Private sector	444.0	270
18	Metnor House		176.6	180
19	Offices 2.1 - DCS Multiserve & Careline Homecare		101.9	120
20	Warehouse 2.1 - PaddlePod		485.8	240
21	Fenwick Warehouse		176.5	140
22	John Lewis & Partners Delivery Hub		545.6	360
23	N204 social housing	Social housing	845.9	480
24	Burradon Community Primary School	Public sector	225.4	370

Figure 30 shows Phase 2 annual heat demand profile. Average, minimum, and maximum heat demand over 24 hours for Phase 2 is shown in Figure 31.

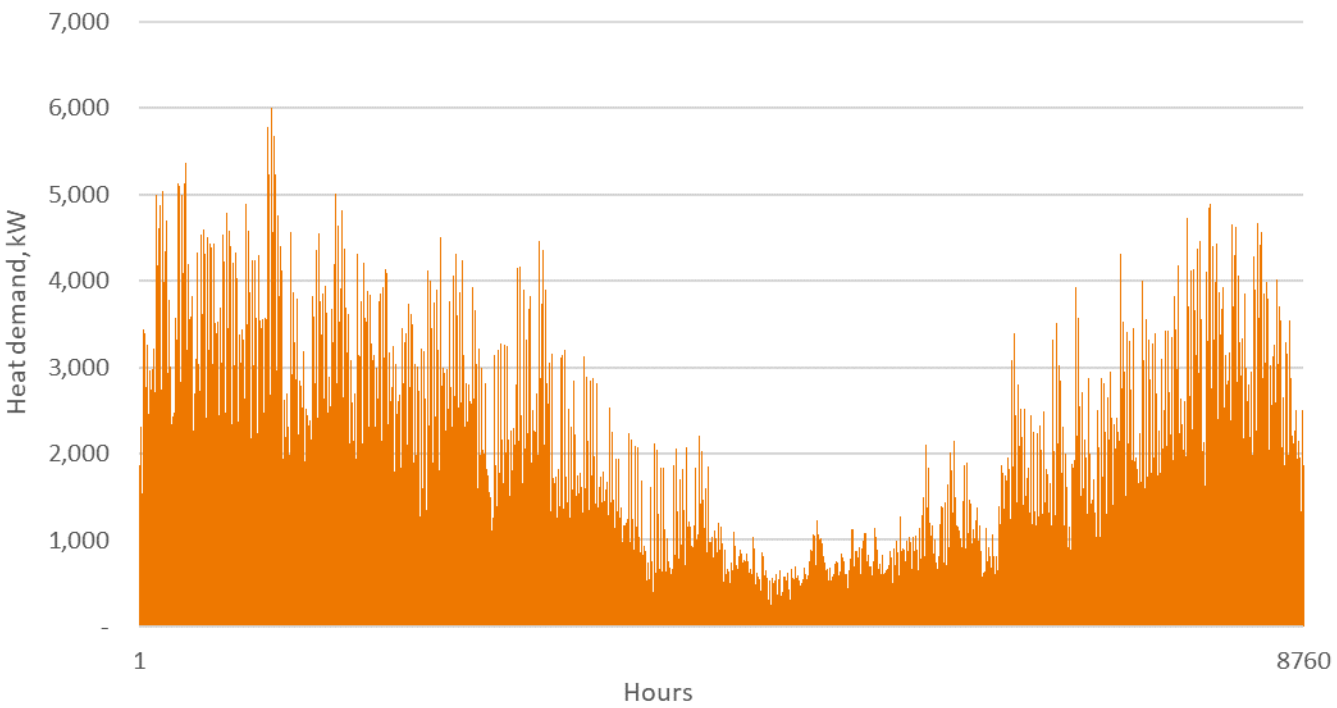

Figure 30: Annual heat demand profile for Phase 2

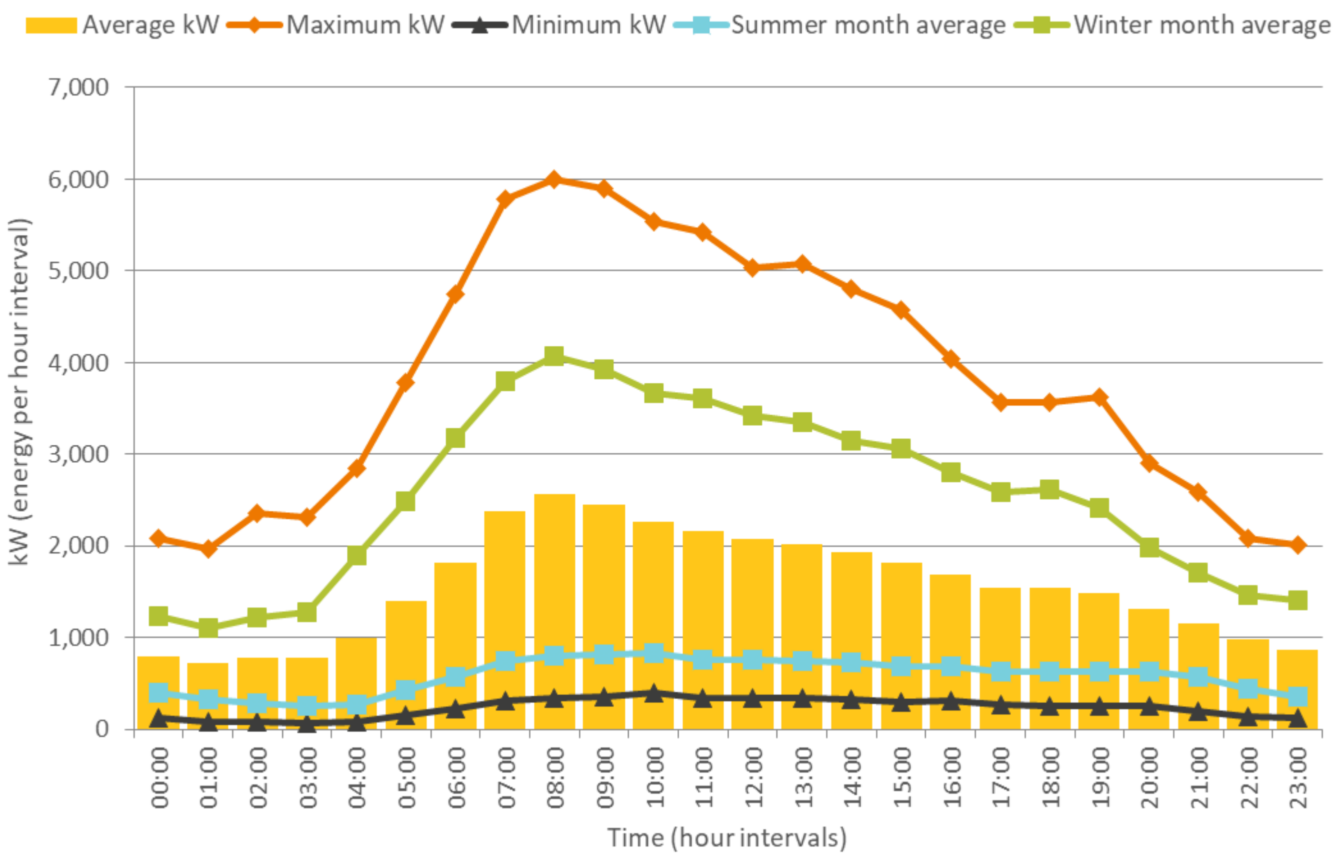

Figure 31: Average, maximum and minimum hourly heat demand for Phase 2

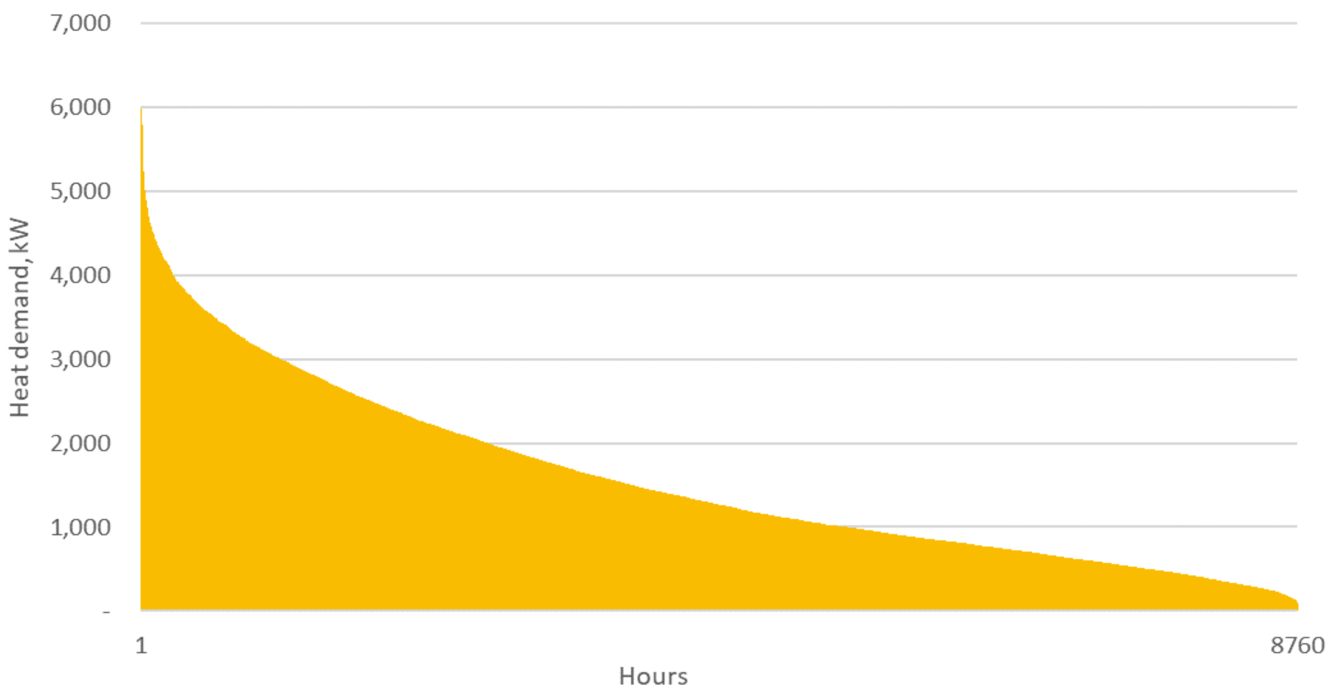

Figure 32: Load duration curve for Phase 2

A summary of the Phase 2 network is shown in Table 17.

Table 17: Phase 2 summary

	Phase 2
Total heat demand (excluding losses)	13,685 MWh
Network length	13,179 m
Peak heat demand	6.0 MW
No. of heat connections / customers	24

6.1.3 Phase 3

Two Phase 3 connections have been identified: planned development and social housing cluster. Since, social housing cluster N106 is nearby planned development it should only be connected if proposed development is brought forward and connected to the Killingworth heat network. The network route and connected buildings are shown in Figure 33.

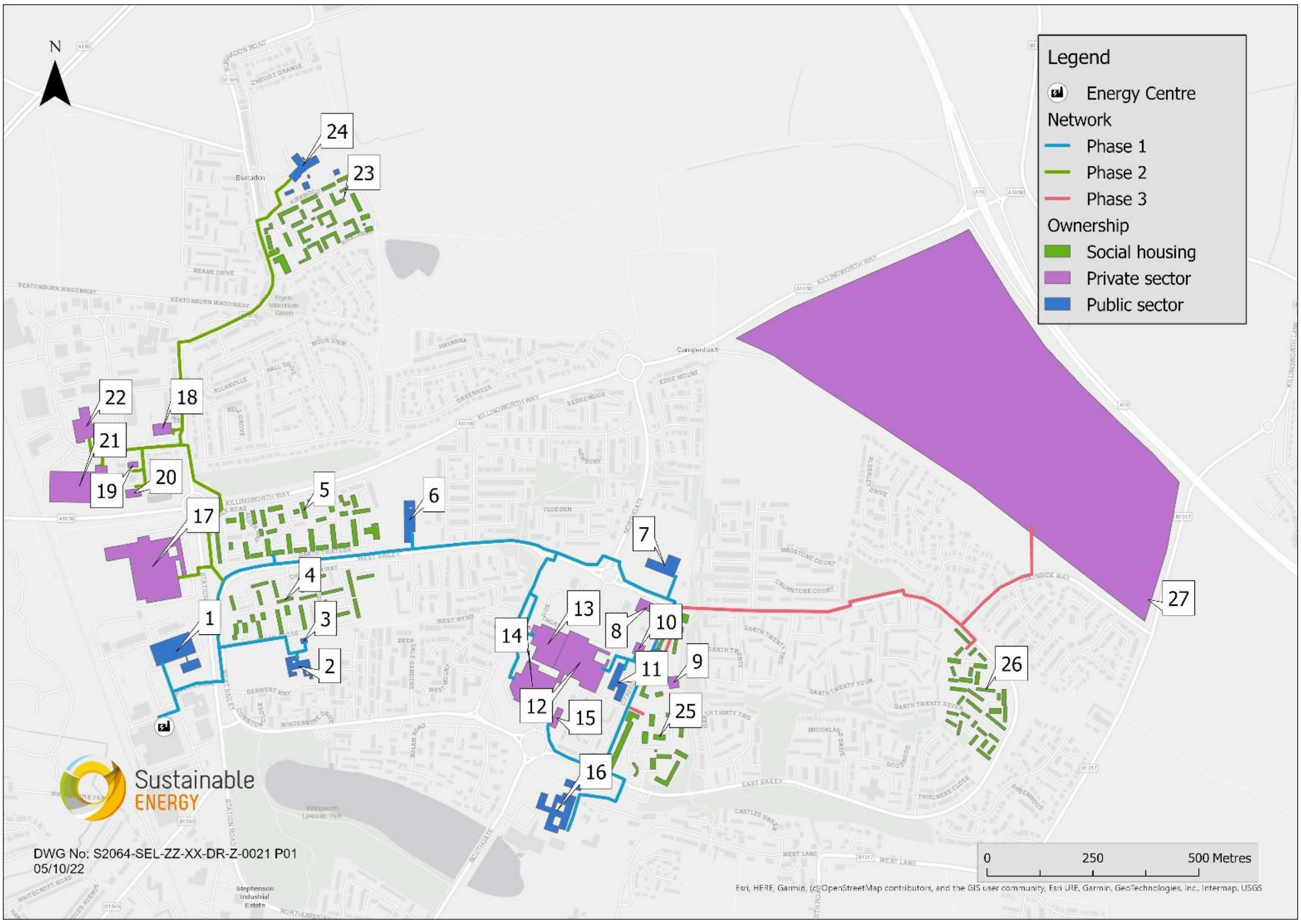

Figure 33: Phase 3 network layout

Table 18: Phase 3 network connections

Map ref	Site name	Site ownership	Annual heat demand, MWh	Connection capacity, kW
25	N102 social housing	Social housing	705.2	480
26	N106 social housing	Social housing	678.8	330

Map ref	Site name	Site ownership	Annual heat demand, MWh	Connection capacity, kW
27	Planned development of Killingworth Lane	Private sector	3,500.4	1,180

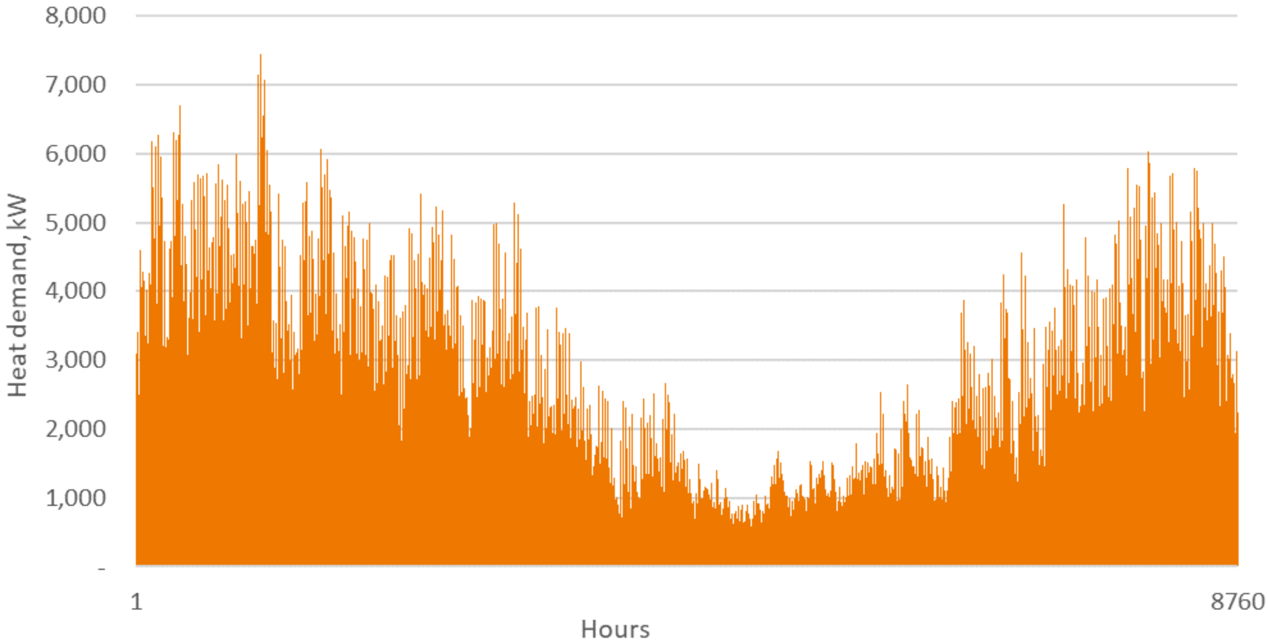

Figure 34: Annual heat demand profile for Phase 3

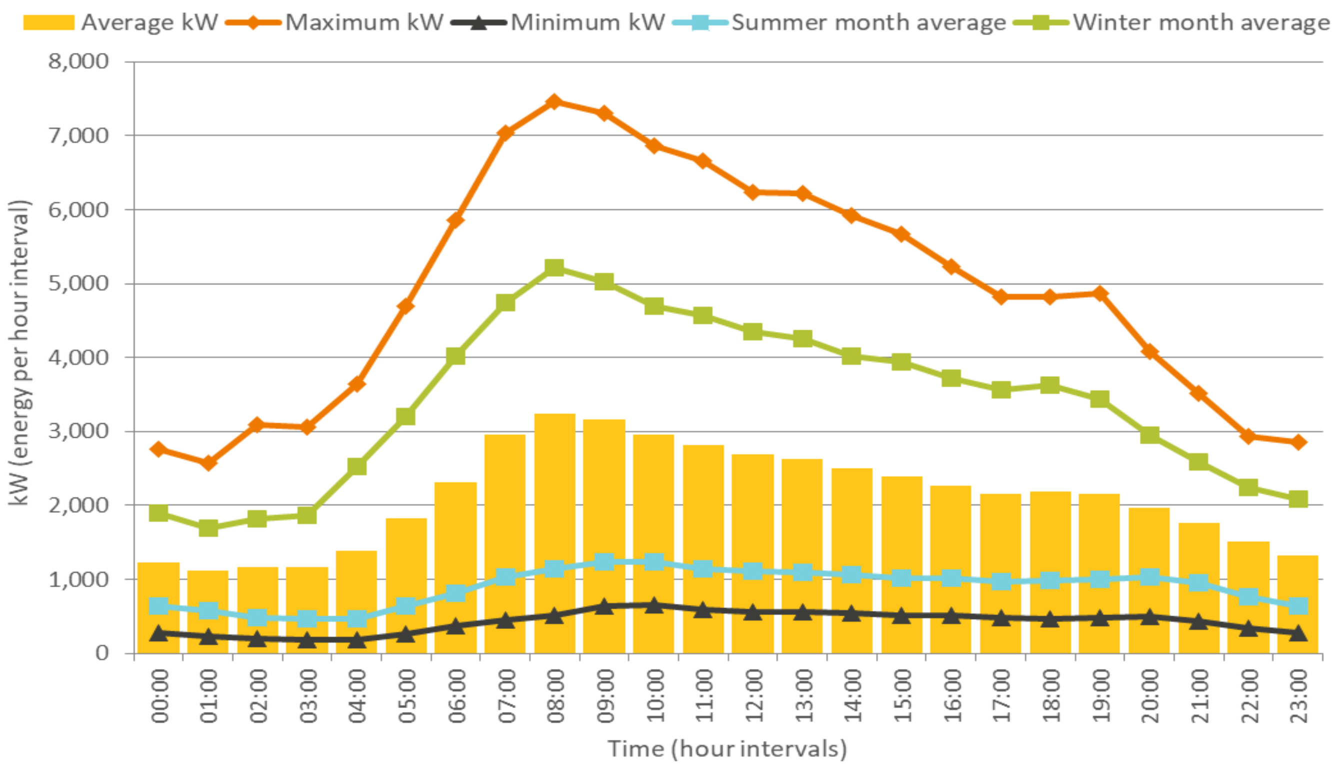

Figure 35: Average, maximum and minimum hourly heat demand for Phase 3

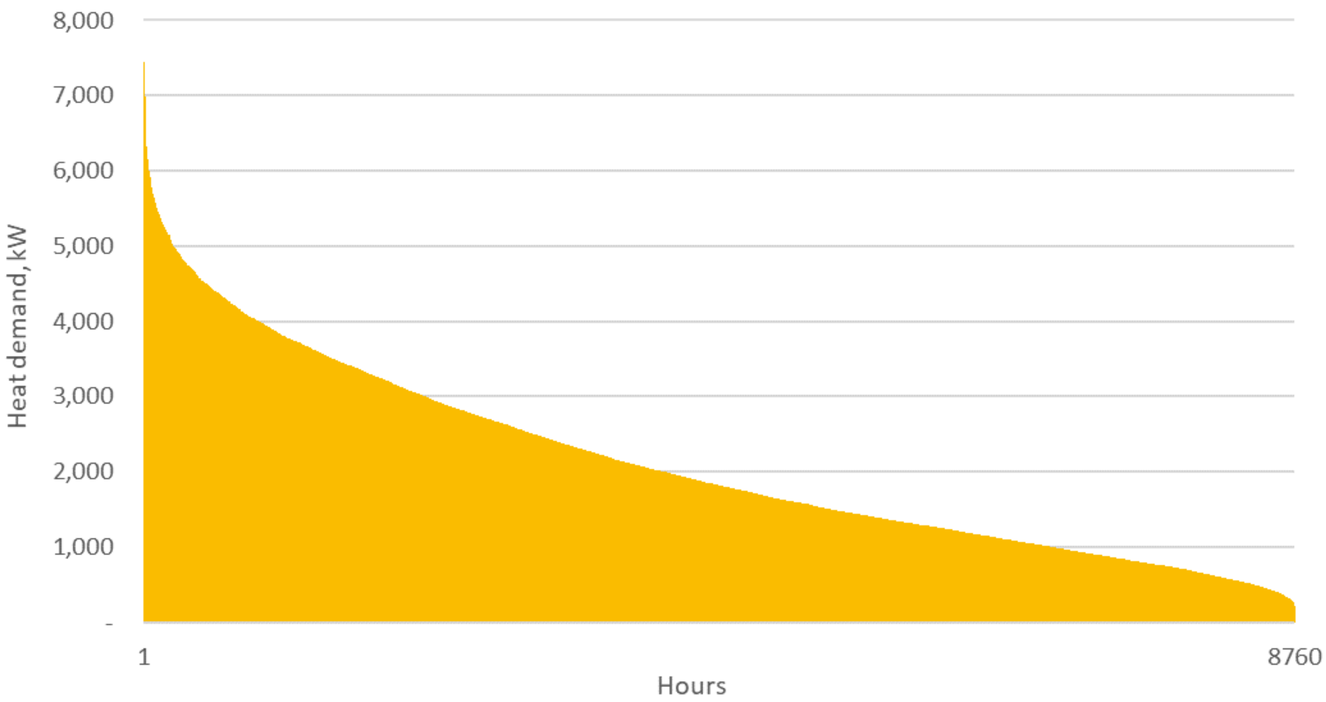

Figure 36: Load duration curve for Phase 3

A summary of the Phase 3 network is shown in Table 19.

Table 19: Phase 3 summary

	Phase 3
Total heat demand (excluding losses)	18,378 MWh
Network length	24,655 m
Peak heat demand	7.4 MW
No. of heat connections / customers	27

6.2 Prioritised Network Option

The heat demand and network assessment identified the most feasible connection for district heat network. Figure 37 shows the heat demand of the prioritised solution split by ownership. Table 20 shows further details on number of connections, ownership, and their demands

The demand for phase 1 heat is split between 27.66% of social housing and 40.88% of public sector buildings. Phase 2 demand is composed of 27.8% of social housing and 33.6% of the public sector. Phase 3 has a 24.7% public sector demand and a 27.9% social housing demand, giving NTC a high level of control over whether they connect. The proposed network is assessed over three phases.

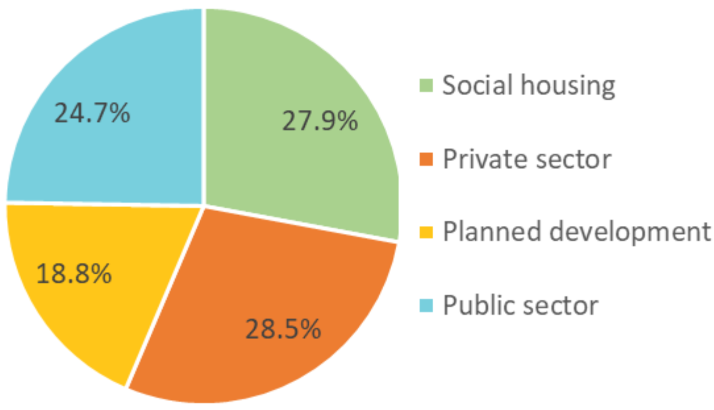

Figure 37: Prioritised network heat demand split by ownership

Table 20: Prioritised network heat demand summary

Ownership	Heat demand, MWh	% heat demand	Estimated using data for similar sites	Estimated using heat demand model	Actual data (metered)	No. of sites
Social housing	5,185	27.9%	-	5,185	-	5
Private sector	5,291	28.5%	5,291	-	-	13
Planned development	3,500	18.8%	-	3,500	-	1
Private housing	0	0.0%	-	-	-	0
Public sector	4,593	24.7%	225	-	4,367	8
Total	**18,570**	**100%**	**29.7%**	**46.8%**	**23.5%**	**27**

A heat network supplied by heat pumps utilising water abstracted from Yard Seam and reinjected into the High Main Seam has been selected as the prioritised network option. However, the abstraction potential requires further assessment.

It is assumed the 2.51 MW heat pump at NTC site energy centre will serve the Phase 1 network. An additional 0.74 MW will support serving the Phase 2 network. Then additional 0.56 MW MWSHP will be installed for Phase 3. In total 3.81 MW of MWSHP will generate enough heat to serve the Phase 3 network. A summary of the network heat generation and supply is shown in Table 21. The key assumptions for the technology and key parameters are shown in Appendix 3: Key Parameters and Assumptions.

Table 21: Network summary

	Phase 1	Phase 2	Phase 3
Network spine length	2,572 m	3,778 m	4,881 m
Total cumulative heat demand, without losses	10,694 MWh	13,699 MWh	18,584 MWh
Total cumulative network heat demand, including losses	11,803 MWh	15,276 MWh	21,372 MWh
Peak heat demand (cumulative), MW	4.6	6.0	7.4
MWSHP capacity (additional), MW	2.51	0.74	0.56
Total heat pump capacity, MW	2.51	3.25	3.81

	Phase 1	Phase 2	Phase 3
Peak and reserve boiler capacity, MW	5	6	8
Heat demand met by heat pumps + thermal store, MWh	11,707	15,140	20,329
Heat demand met by peak and reserve boilers, MWh	0.308	0.436	0.977
% heat demand met by low carbon / renewable technology	97%	97%	95%

Figure 38 shows the hourly network heat demand ordered from highest to lowest. Heat demand below the black, blue and grey lines can be met by the heat pump(s) in each phase. The heat demand above the black, blue and grey lines is met by the thermal stores and peak and reserve boilers.

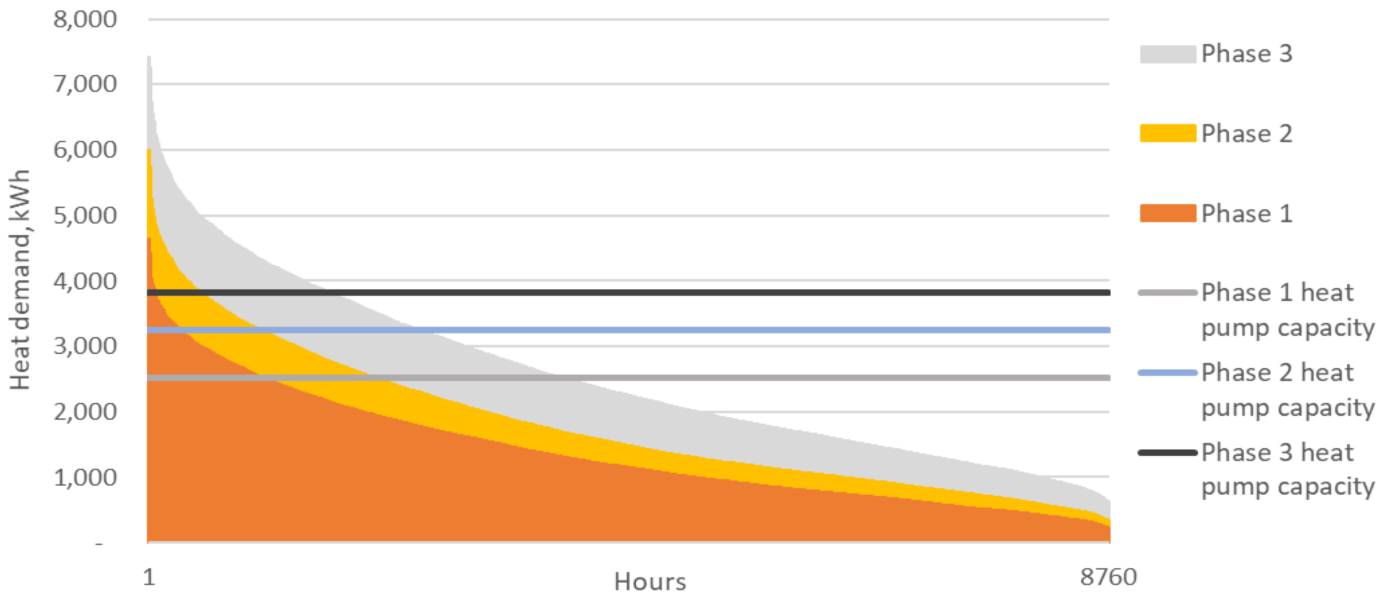

Figure 38: Load duration curve

The heat from the heat pumps will meet between 90% and 98% of the full network heat demand, including heat losses in the network. The remaining of heat demand which is not met by the low carbon technology will be met by the gas peak and reserve boilers. The peak and reserve boilers will also supply heat in the 2 weeks plant downtime a year included in the assessment for maintenance and repairs to the heat pumps.

Gas boilers were chosen as they will improve economic viability of the project due to lower gas cost against electricity. Electric boilers would also significantly increase fixed charges based on required capacity and significantly increase risk of energy centre reliance on the reliability of 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). Under the modelled assumptions the heat pumps are cheaper to operate than gas boilers and will therefore be prioritised, minimising the emissions from the energy centre.

200,000L thermal storage has been included at the energy centre to maximise the proportion of heat that can be provided from the heat pump and reduce the use of the peak and reserve gas boilers.

More details on the prioritised network option and assumptions are mentioned in section 7.

6.2.1 Energy Balance

Figure 39, Figure 40 and Figure 41 show the energy balance for phases 1, 2 and 3 respectively.

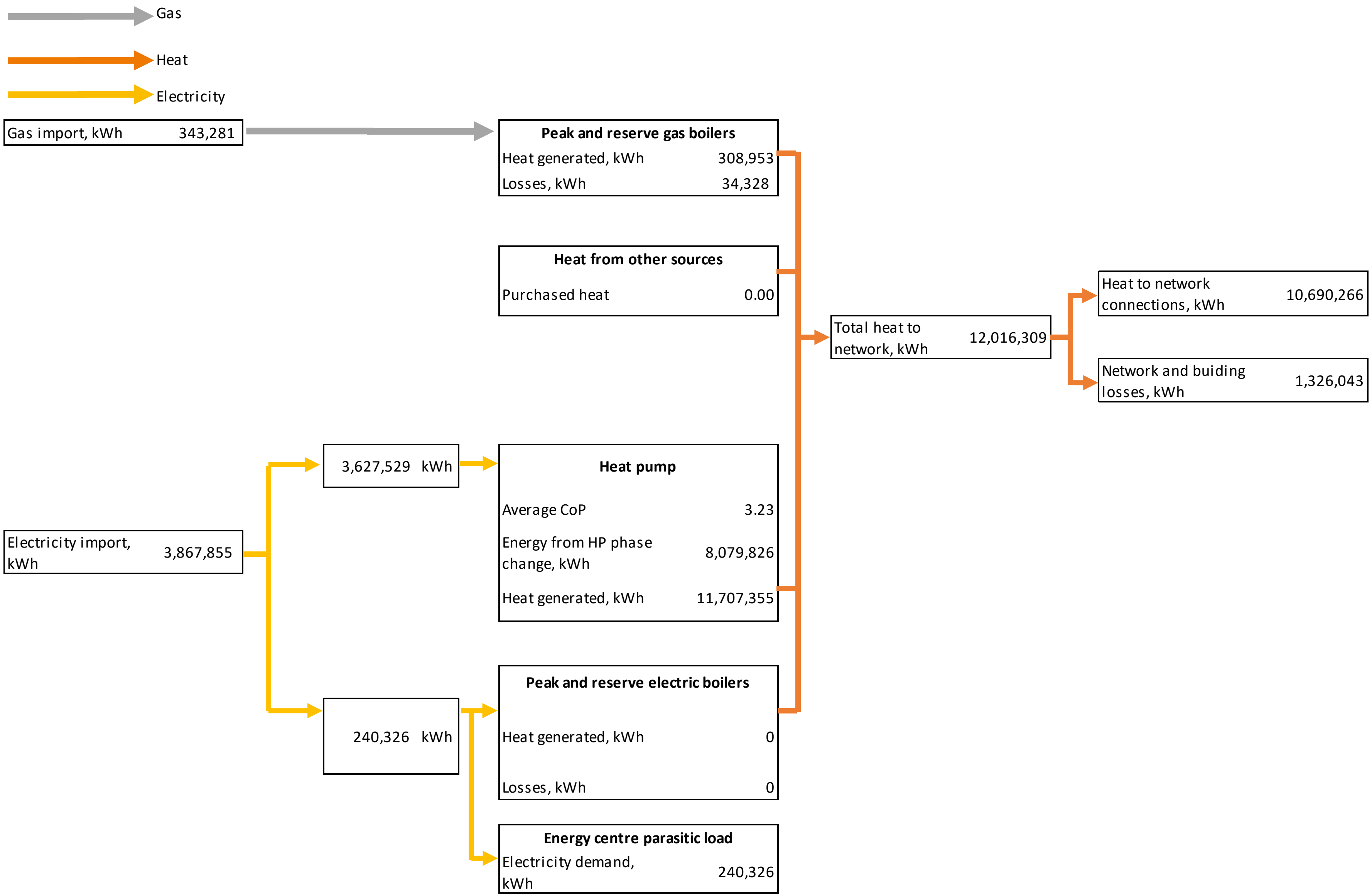

Figure 39: Phase 1 energy balance

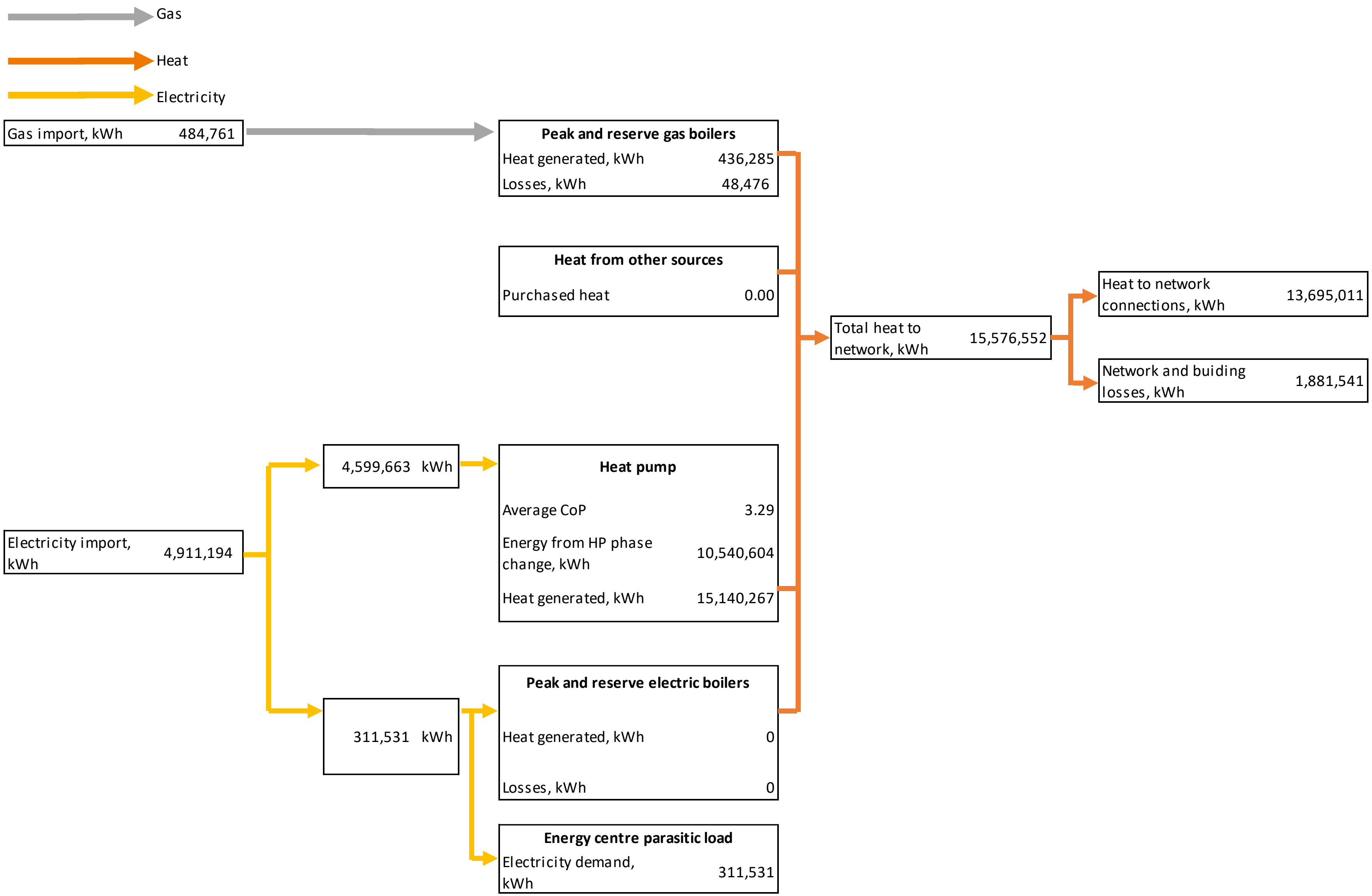

Figure 40: Phase 2 energy balance

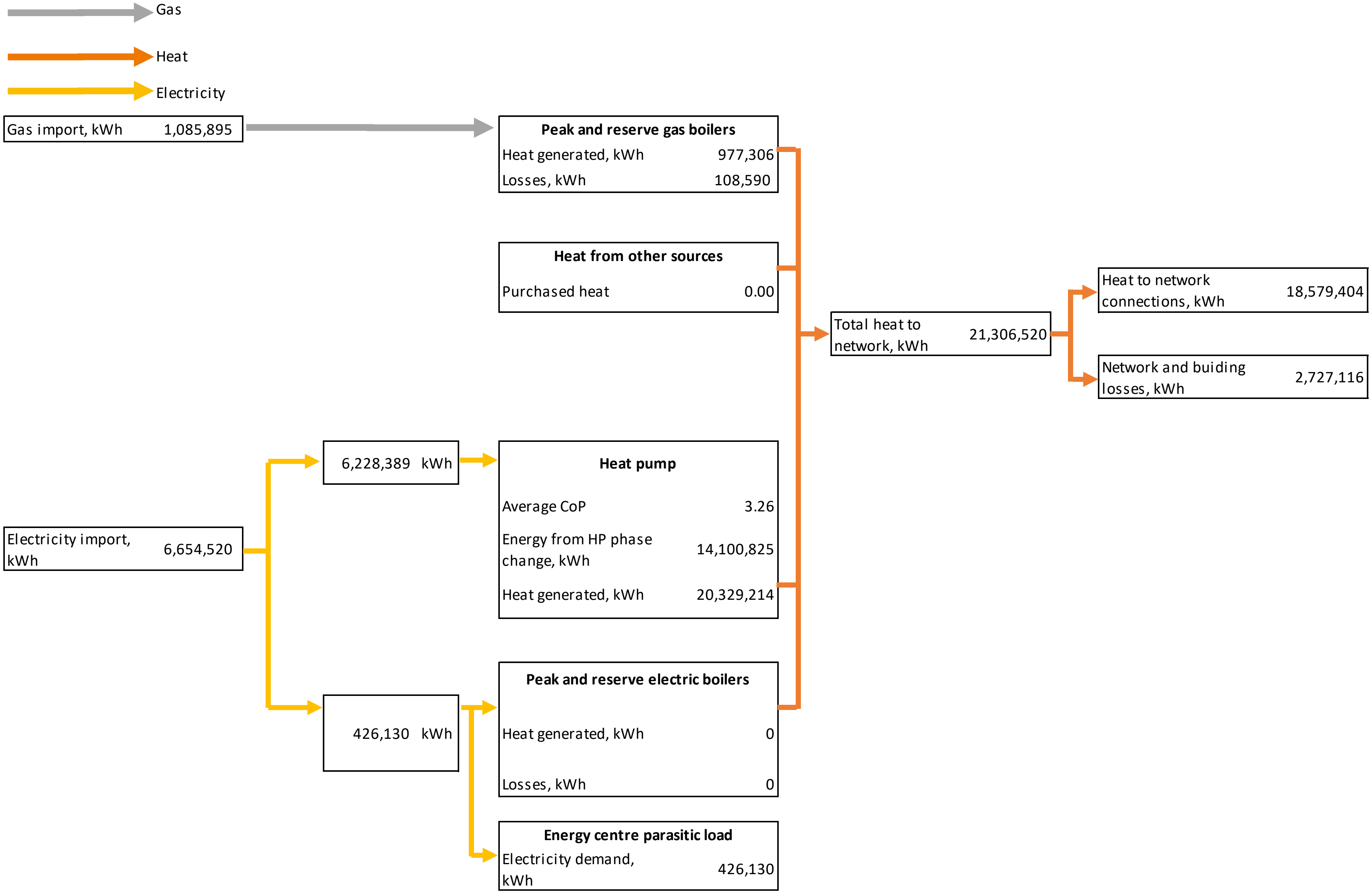

Figure 41: Phase 3 energy balance

6.3 Summary

The proposed network has been assessed over 3 phases. Phase 1 connects key existing council owned buildings, large commercial buildings in the town centre and three social housing clusters. Phase 2 then connects larger loads from the northern industrial estate an additional social housing cluster and council owned Burradon School. Phase 3 connects longer term planned development at Killingworth Lane and a final social housing cluster.

All phases will be supplied with heat from the NTC Killingworth Site energy centre using mine water. For each phase additional mine water heat pumps will be installed to supply low carbon heat. Further assessment from the coal authority is required to confirm the potential for abstraction from the mine workings.

7 CONCEPT DESIGN

This chapter describes the scheme concept design and includes details of the primary heat sources, peak and reserve boilers, other energy centre equipment, utilities connection requirements and metering.

7.1 Futureproofing

Futureproofing measures have been considered throughout the concept design process for the network options. There is sufficient capacity in the energy centre design to accommodate further building connections, but this will need to be assessed on a case-by-case basis.

7.2 Killingworth Depot Energy Centre

The proposed energy centre utilises mine WSHPs. The backup gas boilers will be located within the energy centre building and will be used to provide heat at times of peak demand (if this exceeds the capacity of the heat pumps and thermal stores). Controls will prioritise heat from the heat pumps using thermal stores over the peak and reserve gas boilers to maximise the use of renewable technologies. A summary of the technology capacities for Phase 1 and additional requirements for Phase 2 and Phase 3 at the proposed energy centre are shown in Table 22. Figure 42 shows process flow diagrams (PFDs) for the proposed energy centre and Figure 43 shows RIBA Stage 2 energy centre design.

Table 22: Killingworth site energy centre summary

	Phase 1	Phase 2	Phase 3
MWSHP capacity	2,515 kW	3,246 kW	3,811 kW
Peak and reserve boiler capacity	5,000 kW	6,000 kW	8,000 kW
Thermal store capacity	200 000 L	-	-
Energy centre footprint (approx.)	693 m^2	-	-

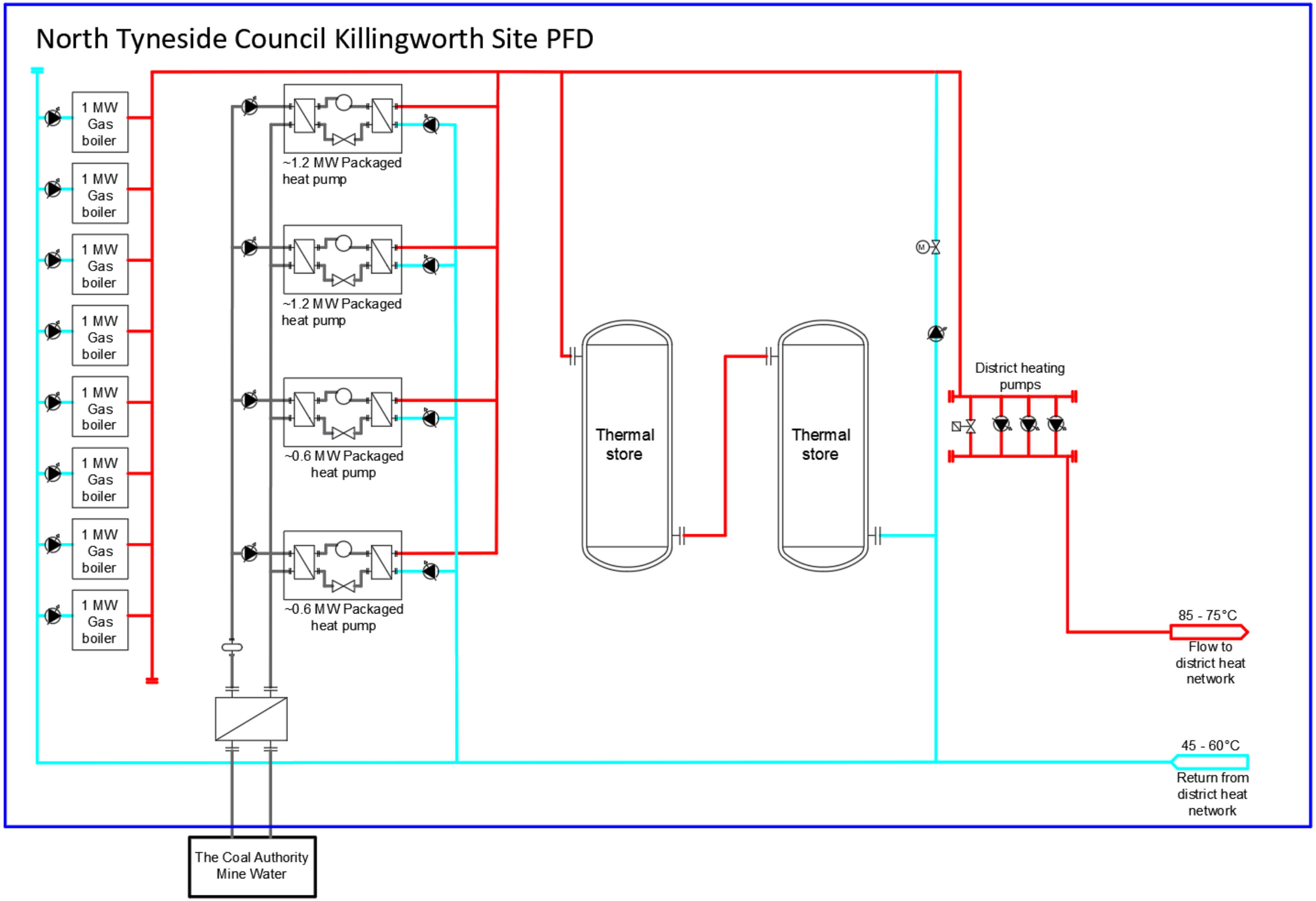

Figure 42: NTC Killingworth Site PFD – Fully built out Phase 1,2 and 3

7.2.1 Energy Centre Footprint

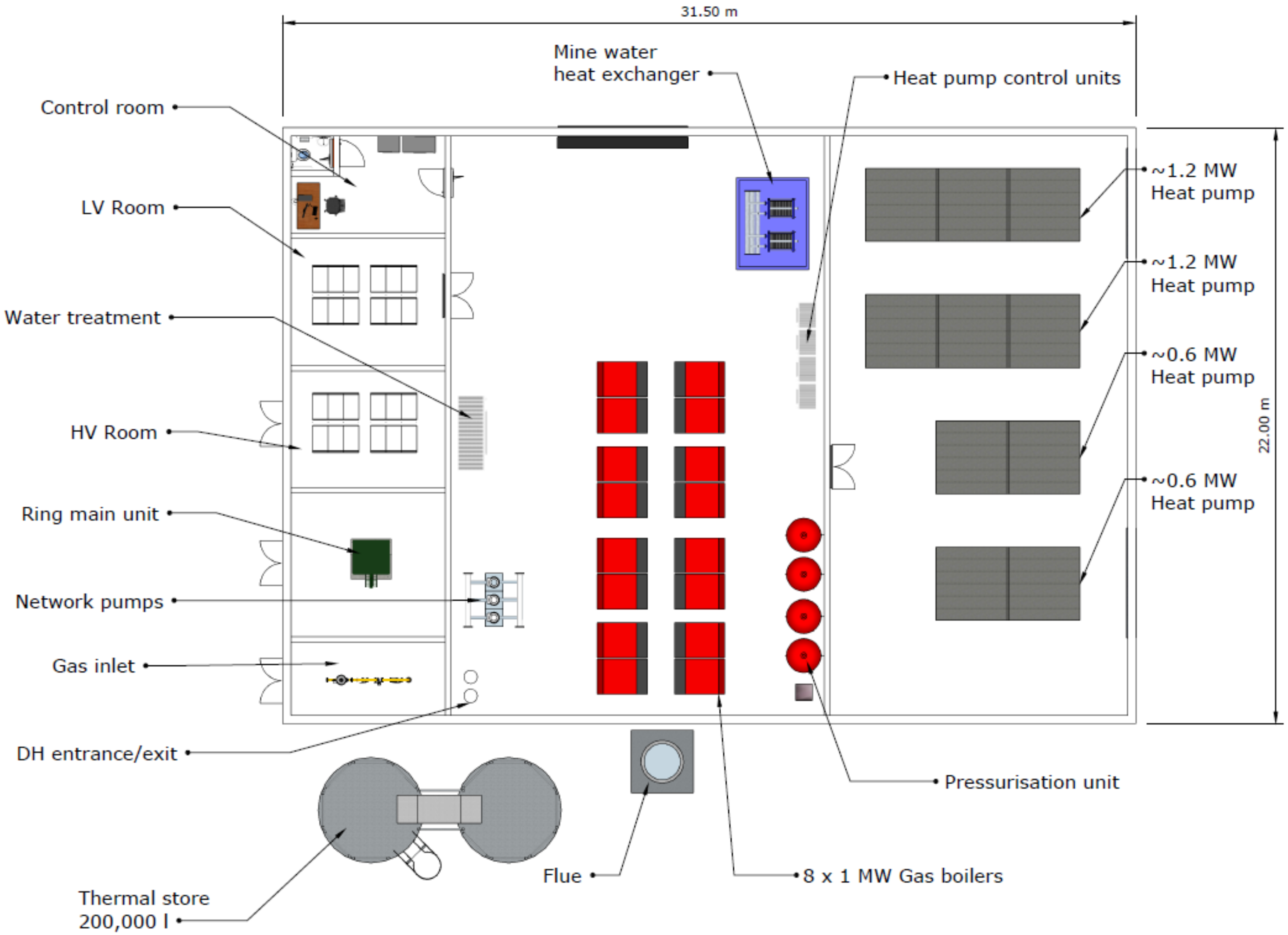

Figure 43: NTC Killingworth Site energy centre general arrangement – Fully built out Phase 3

7.2.2 Technology Sizing

Heat Pumps

The heat pumps will be packaged units connected within the energy centre to two main circuits; the abstraction water source circuit and the primary heating circuit. The abstraction source circuit(s) operates by running a low-temperature, low pressure refrigerant fluid through a heat exchanger to extract the heat from the mine water.

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 refrigerant. Current refrigerant in the modelled solutions is propane (R290) with a GWP of 3. More details on disadvantages and advantages of different refrigerants can be found in Appendix 8: Heat pump refrigerant. In addition to the heat pump the energy centre will include heat exchanger and water treatment unit for the mine water.

The refrigerant fluid 'absorbs' the heat and boils at low temperature with the resulting gas being 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.

The heat pump capacity will be limited based on the phased network demand and the flow rate of water pumped from the mines. Consideration has also been given to the optimum balance between heat generation capacity, capital cost, maintenance costs and physical size.

A detailed sizing exercise has been undertaken using SEL's heat pump and thermal store sizing tool. The tool analyses the hourly network heat demand, network losses, water/air source temperature, heat pump capacity and modulation and thermal store size on an hourly basis for a full year taking into account hourly, daily and seasonal variation as well as peak and off peak electricity tariffs. Heat pump sizing is further assessed in Appendix 5: Technology Sizing including further details of SEL's heat pump and thermal sizing tool. Following this exercise, a total of ~3.8 MW of mine water source heat pumps are required to serve the 3 phases.

Abstraction and reinjection boreholes

Mine water would be abstracted via an 'open-loop' system. The mine water is pumped up from the well or borehole, 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, the abstraction and reinjection boreholes are located within different seams within the same mine as shown in Figure 44. There are potentially 4 possible seams that mine water could be extracted from as discussed in section 4.2. It is preferential to abstract from a lower seam and reinject into a higher seam as the water temperature will increase with increasing depth. This study assumes that water will be abstracted from the Yard Seam and reinjected into the High Main Seam.

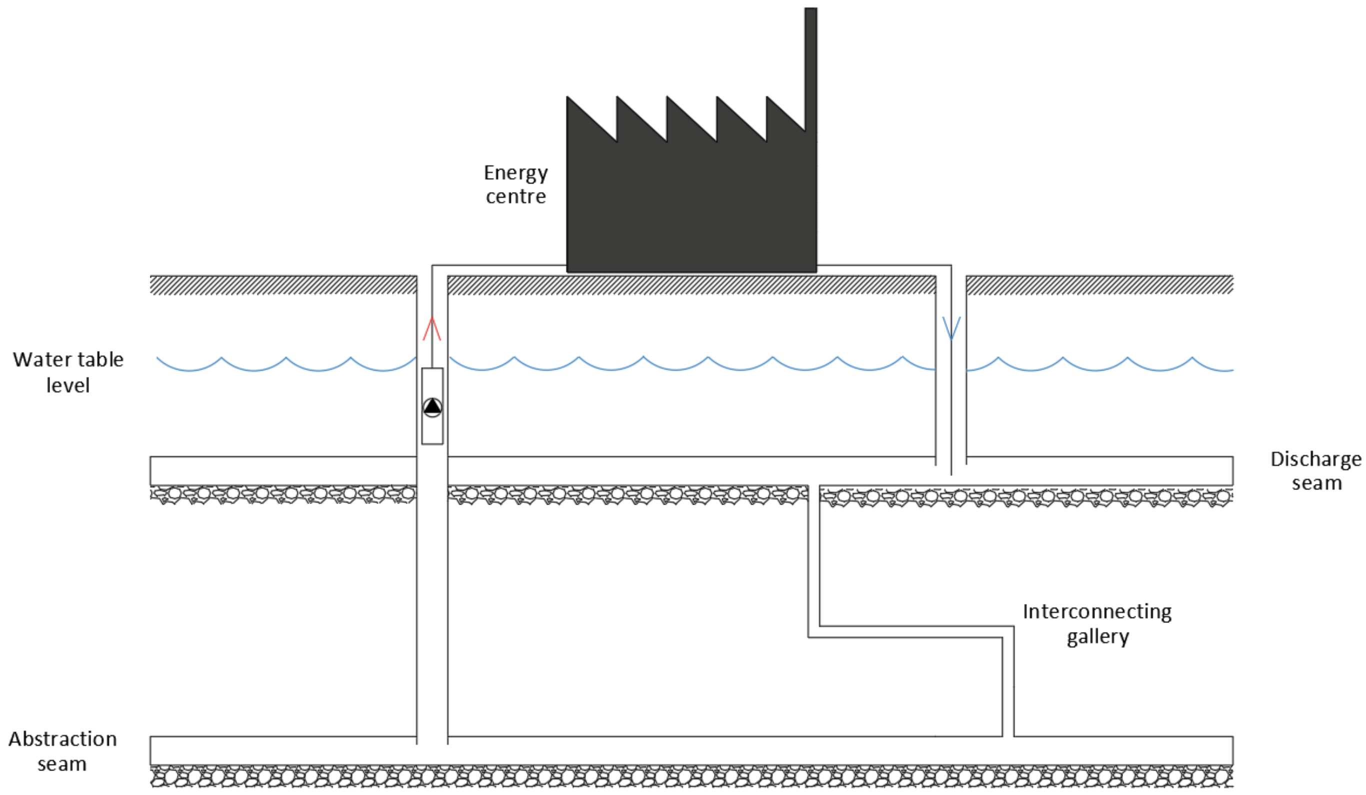

Figure 44: Mine water abstraction

Peak and Reserve Boilers

The gas boilers have been sized to ensure that failure of any one item of equipment will not prevent the peak heat demand from being met. Gas peak and reserve boilers have been sized using an n+1 methodology to allow multiple boilers to modulate in unison to meet heat demands, this will provide redundancy and allow boilers to operate at their highest efficiency throughout the range.

7.2.3 Thermal Storage

Thermal storage has been included at the energy centre to maximise the proportion of heat that can be provided from the heat pump and reduce the use of the peak and reserve gas boilers. The thermal storage comprises large cylindrical, insulated water tanks which will be connected in series with each other to maximise the stratification of the stored volume. The thermal storage will be connected in parallel with the heat pump so that a proportion of low carbon heat is always used to charge the thermal stores when they are below full capacity.

7.2.4 Flues

The design of the flues needs to achieve sufficient velocity of exhaust gas to achieve adequate dispersion, avoiding concentrations of harmful gasses such as nitrogen oxides (NOx). The effects of wind loading, and structural requirements of the flues must also be assessed and incorporated into the structural design of the energy centre.

Gas boilers are expected to only operate for short periods of time and discussion with North Tyneside Counsel Air Quality manager is required. If possible, gas boiler will be ultra-low NOx versions and will run only when the network demand exceeds the capacity of the installed heat pumps and thermal stores, therefore impact on the air quality will be minimal. If required by local air quality officers, dispersion modelling can be conducted to ensure that any impact is within regulatory limits and meets local air quality objectives (and this information will be fed back into the flue design process).

Flue dispersion modelling may be required to assess the impact on surrounding buildings, including nearby tall buildings.

7.2.5 Operating Conditions

A detailed assessment of the proposed network has been undertaken and the proposed operating conditions reflect the optimal network efficiency. To ensure heat network losses are kept below 10%[3], and to effectively serve a combination of new build developments and existing buildings with varying secondary systems, the heat network will need to operate variable temperature conditions.

Primary Network Temperatures

The primary heat network will provide heat via plate heat exchangers which means the flow temperature on the primary network into each building will be slightly higher at circa 85°C at peak conditions and 65°C to 75°C flow temperatures for summer conditions.

The energy generating plant in the energy centre will be made up of various technologies that have different temperature conditions that affect the efficiency of each technology (i.e. gas boilers and heat pump). Gas boilers can operate at higher temperatures of 90°C without impacting negatively on efficiency. Heat pumps, however, have a performance which is significantly impacted by the temperature conditions of the network and, to maintain effective performance, network flow and return temperatures should be as low as possible.

Controlled scheduling of heat pumps and gas boilers will be required to maintain an overall efficiency of each technology. Heat pumps will not be used to supply higher temperature peak demands, so the higher temperatures required for peak demands will be supplied by gas boilers. However, when temperatures and loads are lower (e.g. summer conditions), the heat pump will supply higher levels of demand. Detailed modelling and sizing have been carried out to consider varying demand profiles, temperature conditions and carbon impacts.

Secondary System Temperatures

The proposed network comprises mainly existing buildings and limited planned developments. It is assumed the existing buildings are currently operating at flow temperatures within a range of 80-82°C flow and return temperatures of 60-71°C. These buildings will require upgrades to their secondary systems and controls to make them 'district heat ready'[4]. The assessments undertaken indicate that, by replacing hot water systems and improving control for space heating systems in existing buildings[5], target secondary side temperatures could be 70 °C flow and 45 °C return for peak conditions, and 65 °C flow and 35 °C return for summer conditions. If buildings operate at higher temperatures, then supply temperature from the heat pump needs to be higher, this has a negative impact on the SPF of the heat pump, see section 10.1.6.

Building regulations Part L Volume 1: Dwellings and Part L Volume 2: Buildings other than dwellings both require wet heating systems to be designed with a maximum flow temperature of 55°C. Any planned developments will be required to be built to these new regulations so the secondary side temperatures should be in accordance with CIBSE / ADE CP1. When connected to district heat networks, this will result in lower average return temperatures and therefore increase the efficiency of the network and the heat generating technologies. Target secondary side temperatures for planned developments should be 55°C flow and 30°C return.

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[3] The CIBSE/ADE HNCoP states that the calculated annual heat loss from the network up to the point of connection to each building when fully built out is typically expected to be less than 10 %

[4] DH ready buildings have the infrastructure in place to connect to the district heat network in line with the HNCoP and other best practice

Operating Pressure

The topography of the Killingworth area has minimal height variation. The calculated static pressure required in the network will be circa 3.5 bar. Hydraulic separation will be required in high rise buildings (over 4 storeys).

The pumping pressure defines the maximum operating pressure to generate enough head to deliver the flow rate to all buildings. Hydraulic modelling was carried out to assess how the pressure in the network will vary throughout the seasons and the concept design considers maintaining maximum pressure in the system at less than 9 bar.

7.2.6 Variable Speed Pumps

The design utilises variable speed pumps in a multi-pump arrangement (3 pumps – 1no. duty, 1no. assist and 1no. standby). They will be controlled to maintain a minimum pressure difference at specific locations using index differential pressure sensors within the network. The pump set will be sequenced, and speed controlled (on a demand basis) to maintain a differential pressure that is influenced by the pressure independent control valves controlling heat demand to ensure heat demands are satisfied and flow rates are minimised.

The benefits of the variable speed function will be realised as peak flow rate conditions will typically only occur for brief periods during a heating season, with average demands being much lower.

7.2.7 Utilities Connections

A gas connection able to supply the peak and reserve boilers up to 8 MW will be required for the North Tyneside Counsel site. A budget quote was requested from Northern Gas for the North Tyneside Counsel site; however, this was not received prior to the completion of this study. An estimate figure based on similar projects has been used in the assessment.

An electricity connection able to supply the heat pumps and the energy centre will be required at with a 1.4 MVA peak capacity required at North Tyneside Council site. The budget quote from Northern PowerGrid was requested; and a budget quote of £94,422.78 (incl. VAT) was received for electrical connection. A gas connection quote was not received prior to the completion of this study therefore an estimate figure based on similar projects has been used in the assessment.

A mains water supply and drainage will be required for energy centre.

7.2.8 Metering

All metering should be specified with suitable accuracy class in accordance with the Measurement Instrumentation Directive to satisfy the utility requirements for the purchase and sale of heat, gas, water, and electricity for the energy centre.

Heat

The energy centre will have at least three heat meters installed: one combined mine water heat pump heat meter, a combined gas boiler heat meter and a combined export heat meter. The ultrasonic flow sensors measure flow and return temperatures and flow rates and the multi-function meters will calculate the heat energy exported. The heat meters will provide output signals (via Mbus) for instantaneous measurements and cumulative measure of flow and energy. Data from all meters will be imported into the control system and used for control and monitoring of system performance.

Water

There will be water meters to determine the cumulative use by each of the system pressurisation units, water treatment plant and the overall incoming mains water to each of the energy centres. All data will be collected by the control system.

Electricity

Electricity meters will be fitted to measure the supply to the heat pumps and the import electricity from the grid.

7.3 Building Connections

All network connections are assumed to be indirect (where a heat exchanger separates the heat network hydraulically from the building space heating and hot water systems). The commercial connections will consist of a heat substation.

The HIU and substation packages will include:

- Supplier meter to meter all heat usage on the primary side of the connection.
- Two-port differential pressure control to control the supply flowrate and temperatures across the heat exchanger via two-port control methodology. Control valves can either be a single PICV or a DPCV with a separate two-port control valve.
- Plate heat exchanger (PHE) at which the district heat is transferred to the customer secondary side network. PHEs will be specified with a maximum 3°C temperature drop between primary and secondary side and a maximum 80kPa pressure drop on the secondary side of exchanger.
- Means of flow measurement and test points on both sides for commissioning purposes.
- Filtration to protect the plate heat exchangers and valves from fouling.
- Flushing, filling and draining details for chemical flushing of all pipework on the primary and secondary side.
- Pressure relief, control and instrumentation to allow the supplier control and monitor of the supply of heat.

Commercial Connection

The commercial connections will consist of a heat substation. The substation includes heat exchangers, control valves and heat metering and will be maintained by the network operator. The substation can include one or more plate heat exchangers (PHEs) (two shown in the example in Figure 45), 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, provide a full thermal range, and some redundancy to permit service and maintenance periods. Larger substations may include more than two PHEs. Only the key functional features are shown in the simplified schematic in Figure 45.

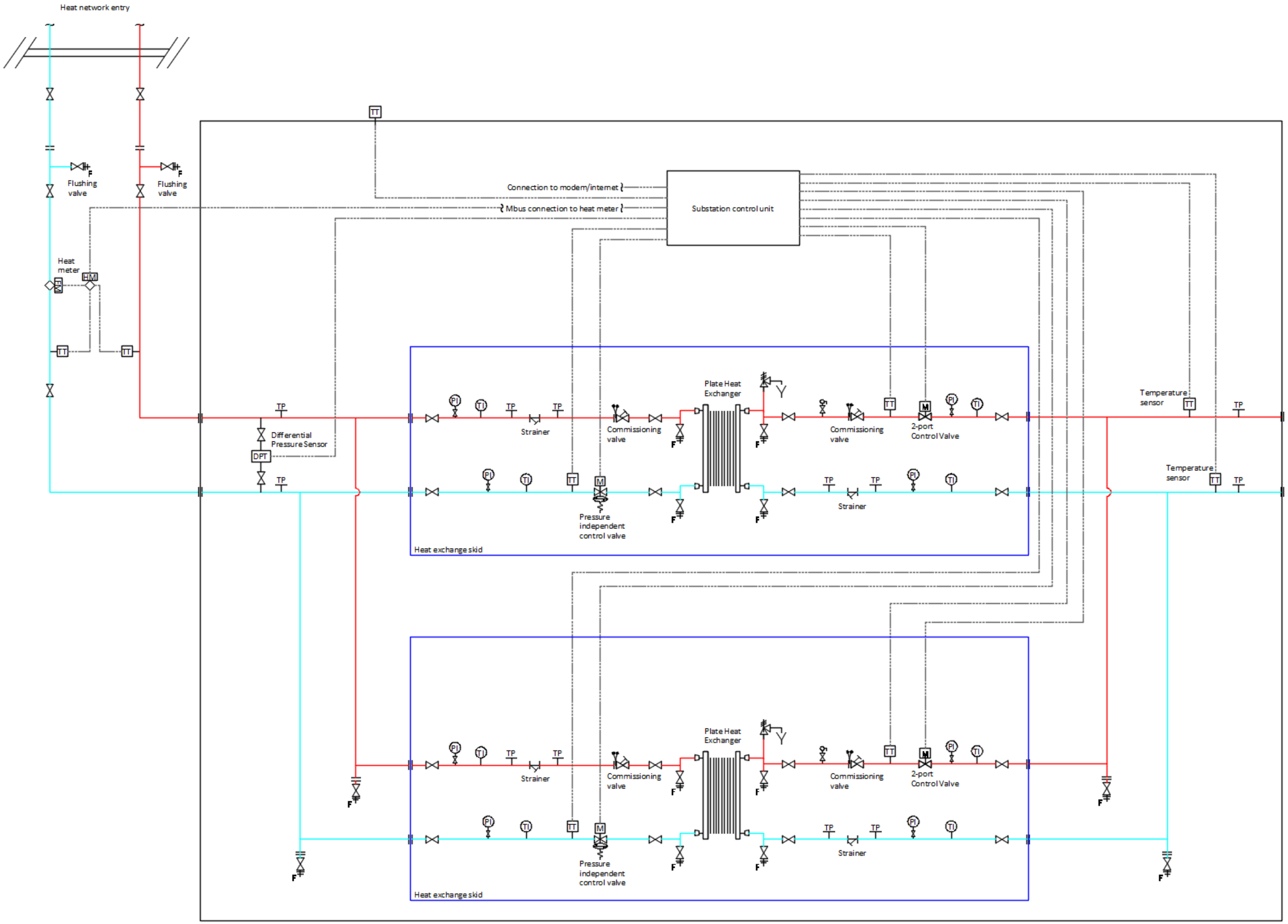

Figure 45: Example of typical substation connection for commercial development

Residential Connection

The HIU includes a plate heat exchanger for the space heating, a plate heat exchanger for instantaneous domestic hot water, pressure independent/differential pressure control valves and a heat meter. The key functional features are shown in the simplified schematic in Figure 46.

HIUs are comparable in size to a domestic combination boiler and are usually wall hung. The hot water is best provided via an instantaneous PHE with a suitable means to ensure the network side of the plate is controlled (to ensure satisfactory hot water supply response to dwelling taps whilst minimising the supply pipework heat losses during standby periods). Space heating supply will be an in-direct connection (where a PHE is used to transfer supply heat into the secondary circuit).

The location of the HIU should be as close as possible to the main district heat network to minimise pipe lengths and network losses. Ideally the HIU will be accessed from outside the dwelling to enable access for maintenance.

The utilities required for the HIU are:

- 240 V spur connection
- 15 mm mains cold water service (MCWS) connection
- Suitable drain point

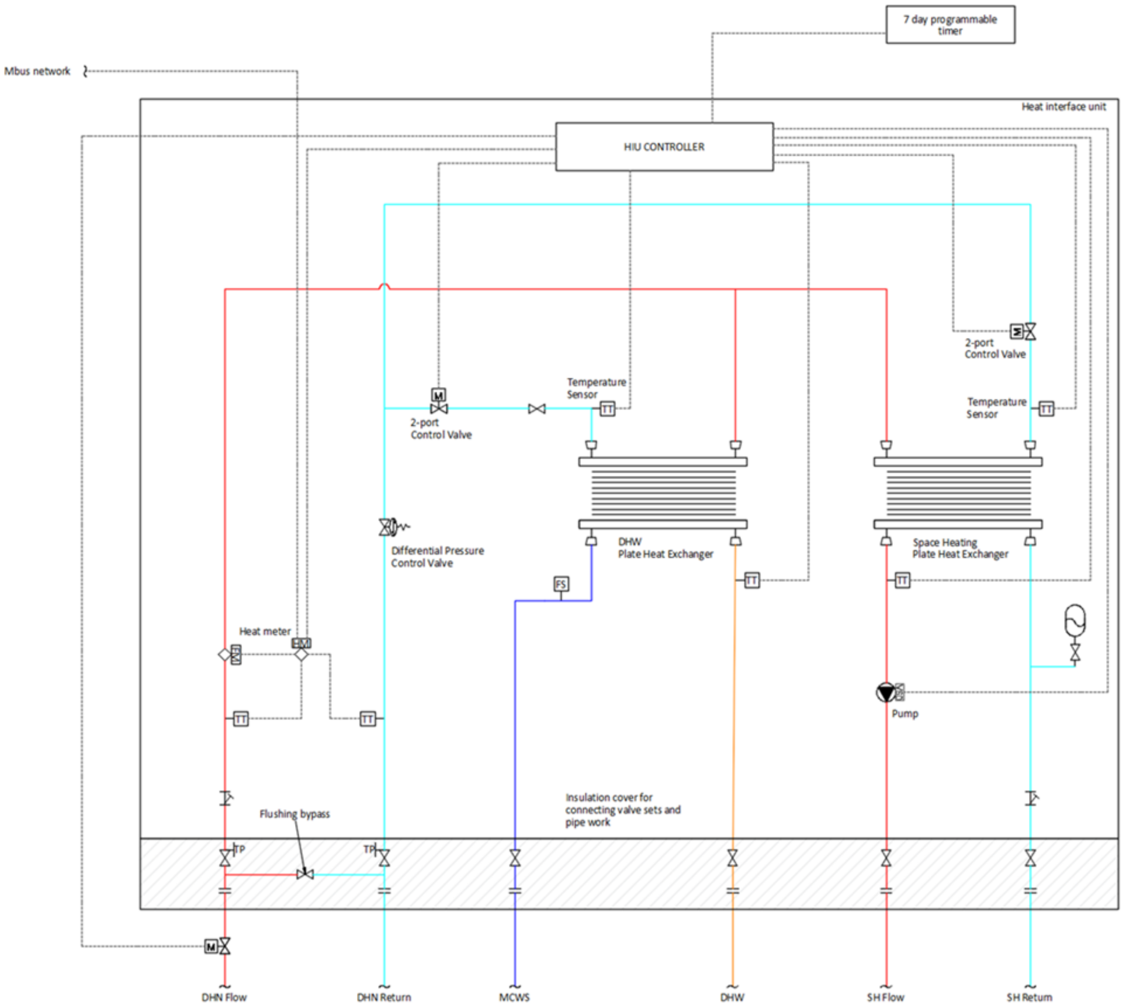

Figure 46: Example of typical domestic HIU connection

7.4 Heat Network

7.4.1 Futureproofing

The optimised network route has been designed to consider possible future connections with the main network leaving the energy centre allowing for sufficient over capacity. The connections to the clusters have been consider in section 5.3. For the TEM assessment no private housing has been considered to connect. However, the spine and branch connections to the connected clusters have been sized to allow full connection of private houses in these clusters to ensure that private dwellings could connect to the network if they choose. The PEX pipework that will be used in the housing clusters allows hot tapping to connect additional dwellings without disturbing network operations.

7.4.2 Operating Conditions

A detailed assessment of the proposed network has been undertaken and the proposed operating conditions reflect the optimal network efficiency. To effectively serve the existing connections and new build developments the heat network will operate with variable temperature conditions based on the ambient outside temperature to reduce heat losses as much as possible.

7.4.3 Optimised Route

The pipe routes have been designed to consider pipe length and barriers such as existing utilities, highways and construction limitations (see section 5). The network has been designed with futureproofing to allow expansion of the scheme. Where social housing clusters have been connected to the network, the spine has been designed to allow connection of all private housing in that cluster.

7.4.4 Pipe Sizing and Insulation

The prioritised network route was imported into network modelling software to determine the characteristics and sizing for each part of the network with the aim of minimising pumping energy costs and heat losses in the network. The software allows different scenarios to be modelled and pipe characteristics, such as velocity, pressure loss and temperatures in the pipe are calculated to determine the optimum pipe size. Energy centre pumping requirements are also considered to ensure the optimum pipe size is selected. Figure 47 shows an example output displaying pipe velocity under diversified load conditions.

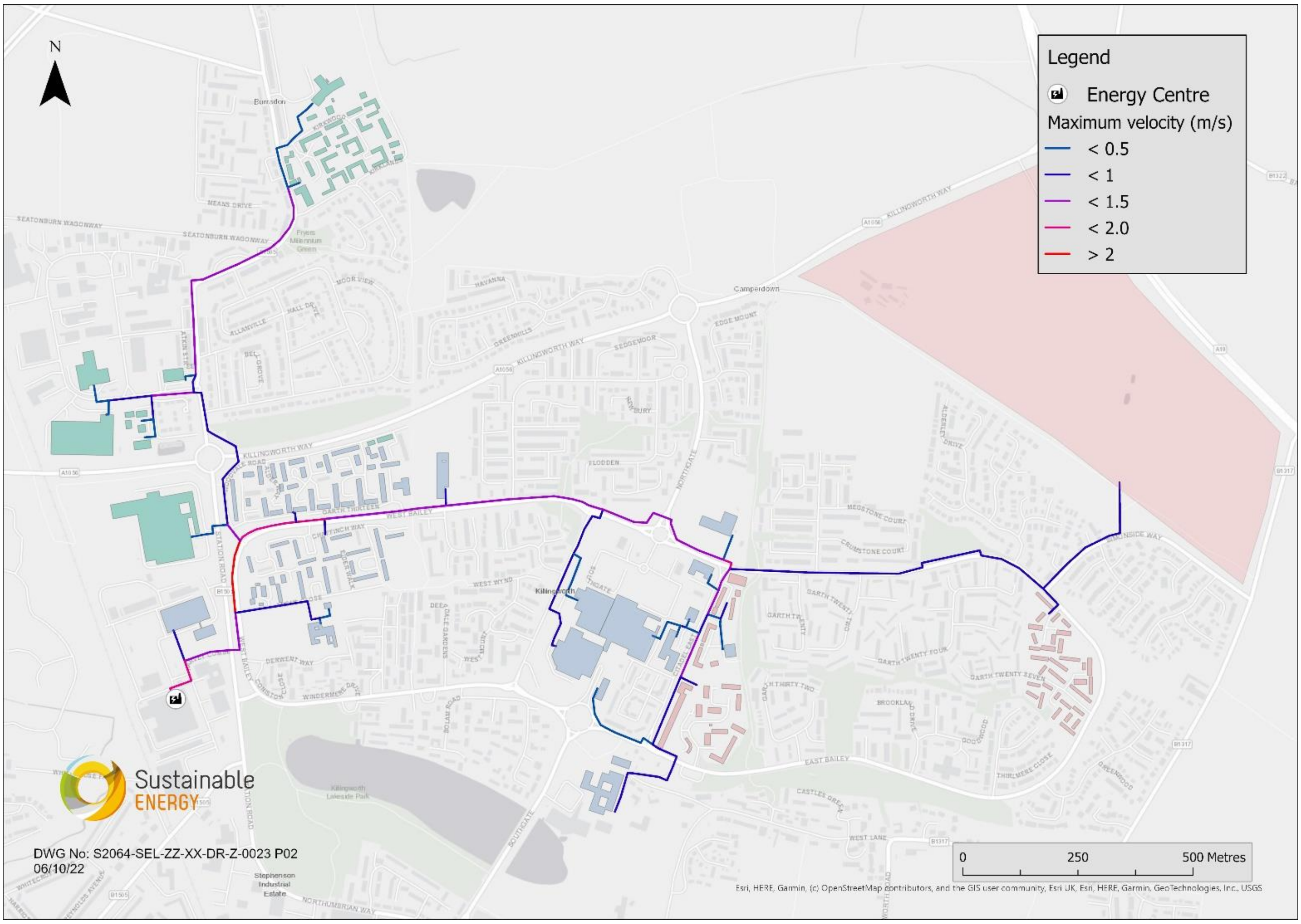

Figure 47: Pipe velocity under diversified load conditions

7.4.5 Network Costing

Factors considered when costing the network include dig conditions, percentage of straight or curved pipework, number of elbows, joints etc. Additional cost elements such as traffic management and avoiding utilities were added to sections of the network where appropriate.

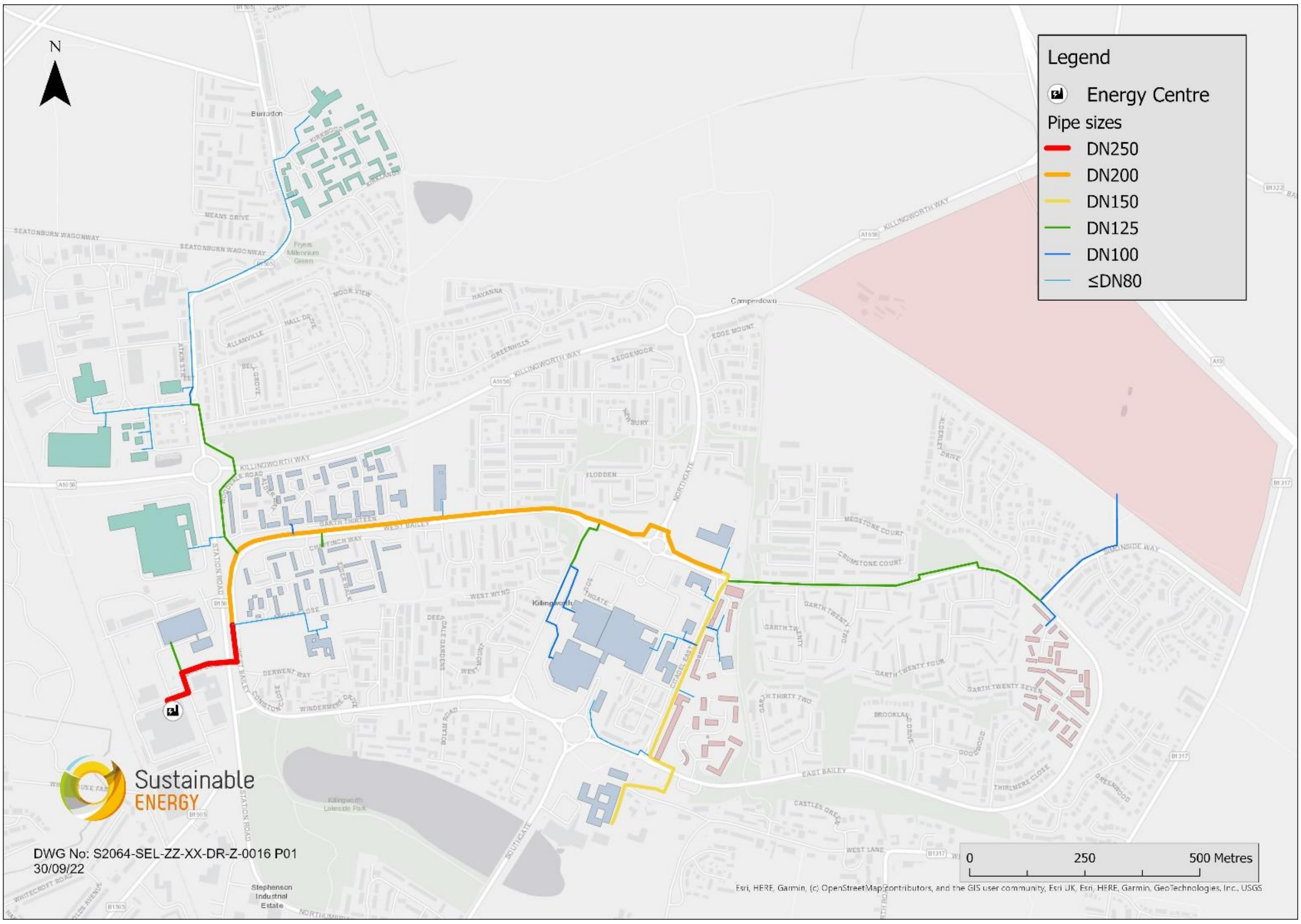

Figure 48: Example of optimised network sizing

8 TECHNO-ECONOMIC MODELLING

A TEM has been constructed to assess the economics of the prioritised heat pump network option. The key assumptions for the TEM and key parameters are shown in Appendix 6: Techno Economic Modelling – Key Parameters.

The sensitivity of all key assumptions and energy tariffs has been assessed, see section 10.1. The TEMs provided with this report allows key variables to be revised and the associated impact assessed.

8.1 Model Structure

Figure 49 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. Inputs in these tabs have been input from the SEL technology sizing tool (see Appendix 5: Technology Sizing) and are set for each phase. A user guide and full list of assumptions have also been included in the TEM.

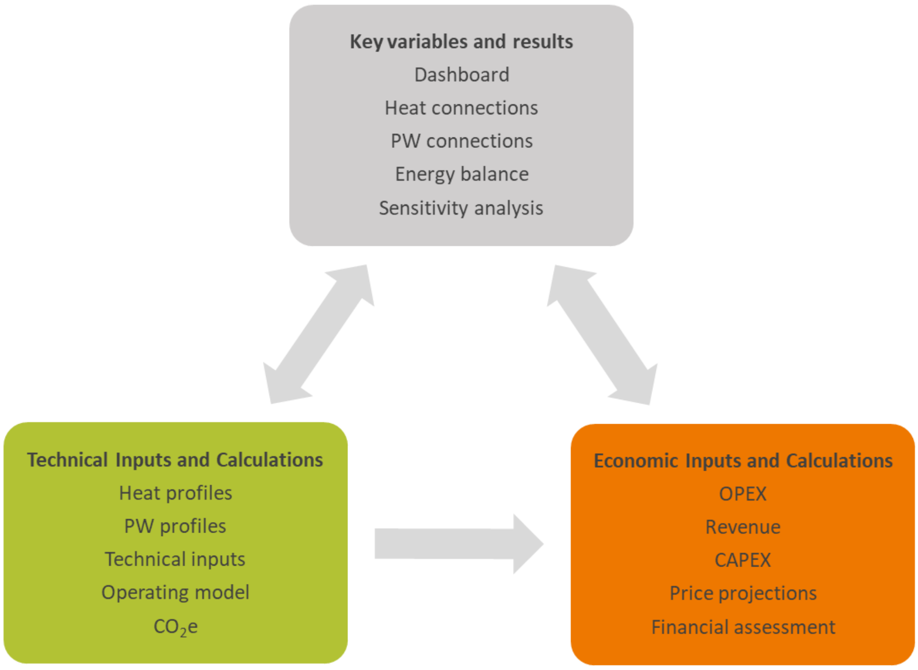

Figure 49: TEM tab structure

8.2 Energy Tariffs

8.2.1 Energy Sales Tariffs

Energy sales tariffs used in economic assessments have been based on heat network energy tariffs used by clients from previous projects for commercial connections. These have been calculated based on the current cost of heat. Tariffs are made up of a variable tariff, daily standing charge and capacity charge. Energy sales tariffs have been set for each individual network connection based on the required connection capacity and annual heat demand and BEIS price projections have been used, as stated in Appendix 3: Key Parameters and Assumptions. These can be varied in the TEM.

8.2.2 Energy Centre Tariffs

Due to current energy crisis and uncertain energy prices gas and electricity purchase tariffs for the energy centre have been based on October 2022 commercial price cap energy tariffs. CCL has been included for all gas required for the peak and reserve boilers and all electricity imported from the national grid. These proposed rates have been used (0.775 p/kWh for electricity and 0.672 p/kWh for natural gas).

8.3 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 expected equipment lifetime and fractional repairs are shown in Appendix 3: Key Parameters and Assumptions.

Capital costs for the scheme are based on a combination of previous project experience, quotations for recent similar works and soft market testing. Soft market testing has been conducted with potential suppliers of plant and equipment.

To develop an accurate estimate of the heat network costs, the proposed network has been broken down into constituent parts (i.e. straight pipe lengths, pipe bends, valves, valve chambers, welds, weld inspections, etc.) for each pipe section. These quantities have then been multiplied by the average rates taken from numerous quotations obtained for similar work. A complexity factor has been added to this to account for the areas of lower implementation or construction complexity and areas of higher complexity such as main roads, key intersections and areas of congested utilities. This value was then assessed against the price provided via specific soft market testing.

Estimated capital costs for key plant items (such as heat pumps, thermal storage tanks, etc.) have been obtained from the respective suppliers.

By using the above methodology, CAPEX estimates are within the tolerance stated in the project requirements and ITT and contingency has been applied to each element of capital expenditure as appropriate. A breakdown of capital costs and contingency values for each phase are shown in Appendix 6: Techno Economic Modelling – Key Parameters.

8.3.1 Connections Cost and Connections Charges

It has been assumed the network operator covers costs of all connections due to the high proportion of council owned sites. A connection charge could be charged to private connections based on avoided costs of installing low carbon heating which would improve network economics. Connection charges for all planned developments have been included in the base case assessment as the avoided costs of installing individual ASHPs at £8,125 per dwelling.

8.4 BEIS Energy Price Projections

To assess the impact of expected future price changes on the financial outputs, the BEIS central scenario price projections for natural gas and electricity have been used (last updated June 2021). The projected changes in prices for electricity and natural gas for residential, services and industrial is illustrated in Figure 50. The projected price variations have been applied to the energy tariffs calculated as discussed in section 8.2.

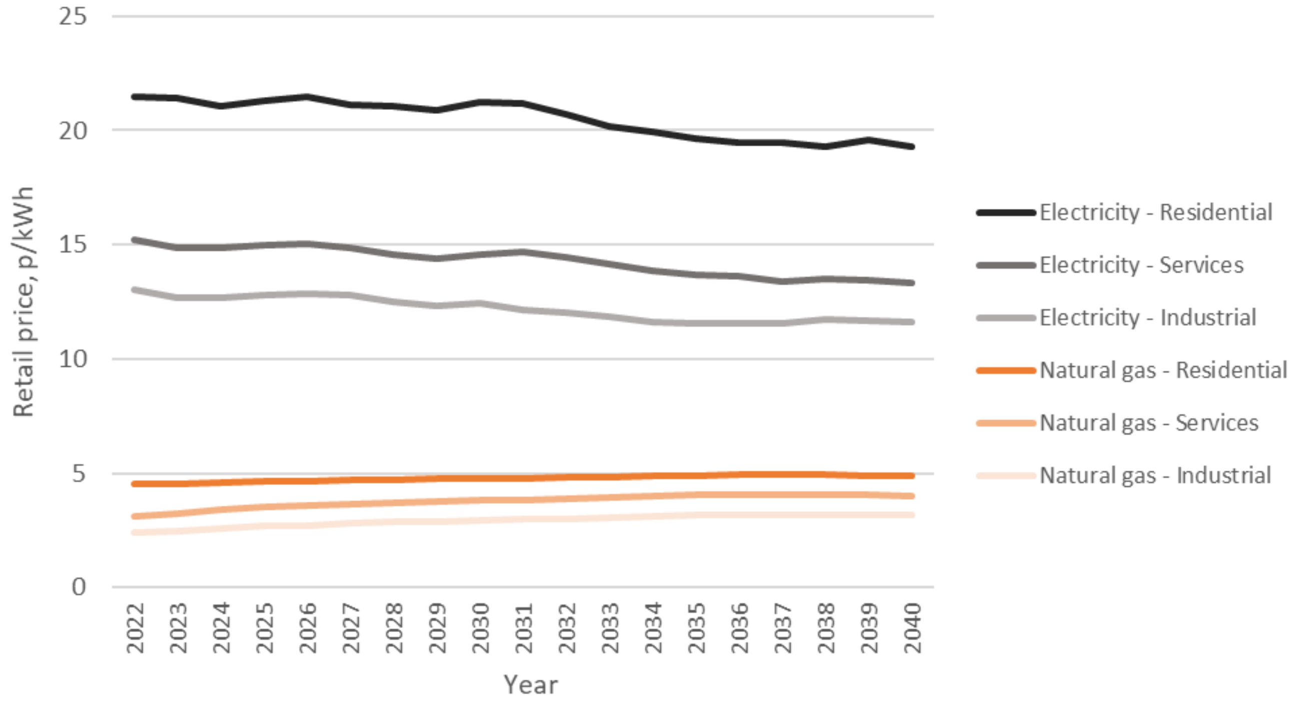

Figure 50: BEIS price projections – central scenario, updated June 2021

The above projections indicate that while both gas and electricity prices are predicted to increase in the short and medium term, in the long term, electricity prices are expected to show a decreasing trend, while gas prices continue to increase. This will result in improved viability of heat from heat pumps. The BEIS low and high scenarios, as well as a fixed indexation rate has also been assessed for the network option and their effect is shown in section 10.1.

8.5 Network Summary

A summary of the network is shown in Table 23. Figures shown give later phases as additional to the previous phase, the total column shows figures for the fully built out network.

Table 23: Network summary

	Phase 1	Phase 2	Phase 3	Total
Network heat demand	10,690 MWh	3,005 MWh	4,884 MWh	18,579 MWh
Network spine trench length	2,572 m	1,206 m	1,103 m	4,880 m
Feed and cluster trench length	6,252 m	3,149 m	10,383 m	19,784 m
Network spine linear heat density	4.2 MWh/m	2.5 MWh/m	4.4 MWh/m	3.8 MWh/m
Network losses	1,113 MWh	450 MWh	1,212 MWh	2,793 MWh
Heat pump capacity	2.51 MW	0.74MW	0.56 MW	3.81 MW
Heat supplied by heat pump	11,707 MWh	3,433 MWh	5,189 MWh	20,329 MWh
Heat supplied by peak and reserve gas boilers	0.308 MWh	0.128 MWh	0.541 MWh	0.977 MWh
% low carbon / renewable heat	97%	97%	95%	95%
Estimated phase start year	2024	2026	2028	-

8.6 Economic Assessment

The 25 year, 30 year and 40 year economic assessments for each phase of the network are shown in Table 24. Detailed breakdown of capital costs and contingency are shown in Appendix 6: Techno Economic Modelling – Key Parameters.

Table 24: Economic assessment

		Phase 1	Phase 2	Phase 3
Capital costs for each phase (including contingency)		£15,054,434	£5,071,053	£5,958,336
Total capital costs (including contingency)			£20,125,487	£26,083,823
25 years	IRR	-0.9%	-1.3%	1.0%
	NPV	-£6,260,120	-£8,665,880	-£5,509,740
	Simple payback	0 years	0 years	23 years
	Net income	-£1,670,049	-£3,062,272	£3,215,703
30 years	IRR	0.2%	-0.1%	2.0%
	NPV	-£5,526,355	-£7,743,173	-£3,928,322
	Simple payback	29 years	0 years	23 years
	Net income	£546,762	-£241,771	£7,868,604
40 years	IRR	1.5%	1.2%	3.0%
	NPV	-£4,406,989	-£6,343,057	-£1,667,671
	Simple payback	31 years	32 years	24 years
	Net income	£4,980,383	£5,388,470	£16,849,271

The capital costs, operational expenditure, revenue, and cumulative cash flow for the full network is shown in Figure 51 for 40 years.

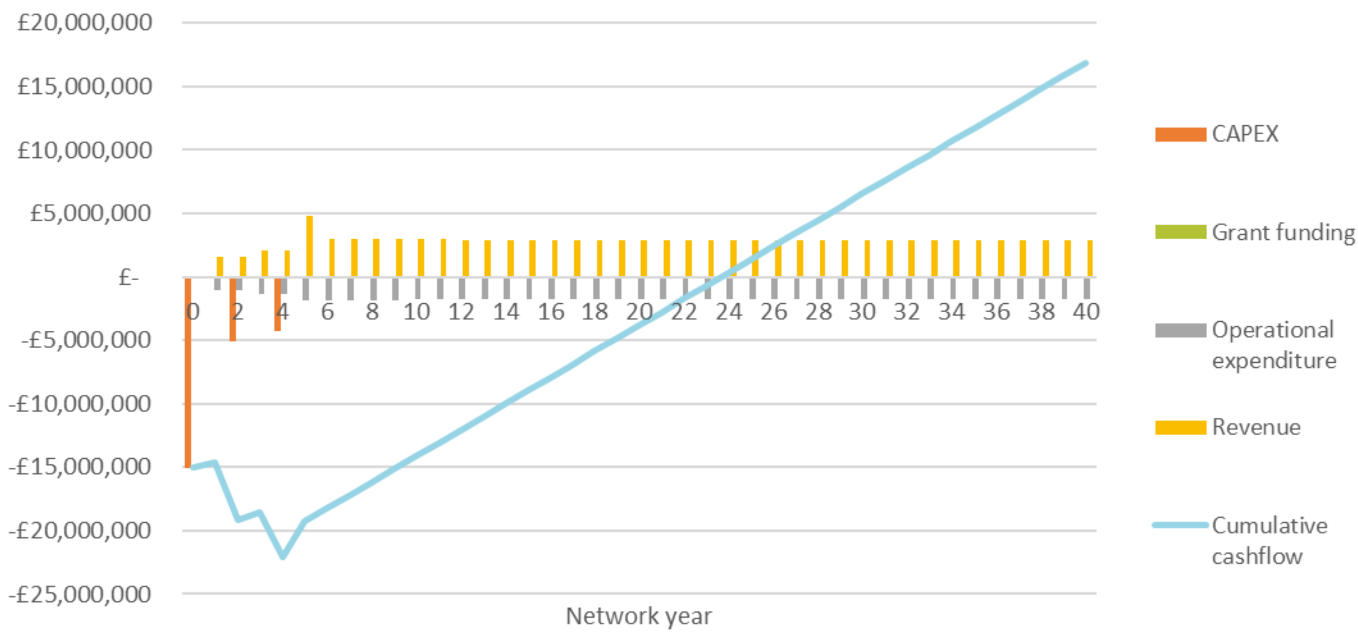

Figure 51: Heat network - cumulative cash flow - 40 years

8.7 Green Network Fund

BEIS provides capital support for heat network developments seeing them as a key part of delivering the UK's legally binding commitment to achieve net zero by 2050. As such they have made capital support available to projects via the Green Heat Network Fund (GHNF) which is launched in April 2022.

GHNF is a £288m fund available to support heat network project with capital grants available to up to but not including 50% of the project capex.

Table 25 shows GHNF criteria and preferred option parameters.

Table 25: Green Heat Network Fund core metrics

Metric	Minimum score	Preferred option
Carbon gate	100 gCO_2e/kWh thermal energy delivered	91 gCO_2e/kWh reached in year 1 of operation
Customer detriment	Domestic and micro-businesses must not be offered a price of heat greater than a low carbon counterfactual for new buildings and a gas/oil counterfactual for existing buildings	Commercial customers and planned development sale tariffs have been calculated using an ASHP counterfactual. Social housing customers heat sale tariffs have been calculated using gas boiler counterfactual.
Social IRR	Projects must demonstrate a Social IRR of 3.5% or greater over a 40-year period	The 40-year social IRR is 6.8% for Phase 1
Minimum demand	For urban networks, a minimum end customer demand of 2GWh/year. For rural networks, a minimum number of 100 dwellings connected	End customer demand is 10.6 GWh/year for Phase 1 and 18.6 GWh/year for the fully built network
Maximum capex	Grant award requested up to but not including 50% of the combined total capex + commercialisation costs (with an upper limit of £1 million for commercialisation)	Grant funding request amount to be determined
Capped award	The total 15-year kWh of heat/cooling forecast to be delivered will not exceed 4.5 pence of grant per kWh delivered (subject to review by GHNF)	The maximum grant funding available according to this metric is £11.4m. The Phase 1, 2 and 3 CAPEX is £26.7m, therefore this limit is will likely be the limiting metric
Non-heat/cooling cost inclusion	For projects including wider energy infrastructure in their application, the value of income generated/costs saved/wider subsidy obtained should be greater than or equal to the costs included.	No non-heat/cooling infrastructure included

The GHNF grant is required to be spent by end of 2025 if a scheme is awarded. Therefore, only Phase 1 is likely to be spent within this period. If the maximum grant funding (49%) is achieved for Phase 1 then the project economics are given in Table 26.

Table 26: Economics assessment with 49% GHNF in Phase 1

		Phase 1	Phase 2	Phase 3
Capital costs for each phase (including contingency)		£15,054,434	£5,071,053	£5,958,336
Total capital costs (including contingency)			£20,125,487	£26,083,823
Grant funding		£7,376,673	-	-
25 years	IRR	4.8%	2.5%	4.7%
	NPV	£1,116,553	-£1,289,207	£1,866,933
	Simple payback	15 years	19 years	16 years
	Net income	£5,706,623	£4,314,401	£10,592,376
30 years	IRR	5.3%	3.3%	5.3%
	NPV	£1,850,318	-£366,501	£3,448,350
	Simple payback	15 years	20 years	16 years
	Net income	£7,923,434	£7,134,902	£15,245,276
40 years	IRR	5.8%	4.0%	5.8%
	NPV	£2,969,684	£1,033,616	£5,709,002
	Simple payback	16 years	21 years	17 years
	Net income	£12,357,056	£12,765,143	£24,225,943

The capital costs, operational expenditure, revenue, and cumulative cash flow for the full network with GHNF funding in Phase 1 is shown in Figure 52 or 40 years.

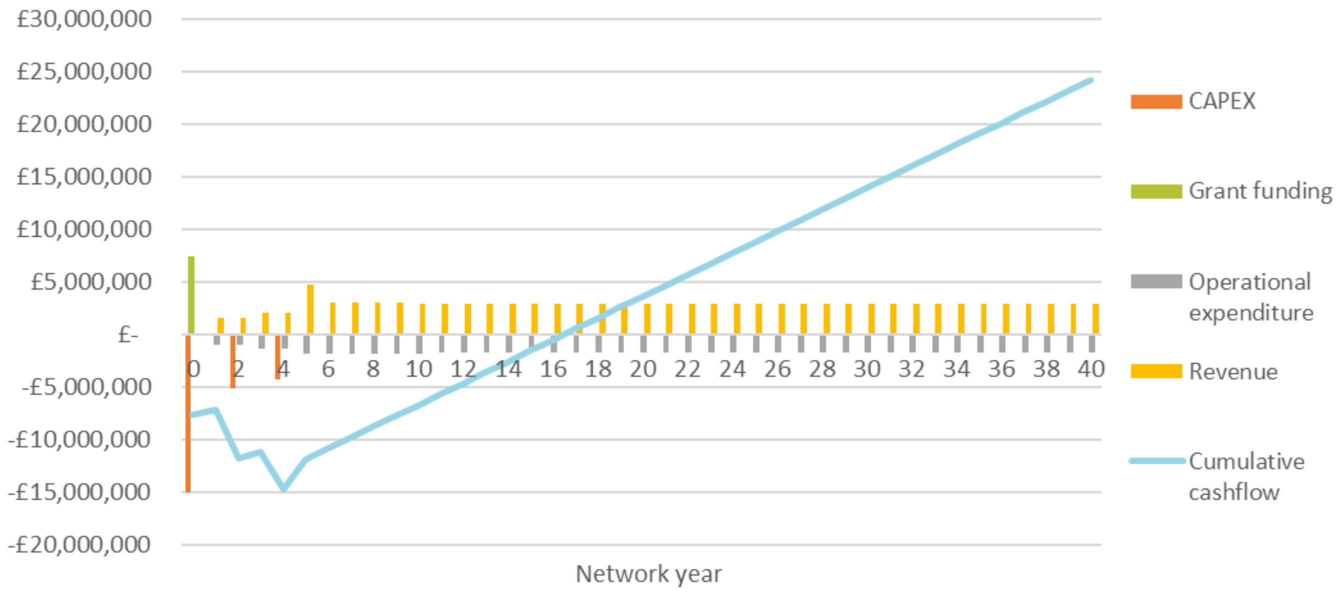

Figure 52: Heat network - cumulative cash flow with GHNF in Phase 1 - 40 years

9 ENVIROMENTAL BENEFITS AND IMPACTS

The following section describes the benefits and impacts associated with the recommended network options. The CO_2e emissions have been assessed annually for each phase for 40 years. This has been compared to the business as usual (BAU) emissions and overall CO_2e savings calculated.

9.1 CO_2e emission assessment

The CO2e emissions have been assessed annually for each network option for 25, 30 and 40 years. This has been compared to the business as usual (BAU) emissions and overall CO_2e savings calculated.

CO2e intensity projections for grid electricity and natural gas are shown in Figure 53. The CO_2e emissions for the electricity grid are expected to reduce over time due to the increase in wind, solar and nuclear power and the closure of coal power stations.

Two CO2e projections for grid electricity have been considered:

- BEIS long run marginal figure (commercial)
- BEIS long run marginal figures (residential)

The BEIS 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. They also give an indication of the impact of the uncertainty around some of these input assumptions. 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.

These figures have been used for all electricity imported from the grid (i.e., for heat pump and energy centre electricity demand).

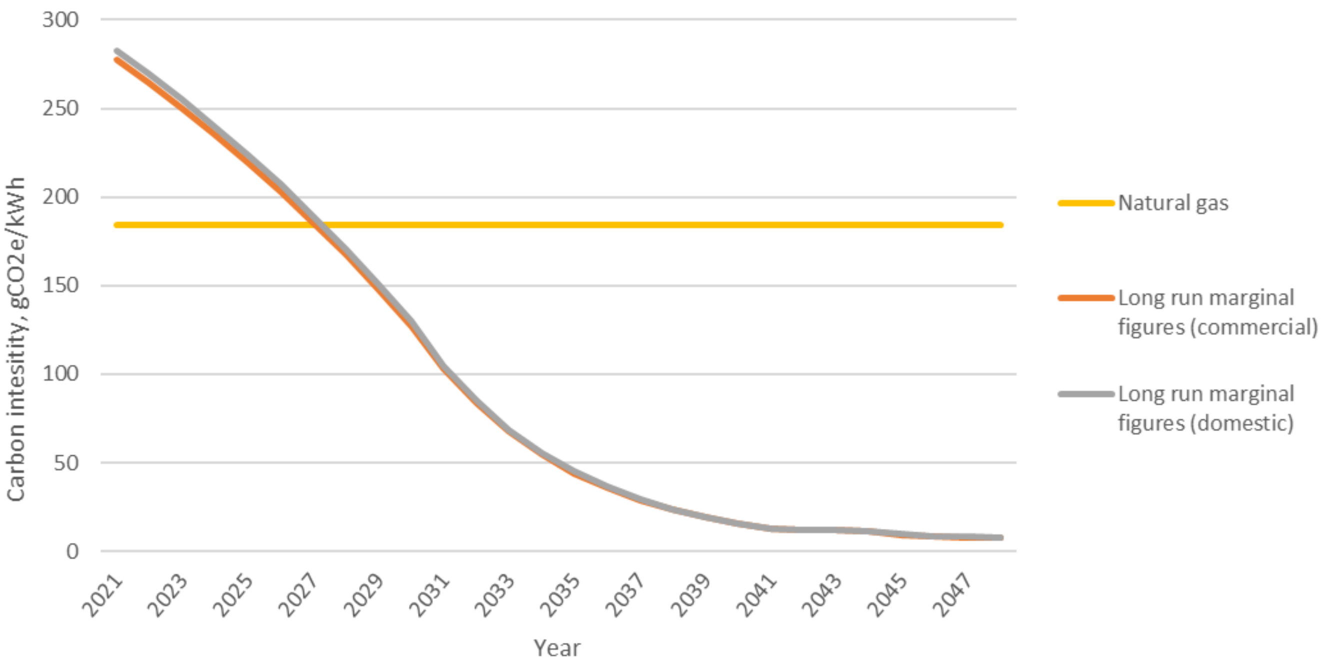

Figure 53: CO2e emissions projections, updated June 2021

9.1.1 Network emission

Individual gas boilers have been assessed as the carbon emissions base case BAU for the network. BAU CO_2e emissions, network CO_2e emissions and CO_2e savings for the network are shown in Figure 54 and Table 27. The yellow line shows the difference between CO_2e emissions in the BAU emissions and the network emissions. The BAU emissions remain constant due to the constant natural gas emissions factor used in assessments and only increases with the increase in heat demand with each network phase. The network emissions reduce marginally over time as the grid decarbonises. Carbon savings compared with individual ASHP would be negative as network distribution losses are avoided.

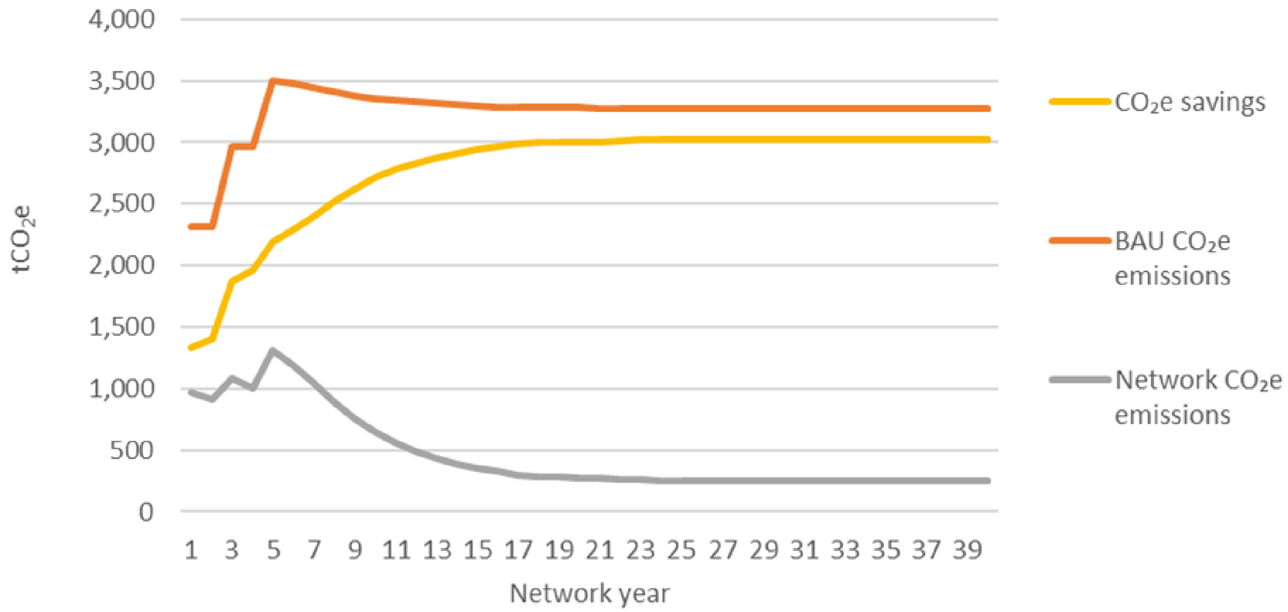

Figure 54: Network CO_2e emissions and savings – 40 years

Table 27: Network CO_2e emissions and savings

		Phase 1	Phase 2	Phase 3
25 years	Network CO_2e emissions, tCO_2e	8,706	10,745	14,633
	CO_2e savings against BAU, tCO_2e	49,106	62,017	66,195
30 years	Network CO_2e emissions, tCO_2e	9,155	11,357	15,815
	CO_2e savings against BAU, tCO_2e	60,220	76,217	81,016
40 years	Network CO_2e emissions, tCO_2e	10,050	12,581	18,176
	CO_2e savings against BAU, tCO_2e	82,449	104,618	111,372
Annual CO2e savings (year 1), tCO_2e		1,338 tCO_2e		
CO2e intensity of heat delivered (year 1), gCO_2e/kWh		91 gCO_2e/kWh		
CO2e intensity of heat delivered (40-year average), gCO_2e/kWh		23.5	23.9	27.3

The CO_2e intensity of heat delivered in the first year of network operation (91 gCO_2e/kWh) is significantly lower than the SBEM/SAP (2012) figure for notional building connected to a district heat network of 190 $g/CO_2e/kWh$, proposed 350 gCO_2e /kWh threshold for existing network in the Part L 2022 uplift and GHNF criteria of 100 gCO_2e/kWh.

9.2 Air Quality

Gas boilers have been included in the base case, they should be compliant with the Medium Combustion Plant Directive. Gas boilers will be low NOx versions and will run only at peak heat demands and when the heat pumps are not operating. The low carbon technology has been sized to meet >90 % of the network heat demand in wherever possible.

If electric peak and reserve boilers are installed, they will decrease the economic viability of the network due to the increased cost of electricity versus gas and the increased fixed charge based on required capacity (particularly in the short term) and significantly increase risk associated with the resilience and reliability of the centralised heat pumps (if the heat pumps are unavailable for significant periods, the operation electric peak and reserve boilers may be an unacceptable risk for O&M contractors obligated to deliver heat at a specific price).

Dispersion modelling should be conducted at detailed project development (DPD) stage, if a district heating project is progressed with gas boilers, to ensure that any impact is within regulatory limits and meets local air quality objectives (and this information will be fed back into the flue design process). Air dispersion analysis simulates the exhaust gases for each hour and models the dispersion of gases and, where appropriate, particulate emissions (although these are considered negligible for natural gas fuelled plant) over a wide geographical area. The output of the analysis provides concentrations levels of particulates and NOx at specified locations.

9.3 Social IRR and NPV

The environmental benefits to the scheme are determined by monetising the CO_2e savings and the improvements in air quality against the use of individual gas boilers. The economic value of the carbon and air quality improvements are included in the project cashflow to generate a social IRR and NPV, shown in Table 28. The social IRR helps to identify the wider benefits of the scheme for the community and is a vital consideration for local authorities.

Table 28: Social IRR and NPV

		IRR	Social IRR	NPV	Social NPV
Phase 1	25 years	-0.88%	5.37%	-£6,260,120	£3,526,262
	30 years	0.23%	6.10%	-£5,526,355	£5,899,748
	40 years	1.47%	6.76%	-£4,406,989	£9,578,615
Phase 2	25 years	-1.25%	5.03%	-£8,665,880	£3,654,185
	30 years	-0.08%	5.81%	-£7,743,173	£6,672,067
	40 years	1.22%	6.51%	-£6,343,057	£11,342,662
Phase 3	25 years	1.05%	7.07%	-£5,509,740	£10,332,865
	30 years	2.03%	7.71%	-£3,928,322	£14,704,179
	40 years	3.02%	8.21%	-£1,667,671	£21,319,552

10 SENSIVITY ANALYSIS, RISK AND ISSUES

10.1 Sensitivity Analysis

Sensitivity analysis has been undertaken for the prioritised network based on the key network risks, parameters, and variables. The base case 40-year IRRs are shown in grey cells in the tables.

Key risks for the network include:

- Capital costs
- Grant funding
- Network heat demand and key sites not connecting
- Energy tariffs including heat sales tariffs, energy centre fuel purchase tariffs and indexation of energy tariffs
- Heat pump SPF

10.1.1 Capital Cost

The effect of a variance in capital costs is shown in Figure 55 for each network phase. A decrease in capital costs of approximately 9% would be required for Phase 1 to achieve a positive 40-year IRR.

A cost of £2,000 per m^2 (£2,300 with contingency) has been used for the energy centre building and assumes an industrial unit standard building specification. Should the Phase 1 energy centre be designed to a higher specification with additional architectural design, the costs could increase as high as £4,000 per m^2 (not including contingency). This would increase the overall CAPEX by 10.2% and result in a 40-year IRR of 0.9%.

Figure 55 shows the 40-year IRR for each network phase

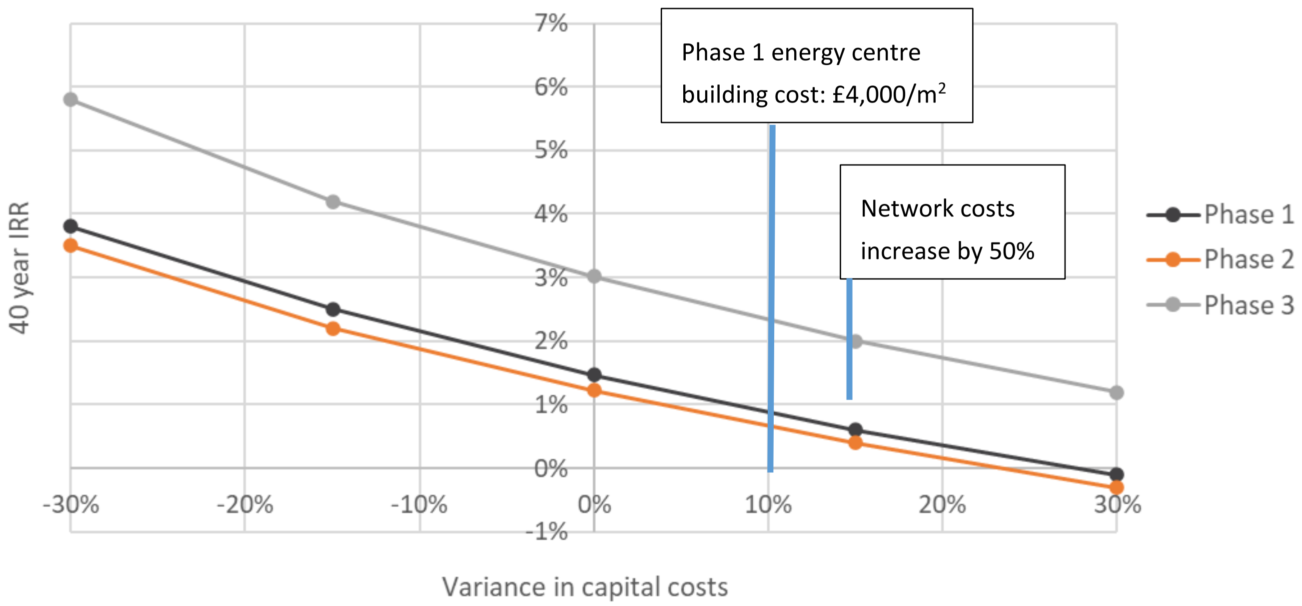

Figure 55: Variance in capital costs

Generation and Supply CAPEX

Table 29 shows the effect of an increase of generation and supply CAPEX, this would result in a significant impact on the 40-year IRR.

Table 29: Effect of an increase in generation and supply technology CAPEX on Phase 1

Generation and supply CAPEX scenario (before contingency)	CAPEX (including contingency)	Phase 1 40-year IRR
15% decrease	£14,822,939	1.5 %
Base case	£15,054,434	1.5 %
15% increase	£15,285,929	1.4 %

Network CAPEX

Table 30 shows the effect of an increase network CAPEX, this would result in a significant impact on the 40-year IRR.

Table 30: Effect of an increase in network CAPEX

Network CAPEX scenario (before contingency)	Phase 1 CAPEX (incl. contingency)	Phase 1 40-year IRR	Phase 3 40-year IRR
30% decrease	£12,872,400	2.3 %	3.8 %
Base case	£15,054,434	1.5 %	3.0 %
10% increase	£15,781,779	1.2 %	2.8 %
30% increase	£17,236,468	0.8 %	2.4 %
50% increase	£18,691,157	0.3 %	2.0 %

10.1.2 Green Heat Network Fund

Figure 56 shows that the maximum available grant (49%) achieves a Phase 1 40-year IRR of 5.9%. This is with grant funding only applied to the capital spend in Phase 1. It assumes the other phases do not receive additional grant funding.

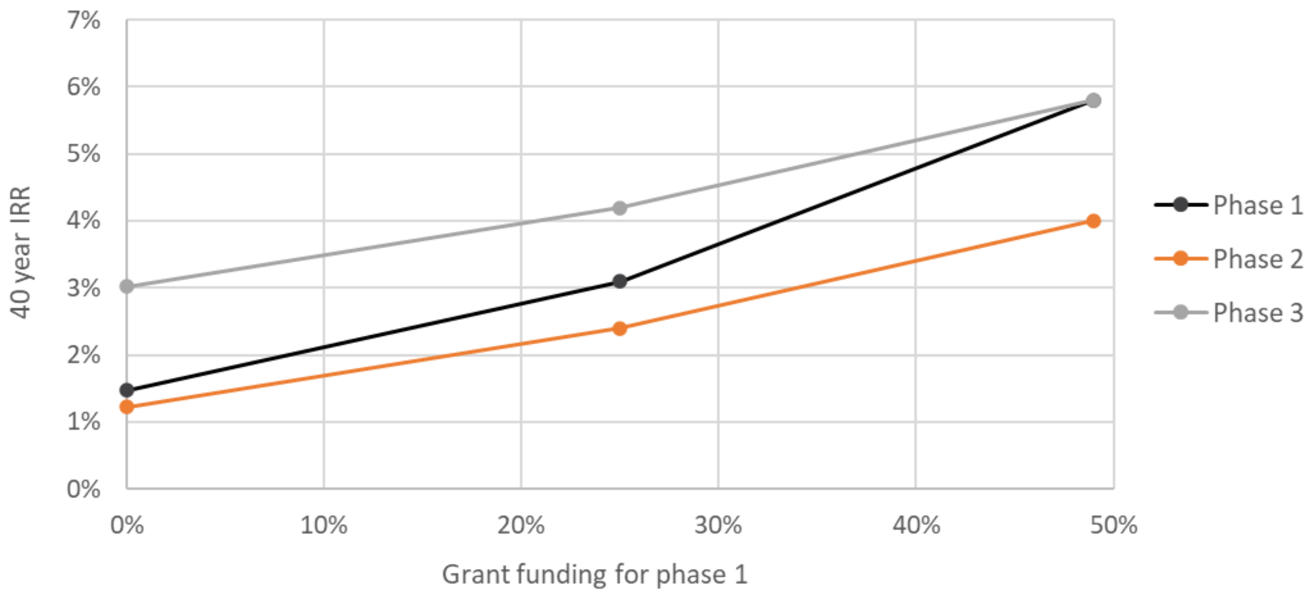

Figure 56: Impact of grant funding on 40-year IRR

10.1.3 Heat Demand

Figure 57 shows the effect of a variance in the total network heat demand for each phase, with all other parameters remaining constant. A reduction in heat demand results in a detrimental reduction in the 40-year IRR, this is due reduction in kWh sold but capital cost remaining constant. An increase in heat demand is shown to have a positive impact on the IRR for all phases. This is due to the heat pump increasing heat output in response to the increased demand and keeping the percentage of heat from the heat pump at a similar level. The cost of heat from the heat pump is cheaper than the gas boilers at the assumed energy input tariffs. It does not consider the installation of additional or larger capacity heat pumps.

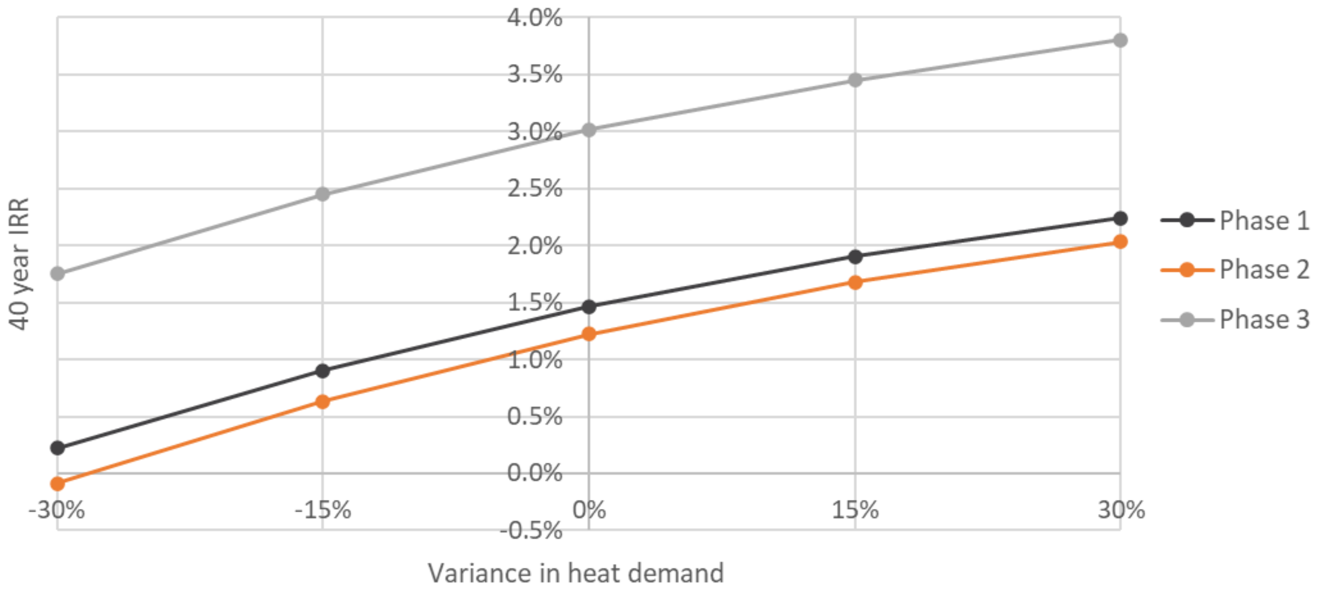

Figure 57: Variance in heat demand

Table 31 shows the impact of the key buildings not connecting to heat network. If these buildings do not connect, then the network may not be viable. There is a large social housing demand that will negatively affect the network if they are not connected.

Not connecting planned development has a negative effect on the Phase 3 IRR, mainly due to the assumed heat connection fee being lost. Therefore, if the developer is not engaged at an early stage, then it may not be economically viable to proceed with Phase 3 and therefore a large section of social housing will not connect to the network and alternative low carbon heating arrangements for these dwellings will need to be found.

Table 31: Impact of buildings not connecting to the network

Heat demand scenarios	Phase 1 40-year IRR	Phase 2 40-year IRR	Phase 3 40-year IRR
Base case	1.5%	1.2%	3.0%
3 largest non-council connections do not connect to the network (Matalan/Home Bargains, Morrisons, West Rock Newcastle)	-0.1%	-0.2%	2.2%
No social housing connected to the network	-0.7%	-1.1%	1.1%
Planned developments do not connect to network	1.5%	1.2%	0.5%

10.1.4 Energy Tariffs

Energy Centre Gas Tariffs

Figure 58 shows the effect of a variance in gas purchase price for the energy centre. For the base case assessment, a gas tariff of 7.5 p/kWh has been used. It can be seen that energy centre gas tariff has little impact on the 40-year IRR as the scheme uses gas only to supply peak and reserve, therefore it has a very low gas demand. (> 95% of the heat demand is met by low carbon technology).

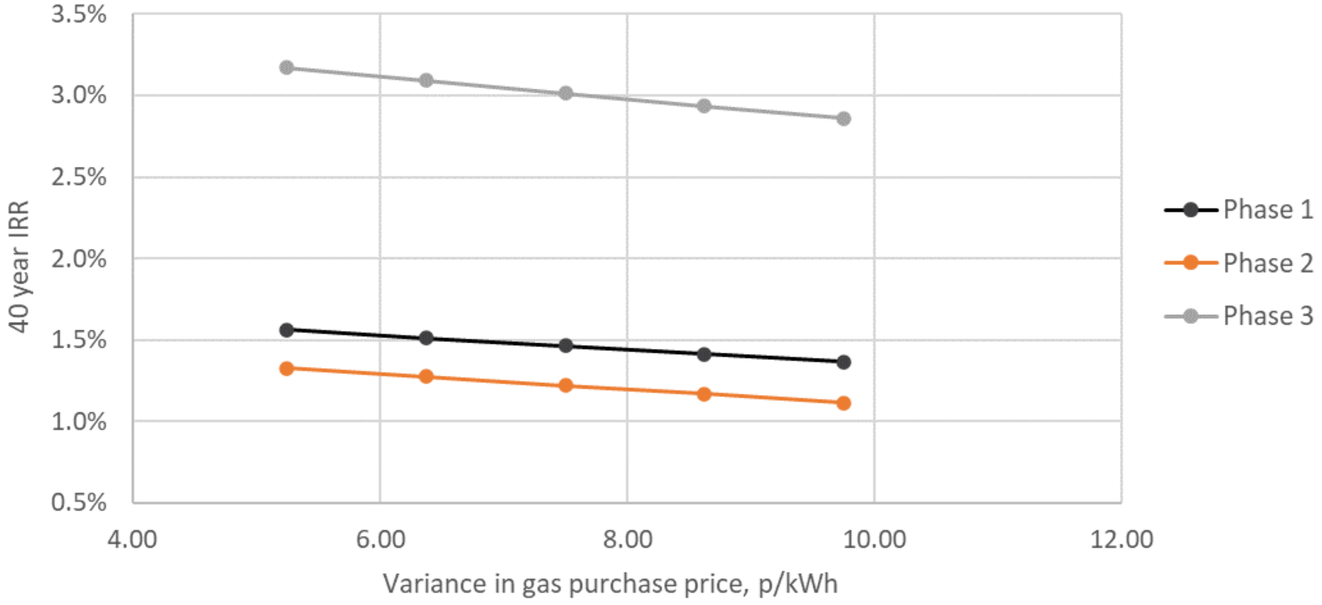

Figure 58: Variance in gas purchase price, p/kWh

Energy Centre Electricity Tariffs

Figure 59 shows the effect of a variance in electricity purchase tariff for the energy centre. For the base case assessment, 21 p/kWh for day and night electricity tariff has been used.

This has a significant effect on the 40-year IRR for all network phases as all the energy centre electricity demand is met by import from the grid and makes up the highest operational expenditure for the network.

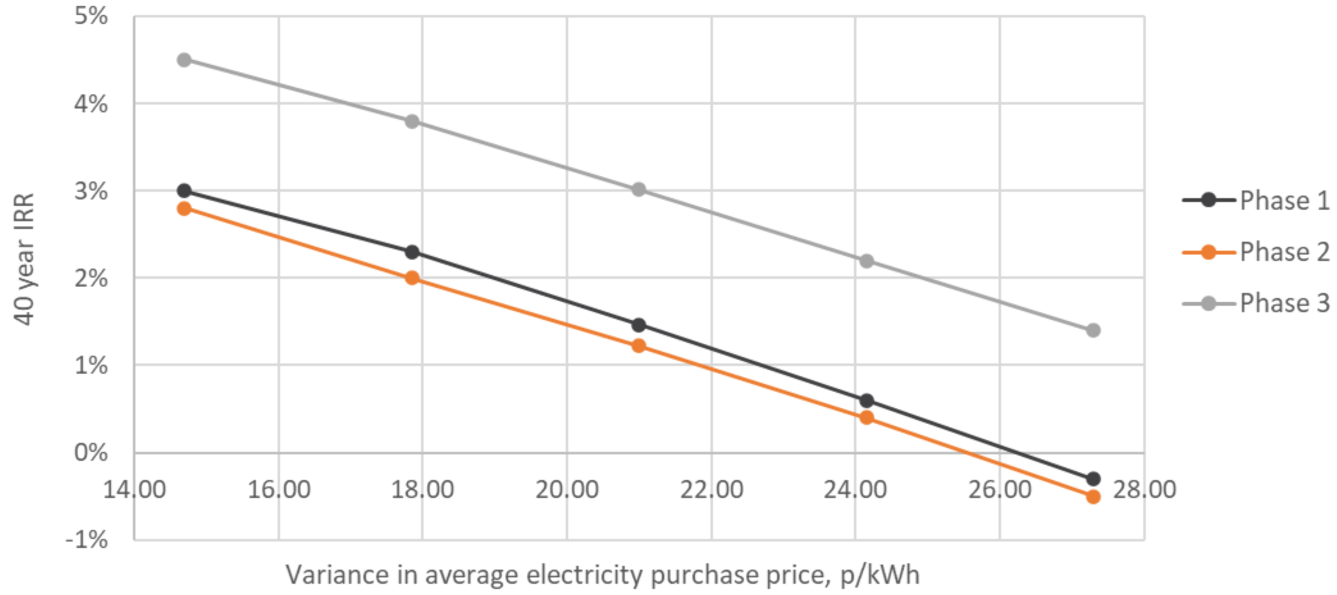

Figure 59: Variance in electricity purchase price, p/kWh

Heat Sales

Figure 60 shows the effect of a variance in heat sales tariff. It has been assumed as a base case that the variable element of the heat sales tariff will vary in line with the cost of electricity (based on the BEIS central scenario price projections for electricity). Heat sales tariffs have been calculated as a 3% saving on an ASHP counterfactual.

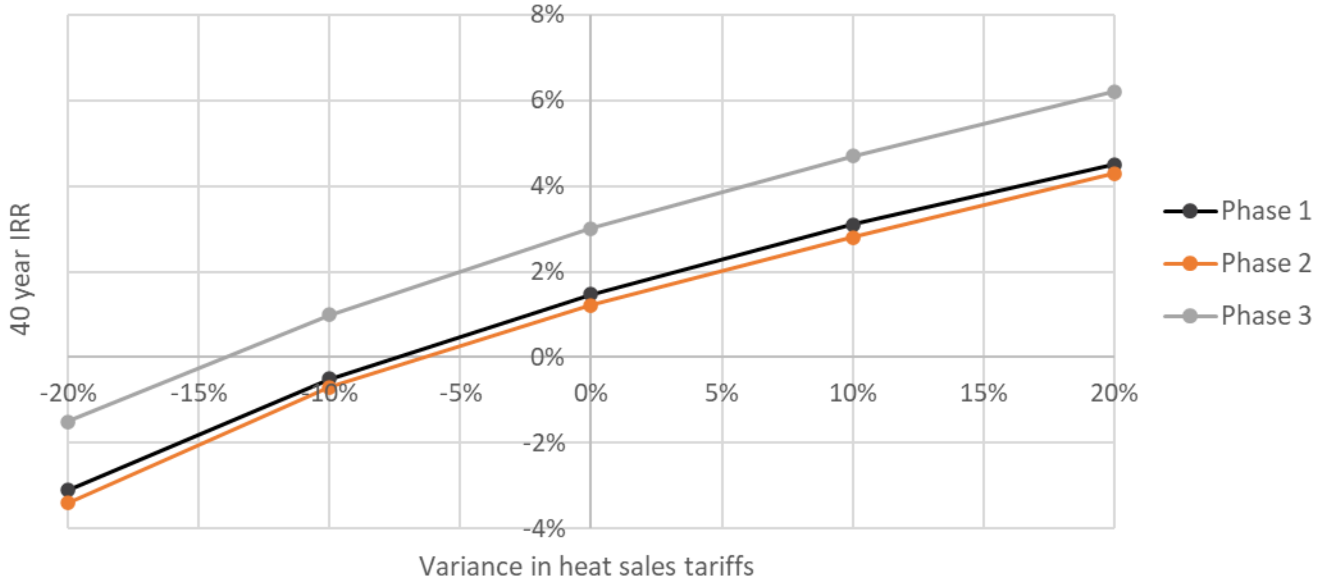

Figure 60: Variance in heat sales tariffs

Energy centre gas tariffs and heat sales

Figure 61 shows the effect of a variance in heat sales tariff and gas purchase price. It has been assumed as a base case that the variable element of the heat sales tariff will vary in line with the cost of gas (based on the BEIS central scenario price projections for natural gas). As only about 3% of the total demand is met by gas, its impact on the 40-year IRR is minimal. As a result, an increase in the heat sales tariff and the price of gas purchased results in a major increase in the IRR due to the increased heat sales and minimal impact of the gas price.

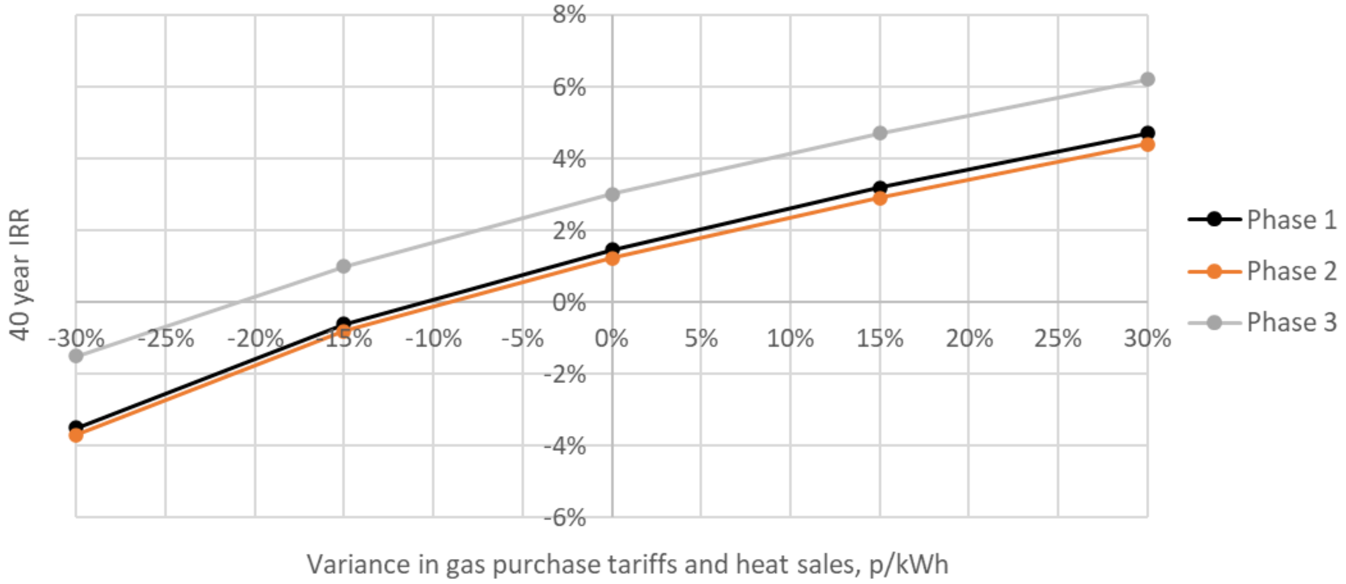

Figure 61: Variance in gas purchase tariffs and heat sales

Energy centre electricity tariffs and heat sales

Figure 62 shows the effect of a variance in heat sales tariff and electricity purchase price. It has been assumed as a base case that the variable element of the heat sales tariff will vary in line with the cost of electricity (based on the BEIS central scenario price projections for electricity). An increase in heat sales and electricity purchase price has a smaller impact on the 40-year IRR than an increase in heat sales and gas price. Due to the fact that the price of electricity is a key variable in determining the viability of the heat network. Therefore, the advantages of the increased heat sale tariff will be diminished when electricity purchase price increases.

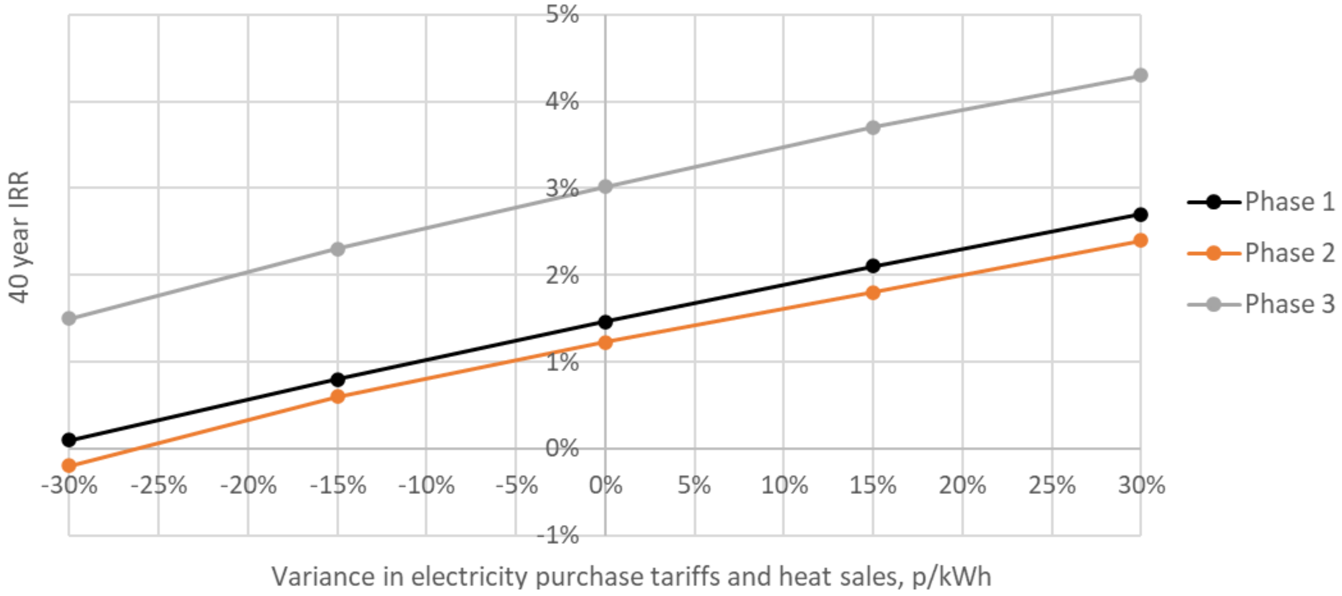

Figure 62: Variance in electricity purchase tariffs and heat sales

Energy Price Indexing

The effect of price indexing on all energy tariffs is shown in Table 32. If tariffs are indexed at a fixed rate, this reduces the 40-year IRR for all phases.

Table 32: Effect indexing on all energy tariffs

	40-year IRR		
Indexing for energy tariffs	**Phase 1**	**Phase 2**	**Phase 3**
BEIS central scenario	1.5%	1.2%	3.0%
BEIS low scenario	0.8%	0.6%	2.6%
BEIS high scenario	2.2%	1.9%	3.6%
Fixed rate: 0 %	1.3%	1.0%	2.9%
Fixed rate: 2.5 %	1.4%	1.1%	3.0%

Table 33 shows the effect of assuming variable heat sales tariffs only, and fixed and variable tariffs. In the base case, it has been assumed that the heat sales tariff would include a fixed and variable element with the variable tariff fluctuating in line with the BEIS natural gas price projections and the fixed tariff remaining constant. It is recommended that there is a fixed and variable element to the heat sales tariff. Table below shows the importance of the split between fixed and variable tariffs as with variable heat sales tariffs only has a negative effect on the 40- year IRR.

Table 33: Effect of variable and fixed heat sales tariffs

	40 year IRR		
Heat sales tariffs	**Phase 1**	**Phase 2**	**Phase 3**
Fixed and variable heat sales tariffs	1.5%	1.2%	3.0%
Variable heat sales tariffs only	1.3%	1.1%	2.9%

10.1.5 Availability of Heat

In the base case it has been assumed that the heat pumps would operate for 50 weeks of the year. If this was reduced it could have a negative effect on the IRR, carbon intensity and network economics, as shown in Figure 63.

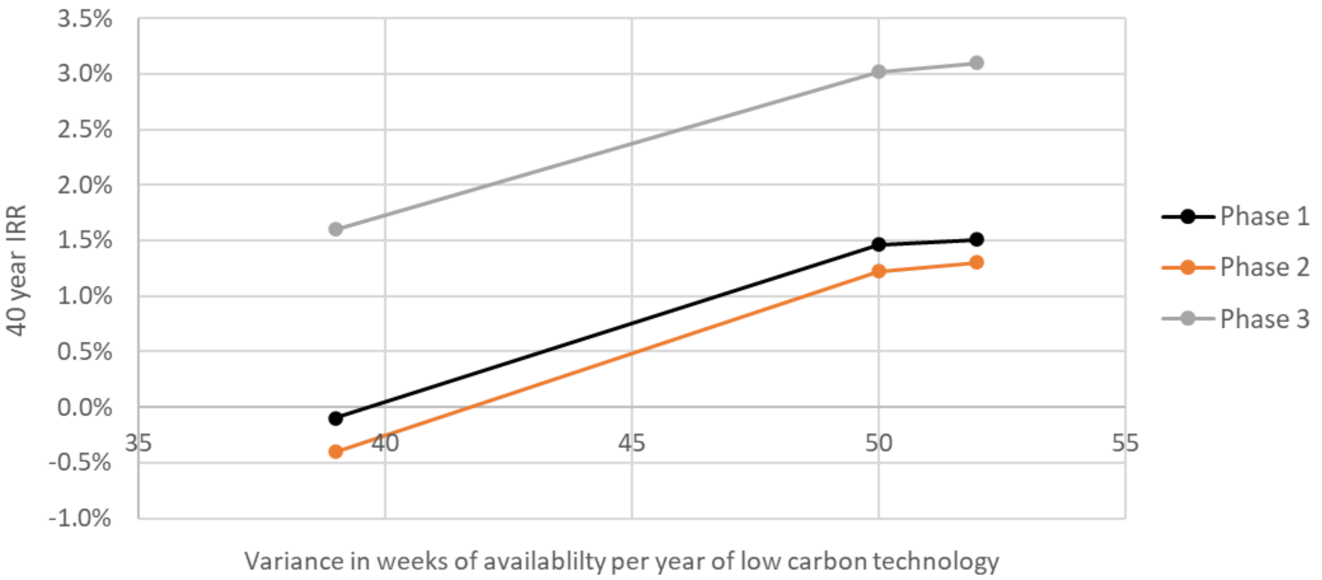

Figure 63: Variance in availability of low carbon technology

10.1.6 Heat Pump SPF_{H2}

Figure 64 shows the effect of variance in the SPF_{H2} of the heat pumps. SPF_{H2} includes electrical input measurements of heat pump and abstraction pumps. If the electricity requirements for abstraction pumps increase, the project IRR will decrease.

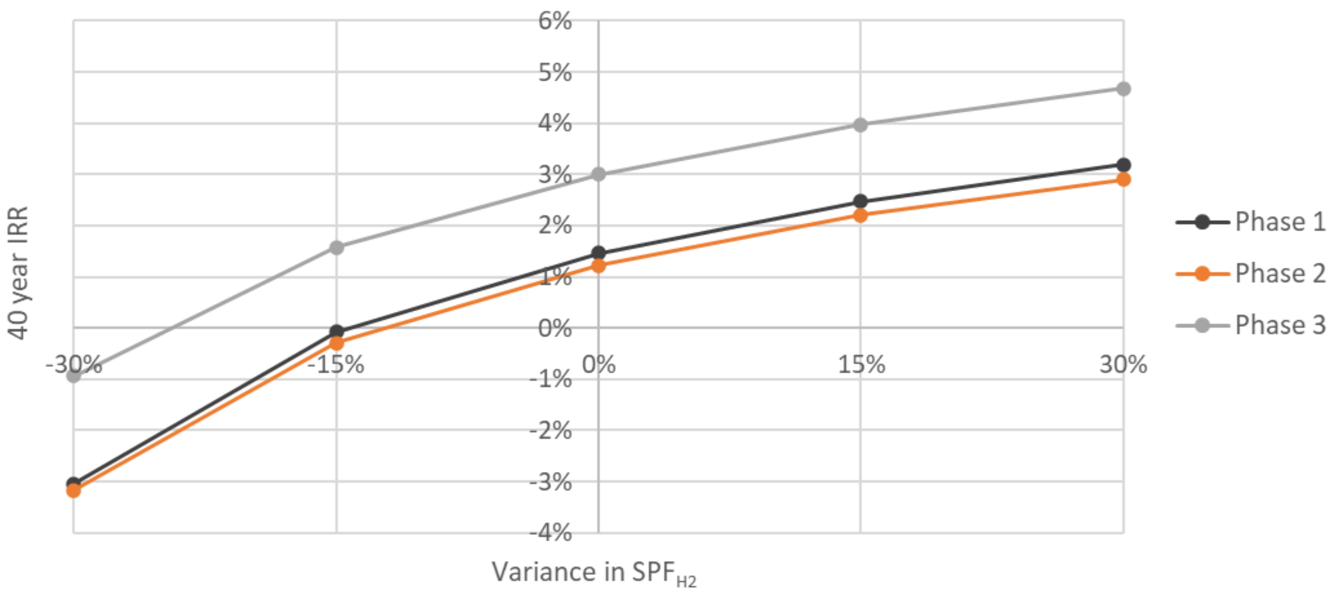

Figure 64: Variance in SPF_{H2}

10.2 Sensitivity Summary

Key sensitivity parameters for the prioritised network areas include:

- Capital costs
- Network heat demand and key sites not connecting
- Energy tariffs including heat sales tariffs, energy centre fuel purchase tariffs and indexation of energy tariffs
- Grant funding

10.3 Risk and Issues

The main risks and constraints for the implementation of the proposed district heating network options have been considered and assessed. Table 35 outlines potential risks and issues that apply to all networks including both current risk and re-scored values.

Risk ratings are the product of impact and likelihood. The impact measures how much of an affect the risk being realised would have, and the likelihood is a measure of how probable the risk realisation is. The score associated with current risk is the level of risk present if no further action is taken, and re-scored risk levels are a measure of the risk present once the mitigating measures have been carried out.

A key showing the level of risk is shown in Table 34.

Table 34: 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 35: Summary of risks and issues

	Ref	Risk / issue	Risk rating Impact	Likelihood	Rating	Rationale	Mitigating measure / action
Energy demand assessment	ED1	Heat demands for the planned developments based on high level information.	Risk rating			Heat demands for the planned developments, especially for Phase 3, have been based on high level information that is likely to change as development plans are progressed.	Energy demands for all planned have been calculated based on the most recent information available. Energy demands should be reconsidered as development plans progress. Only Phase 3 has a significant demand from planned developments
			3	4	12		
			Re-scored risk rating				
			3	3	9		
	ED2	Where actual data has not been received heat demands and profiles have been modelled.	Risk rating			Heat demand profiles have a significant impact on technical and financial viability of the proposed network.	The hourly, daily and annual heat demand of the individual buildings has been estimated based on building use, occupancy patterns and local temperature data. The consultant team has a database of hundreds of hourly annual demand profiles for a wide range of building types and these have been adapted to provide an indicative hourly annual heat demand profile for each building.
			4	3	12		
			Re-scored risk rating				
			3	2	6		
	ED3	Potential heat connections do not connect	Risk rating			Heat demand significantly impacts on network viability. If key buildings do not connect, or key planned developments are either not built out, or are built out but do not connect, then this will reduce the viability of network options.	The proposed Phase 1 network has been selected based on the number of stakeholders and potential connection risk. A large proportion of Phase 1 demands are council buildings with a high certainty of connecting. Engagement with key heat demand stakeholders has commenced, continued stakeholder engagement will be required as the project progresses. Sensitivity analysis has been undertaken to show the effect of key sites not connecting to the network.
			4	4	16		
			Re-scored risk rating				
			4	2	8		
	ED4	Build-out rate and developer engagement have a significant impact upon project economics.	Risk rating			Phase 3 of the future network is highly influenced by planned developments.	Effective, continued engagement with developers is essential and the benefits of connecting buildings to a network (and the impact of the timing of these connections) needs to be quantified. Planning policy should be sufficiently robust and requires appropriate developer engagement. Planners should consider the findings of this study to support developer engagement.
			4	4	16		
			Re-scored risk rating				
			4	3	12		

Sustainable ENERGY

Section	Ref	Risk / issue	Risk rating: Impact	Risk rating: Likelihood	Risk rating: Rating	Rationale	Mitigating measure / action
Heat sources and energy centre	EC1	Energy centre design does not allow for connection of potential future heat sources, meaning there is little futureproofing measures	4	4	16	Consideration should be given to futureproofing to ensure the energy centre could connect to a large low carbon heat source.	The current energy centre includes future proofing to allow for expansion to meet the site demand.
		Re-scored risk rating	4	3	12		
Heat sources and energy centre	EC2	Heat pump working fluids require consideration	4	3	12	The network is reliant on a suitable energy centre locations being secured with ease of access to mine water and utilities.	The local authority has identified the Killingworth Depot site as an energy centre location. This site is being partially demolished with no secure plans for other buildings. The Coal authority have also confirmed the potential suitability of the site to abstract mine water. Further work should be undertaken to safeguard the site as an energy centre location.
		Re-scored risk rating	5	2	10		
Heat sources and energy centre	EC3	Securing suitable sites for energy centres.	5	3	15	The network is reliant on a suitable energy centre locations being secured with ease of access to mine water and utilities.	The local authority has identified the Killingworth Depot site as an energy centre location. This site is being partially demolished with no secure plans for other buildings. The Coal authority have also confirmed the potential suitability of the site to abstract mine water. Further work should be undertaken to safeguard the site as an energy centre location.
		Re-scored risk rating	5	2	10		
Heat sources and energy centre	EC4	Utility connections to the energy centre	4	3	12	The required large utility connections pose a technical and economic risk. Likely requirement for electrical infrastructure reinforcement in the area of the energy centres.	Budget quotes have been requested from the DNOs. Where quotes have been received, they have been included in the techno-economic assessment. Where these have not been received a conservative estimate has been included based on similar sites in nearby locations.
		Re-scored risk rating	3	3	9		
Heat sources and energy centre	EC5	The visual and noise impact of the energy centre	5	2	10	The visual impact of the building is unlikely to be significant. Should it be deemed significant, it may increase design costs, or limit the energy centre size.	The energy centre location is in an industrial estate with no residential dwellings or sensitive noise receptors close by.
		Re-scored risk rating					

	Ref	Risk / issue	Risk rating			Rationale	Mitigating measure / action
			Impact	Likelihood	Rating		
		is deemed significant.	5	1	5		
	EC6	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 detailed project development phase 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.
			5	4	20		
			Re-scored risk rating				
			5	2	10		
	EC7	Availability of mine water heat resource.	Risk rating			The heat energy available from the mine water is dependent on the abstraction availability, and water temperatures.	The abstraction availability is unknown at this stage, therefore a high-level assumption has been made and agreed with the Coal Authority. Further work required by the Coal Authority to determine the abstraction availability
			5	4	20		
			Re-scored risk rating				
			5	3	15		
	EC8	Operation of the MWSHP will be negatively impacted by equipment fouling.	Risk rating			The mine water is iron rich and is prone to fouling equipment including heat exchangers and pumps. This will negatively affect operation of the equipment and result in increased maintenance costs and potential breakdown.	Experience of other mine water projects shows increased fouling if the mine water is exposed to air. This system will be fully sealed and should not allow air to enter. The heat exchanger and mine water equipment will be made of corrosion resistant materials. This will be further addressed as part of the developed design.
			5	4	20		
			Re-scored risk rating				
			5	2	10		
Heat network and building connections	N1	Network options presented do not allow connection of additional heat demands.	Risk rating			Consideration has been given to futureproofing to ensure that the network has the capacity to serve potential future network phases and planned developments.	Future potential energy loads have been identified and local plans have been considered. The most up to date planned development details should be used in future project development. Where existing buildings have not been connected (e.g. housing clusters), the network spine design allows for additional buildings.
			3	3	9		
			Re-scored risk rating				
			3	2	6		
	N2	Network construction difficulties	Risk rating			Problems with network construction increase CAPEX and impact project programme.	The main physical barriers, issues and constraints within the study area have been considered and, where possible, avoided during the network prioritisation process. GIS layers and utility maps have been reviewed.
			5	3	15		
			Re-scored risk rating				
			4	2	8		

	Ref	Risk / issue	Risk rating Impact	Likelihood	Rating	Rationale	Mitigating measure / action
	N3	Existing buildings heating system operation having an negative impact on the network operation	Risk rating			Increase peak boilers usage leading to an increase in OPEX and CO_2 emissions.	This has been taken into account when sizing heat generation. Secondary side upgrades included within CAPEX.
			5	4	20		
			Re-scored risk rating				
			4	2	8		
Economic assessment	EA1	Capital costs are significantly higher than estimated.	Risk rating			Sensitivity analysis indicates that the impact of increasing capital costs would be significant for all network phases. If the TEM does not include robust project capital costs of the network, and the likely financial benefits or the financial assessment does not provide sufficient information to secure funding, then the network plan will not progress.	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 a broad knowledge of the actual costs of installing DH schemes including costs for equipment supply and installation, distribution pipe work supply and installation, trench excavation and re-instatement. Sensitivity analysis has been undertaken for network options to show the effect of a variance in capital costs. Contingency has been applied to all items of capital costs.
			5	4	20		
			Re-scored risk rating				
			4	3	12		
	EA2	Developers do not connect building to the network and connection charge revenue is not received	Risk rating			The Phase 1 network is not reliant on connection charges. However future phases include more planned developments. The base case assumes a connection charge for the developers that is lower than the counterfactual option of installing low carbon heat generating technologies.	Effective early engagement with developers is essential and the benefits of connecting new buildings to the network need to be made clear. Planning policy may be implemented to ensure network connection requirement. Creation of Heat Zones
			4	4	16		
			Re-scored risk rating				
			4	2	8		
	EA3	The project will require grant funding	Risk rating			The project has been developed to fully consider grant funding options and the scheme meets the current eligibility criteria for the Green Heat Network Fund (GHNF).	Ensure a robust grant funding bid is submitted.
			5	5	25		
			Re-scored risk rating				
			5	2	10		
	EA4	Phase 1 of the project will	Risk rating			Phase 1 options are likely to be marginally economic as they include futureproofing measures for later network phases.	GHNF provides support with the expectation of additionality and ensuring that Phase 1 is futureproofed for expansion may qualify for support under this
			5	5	25		

	Ref	Risk / issue	Risk rating Impact	 Likelihood	 Rating	Rationale	Mitigating measure / action
		require grant funding.	Re-scored risk rating				condition. Grant funding analysis has been undertaken within the study and can be further revised and updated using the TEM.
			5	3	15		
General	G1	Senior decision makers and elected members 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.	Engagement with senior members is ongoing ensuring key findings from project work to date are understood
			5	3	15		
			Re-scored risk rating				
			5	2	10		
	G2	The Local Authority Planning team is not fully engaged / aware of the study outputs	Risk rating			Planning officers have a key role to play in ensuring the viability of the project. The role of planners in DH is to provide appropriate policy and supporting guidance to developers in the development or extension of networks.	Engagement with planning officers is ongoing and will be further strengthened as the project progresses. It is recommended that the technical and financial work in this study is appropriately re-used to provide an evidence base for planning policy.
			4	3	12		
			Re-scored risk rating				
			4	3	12		
	G3	Planned developments are brought forward prior to network development	Risk rating			Developers may install alternative heating systems within planned developments if DHNs are not in place prior to construction. Alternatively, temporary boilers may be required to serve planned developments until networks are brought forward.	Network phases have been assessed based on information currently available on timing of planned developments. This should be reassessed as networks are progressed and more information on planned developments becomes available.
			4	4	16		
			Re-scored risk rating				
			4	3	12		

11 GOVERNANCE, COMMERCIAL AND PLANNING POLICY CONSIDERATIONS

This section sets out the key considerations for commercial and governance structures to progress a district heat network project in the Killingworth area. North Tyneside Council have several options to consider and these include doing nothing by allowing the scheme to be private sector led, or playing a leading, supporting and facilitating role for any network developments.

NTC-led scheme

If the economics of the scheme do not attract private investment and the project is still to be carried forward, then NTC could play a more active role in the network development. This could either be via direct operation of the network or by setting up a Special Purpose Vehicle (SPV) to own and operate the network. An NTC-led SPV would allow NTC to retain control and ensure project priorities are implemented and potentially provide access to grant funding while allowing flexibility. However, there may be some potential for partnering with private sector stakeholders. Key roles including design, build, operate and maintain will be outsourced.

If the scheme is to be NTC-led then it is likely that a Special Purpose Vehicle (SPV) will need to be set up to operate as an Energy Services Company (ESCo), owning and operating the network. The ESCo will need to contract with specialist companies for the design, build, operation and maintenance of the schemes and, potentially, to sell heat to customers. The ESCo would then be responsible for volume and price risk, however these can be mitigated through diverse customer bases, fixed charge elements, termination notices and indexing of heat sale prices.

BEIS has established a dynamic purchasing system (DPS) for heat networks - the BEIS Heat Investment Vehicle (BHIVE). It will allow public sector heat network owners and developers to procure funding and funding-related services for their heat network projects from a range of potential funding providers. All public sector applicants seeking provisional GHNF awards must notify the BEIS Heat Investment Vehicle (BHIVE) to consider suitability of the project for third party funding and this should be the preferred method for seeking third party finance for such projects. Engagement with BHIVE is required to understand the potential opportunities for third party funding.

BEIS Heat Investment Vehicle – GHNF (tp-heatnetworks.org)

Private sector-led scheme

If the scheme is to be private sector-led, then grant funding is likely to be required and project risks will need to be minimised to allow a private company to take a long-term view on investing in the network. Risk to the private sector company would need to be reduced by:

- Ensuring that every new development connects to a network
- Ensuring all large public sector heat loads connect
- The provision of NTC-owned land for network pipes and generation assets
- Where risk cannot be fully accepted by the private sector party, pre-agreed risk sharing (e.g. demand / revenue guarantees)

As heat networks are becoming a key part of the governments climate change policy more private sector investment is becoming available, and lower rates of return may be acceptable for private sector companies that can take a long term view on the investment.

11.1 Planning Policy

Planning policy can be used to promote and facilitate the development of district heat networks and the NTC planning team has an important role to play in developing and supporting guidance and working with developers. NTC and its planners are critical to the effective development of heat networks in that they:

- Develop the planning policy that sets out requirements for developers to comply with CIBSE/ADE CP1 standards

- Influence financial mechanisms / developer contributions that can support the strategic development of heat networks
- Promote the benefits of the project to developers
- Set out heat priority areas within development plans
- Safeguard network routes and energy centre sites in development plans
- Identify carbon reduction targets for strategic sites in development plans
- Review energy statements and set viability requirements for district heating connection

The findings and recommendations in this study should inform policy, guidance, and developer engagement.

11.1.1 National Policy

The key national policy objectives for district heat networks are:

- National Planning Policy Framework (2012) - promotes sustainable development and encourages local authorities to establish low carbon energy generation schemes
- The future of heating: Meeting the challenge (2013) - heat networks are included as one of five options for building heat infrastructure
- Clean Growth Strategy (2017) – promotes the building and extension of heat networks across the country
- National Policy Statement for Renewable Energy Infrastructure EN-3 – promotes development of new energy infrastructure to deliver a secure, diverse, and affordable energy supply
- UK's 2050 net zero target (2019) – to bring all greenhouse gas emissions to net zero by 2050
- National Planning Policy Framework update (2019) – states that developments should identify opportunities to draw their energy supply from decentralised, renewable, or low carbon energy supply systems
- New Part L (2021) building regulations have been implemented in June 2022 and aims to reduce CO2e emissions of dwellings by 31% compared with current levels – with gas boiler heating:
    - Significant improvement in building fabric
    - 40% ground floor area in solar PV
    - Waste water heat recovery
    - Maximum supply temperatures of 55°C to allow for future low carbon heating
- Future Homes Standard (expected in 2025) aims to reduce CO2e emissions of dwellings by 75-80% compared with current levels
    - Requires low carbon heating (no gas boilers)
    - Slight improvement in building fabric (compared with 2021)
- Heat and Building Strategy (2021) - sets out the government ambition to phase out the sale of gas boilers by 2035
- Consultation: Proposals for heat network zoning (2021) – proposal for central government, local government, industry and local stakeholders to designate areas within which heat networks are the lowest cost, low carbon solution for decarbonising heating

11.1.2 Planning Recommendations

NTC should undertake further corporate actions to promote and enable schemes including:

- Provision of council-owned land for energy centres, substations and pipe routes
- Engagement and support with planning consents and highways activities for networks
- Providing resource and financial assistance to deliver feasibility and design work for the network
- Use the evidence provided in this report to inform planning requirements and engagement activities for specific developments
- Provide resource and financial assistance to deliver project development and design work for the network
- Produce a developer's pack to inform developers of the requirements for their developments to develop/connect to district heating schemes (to include short, medium and long term considerations e.g. the timing of the proposed project)

12 CONCLUSION

The conclusions for the Killingworth Feasibility Update Study are outlined discussed below.

Energy Demand Assessment

The total estimated heat demand for the Killingworth area is 70.4 GWh. Private housing accounts for 61% of this heat demand. However, for the purposes of this study private housing has been discounted as a connection to a heat network as it was assumed that challenges in connecting and engaging individual private dwellings at this stage are too great.

After excluding private dwellings from the network demands, council owned and operated buildings (including social housing) account for 49% of the demand, private sector 35% and planned developments account for 16% of the estimated 27.4 GWh of heat demand. Key heat demands include NTC Killingworth Site, Matalan/Home Bargains and Morrisons in the town centre shopping area.

Actual half hourly gas data was available for all large council sites. No data was received for private commercial connections. Where actual data was not available the energy demand assessment has been performed using high level building information and use type and should be reviewed when such information becomes available.

Energy Supply Assessment

Heat pumps, waste heat, biomass and gas CHP technologies were assessed as options to supply potential heat networks. The key potential source of renewable heat has been identified as mine water for water source heat pumps (WSHPs).

In discussion with North Tyneside Council officers, the preferred energy centre location is the Killingworth Depot site. This is a council owned site adjacent to the Killingworth Site. The site is also ideally located as it sits directly above four potential mine seams.

Network Assessment

The network was assessed over three phases. Phase 1 connections have been assessed as low risk connections, they include existing council buildings, social housing clusters located close to the main network spine and large commercial connections in Killingworth town centre. Phase 2 extends to connect larger connections in the northern industrial site as well as Burradon School and the adjacent social housing cluster. Phase 3 includes long term planned housing development at Killingworth Lane and the high density social housing cluster near to this development.

The DH network will be developed over three phases (see below):

	Phase 1	Phase 2	Phase 3
Network spine length	2,572 m	3,778 m	4,881 m
Total cumulative heat demand, without losses	10,694 MWh	13,699 MWh	18,584 MWh
Total cumulative network heat demand, including losses	11,803 MWh	15,276 MWh	21,372 MWh
Peak heat demand (cumulative), MW	4.6	6.0	7.4
MWSHP capacity (additional), MW	2.51	0.74	0.56
Total heat pump capacity, MW	2.51	3.25	3.81
Peak and reserve boiler capacity, MW	5	6	8
Heat demand met by heat pumps + thermal store, MWh	11,707	15,140	20,329
Heat demand met by peak and reserve boilers, MWh	0.308	0.436	0.977
% heat demand met by low carbon / renewable technology	97%	97%	95%

Killingworth Depot Energy Centre Concept Design

Technology sizing scenarios have been assessed to determine the optimal heat pump and thermal store for each network phase. The optimised solution includes a 2.5 MW mine water heat pump installed at Killingworth Depot in Phase 1, with an additional 0.74 MW mine water heat pump in Phase 2 and 0.56 MW mine water heat pump in Phase 3. 200,000 litres of thermal storage will be installed for Phase 1. The fully built out energy centre requires a land area of approximately 693m^2.

The scheme will also require peak and reserve gas boilers for times of peak demand (e.g. during coldest weather) or when the renewable or low carbon plant is not operational. The peak and reserve boilers would be located within the energy centre.

Scheme CAPEX

Capital costs for the scheme are based on a combination of previous project experience, quotations for recent similar works and soft market testing. Soft market testing has been conducted with potential suppliers of plant and equipment.

A summary of the scheme CAPEX is shown in table below.

	Contingency	CAPEX including contingency			
		Phase 1	Phase 2	Phase 3	Total
Energy centre	10-20%	£5,063,649	£840,053	£545,129	£7,169,966
Network	20%	£7,273,446	£3,011,299	£3,426,123	£13,710,868
Building connections	10-20%	£1,639,142	£873,273	£1,582,229	£4,094,644
Further project development and in construction clients engineer	20%	£1,078,197	£346,428	£404,856	£1,829,481
Total		**£15,054,434**	**£5,071,053**	**£5,958,336**	**£26,083,823**

Economics

The 25-year, 30-year and 40-year economic assessments for each phase of the network are shown in table below.

		Phase 1	Phase 2	Phase 3
Capital costs for each phase (including contingency)		£15,054,434	£5,071,053	£5,958,336
Total capital costs (including contingency)			£20,125,487	£26,083,823
25 years	IRR	-0.9%	-1.3%	1.0%
	NPV	-£6,260,120	-£8,665,880	-£5,509,740
	Simple payback	0 years	0 years	23 years
	Net income	-£1,670,049	-£3,062,272	£3,215,703
30 years	IRR	0.2%	-0.1%	2.0%
	NPV	-£5,526,355	-£7,743,173	-£3,928,322
	Simple payback	29 years	0 years	23 years
	Net income	£546,762	-£241,771	£7,868,604
40 years	IRR	1.5%	1.2%	3.0%
	NPV	-£4,406,989	-£6,343,057	-£1,667,671
	Simple payback	31 years	32 years	24 years
	Net income	£4,980,383	£5,388,470	£16,849,271

The economics of the heat network are marginal and grant funding is likely to be required. This is available through the Green Heat Network Fund for new and existing district heat networks designed to increase the utilisation of low-carbon heat in district heat networks in the UK. There is also potential for regulations and taxation to further disincentivise or ban the use of fossil fuel heating systems.

Key Sensitivities and Risks

Key sensitivity parameters for the prioritised network areas include:

- Capital costs
- Network heat demand and key sites not connecting
- Energy tariffs including heat sales tariffs, energy centre fuel purchase tariffs and indexation of energy tariffs
- Grant funding

Key risks that should be addressed by NTC whenever possible are:

- Securing energy centre site,
- Developing planning policy for new developments requiring to investigate low carbon heating solutions
- Procure Stage 2 Coal Authority report to confirm mine water available flowrates and therefore heat capacities
- Engagement with Northumberland Estates about development at Land Off Killingworth Lane,
- Engagement with GHNF team to fully understand requirements to ensure a robust grant funding bid is submitted

The network is reliant on suitable energy centre locations being secured. The Killingworth Depot energy centre site was highlighted as a priority site for an energy centre by North Tyneside Council officers. Following consultation from the Coal Authority the energy centre site is likely to be a suitable location to abstract and re-inject mine water. However, the available flow rate and temperatures from the mines requires further investigation.

13 NEXT STEPS

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

	Action	Responsibility	Timing: Short term	Timing: Medium term	Timing: Long term
Heat demand	Update energy assessment if further details are known for planned developments or if development plans change	Project team			
EC / heat source	Work with Local Authority planners to safeguard energy centre site				
	Continued engagement with the Coal Authority to develop, technical viability of utilising mine water from the proposed energy centre location, assess other potential locations to utilise mine water and commercial structure of heat supply				
Heat network & connections	Work with Local Authority planners to safeguard network route within development areas				
	Re-assess network phase following further engagement with potential stakeholders				
	Liaise with local highways, structures, and planning and utilities companies to assess any changes and refine network route				
	Further engage with developers to ensure developments are DH ready, including safeguarding network routes and potential energy centre locations				
	Confirmation of network design and installation strategy				
	Once project timeline established, further investigate around peak and reserve boilers required				
Economics	Early engagement with GHNF team				
	Engage with utilities companies to obtain quoted import tariffs for gas and electricity				
	Engage with DNOs to obtain gas and electricity connection costs for the energy centre				
	Establish whether North Tyneside Council can secure funding to support the project in the required timescales				
	Identify suitable commercial structures to implement and operate the scheme				
	Develop financial and commercial information required to apply for GHNF funding (including CAPEX quotes and financial modelling)	Project team			
General	Present the findings of the report to relevant stakeholders including North Tyneside Council senior staff and elected members				
	Once route for progression has been agreed, develop project plan that may include further network design work, initial network procurement, network installation, developed design for energy centre, planning consent process, procurement of energy centre contract, energy centre construction, initial heat on date and network phasing				
	Ensure the technical and economic work undertaken in this study will provide an evidence base for planning policy				

APPENDIX 1: ENERGY DEMAND ASSESSMENT

Table 36: Key energy loads

Building name	Status	Building use	Ownership	Heat Demand, MWh	Source of Data	Electricity Demand, MWh	Source of Data	Included in TEM?
Killingworth Site	Existing	Public buildings	Public sector	1,521.5	Actual data (metered)	1,524.4	Actual data (metered)	Y
West Rock Newcastle	Existing	Industrial	Private sector	444.0	Estimated using data for similar sites	308.6	Estimated using data for similar sites	Y
Vehicle Maintenance Unit - Killingworth Site	Planned development	Industrial	Planned development	7.1	Estimated using data for similar sites	94.7	Estimated using data for similar sites	N
Bailey Green Primary	Existing	Education	Public sector	203.3	Actual data (metered)	109.8	Actual data (metered)	Y
White Swan Centre	Existing	Education	Public sector	858.4	Actual data (metered)	304.1	Actual data (metered)	Y
Silverdale Primary	Existing	Education	Public sector	292.3	Actual data (metered)	91.8	Actual data (metered)	Y
Grasmere	Existing	Education	Public sector	211.5	Actual data (metered)	70.4	Actual data (metered)	Y
Amberley Primary	Existing	Education	Public sector	295.0	Actual data (metered)	97.5	Actual data (metered)	Y
George Stephenson	Existing	Education	Public sector	985.3	Actual data (metered)	435.0	Actual data (metered)	Y
Matalan / Home bargains	Existing	Retail	Private sector	1,277.2	Estimated using data for similar sites	525.9	Estimated using data for similar sites	Y
Killingworth Shopping centre	Existing	Retail	Private sector	169.2	Estimated using data for similar sites	6,562.2	Estimated using data for similar sites	Y
Morrisons	Existing	Retail	Private sector	1,212.4	Estimated using data for similar sites	3,630.1	Estimated using data for similar sites	Y
Morrisons petrol station	Existing	Retail	Private sector	74.1	Estimated using data for similar sites	30.5	Estimated using data for similar sites	N
Telephone Exchange building	Existing	Offices	Private sector	104.8	Estimated using data for similar sites	72.8	Estimated using data for similar sites	Y
Kings Arms	Existing	Hospitality and entertainment	Private sector	231.0	Estimated using data for similar sites	85.8	Estimated using data for similar sites	Y
McDonalds	Existing	Hospitality and entertainment	Private sector	177.4	Estimated using data for similar sites	43.2	Estimated using data for similar sites	N

Building name	Status	Building use	Ownership	Heat Demand, MWh	Source of Data	Electricity Demand, MWh	Source of Data	Included in TEM?
Wellspring Medical Practice	Existing	Healthcare	Private sector	122.9	Estimated using data for similar sites	99.7	Estimated using data for similar sites	Y
KFC	Existing	Hospitality and entertainment	Private sector	96.8	Estimated using data for similar sites	23.5	Estimated using data for similar sites	N
Killingworth Social Club	Existing	Hospitality and entertainment	Private sector	244.0	Estimated using data for similar sites	55.7	Estimated using data for similar sites	Y
N01 social housing	Existing	Residential	Social housing	1,193.4	Estimated using heat demand model	0.0	-	Y
N02 social housing	Existing	Residential	Social housing	1,762.0	Estimated using heat demand model	0.0	-	Y
N03 social housing	Existing	Residential	Social housing	1,635.4	Estimated using heat demand model	0.0	-	N
N01 Private	Existing	Residential	Private housing	1,218.0	Estimated using heat demand model	0.0	-	N
N02 Private	Existing	Residential	Private housing	1,152.0	Estimated using heat demand model	0.0	-	N
N03 Private	Existing	Residential	Private housing	1,167.8	Estimated using heat demand model	0.0	-	N
N04 Private	Existing	Residential	Private housing	1,424.0	Estimated using heat demand model	0.0	-	N
N05 Private	Existing	Residential	Private housing	1,520.9	Estimated using heat demand model	0.0	-	N
N06 Private	Existing	Residential	Private housing	2,322.6	Estimated using heat demand model	0.0	-	N
N07 Private	Existing	Residential	Private housing	965.2	Estimated using heat demand model	0.0	-	N
N08 Private	Existing	Residential	Private housing	4,459.5	Estimated using heat demand model	0.0	-	N
N09 Private	Existing	Residential	Private housing	2,217.8	Estimated using heat demand model	0.0	-	N
Warehouse 2.1 - PaddlePod	Existing	Sports and recreation	Private sector	485.8	Estimated using data for similar sites	196.5	Estimated using data for similar sites	Y
Offices 2.1 - DCS Multiserve & Careline Homecare	Existing	Workshops and warehouses	Private sector	101.9	Estimated using data for similar sites	70.8	Estimated using data for similar sites	Y

Building name	Status	Building use	Ownership	Heat Demand, MWh	Source of Data	Electricity Demand, MWh	Source of Data	Included in TEM?
Warehouses 2.2	Existing	Workshops and warehouses	Private sector	190.0	Estimated using data for similar sites	41.6	Estimated using data for similar sites	N
Fenwick Warehouse	Existing	Workshops and warehouses	Private sector	176.0	Estimated using data for similar sites	139.2	Estimated using data for similar sites	Y
Scania Truck Dealer	Existing	Workshops and warehouses	Private sector	193.7	Estimated using data for similar sites	280.0	Estimated using data for similar sites	N
John Lewis & Partners Delivery Hub	Existing	Workshops and warehouses	Private sector	545.6	Estimated using data for similar sites	548.8	Estimated using data for similar sites	Y
Tyne Pressure Testing	Existing	Workshops and warehouses	Private sector	83.7	Estimated using data for similar sites	613.0	Estimated using data for similar sites	N
ABCA Systems	Existing	Workshops and warehouses	Private sector	36.5	Estimated using data for similar sites	25.4	Estimated using data for similar sites	N
Primal Fitness	Existing	Workshops and warehouses	Private sector	251.0	Estimated using data for similar sites	91.3	Estimated using data for similar sites	N
KD Building Solution Ltd + other shops	Existing	Workshops and warehouses	Private sector	156.6	Estimated using data for similar sites	190.5	Estimated using data for similar sites	N
Turner Workshop site	Existing	Workshops and warehouses	Private sector	19.0	Estimated using data for similar sites	309.3	Estimated using data for similar sites	N
Entek International	Existing	Workshops and warehouses	Private sector	860.9	Estimated using data for similar sites	1,244.3	Estimated using data for similar sites	N
Thomson Bros	Existing	Workshops and warehouses	Private sector	119.0	Estimated using data for similar sites	94.5	Estimated using data for similar sites	N
NGN	Existing	Workshops and warehouses	Private sector	30.5	Estimated using data for similar sites	21.2	Estimated using data for similar sites	N
NBT Group-Vytech Solutions-extra warehouse	Existing	Workshops and warehouses	Private sector	121.2	Estimated using data for similar sites	118.8	Estimated using data for similar sites	N
Mylord Crescent Warehouses (x2) 8,9 Mylord Cres	Existing	Workshops and warehouses	Private sector	48.8	Estimated using data for similar sites	59.4	Estimated using data for similar sites	N
Mylord Crescent Offices (Shiremoor Press + UK Service)	Existing	Workshops and warehouses	Private sector	89.2	Estimated using data for similar sites	62.0	Estimated using data for similar sites	N

Building name	Status	Building use	Ownership	Heat Demand, MWh	Source of Data	Electricity Demand, MWh	Source of Data	Included in TEM?
Killingworth Shed & Summerhouse Centre	Existing	Workshops and warehouses	Private sector	38.7	Estimated using data for similar sites	10.4	Estimated using data for similar sites	N
5d Mylord Cres (DTM Cars?)	Existing	Workshops and warehouses	Private sector	11.3	Estimated using data for similar sites	13.7	Estimated using data for similar sites	N
Ashby House	Existing	Workshops and warehouses	Private sector	9.4	Estimated using data for similar sites	6.5	Estimated using data for similar sites	N
Shield House	Existing	Workshops and warehouses	Private sector	14.1	Estimated using data for similar sites	9.8	Estimated using data for similar sites	N
PA Timber Products	Existing	Workshops and warehouses	Private sector	33.0	Estimated using data for similar sites	40.2	Estimated using data for similar sites	N
Freight air Services	Existing	Workshops and warehouses	Private sector	30.7	Estimated using data for similar sites	21.3	Estimated using data for similar sites	N
Doree Bonner	Existing	Workshops and warehouses	Private sector	86.7	Estimated using data for similar sites	19.0	Estimated using data for similar sites	N
J Dalby & Son	Existing	Workshops and warehouses	Private sector	42.3	Estimated using data for similar sites	51.5	Estimated using data for similar sites	N
Trend House	Existing	Workshops and warehouses	Private sector	159.3	Estimated using data for similar sites	185.2	Estimated using data for similar sites	N
Killingworth Log Cabins	Existing	Workshops and warehouses	Private sector	48.6	Estimated using data for similar sites	10.6	Estimated using data for similar sites	N
8 Locomotion Way	Existing	Workshops and warehouses	Private sector	30.4	Estimated using data for similar sites	21.2	Estimated using data for similar sites	N
Unit 2 Locomotion Way	Existing	Workshops and warehouses	Private sector	87.7	Estimated using data for similar sites	23.6	Estimated using data for similar sites	N
Ed Tech Business Park	Existing	Workshops and warehouses	Private sector	86.8	Estimated using data for similar sites	79.6	Estimated using data for similar sites	N
Unit 1 Locomotion Way	Planned development	Workshops and warehouses	Planned development	98.6	Estimated using data for similar sites	120.0	Estimated using data for similar sites	N
Unit 21 Mylord Cres	Existing	Workshops and warehouses	Private sector	18.9	Estimated using data for similar sites	23.0	Estimated using data for similar sites	N
Metnor House	Existing	Workshops and warehouses	Private sector	176.6	Estimated using data for similar sites	122.7	Estimated using data for similar sites	Y
N201 social housing	Existing	Residential	Social housing	355.7	Estimated using heat demand model	0.0	-	N

Building name	Status	Building use	Ownership	Heat Demand, MWh	Source of Data	Electricity Demand, MWh	Source of Data	Included in TEM?
N203 social housing	Existing	Residential	Social housing	339.2	Estimated using heat demand model	0.0	-	N
N204 social housing	Existing	Residential	Social housing	845.9	Estimated using heat demand model	0.0	-	Y
N201 Private	Existing	Residential	Private housing	4,374.3	Estimated using heat demand model	0.0	-	N
N202 Private	Existing	Residential	Private housing	1,390.8	Estimated using heat demand model	0.0	-	N
N203 Private	Existing	Residential	Private housing	2,334.4	Estimated using heat demand model	0.0	-	N
N204 Private	Existing	Residential	Private housing	217.6	Estimated using heat demand model	0.0	-	N
N101 social housing	Existing	Residential	Social housing	0.0	Estimated using heat demand model	0.0	-	N
N102 social housing	Existing	Residential	Social housing	705.2	Estimated using heat demand model	0.0	-	Y
N103 social housing	Existing	Residential	Social housing	546.2	Estimated using heat demand model	0.0	-	N
N104 social housing	Existing	Residential	Social housing	608.4	Estimated using heat demand model	0.0	-	N
N105 social housing	Existing	Residential	Social housing	579.4	Estimated using heat demand model	0.0	-	N
N106 social housing	Existing	Residential	Social housing	678.8	Estimated using heat demand model	0.0	-	Y
N107 social housing	Existing	Residential	Social housing	116.2	Estimated using heat demand model	0.0	-	N
N108 social housing	Existing	Residential	Social housing	237.2	Estimated using heat demand model	0.0	-	N
N110 social housing	Existing	Residential	Social housing	0.0	Estimated using heat demand model	0.0	-	N
N101 Private	Existing	Residential	Private housing	2,349.7	Estimated using heat demand model	0.0	-	N
N102 Private	Existing	Residential	Private housing	813.8	Estimated using heat demand model	0.0	-	N

Building name	Status	Building use	Ownership	Heat Demand, MWh	Source of Data	Electricity Demand, MWh	Source of Data	Included in TEM?
N103 Private	Existing	Residential	Private housing	1,063.3	Estimated using heat demand model	0.0	-	N
N104 Private	Existing	Residential	Private housing	1,180.3	Estimated using heat demand model	0.0	-	N
N105 Private	Existing	Residential	Private housing	1,546.5	Estimated using heat demand model	0.0	-	N
N106 Private	Existing	Residential	Private housing	933.2	Estimated using heat demand model	0.0	-	N
N107 Private	Existing	Residential	Private housing	938.1	Estimated using heat demand model	0.0	-	N
N108 Private	Existing	Residential	Private housing	1,736.5	Estimated using heat demand model	0.0	-	N
N109 Private	Existing	Residential	Private housing	1,180.1	Estimated using heat demand model	0.0	-	N
N110 Private	Existing	Residential	Private housing	2,783.4	Estimated using heat demand model	0.0	-	N
N111 Private	Existing	Residential	Private housing	2,537.2	Estimated using heat demand model	0.0	-	N
N112 Private	Existing	Residential	Private housing	2,082.0	Estimated using heat demand model	0.0	-	N
Burradon Community Primary School	Existing	Education	Public sector	225.4	Estimated using data for similar sites	85.4	Actual data (metered)	Y
Planned development of Killingworth Lane	Planned development	Residential	Planned development	3,500.3	Estimated using heat demand model	0.0	-	Y

APPENDIX 2: HEAT DEMAND MODELLING METHODOLOGY

Using data provided by the council, we were able to group every residential dwelling in the assessment area into both an age band, and one of five property types: Detached, Semi–detached, End–terrace, Mid–terrace, and Flats. By taking multiple measurements from 3D models, available on Google Earth, we were able to obtain an 'average' Killingworth house for each property type. Dwellings were assigned U–values based on property age which, in combination with average building layouts, allowed us to produce heat demand models for each type of property, and for each age band. U–values were taken from 'The Government's Standard Assessment Procedure (SAP) for Energy Rating of Dwellings' 2012, as show in Table 37.

Table 37: U–values used in heat demand assessment

Type	Assumed U Value (W/m²K)						
	A: 1900–1929	B: 1930–1949	C: 1950–1966	D: 1967–1982	E: 1983–1995	F: Post–1996	G: Pre–1900
Floors	1.2	1.2	1.2	1.2	0.86	0.3	1.2
Walls	0.5	0.5	0.5	0.45	0.35	0.33	0.5
Glazing	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Doors	3.0	3.0	3.0	3.0	3.0	2.0	3.0
Roof	0.3	0.3	0.3	0.3	0.3	0.2	0.3

Table 38 shows the heat demand benchmark figures (kWh/m^2) calculated under consideration of factors such as building layouts, occupancy assumptions, estimated solar gains, and hot water usage, for each type of residential dwelling assessed.

Table 38: Heat demand benchmarks (kWh/m^2)

	Property Type				
Property Age Bracket	**1: Detached**	**2: End–terrace**	**3: Mid – terrace**	**4: Semi–detached**	**5: Flat**
A: 1900–1929	132	140	132	127	44
B: 1930–1949	132	140	132	127	44
C: 1950–1966	132	140	132	127	44
D: 1967–1982	130	139	131	126	43
E: 1983–1995	121	129	123	117	41
F: Post–1996	87	93	88	84	40
G: Pre–1900	*N/A*	140	132	127	*N/A*

A weighted average heat demand benchmark (kWh/m^2) was calculated for each cluster, this was calculated as follows:

$$\Sigma \left(\frac{\textbf{No. of properties of specific type \& age}}{\textbf{Total no. of properties in cluster}}\right) \times (\textbf{kWh}/\textbf{m}^2 \textbf{ for property of specific type \& age})$$

Killingworth area has been split into clusters and differentiated by housing type: social or private. To determine heat demand of each cluster heat demand benchmark developed from heat demand models and floor areas provided by council were used.

Table 39: Heat demand modelling results

Cluster name	Average floor area (m^2)	Average Occupancy (no. of people)	Heat demand benchmark (kWh/m^2)	No. of Properties in cluster	Cluster heat demand (kWh)
N01 – Private	83.10	3.00	152.68	96	1,218,012
N01 – Social	69.95	2.78	134.34	127	1,193,407
N02 – Private	80.88	3.03	184.98	77	1,152,010
N02 – Social	77.46	3.01	234.51	97	1,762,046
N03 – Private	83.66	3.07	104.17	134	1,167,817
N03 – Social	81.61	3.06	215.47	93	1,635,382
N04 – Private	122.42	3.80	143.61	81	1,424,012
N05 – Private	86.76	3.17	132.80	132	1,520,907
N06 – Private	74.89	2.70	120.67	257	2,322,575
N07 – Private	72.10	2.83	152.12	88	965,167
N08 – Private	73.60	2.72	125.97	481	4,459,535
N09 – Private	85.55	3.45	199.41	130	2,217,759
N101 – Private	75.63	3.24	152.30	204	2,349,718
N102 – Private	66.44	2.46	101.23	121	813,790
N102 – Social	61.83	2.09	76.04	150	705,198
N103 – Private	83.60	3.00	153.23	83	1,063,263
N103 – Social	68.17	3.00	157.09	51	546,151
N104 – Private	81.26	3.00	152.89	95	1,180,274
N104 – Social	64.85	3.00	159.01	59	608,410
N105 – Private	84.76	3.00	153.33	119	1,546,510
N105 – Social	78.48	3.00	153.82	48	579,443
N106 – Private	83.28	3.00	153.50	73	933,223
N106 – Social	73.96	3.00	155.57	59	678,845
N107 – Private	79.88	3.28	126.28	93	938,142
N107 – Social	45.62	3.00	169.79	15	116,186
N108 – Private	80.37	3.09	152.16	142	1,736,484
N108 – Social	79.20	2.71	124.78	24	237,184
N109 – Private	61.06	3.15	154.61	125	1,180,056
N110 – Private	83.03	3.56	144.50	232	2,783,408
N111 – Private	101.92	3.94	145.58	171	2,537,194
N112 – Private	110.72	3.85	142.46	132	2,082,046
N201 – Private	80.40	3.00	140.59	387	4,374,290
N201 – Social	68.10	3.00	87.05	60	355,694
N202 - Private	80.43	3.00	140.58	123	1,390,766
N203 – Private	78.42	3.00	141.08	211	2,334,379
N203 – Social	73.59	3.00	85.36	54	339,224
N204 – Private	81.15	3.11	141.14	19	217,613
N204 – Social	62.81	2.25	89.79	150	845,923

APPENDIX 3: KEY PARAMETERS AND ASSUMPTIONS

Energy Tariffs

Energy sales tariffs used in economic assessments have been based on heat network energy tariffs used by clients from previous projects for commercial connections and average domestic tariffs for the area for residential connections. These have been calculated based on the current cost of heat. Tariffs are made up of a variable tariff, daily standing charge and capacity charge. Energy sales tariffs have been set for each individual network connection based on the required connection capacity and annual heat demand and BEIS price projections have been used. These can be varied in the TEM.

An example calculation for the heat sales tariffs used in assessments for commercial sites is shown in Table 40.

Table 40: Example commercial heat sales tariffs calculation with ASHP counterfactual

	Calculation	Value
Annual demand, kWh		1,000,000
Peak heat demand, kW		600
Assumed ASHP capacity (assumed as 2 units at 60% capacity), kW	600 x 60% x 2	720
Estimated annual replacement costs		£23,400
Estimated annual maintenance costs		£15,000
Total annual fixed costs	£23,400 + £15,000	£38,400
Current fixed cost, £/day	**£38,400 / 365**	**£105.21**
Electricity tariff, p/kWh		21
ASHP CoP		2
Current variable cost of heat, p/kWh	**21 / 2.2**	**10.5**

Table 41: Current residential tariffs

Supplier	Gas unit rate, p/kWh	Gas standing charge, p/day	Electricity tariff, p/kWh
Price Cap	10.3	28.49	34.00

Final heat sales tariffs derived based on the counterfactual options, ASHP for commercial buildings and planned development and gas boilers for social housing clusters are shown in Table 42 and Table 43.

Table 42: Heat sales tariffs calculated from cost of heat using low carbon counterfactual (ASHPs)

Site name	Annual heat demand, kWh	Peak heat demand, kW	Estimated total ASHP capacity, kW	ASHP Variable current heat tariff, p/kWh	ASHP Fixed current heat tariff, £/day	Variable heat sales tariff, p/kWh	Fixed heat sales tariff, £/day
Killingworth Site	1,522,164	911	1100	10.89	£ 160.5	10.56	£155.66
West Rock Newcastle	444,520	225	270	10.89	£ 44.5	10.56	£43.12

Site name	Annual heat demand, kWh	Peak heat demand, kW	Estimated total ASHP capacity, kW	ASHP Variable current heat tariff, p/kWh	ASHP Fixed current heat tariff, £/day	Variable heat sales tariff, p/kWh	Fixed heat sales tariff, £/day
Bailey Green Primary	203,337	257	310	10.89	£ 37.9	10.56	£ 36.75
White Swan Centre	859,010	333	400	10.89	£ 72.1	10.56	£69.93
Silverdale Primary	292,794	152	190	10.89	£ 31.4	10.56	£30.42
Grasmere	211,275	282	340	10.89	£ 40.7	10.56	£ 39.46
Amberley Primary	294,865	313	380	10.89	£ 47.3	10.56	£ 45.92
George Stephenson	985,475	1,432	1720	10.89	£193.6	10.56	£187.83
Matalan / Home bargains	1,278,322	584	710	10.89	£ 15.7	10.56	£112.23
Killingworth Shopping centre	169,157	78	100	10.89	£ 18.0	10.56	£17.50
Morrisons	1,213,492	555	670	10.89	£109.5	10.56	£ 106.20
Telephone Exchange	105,290	37	50	10.89	£ 10.4	10.56	£10.10
Kings Arms	231,545	145	180	10.89	£ 28.0	10.56	£27.12
Wellspring Medical Practice	123,404	102	130	10.89	£ 19.0	10.56	£18.42
Killingworth Social Club	244,683	168	240	10.89	£ 31.1	10.56	£ 30.19
Warehouse 2.1 - PaddlePod	486,628	131	120	10.89	£43.6	10.56	£42.33
Offices 2.1 - DCS Multiserve & Careline Homecare	102,513	93	140	10.89	£ 17.2	10.56	£16.68
Fenwick Warehouse	176,677	110	360	10.89	£ 22.1	10.56	£21.43
John Lewis & Partners Delivery Hub	546,316	298	180	10.89	£56.0	10.56	£54.35
Metnor House	177,161	148	240	10.89	£ 25.7	10.56	£24.95
Burradon Community Primary School	225,007	301	370	10.89	£43.7	10.56	£42.36
Planned development of Killingworth Lane	3,500,350	980	1180	13.60	£-	13.19	£ -

Table 43: Heat sales tariffs calculated from cost of heat using gas boiler counterfactual

Site name	Annual heat demand, kWh	Peak heat demand, kW	Gas boiler Variable current heat tariff, p/kWh	Gas boiler Fixed current heat tariff, £/day	Variable heat sales tariff, p/kWh	Fixed heat sales tariff, £/day
N01 social housing	1,193,407	382	12.88	119.69	12.49	116.10

Site name	Annual heat demand, kWh	Peak heat demand, kW	Gas boiler Variable current heat tariff, p/kWh	Gas boiler Fixed current heat tariff, £/day	Variable heat sales tariff, p/kWh	Fixed heat sales tariff, £/day
N02 social housing	1,762,046	581	12.88	91.42	12.49	88.67
N204 social housing	845,923	259	12.88	141.37	12.49	137.12
N102 social housing	705,198	211	12.88	141.37	12.49	137.12
N106 social housing	678,845	269	12.88	55.60	12.49	53.94

Energy Centre Tariffs

Gas and electricity purchase tariffs for the energy centre have been based on current energy tariffs for existing energy centres, identified in previous projects. CCL has been included for all gas (if selected) required for the peak and reserve boilers and all electricity imported from the national grid. These proposed rates have been used (0.775 p/kWh for electricity and 0.672 p/kWh for natural gas).

Key Technology Parameters

Key technology parameters for the network are shown in Table 44. Heat pumps COPs and capacities come from manufacturer performance curves based on the Solid Energy LW252, LW172, LW170 heat pump models. Mine water temperature available was assumed to be 12 °C. The yield of each borehole was assumed to be 60 l/s.

Table 44: Technical inputs

Parameter	Value	Source of data / assumption
SPF_{H1} for heat pump	Various	Varies for each network phase derived from manufacturers performance curves based on the selected heat pump, potential water conditions for the site and required network temperatures.
Availability of heat from heat pump	50 weeks	The base case assessed assumes 2 weeks plant downtime a year. It has been assumed that half the downtime will occur from the first week of January and half the downtime from the first week of July.
Peak and reserve boiler efficiency	90%	Expected efficiency of new gas boilers based on experience of 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 45.

Table 45: Plant and equipment lifetime

Plant / equipment	Lifetime
Heat pumps	20 years
Peak and reserve boilers	30 years
Customer building connections	20 years

Table 46: Energy centre building costs

Energy centre	Cost, £/m^2
693	2,000

BEIS Energy Price Projections

To assess the impact of expected future price changes on the financial outputs, the BEIS central scenario price projections for natural gas and electricity have been used (last updated October 2020). The projected changes in prices for electricity and natural gas for residential, services and industrial is illustrated in Figure 65. The projected price variations have been applied to the energy tariffs calculated as discussed in section 10.1 above.

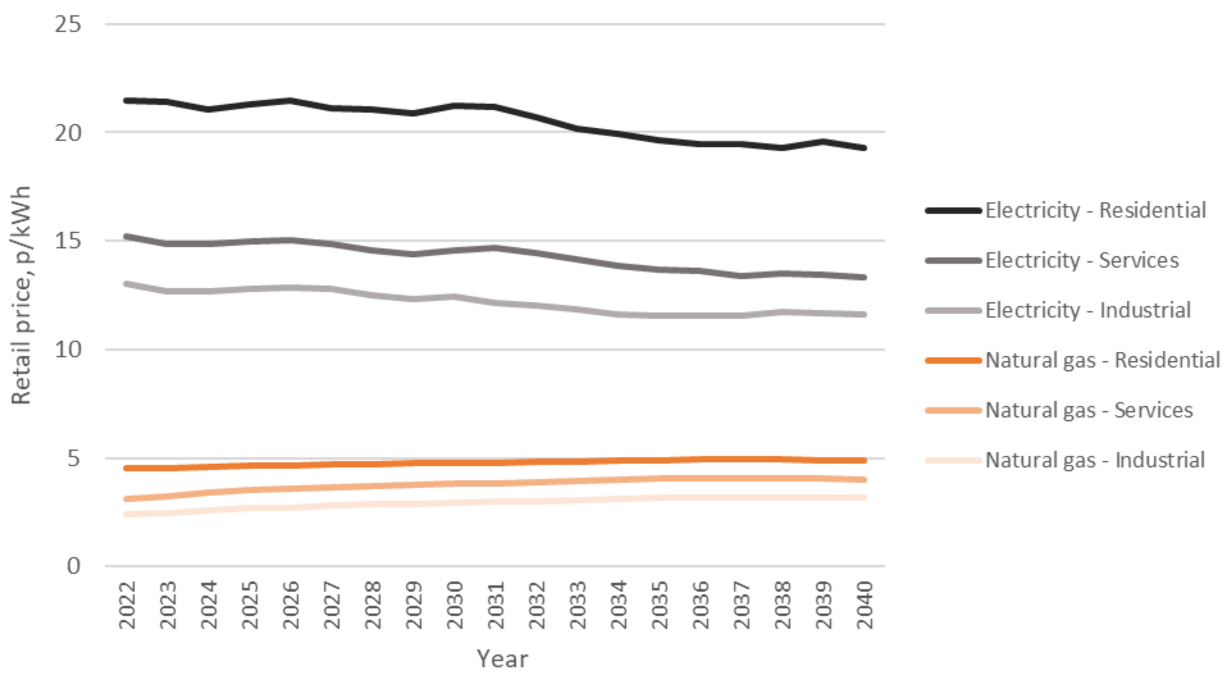

Figure 65: BEIS price projections, updated June 2021

The above projections indicate that while both gas and electricity prices are predicted to increase in the short and medium term, in the long term, electricity prices are expected to show a decreasing trend, while gas prices continue to increase. This will result in improved viability of heat from heat pumps. The BEIS low and high scenarios, as well as a fixed indexation rate has also been assessed for the network option.

The BEIS fossil fuel price projections (central scenario) are shown in Table 47.

Table 47: BEIS fossil fuel price projections

Sector		Units	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Electricity	Industrial	p/kWh	12.4	12.9	13.0	12.7	12.7	12.8	12.9	12.8	12.5	12.3	12.4	12.2	12.0	11.8	11.6	11.5
	Residential	p/kWh	19.2	21.1	21.5	21.4	21.1	21.3	21.5	21.1	21.0	20.9	21.3	21.2	20.7	20.2	19.9	19.6
	Services	p/kWh	14.5	15.0	15.2	14.8	14.9	15.0	15.0	14.9	14.5	14.4	14.6	14.7	14.5	14.1	13.8	13.7
Natural gas	Industrial	p/kWh	2.2	2.3	2.4	2.5	2.6	2.7	2.7	2.8	2.8	2.9	2.9	3.0	3.0	3.1	3.1	3.1
	Residential	p/kWh	4.0	4.3	4.5	4.6	4.6	4.6	4.7	4.7	4.7	4.7	4.8	4.8	4.8	4.8	4.9	4.9
	Services	p/kWh	2.9	3.0	3.1	3.2	3.4	3.5	3.6	3.7	3.7	3.8	3.8	3.8	3.9	3.9	4.0	4.0

CO_2e Emissions Factors

The electricity grid CO_2e emissions figures used in assessments are shown in Table 48.

Table 48: Electricity grid CO_2e emissions

Electricity grid CO_2e emissions, gCO_2e/kWh				Electricity grid CO_2e emissions, gCO_2e/kWh			
Year	LCP marginal	IAG marginal (commercial)	DEFRA average	Year	LCP marginal	IAG marginal (commercial)	DEFRA average
2021	395.4	277.7	282.8	2036	263.8	35.7	36.4
2022	401.9	264.4	269.3	2037	250.0	28.9	29.4
2023	382.8	250.4	255.0	2038	248.9	23.4	23.8
2024	381.1	235.6	240.0	2039	249.5	18.9	19.3
2025	381.2	219.9	224.0	2040	243.4	15.3	15.6
2026	382.0	203.4	207.2	2041	239.3	12.7	12.9
2027	367.9	185.9	189.4	2042	249.0	12.1	12.3
2028	359.2	167.4	170.6	2043	246.9	11.8	12.0
2029	333.8	147.9	150.7	2044	228.7	11.1	11.3
2030	311.9	127.3	129.7	2045	228.7	9.4	9.6
2031	316.1	103.0	104.9	2046	228.7	8.6	8.7
2032	293.0	83.3	84.9	2047	228.7	7.9	8.0
2033	279.5	67.4	68.7	2048	228.7	7.5	7.6
2034	260.0	54.6	55.6	2049	228.7	7.0	7.1
2035	248.3	44.1	45.0	2050	228.7	6.9	7.0

Table 49: Natural gas CO_2e emissions

Parameter	Value
Natural gas CO_2e emissions factor, gCO_2e/kWh	183.9
Average efficiency for BAU gas boilers	80%

APPENDIX 4: NETWORK ASSESSMENT

The pipe routes have been designed to consider pipe length and barriers such as highways and construction limitations.

Pipe lengths, CAPEX and layouts are based on high level information provided and installing pipes in a coordinated manner and connecting houses in line with best practice. The dwellings on the right in Figure 66 and Figure 67 reflect the assumptions used and show shared feed pipes from the road to the front of the dwelling and heat interface units (HIUs) located at the nearest point to the network branches respectively. If this is not achieved, then additional network length will be required as shown in the dwellings on the left in Figure 66 and Figure 67, and CAPEX and network heat losses will increase, which will significantly impact the scheme economics.

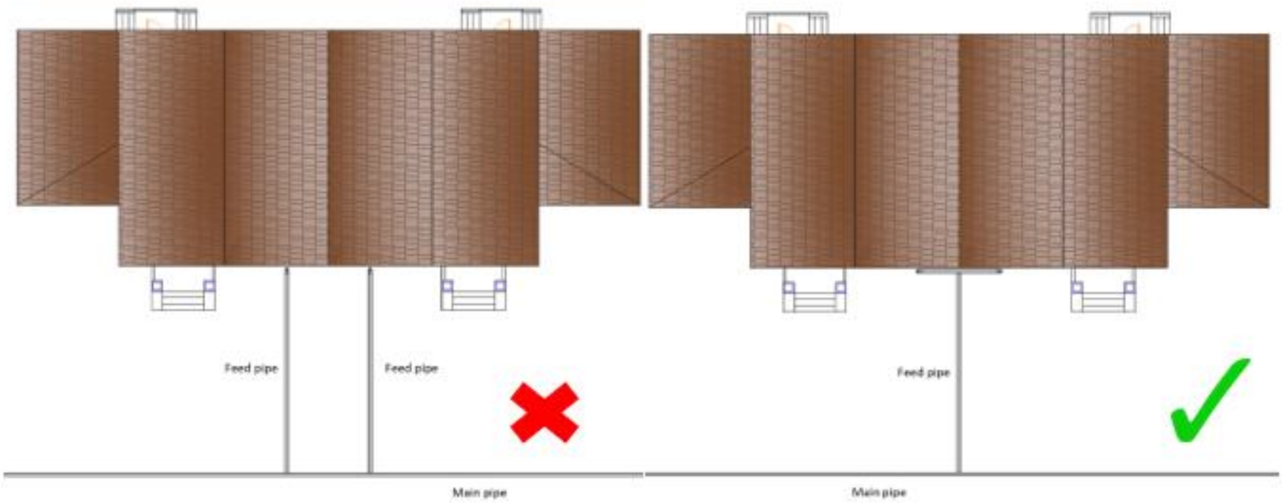

Figure 66: Shared feed pipes to terraced and semi-detached dwellings

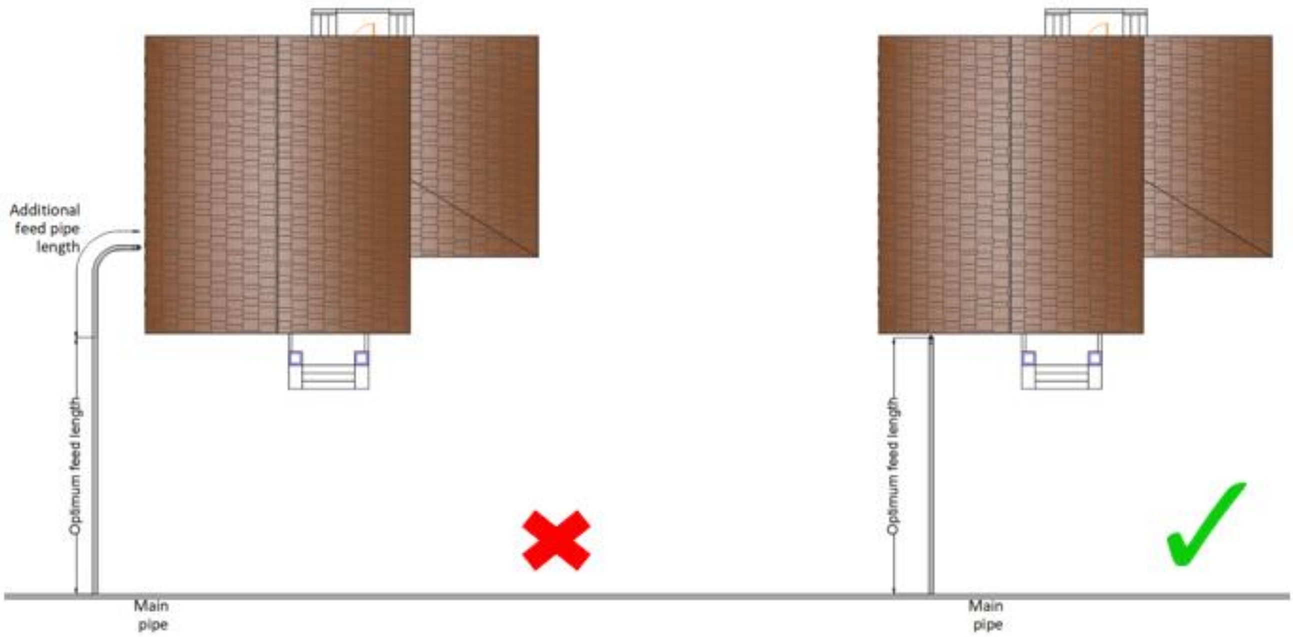

Figure 67: Heat network connection and HIU location

The heat network has been assumed to be a pre-insulated ridged steel pipe system for larger pipe diameters and where possible flexible pre-insulated polymer pipe for smaller diameters. The pre-insulated pipe will either be installed as single pipe (with a separate pipe for the flow and the return) or twin pipe where both the flow and return pipe are housed within the same casing, see Figure 68.

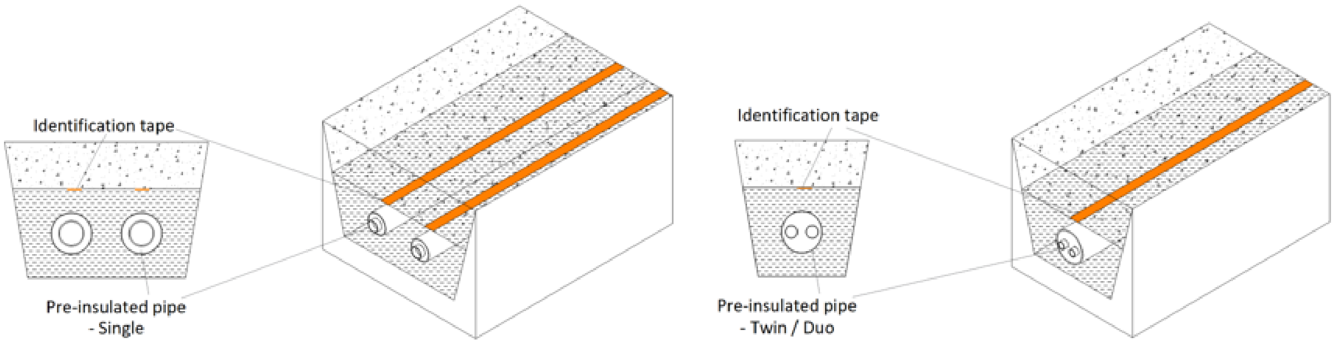

Figure 68: Pipes in trench

Insulation will be CFC free rigid polyurethane foam homogenously filling the space between the service pipe and casing over the total length and in compliance with standard EN 253. The high density polyethylene (HDPE) pipe casing and all fittings and joints will be manufactured in compliance with EN 253 standards. The heat losses and size of trenches for the spine network have been based on a series two insulation thickness of polyurethane foam with diffusion barrier.

Pipework will include a pipe surveillance system in full compliance with BC EN 14419, suitable for both raising alarm of a fault and detecting the location of a fault within all routes of the network. The alarm system will allow provision of outputs to the energy centre control system.

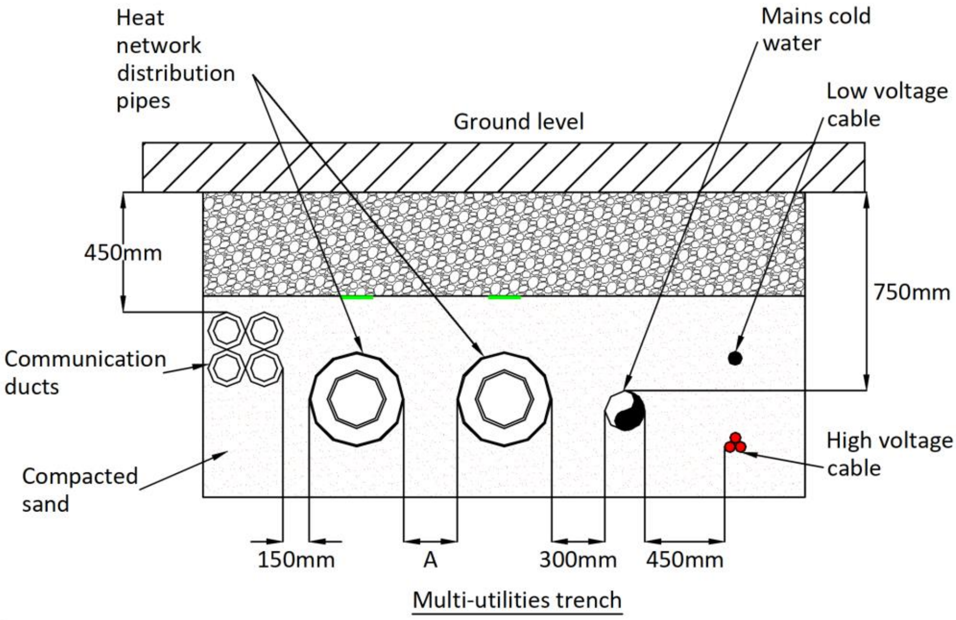

Figure 69: Multi-utilities trench

When multiple utilities are present in a trench it is important to ensure that they are positioned a safe/workable distance from each other. The NJUG Guidance for Buried Utilities outlines how this can be achieved. Figure 69 shows an example of a multi-utility trench.

APPENDIX 5: TECHNOLOGY SIZING

Energy generation technologies are assessed using in house software that has been developed to allow detailed sizing of plant and thermal storage, modelling of operating parameters and conditions, financial assessment, and sensitivity analysis. The software utilises hourly network demands for each day of the year and considers hourly energy outputs from low carbon technologies, thermal storage and peak and reserve plant considering modulation limits, efficiencies and plant down time for maintenance. A range of plant and thermal store sizes and number of units are assessed and optimised to ensure key operating and financial/investment criteria are met.

The tools consider:

- Heat and electricity demand that can be served by the plant (including private wire options)
- Thermal storage - used to supply heat loads below modulation limits or peaks above plant capacity and minimise plant firing e.g. for heat pump, store size will be modelled, optimised and cost/benefit analysis conducted to consider the optimum operating strategy for heat generation
- Supply strategy - consideration of issues such as varying seasonal or diurnal operation, continuous operation, modulated or full output, primary energy source or base load only and peak and reserve plant requirement
- Peak and reserve boiler sizing - according to the diversified peak demand of the various network phases, predicted operating requirements and redundancy
- Peak supply and minimum load - this will consider plant modulation limits and the number of units
- Carbon savings - these will be calculated against the 'business as usual' case and include annual and lifetime savings based on the most up to date BEIS carbon emissions projections

Where heat pumps have been included, these have been sized based on network heat demand and have been maximised to provide the greatest economic and CO_2e savings for the network option and to provide the optimum balance between heat generation capacity, capital cost, maintenance costs and physical size.

The heat pumps and thermal stores have been sized with consideration of the hourly annual network heat demand. Peak and reserve boilers will meet any remaining demand. Technology sizing is based on an iterative process within the technical model to identify the optimal balance of the priorities.

Figure 70 shows an output from our technology sizing tool for the full network served by 3.81 MW heat pump. The load duration curve shows the heat demand for every hour of a year, ordered from highest to lowest. The black line shows the total low carbon and renewable capacity installed in the energy centre. The heat demand above the black line is met by thermal storage and peak and reserve boilers.

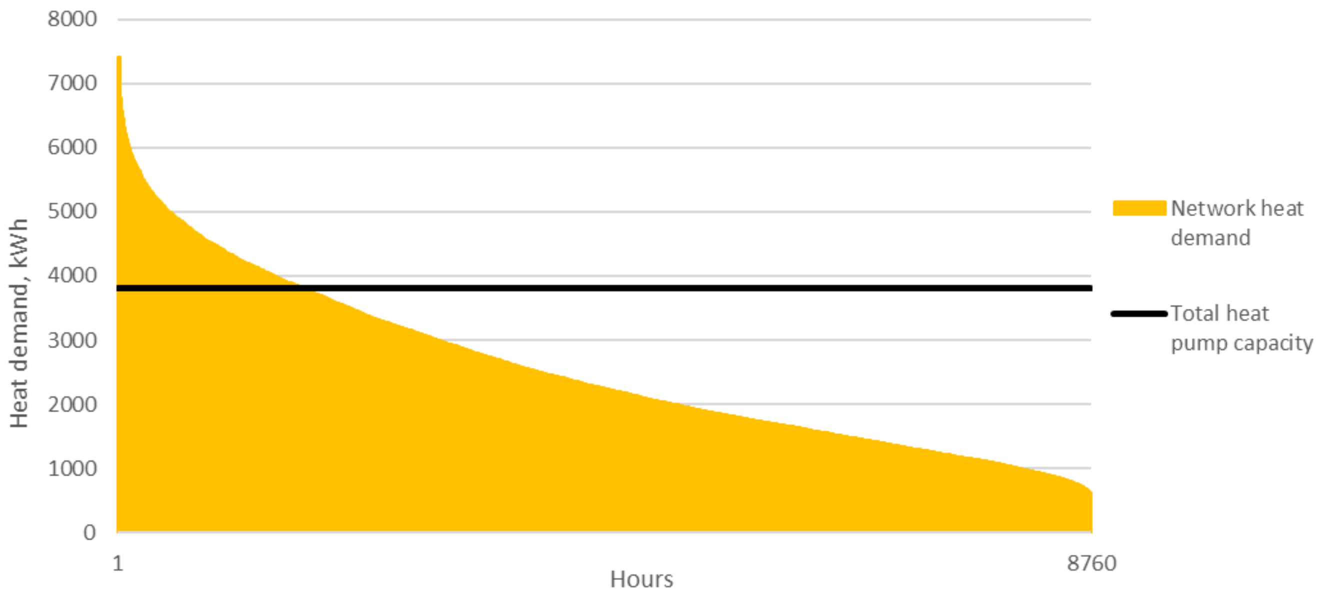

Figure 70: Load duration curve for example network

Figure 71 and Figure 72 show the proportion of the heat demand supplied by the heat pump, charge and depletion of the thermal store and heat demand supplied by peak and reserve boilers for fully built network for 1st and 2nd January and 1st and 2nd August respectively. The heat pump and thermal stores meet the majority of the baseload heat demand with a small proportion of the demand met by peak and reserve boilers. Where the thermal store charge and depletion is greater than the total heat demand shown in Figure 71 and Figure 72, the thermal store is being charged. Where the thermal store charge & depletion is below the total heat demand, the thermal stores are being depleted.

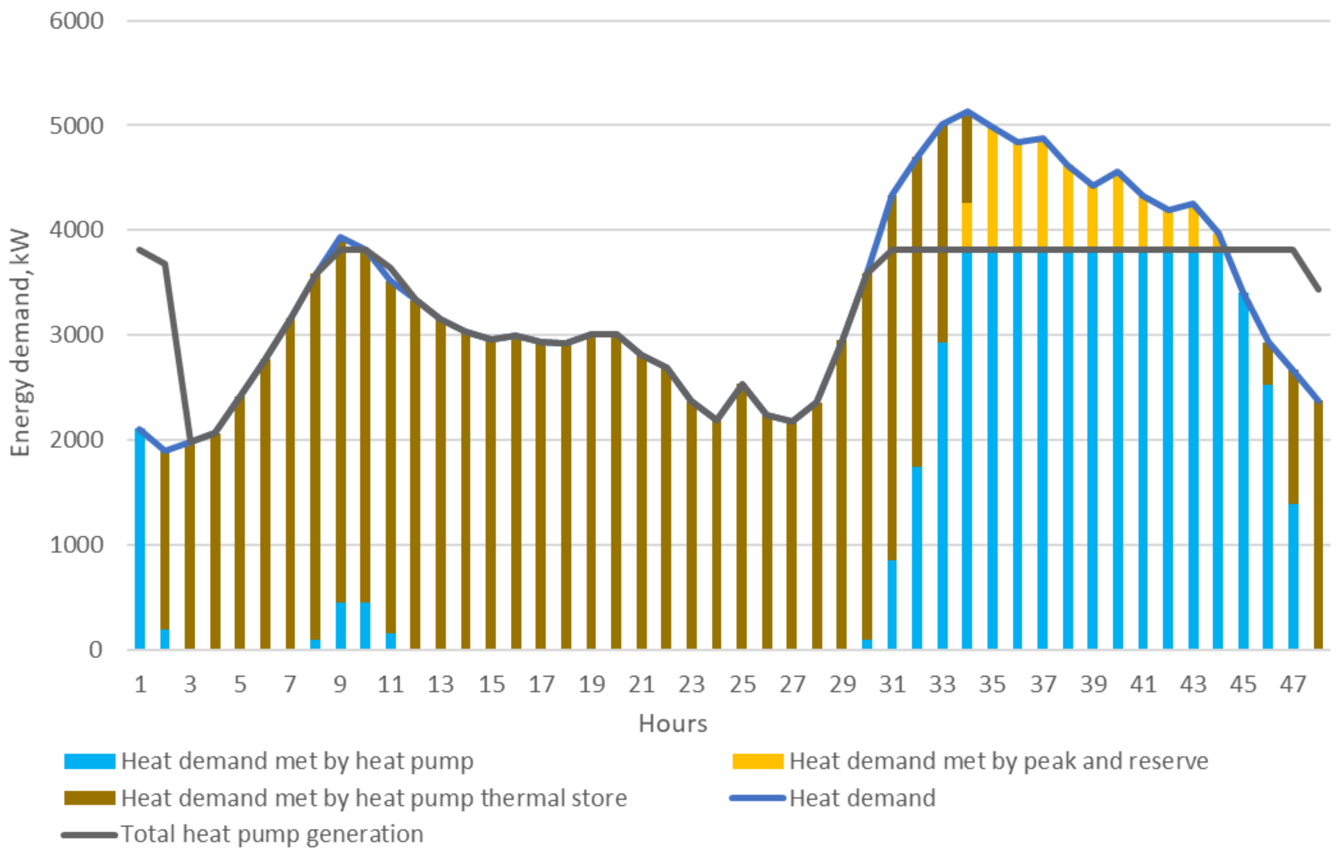

Figure 71: Heat generation 1st and 2nd January

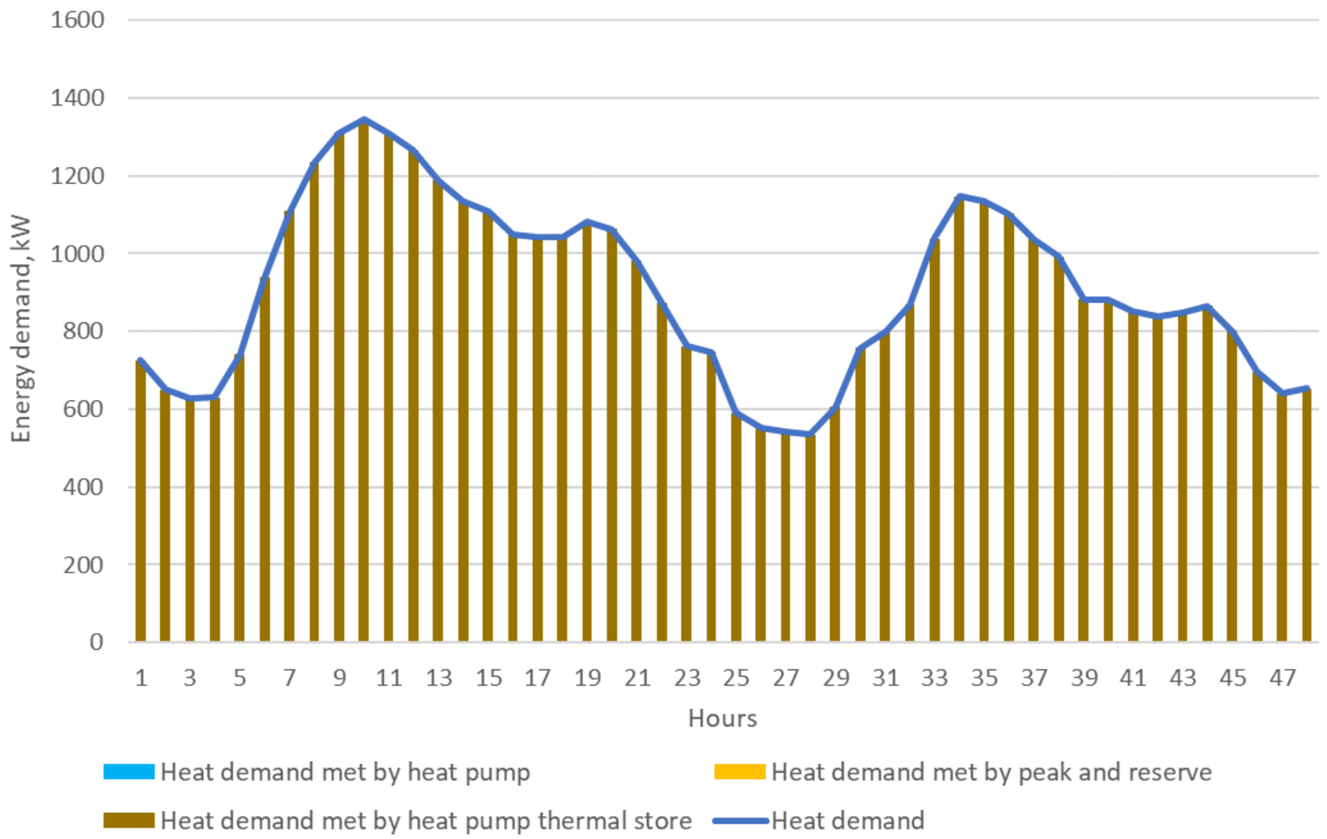

Figure 72: Heat generation 1st and 2nd August

Thermal stores have been sized based on hourly network heat demand, heat pump capacities, modulation limits and capital costs. Figure 73 shows the hourly operation of the heat pump for the example network with and without a thermal store. The thermal store provides significant benefits at times of peak network demand and when heat generation is restricted by modulation limits.

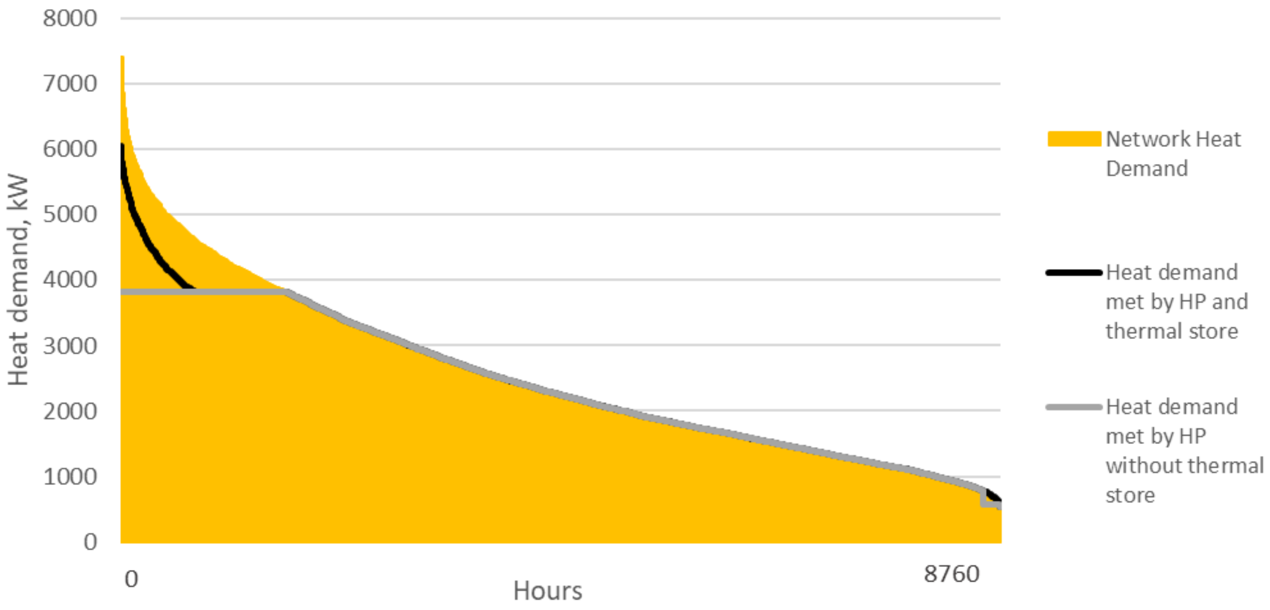

Figure 73: Load duration curve and thermal store usage

APPENDIX 6: TECHNO ECONOMIC MODELLING – KEY PARAMETERS

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 expected equipment lifetime and fractional repairs are shown in the section "Key Technology Parameters"

Capital costs for the scheme are based on a combination of previous project experience, quotations for recent similar works and soft market testing. Soft market testing has been conducted with potential suppliers of plant and equipment.

To develop an accurate estimate of the heat network costs, the proposed network has been broken down into constituent parts (i.e. straight pipe lengths, pipe bends, valves, valve chambers, welds, weld inspections, etc.) for each pipe section. These quantities have then been multiplied by the average rates taken from numerous quotations obtained for similar work. A complexity factor has been added to this to account for the areas of lower implementation or construction complexity and areas of higher complexity such as main roads, key intersections and areas of congested utilities.

Estimated capital costs for key plant items (such as heat pumps, thermal storage tanks, etc.) have been obtained from the respective suppliers.

By using the above methodology, CAPEX estimates are within the tolerance stated in the project requirements and ITT and contingency has been applied to each element of capital expenditure as appropriate.

Capital Costs

Capital costs for the scheme are based on a combination of previous project experience, quotations for recent similar works and soft market testing. Soft market testing has been conducted with potential suppliers of plant and equipment.

A summary of network capital costs is shown in Table 50.

Table 50: Capital costs

	Contingency	CAPEX including contingency		
		Phase 1	Phase 2	Phase 3
Energy centre building	15%	£1,543,300	-	-
Heat pump (MWHP)	15%	£1,075,588	£247,385	£301,165
Abstraction and discharge connecting pipework and civils	15%	£460,000	£230,000	
Heat pump M&E	20%	£280,588	£64,535	£78,565
Peak and reserve gas boilers	10%	£262,350	£79,145	£86,187
Pressurisation	10%	£83,080	-	-
Water treatment	20%	£118,854	-	-
Peak and reserve boiler flues	20%	£55,440	£33,264	
Main district heat network pumps	10%	£79,659	£47,795	
Controls	20%	£156,470	£46,941	£46,941
Other energy centre M&E	10%	£349,455	£90,987	£32,272
Thermal store(s)	10%	£440,000		
Heat network spine (pipe and trench costs)	10%	£3,754,826	£1,323,874	£1,257,881
Heat network branches (including pipe, trench, traffic management, etc.)	10%	£3,518,620	£1,687,425	£2,168,242
Cost of connections at heat user locations	20%	£1,639,142	£873,273	£1,582,229

	Contingency	CAPEX including contingency		
		Phase 1	Phase 2	Phase 3
Gas grid connection	10%	£55,000	-	-
Electricity grid connection	10%	£103,865	-	-
Further project development (e.g. professional fees, legal, design, surveys, etc.)	10%	£1,078,197	£346,428	£404,856
Total		**£15,054,434**	**£5,071,053**	**£5,958,336**

Connection Costs and Connection Charges

It has been assumed the network operator covers costs of all connections with the initial CAPEX investment. Any future planned developments would be required to pay a connection charge which would cover the costs of connecting to the network. The maximum connection charge would be based on the avoided cost of an equivalent low carbon heating solution (e.g. ASHPs) The cost of this would need to be agreed with each future commercial connection. Connection charges for domestic planned developments would also be based on the avoided costs of installing individual ASHPs. These have been included in the base case assessment at £8,125/dwelling.

Network costs

Network costs are shown below in Table 51, Table 52, Table 53 and Table 54.

Table 51: Network spine costs not cumulative (not including contingency)

Pipe size	Trench length, m			Pipe supply, installation, trenching and civils cost cost, £/m			Network costs (spine and branches)		
	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
DN250	326	-	-	£3,518	£0	£0	£567,551	£0	£0
DN200	1,286	-	-	£9,220	£0	£0	£1,813,368	£0	£0
DN150	348	-	-	£6,953	£0	£0	£459,290	£0	£0
DN125	259	391	705	£4,131	£2,255	£3,602	£329,978	£410,646	£756,671
DN100	83	39	397	£4,011	£1,429	£2,026	£111,434	£56,209	£386,856
DN80	270	724	-	£2,600	£2,859	£0	£131,856	£688,960	£0
DN65	-	52	-	£0	£925	£0	£0	£47,706	£0
Total	**2,572**	**1,206**	**1,103**	**£1,327**	**£998**	**£1,037**	**£3,413,478**	**£1,203,522**	**£1,143,528**

Table 52: Network connection costs – Phase 1

Site ref.	Site name	Network connection costs – heat (Secondary side improvements)	Additional network length to connect to main network spine (including network within the cluster), m	Additional network costs to connect to main network spine
1	Killingworth Site	£77,899	71	£81,905
2	Grasmere	£52,844	12	£17,006
3	Silverdale Primary	£35,380	38	£10,906
4	N02 social housing	£276,528	2,155	£820,884
5	N01 social housing	£362,052	2,790	£1,063,180
6	Bailey Green Primary	£52,783	36	£33,094
7	Amberley Primary	£52,920	57	£23,890
8	Wellspring Medical Practice	£29,757	49	£55,018
9	Killingworth Social Club	£49,625	67	£60,620
10	Kings Arms	£35,363	20	£19,614
11	White Swan Centre	£55,908	25	£28,981
12	Killingworth Shopping centre	£29,698	72	£58,725
13	Morrisons	£65,269	133	£144,538

Site ref.	Site name	Network connection costs – heat (Secondary side improvements)	Additional network length to connect to main network spine (including network within the cluster), m	Additional network costs to connect to main network spine
14	Matalan / Home bargains	£65,341	238	£251,112
15	Telephone Exchange building	£21,898	217	£174,943
16	George Stephenson	£102,688	292	£373,057

Table 53: Network connection costs - Phase 2

Site ref.	Site name	Network connection costs – heat (Secondary side improvements)	Additional network length to connect to main network spine, m	Additional network costs to connect to main network spine
17	West Rock Newcastle	£49,765	98	£99,599
18	Metnor House	£35,370	31	£30,713
19	Offices 2.1 - DCS Multiserve & Careline Homecare	£29,735	26	£22,664
20	Warehouse 2.1 - PaddlePod	£49,687	61	£57,435
21	Fenwick Warehouse	£29,777	35	£30,408
22	John Lewis & Partners Delivery Hub	£52,883	63	£64,859
23	N204 social housing	£427,620	2,601	£991,163
24	Burradon Community Primary School	£52,891	233	£237,182

Table 54: Network connections costs – Phase 3

Site ref.	Site name	Network connection costs – heat (Secondary side improvements)	Additional network length to connect to main network spine, m	Additional network costs to connect to main network spine
25	N102 social housing	£168,197	1,483	£564,967
26	N106 social housing	£52,827	77	£85,436
27	Planned development of Killingworth Lane	£1,390,000	11,176	£1,676,340

APPENDIX 7: BUILDLING CONNECTIONS – EXISTING HEATING SYSTEMS

Table 55 and Table 56 show examples for potential improvement measures for existing heating systems and hot water systems respectively.

Table 55: Types of heating system

Heating system	Type	Flow temperature, °C	Return temperature, °C	Potential measures for improvements
Radiators	Traditional or cast iron	82	71	• Recommission flowrates • Rebalance radiator circuits • Replace radiators • Radiator connections to use 'top entry and opposite bottom exit' • Variable speed pumps • Pressure independent TRVs designed for low flow rates to be used • TRVs to be locked with maximum temperature setting of 22 °C • Remove any high bypass flows
	Typical flat panel	80	60/55	
	Retrofit - best practice	70	40	• Radiator connections to use 'top entry and opposite bottom exit' • Variable speed pumps • Pressure independent TRVs designed for low flow rates to be used
	New build – best practice	60	30	
Air handling unit (AHU)	Low surface area	82	71	• Upgrade fan coils to allow function on lower average temperatures • Ensure variable flow
	Best practice	80	60/55	
Underfloor heating	Standard	40	30	• The lower operating temperatures of under floor heating systems are advantageous for heat networks
Electric heating	All	See figures for best practice of chosen technology - typically 70 / 40 °C		• A wet system will need to be installed to connect to the district heating network • Install should be to best practice

Table 56: Types of hot water system

Hot water system	Type	Flow temperature,°C	Return temperature,°C	Potential measures for improvements
Calorifier	Internal coil	82	71	• Recommission flowrates • Use of constant temperature-controlled pumps • Replace heating coil with external plate heat exchanger - Heat exchanger over external plate provides greater performance and lower return temperatures • Consider pre-heat heat exchanger of cold feed
	External PHX	70	25	
Instantaneous hot water PHX		70	25	• The lower operating temperatures of instantaneous hot water systems are advantageous for heat networks
Direct fired hot water		N/A	N/A	• Replace with Instantaneous or semi-instantaneous

APPENDIX 8: 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 Global Warming Potential (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 chilling or heating plant is approximately 15-20 years. Therefore, 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 plant and equipment installed in buildings that contain powerful greenhouse gases. All new buildings should consider the lifetime impacts of the refrigerant as well as efficiency to reduce overall emissions of greenhouse gases.

The main refrigerants used in commercially available heat pumps are summarised in Table 57 below:

Table 57: 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 • 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