Heat Network Support Unit

Raigmore Heat Network Feasibility Study

Final Report

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Contents

Glossary

Term	Definition
AHU	Air Handling Units
ASHP	Air Source Heat Pump
BAU	Business As Usual
BEIS	Business, Energy and Industrial Strategy
BGS	British Geological Survey
CAPEX	Capital Expenditure
CHP	Combined Heat & Power
CL	Closed Loop
CoP	Coefficient of Performance
CO_2	Carbon Dioxide
DHW	Domestic Hot Water
DNO	Distribution Network Operator
dT	Temperature Difference
EB	Electric Boiler
EC	Energy Centre
GHG	Green House Gas Emissions
GSHP	Ground Source Heat Pump
HH	Half Hourly
HN	Heat Network
HP	Heat Pump

Term	Definition
HT	High Temperature
HV	High Voltage
IRR	Internal Rate of Return
LC	Low carbon
LT	Low Temperature
LTHW	Low Temperature Hot Water
NPV	Net Present Value
O&M	Operation & Maintenance
OPEX	Operating Expenditure
PHX	Plate Heat Exchanger
REPEX	Replacement Expenditure
RFI	Request for Information
TS / TES	Thermal Store / Thermal Energy Store
WSHP	Water Source Heat Pump
ZWS	Zero Waste Scotland
4G	Fourth-Generation Heat Network

Executive Summary

This Raigmore Heat Network Feasibility Study report was prepared by Buro Happold Energy Team on behalf of Zero Waste Scotland (ZWS) for The Highland Council (THC). This study was supported by the heat network support unit (HNSU).

Understanding the Project

THC has a target of net zero emissions from operations by 2045, and a 75% reduction in emissions by 2030. Additionally, in line with Scotland's revised Heat in Buildings Bill, a new target will be set for decarbonising heating systems by 2045. One of the key proposals is mandatory clean heating systems; all homes and businesses must switch to clean heating systems by 2045. As part of this, a requirement for public sector buildings to connect to heat networks, where possible, is introduced.

Recent Local Heat and Energy Efficiency Strategy (LHEES)[1] work has identified Raigmore as being potentially suitable for the development of a new heat network. The LHEES identified 3 potential heat networks within Inverness. Two of the three areas have already been assessed through separate feasibility studies, previously undertaken by Buro Happold, the West Bank area and Longman (with a focus around the Maltings and SWH pumping station) – additionally the Inverness Castle area has progressed to delivery of a small local network. This feasibility study within Raigmore is being pursued to give a better understanding of the opportunity to develop the Raigmore Heat Network. The Raigmore Heat Network feeds into the overall strategic piece developed by Buro Happold, which is exploring four potential heat network zones across Inverness.

Report Purpose

The purpose of this heat network feasibility study is to inform The Highland Council of the opportunity to develop a low carbon heat network in Raigmore. The study provides:

- Identification of potential low carbon heat sources and technologies which could offer a suitable heat supply to the network
- An indicative heat network route to connect the potential buildings in Raigmore
- A high-level cost estimate of the capital cost incurred for the development of the Raigmore Heat Network, considering the costs associated with the different heating technologies
- A techno-economic analysis of the Raigmore Heat Network, considering cash inflows and outflows to the energy centre
- Risk mitigation for development of the heat network
- Recommendations and next steps.

Report Audience

The audience for this report is The Highland Council and the Heat Network Support Unit (HNSU) partner organisations – Zero Waste Scotland, Scottish Futures Trust (SFT), and Scottish Government.

Key Findings

The Raigmore Heat Network Feasibility Study indicates that with consideration of grant funding opportunities available, there is scope to develop a heat network in Raigmore. The study identified opportunities to develop heat networks both to the east and west of the A9 in Raigmore. A single heat network opportunity to the east of the A9 was progressed; this option was favoured due to the uncertainty around the data available for the hospital on the west. The hospital is a significant anchor load on the west, and as such, greater confidence in the data would be favourable for pursuing this opportunity. Additionally, the lack of engagement from the hospital indicated significant risk in terms of willingness

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[1] Local Heat and Energy Efficiency Strategy (LHEES) | Local Heat and Energy Efficiency Strategy (LHEES)

to connect to a scheme. Furthermore, the future development of the Freeport in the east, which offers significant heat demand potential, improves the favourability of the east network and makes it important to establish a strategy – to ensure the opportunity it presents for driving a heat network is not missed. These factors, as well as the hospitals engagement after the study completion is discussed further in the accompanying strategic report.

The proposed heat network arrangement considers an air source heat pump (ASHP) heat network solution, with gas boiler back-up / peaking technology. This heat network considers building connections to the east of the A9, with notable anchor loads including UHI Inverness College, the business and retail park area, National Treatment Centre, and the HMP Highland prison development.

The proposed Raigmore Heat Network would be developed over three phases. The phasing strategy has been established based on the status of the existing heating plant in the buildings selected for the network. The buildings with existing low carbon heating plant are to be phased in line with the expiration of their current low carbon plant. Additionally, the selected network for Raigmore includes new developments (as part of Inverness Campus Phase 2). The intention is for these buildings to connect to the Raigmore Heat Network once constructed.

The proposed Raigmore Heat Network is depicted in Figure 0-1.

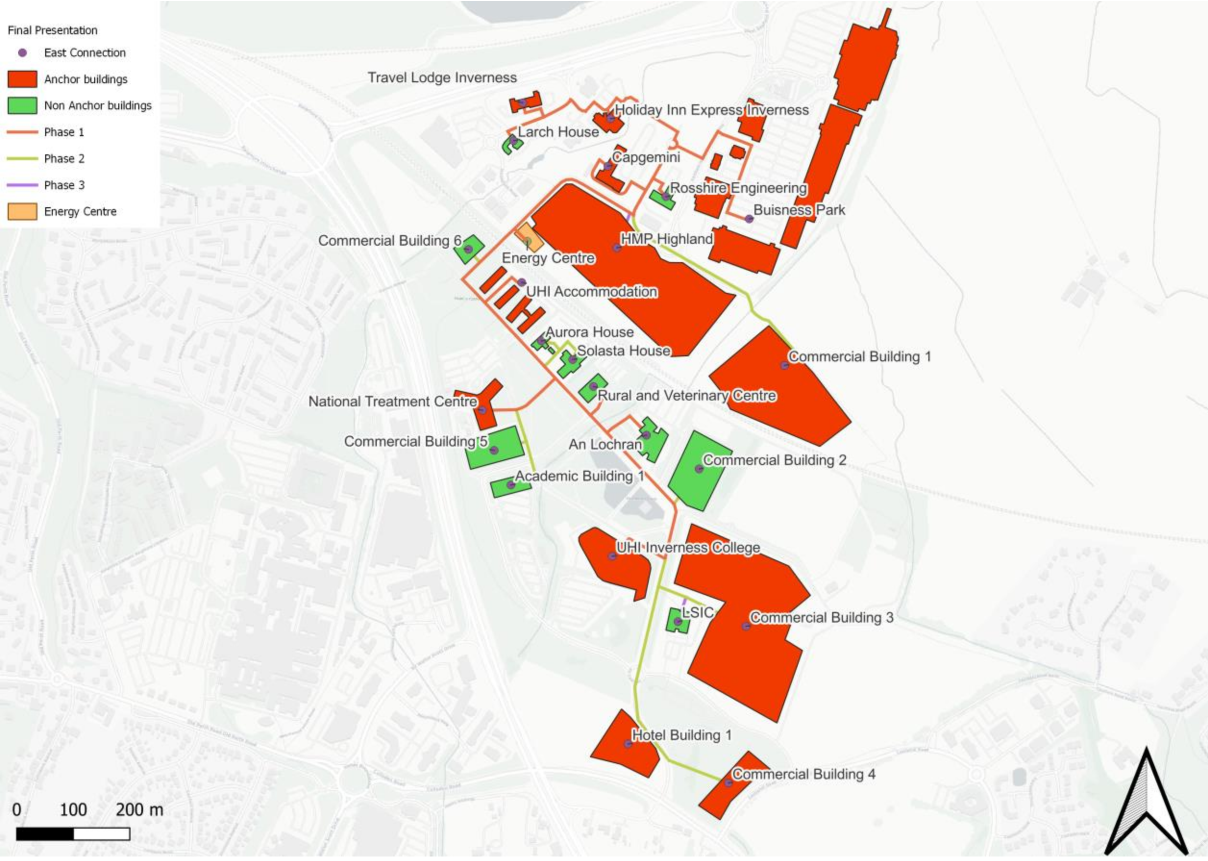

Figure 0-1: Raigmore Heat Network

The overall heat demand for the full build-out heat network is 20,750 MWh/y (excluding losses). The key anchor loads for the core heat network are:

- UHI Inverness College
- HMP Highland prison development
- National Treatment Centre Highland (NHS).

Key parameters of the proposed network extension are presented in Table 0-1.

Table 0-1: Key network parameters

Parameter	Value
Annual heat demand (MWh/a)	20,750
Heat network trench length (m)	4,500
Linear Heat Density (MWh/a/m)	4.6
Baseline LHD (MWh/a/m)	4.0

Energy Centre and Heat Network

The proposal for the energy centre for the Raigmore Heat Network considers:

- Centralised ASHP as the main low carbon heating technology at the energy centre
- Energy centre located adjacent to the HMP Highland prison development
- Equipment at the energy centre:
  - Main heating technology: 3 x 1 MW ASHPs and 1 x 500 kW ASHP
  - Back-up heating technology: gas boilers. Total capacity: 12,000 kW
  - 200 m^3 thermal storage
- Heat network:
  - 3G network – a third-generation heat network has a traditional centralised topology with the energy centre supplying heat outwards to buildings. The heat supply is ~ 90-60°C, with return temperatures of ~ 50-40°C
  - Total trench length: 4.5 km

Capital Cost

A breakdown of the capital costs of the proposed heat network was developed from consultation with manufacturers, industry reference data and previous project experience at Buro Happold. The capital cost assessment carried out has been independently assessed by cost consultants, Thomson Bethune.

The total capital cost, **estimated at £28.3m**, includes:

- Energy centre and heat supply equipment (ASHP, thermal stores, top-up gas boilers, and ancillary equipment)
- Buried network pipework (~ 4.5 km) – trenching and pipe costs considered
- Electricals
- Building connection costs (heat substations, heat meters) – any upgrades required to secondary side systems for the buildings have not been included in the model
- Complex crossing considerations.

Additional costs considered include contingency (10%), prelims (15%) and design fees (10%). For the proposed heat network pipe route, there is the requirement to cross the railway by the HMP Highland development. An additional cost has been added in for this within the capital cost schedule. Within the techno-economic model, the assumption is that at the point of connection, the buildings will be ready to connect to the heat network, with any building enabling works having been carried out separately; hence, these costs have not been factored into the model.

Heat Sales Tariff and Connection Charges

The cost of low carbon heat for a building connected to the network is likely to be higher than the cost of the Business as Usual (BAU) heating, which is largely reflective of fossil fuel heating technology. For this study, the heat sales tariff for the heat network customers is the same as the counterfactual cost of heat. The counterfactual represents the alternative low carbon heating technology which would be instated in the absence of a heat network.

The selected counterfactual for the building connections is building-level ASHP, except for the HMP Highland development, which has a GSHP heating solution. This reflects the movement in the direction of heat decarbonisation, away from fossil fuels over time, as detailed in Table 0-2.

Table 0-2: Calculated BAU and counterfactual heat tariff structures

Metric	Variable tariff (p/kWh)	**Fixed tariff (£/kW)**
BAU – commercial existing	5.7	39.6
BAU – commercial new build	11.05	39.6
Heat network – commercial existing	12.33	73.1
Heat network – commercial new build	11.05	73.1

Connection charges are estimated based on the avoided costs of installing building-level, individual ASHPs. These are included in the techno-economic model, from the perspective of the organisation that owns and operates the heat network. One-off connection charges are estimated at approximately **£7.3m** for the full Raigmore Heat Network.

Techno-Economic Analysis Results

For the ASHP heat network with gas boiler back-up technology, a negative NPV (-£4.2m) is anticipated at the end of the project lifetime (40 years), in the absence of grant funding. This is reflective of an IRR of 1.9%. In terms of network operation, this is unlikely to be a commercially attractive IRR and grant funding would be required to achieve a desirable IRR for a project partner. To achieve an IRR of 12%, the ASHP heat network with gas boiler back-up technology requires £11.9 million in funding, which represents 43% of the total network CAPEX. Given that the maximum available funding is 50% of the total network CAPEX, there is sufficient funding for this solution to reach the 12% IRR, which is a positive outcome.

Carbon Savings

Significant carbon savings, compared to the BAU, are to be observed over 40 years. The lifetime savings are estimated at 2,075 tCO_2e/yr (average). Buildings that connect to a heat network are considered to have low and zero emissions heating systems.

Risk Mitigation

Risk mitigation measures have been considered for the Raigmore Heat Network.

A key risk to mitigate for the Raigmore Heat Network is to coordinate the pipe network route with crossing the railway line by HMP Highland prison development. This will require engagement with National Rail to ensure the network does not interfere with operation of the railway. In this techno-economic model, an allowance for making crossing has been included as an additional cost.

The selected heat network includes Freeport development connections. The heat demand associated with these connections has been benchmarked based on information available in the Masterplan documentation. Given the high-level nature of the information available, continued engagement with the site developers should be sought after to ensure the heat demand estimates are accurate. Moreover, within the heat demand assessment, the heat demand for several of the building connections has been derived from Scotland Heat Map (SHM) data; this data is typically less reliable than metered data. As such, with the performance of the heat network being reliant on the heat demands, accurate metered data would need to be obtained at the next stage of assessment for this network.

Additionally, in the absence of grant funding, the Raigmore Heat Network does not present as a commercially attractive heat network opportunity. Hence, securing grant funding is paramount to progressing the heat network opportunity. The gas boilers would not receive grant funding, so this would need to be considered as a cost for the network. Within the techno-economic model, the grant funding has excluded the gas boiler element of the capital expenditure.

The final key risk to mitigate is the electrical capacity requirement. At present, the local Raigmore primary substation is constrained. There are reinforcement works planned; however, engagement with SSEN will be required to understand the headroom available for the energy centre connection. The reinforcement works have a planned completion date of August 2029; this date is ahead of the transition to full electric boiler back-up plant. As such, the initial selection of gas boiler plant is favourable from an electrical capacity requirement.

Key Next Steps

Further consideration should be given to the commercial arrangement that is sought for development of a heat network in Raigmore. Without funding, the Raigmore Heat Network does not present as an attractive option for a project partner. However, results of the techno-economic assessment indicate that an IRR of 12% can be achieved for the heat network, within the limits of the 50% CAPEX funding available. Hence, there is scope to progress this opportunity further, in line with Scottish Government's approach to heat network development.

When considering a Joint Venture or Partnership approach in the delivery model and commercialisation, the IRR target should be considered further, this could potentially reflect:

a Public ownership type (targeting IRR of approx. 6%)
b Commercial ownership type (targeting IRR of approx. 12%)

There is scope to progress the Raigmore Heat Network to the next stage in project development, which could be Outline Business Case (OBC) with consideration of grant funding. To progress to this more detailed level of study, further review should be given to the following:

- Engagement with SSEN to understand the network constraints in the Raigmore region and ascertain the cost for connection and any potential reinforcement works
- Engagement with the Freeport development site to understand the progress of the development and to determine their appetite for connection to a heat network. Early engagement will ensure an alternative low carbon heat supply is not established for the sites
- Stakeholder engagement – for the building connections where benchmarked or SHM data has been used for the heat demands, further stakeholder engagement should be conducted to acquire more accurate metered data
- The Raigmore Feasibility Study is supplementary to the Inverness City Strategic Heat Networks Study. The strategic piece has identified that, although this study considers the heat network only to the east of the A9, there is still potential to consider the area as a whole. This can be attributed to the increased interest of the hospital following the study, which derisks the west network. As part of this work, there will be further assessment of the development of heat networks in Inverness, as well as the approach to different network delivery models.

1 Introduction

Section Outcomes

Zero Waste Scotland (ZWS) commissioned Buro Happold (BH) to undertake a heat network feasibility study for The Highland Council (THC) for the Raigmore area.

The scenarios considered as part of this feasibility study are as below:

- Scenario 1: Centralised ASHP heat network with back-up gas boilers. Network established to the west of the A9
- Scenario 2: Centralised biomass heat network with back-up gas boilers. Network established to the west of the A9
- Scenario 3: Centralised (closed loop) GSHP with back-up gas boilers. Network established to the east of the A9
- Scenario 4: Centralised ASHP with back-up gas boilers. Network established to the east of the A9
    - Scenario 4a: Centralised ASHP with back-up electric boilers
- Scenario 5: Centralised WSHP (using wastewater as the low-grade heat source) with back-up gas boilers. Network established to the east of the A9.

The study identified the preferred scenario for the Raigmore Heat Network as Scenario 4: Centralised ASHP with back-up gas boilers.

1.1 Feasibility Study Purpose

This feasibility study presents the opportunity for a low carbon heat network in Raigmore, Inverness.

This feasibility study explored the potential building connections in the area, focusing on the anchor loads (heat demand > 500 MWh/y) and those connections close to the low-grade heat source.

A techno-economic analysis is included as part of the study, to understand the economic viability of the different network scenarios. This assessment considers the network heat demands, heating plant efficiency, fuel costs and capital expenditure, and revenue streams from heat sales and connection charges.

Heat Network Delivery Steps

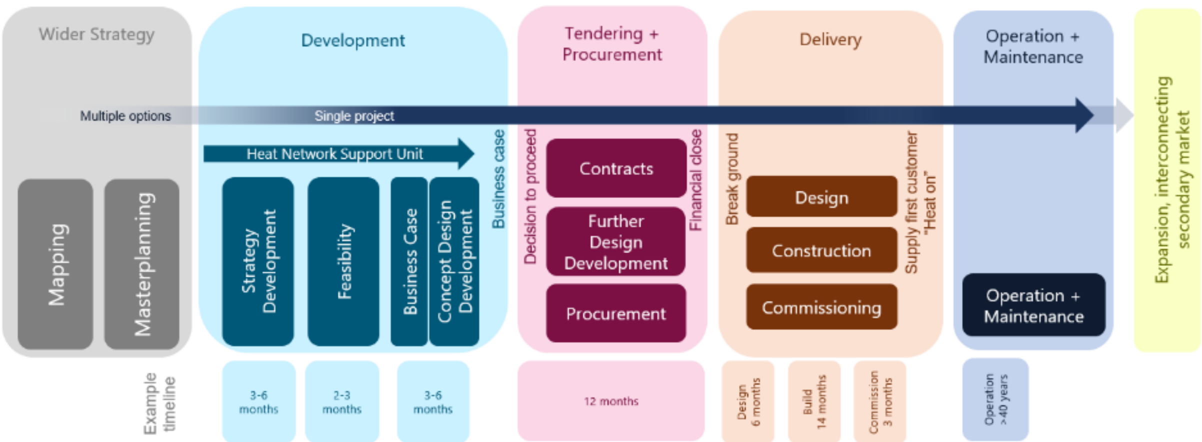

Figure 1-1: Heat Network Project Delivery Steps

1.2 Study Area

Raigmore is an area of Inverness situated in the east of the city. Inverness is the administrative centre for The Highland Council and is regarded as the capital of the Highlands. Raigmore Hospital estate notably occupies a significant proportion of the area; the hospital is managed by NHS Highland. Raigmore Hospital serves patients from the local area and provides specialist services to patients from across the Highland region. The A9 runs to the east of the Raigmore Hospital campus and on the east side of this dual carriageway is Inverness Campus. Inverness Campus is an educational campus, developed by Highlands and Islands Enterprise (HIE), with a focus on life sciences and technology sectors.

Inverness Campus is a community which combines education, research, healthcare and innovation. A masterplan has been developed to expand the offerings of the site and create Inverness Campus Phase 2.

1.2.1 Heat Network Study Area

The initial area considered for the heat network assessment is shown in Figure 1-2. This area covers the full extent of buildings considered for connection to the heat network. The potential HN connections are highlighted below, as informed by the LHEES, The Highland Council, and the understanding of anchor loads (heat demand > 500 MWh/y) in the region.

Figure 1-2: Initial red line boundary

The area comprises both anchor and non-anchor loads, and various potential low-grade heat source opportunities. Within the region, the opportunity to utilise multiple low-grade heat sources exists, including ASHP, GSHP, wastewater, and biomass.

1.3 Existing Infrastructure

1.3.1 Primary Substation

Scottish and South Electricity Networks (SSEN) are the owners and operators of the electricity network in the Raigmore area. The local primary substation located to the south of Raigmore Hospital is classified by SSEN as partially constrained, as shown in Figure 1-3. After engaging with SSEN, it is understood that there are planned reinforcement works for this substation, with anticipated completion date of August 2029. Therefore, within this study, it was assumed that reinforcement works specific to this heat network development are not needed. Hence, at the point of construction, it is assumed that there will be adequate capacity to provide the electrical connection for the energy centre.

Figure 1-3: SSEN heat map

1.3.2 Buried Utilities

A desktop utilities survey was conducted and received as part of this study. To understand the constraints across the network, the utilities surrounding the heat network were mapped alongside the proposed heat network route. The results from this analysis are seen in Figure 1-4.

Figure 1-4: Full build out network with utilities.

Figure 1-4 indicates the presence of various utilities in the area where the proposed pipe route is to be installed. The high-risk items identified from this desktop survey include intermediate to high-pressure gas pipelines and large 33 kV cables, which require special attention during excavation.

Examining the UHI/HIE campus within Figure 1-4, it can be observed that the pipe route intersects with 11 kV cables and freshwater pipelines in the southern section. These utilities should not pose significant constraints to the excavation process. Moving north, the area near the business park is notably busy. However, there are no major concerns; the gas pipelines are low pressure and there is no high voltage cabling in this area. A slight constraint exists in the northwest near Larch House, where intermediate pressure gas pipelines are present. While this does not cause major alarm, caution is advised when trench digging in this area. Please note that the HIE/UHI area is managed by a different Gas Transporter (GT) not associated with SGN which is reflected in the red area above[2]. This could potentially pose a constraint to the network. It is recommended to follow this up with the relevant supplier to ensure no buried constraints are found.

[2] The full utility report for the area did not identify the GT within the UHI/HIE campus. This should be addressed in the next stage of the project.

2 Policy

2.1 Local Heat and Energy Efficiency Strategy (LHEES)

The LHEES underpins an area-based approach to heat and energy efficiency planning and delivery. It sets out the long-term plan for decarbonising heat in buildings and improving their energy efficiency across an entire local authority area.

The LHEES sits below Scotland's National Heat in Buildings Strategy [3] which sets out a national vision that by 2045, homes and buildings will be cleaner, greener, achieving Net Zero emissions by 2045.

Key targets outlined in national plans and strategies:

- Net Zero emissions by 2045 and 75% reduction in emissions by 2030
- By 2038, all publicly owned buildings are to meet the Net Zero emission heating requirement.

2.1.1 Heat Network Zoning

The first iteration of LHEES identifies indicative Heat Network Zones to understand the scale of potential and initial areas of focus.

Heat networks play a crucial role in reducing the carbon intensity of heating and reducing fuel costs. The potential zones present theoretical and technical potential only at a strategic level, prior to any site level feasibility study.

Three opportunity areas were identified for Inverness, with the relevant Raigmore zone shown in Figure 2-1. The zone location is identified as Police Headquarters and Bannatyne Health Clubs. There is no existing heat network in this region.

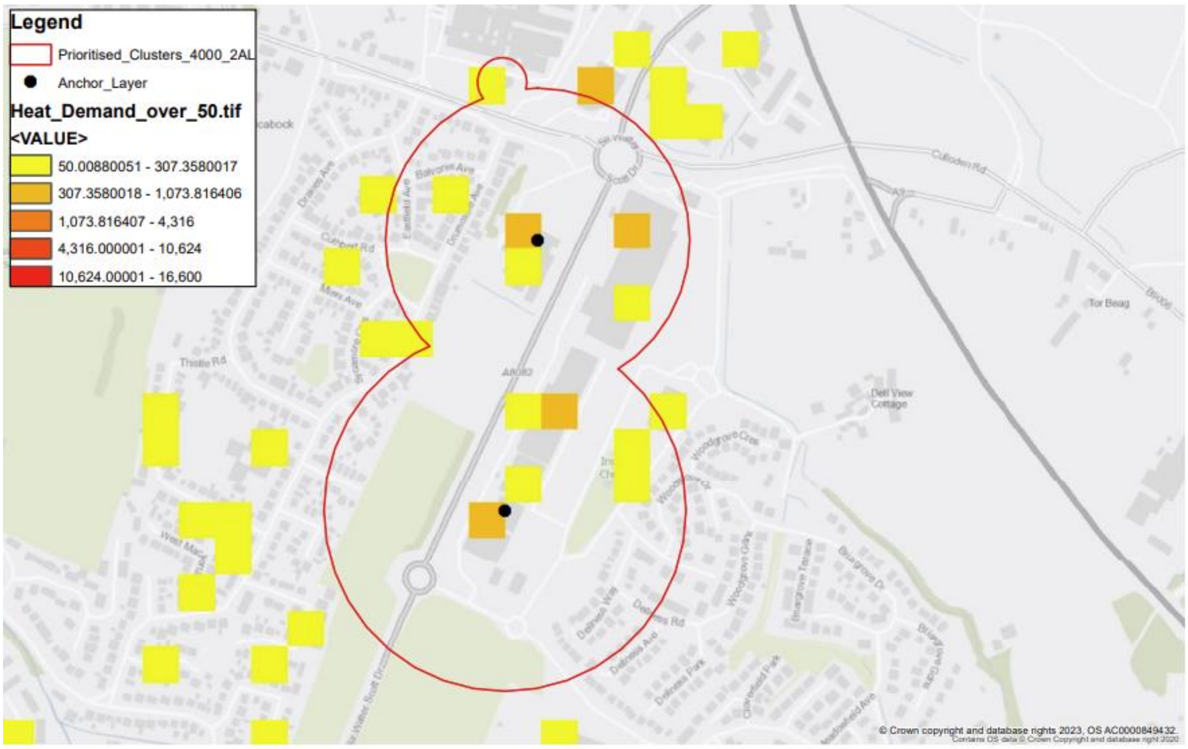

Figure 2-1: LHEES Inverness 3 Potential Heat Network Zone

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[3] Heat In Buildings Strategy: Achieving Net Zero Emissions in Scotland's Buildings

2.2 Freeport

The Freeport development represents the next phase for the UHI/HIE campus, envisioned as a hub for education, research, healthcare, and innovation. Following discussion with The Highland Council, the scheduled completion for this masterplan is assumed as 2035, this second phase aims to attract innovative businesses, expand green spaces, and support the life sciences, technology, and renewables sectors, leveraging Green Freeport incentives.

Addressing the future heating demand of this development is a critical factor, which must be considered when selecting the optimal heat network solution for the area. The masterplan, illustrated in Figure 2-2, outlines the vision for the land, including indicative building types, infrastructure, and green spaces.

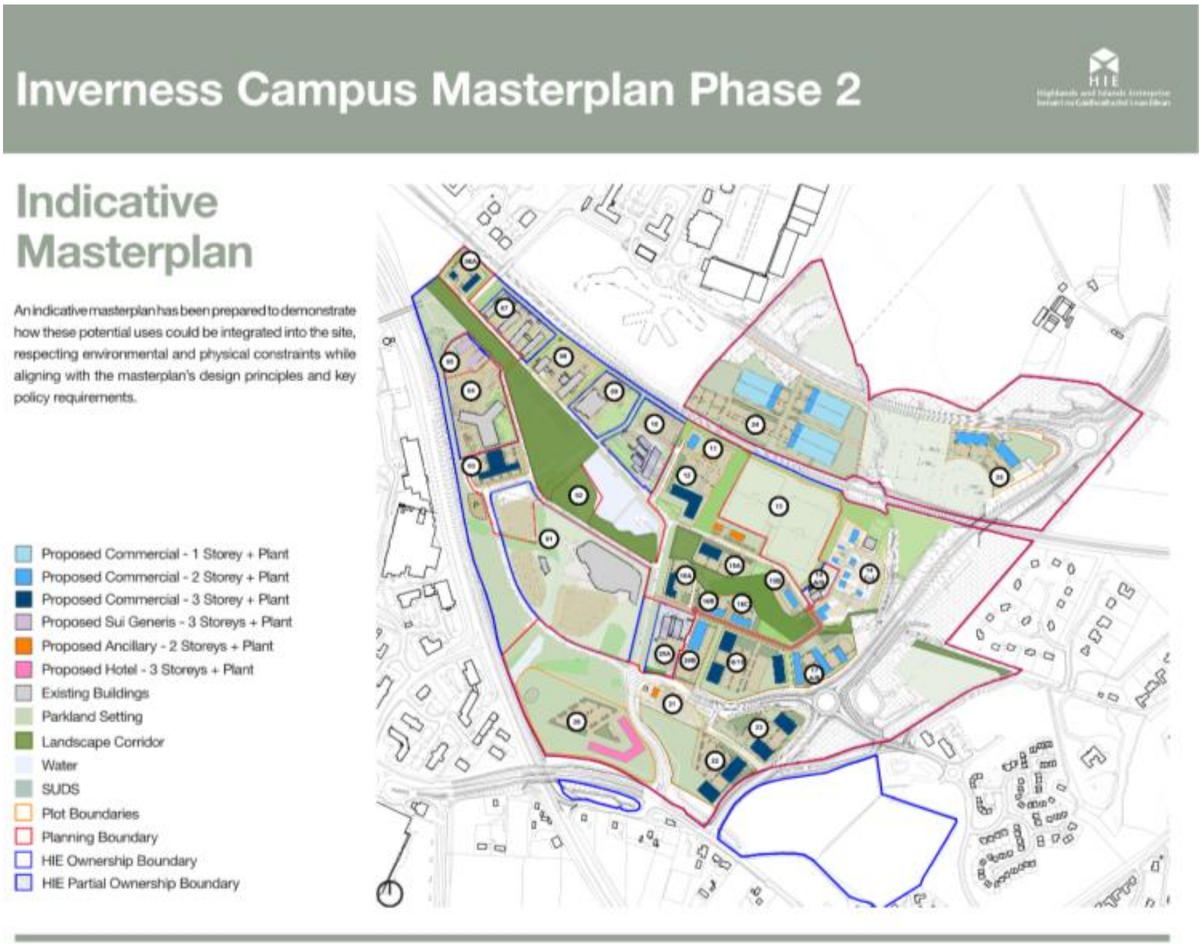

Figure 2-2: Freeport Masterplan

3 Site Visit and Survey

3.1 Site Survey

A site visit was carried out on the 20th of November 2024 by Buro Happold, accompanied by THC and ZWS. The main purpose of the site visit was to allow an assessment of the following key points:

- Building connections – the current heating system in key buildings within the projects scope area. An assessment of the current plant room and space availability at site
- Indicative heat network route – any obvious constraints that may interfere with the proposed HN route
- Potential energy centre locations – consideration of potential locations, looking at those areas close to the network anchor loads
- Stakeholder engagement – to gain local insight into the area and the building connections.

3.2 UHI House

UHI house is an office building, built in 2005, which also provides heat to a dental surgery and NHS Education Scotland. This building houses two plant rooms, both on the first floor. The first plant room contains 7 gas boilers, which meet the heat demand of the building throughout the year. The heat emitters served by these boilers are mainly trench heating, underfloor heating in the 3rd phase section of the building, radiators on the first and upper floors, and radiant ceiling heaters in WCs. In addition to this, 2 X 750 L domestic hot water cylinders with a duty of 2 hours and 2 HVAC systems are included. This information is summarised in Table 3-1.

Table 3-1: UHI house Plant room 1 heating system summary

Heating equipment	Manufacturer and Model	No. Units installed	Capacity (kW)	Operating Temperatures (Flow and Return)	Age
Gas boilers	Ideal EvoMax2	6	150 each (900 kW total)	80C Flow 70C Return	< 1 year
Gas boilers	Ideal EvoMax2	1	100	80C Flow 70C Return	< 1 year

Plant room 2 did not house any boilers however had an additional 2 X 750 L Domestic hot water cylinders and another 2 HVAC systems.

3.3 UHI Accommodation

UHI accommodation, constructed in 2016, was purchased by UHI in 2021. This complex is made up of four blocks, housing around 300 students during term time and tourists in the summer months. These buildings are heated by two plant rooms. The first is located on the ground floor and is connected to the second building, while the second plant room is an isolated room outside. Both plant rooms contain three gas boilers, which provide heat solely for domestic hot water, and a CHP system. Space heating in the blocks is provided by electric radiators, assumed to be powered by the CHP system. The specifications of the heating equipment can be found in Table 3-2.

Table 3-2: UHI Accommodation Heating System Summary

Heating equipment	Manufacturer and Model	No. Units installed	Capacity	Operating Temperatures (Flow and Return)	Age (years)
Gas Boiler (PR1)	Mitie	3	100	74-71 Flow 62 65 Return	8
CHP 2017 (PR1)	Energie	1	**Gas**: 71.43 kW, **Heat** 51.2 kW, **Active Power** 22 kW, **Voltage** 400V, **Apparent power** 23 KVA		8
Gas Boiler (PR2)	Mitie	3	100	74-71 Flow 62 65 Return	8
CHP 2017 (PR2)	Energie	1	**Gas**: 71.43 kW, **Heat** 51.2 kW, **Active Power** 22 kW, **Voltage** 400V, **Apparent power** 23 KVA		8

Additionally, an IT server room was mentioned, which has air conditioning to ensure the room stays cool. It was noted that the BMS is currently not working. A quote was received to repair the BMS; however, it was not economically viable to carry out the repair. There was also a comment about overheating in summer as the building is reliant on natural ventilation. The building is shown in Figure 3-1.

Figure 3-1: UHI Accommodation

3.4 HIE – An Lochran

Figure 3-2: An Lochran

Located on the same campus as the UHI buildings, An Lochran is the head office for HIE, constructed in 2016, shown in Figure 3-2. The building has split ownership, shared between HIE and UHI. There are approximately 100 occupants on the HIE side, with a similar number on the UHI side, where heating takes place from roughly 7 am to 4 pm. The building has a single plant room, operated by HIE. Originally designed for an ASHP system, the plant room contains four gas boilers and a CHP system, which is not in use with additional space this plant room will not need to consider extra spatial considerations. Additionally, there is a thermal store with a capacity of 2 m³ and a DHW cylinder with a capacity of 750 L. Table 3-3 shows a summary of heating equipment in An lochran.

Table 3-3: Heating equipment summary for an Lochran

Heating Equipment	Manufacturer and Model	No. Units installed	Capacity	Operating Temperatures (Flow and Return)
Gas Boiler	Ideal Evomax	4	100 kW	80 °C flow
CHP **(Not in use)**	Energie	1	**Gas**: 102.1 kW, **Heat** 71.6 kW, **Active Power** 33 kW **Voltage** 400V, **Apparent power** 34 KVA	

The main low carbon plan for this site is to consider switching to heat pumps or another low carbon technology in 10 to 15 years when the boilers are due for replacement. The building also includes air conditioning for comfort cooling in meeting rooms.

3.5 HIE - Life Sciences Innovation Centre (LSIC)

Figure 3-3: LSIC ASHP plant

The LSIC is a new building on the HIE/UHI campus, constructed in 2023. It consists of two labs on the ground floor with a multitude of office space on the other floors. Occupancy is an issue for this building with many rooms left empty. The space heating and hot water demands are met by an ASHP which is located on the roof plant along with some air handling units, as shown in Figure 3-3. Alongside this there is a plant room located on the right-hand side of the building on the ground floor, which included a plate heat exchanger, a thermal store and a DHW cylinder.

Furthermore, there was a second plant room which was not inspected on the site visit. On site, it was understood that there are two gas boilers which work as back-up for the ASHP. The summary of heating equipment and capacity can be found below in Table 3-4.

The location of the plant room allows a good access point for a DHN pipework connection once the ASHP needed replacing.

Table 3-4: Heating equipment summary for LSIC

Heating equipment	Manufacturer and Model	No. Units installed	Capacity	Operating Temperatures (Flow and Return)
ASHP	Lochinvar	Information not received	13.5 kW	Information not received
Gas Boilers	Information not received	2	Information not received	Information not received

3.6 HIE - Aurora House

Aurora House, established in 2015, is a dynamic space where HIE supports startups by providing an environment conducive to business growth. The building features a photovoltaic (PV) system and five ASHPs on the roof, which supply both heating and electricity. Currently, the occupancy rate is around 60%. The ASHPs have heating capacities ranging from 31.5 kW to 35 kW and cooling capacities between 22.4 kW and 28 kW. Notably, the large windows in Aurora House result in significant solar gains, making heating almost unnecessary during the summer. Not all heating specific information was received for this building. Figure 3-4 and Figure 3-5 show the ASHP plant found on the roof.

Figure 3-4: Aurora house ASHP system

Figure 3-5: Aurora house ASHP system

3.7 Scottish Ambulance Centre

This site is split into two different heating loads: King Duncan House (KD) and the Ambulance Station workshop. The KD section houses the Ambulance Service's call centre and office space, which is air-conditioned by seven units located on the side of the building. The normal capacity of this building is 48 people during the day and 14 overnight, meaning the office space is heated 24/7. The plant room for KD is located on the ground floor with an outside entrance facing the car park, allowing good access for DHN pipes. The plant room itself is quite small and houses a single gas boiler, which was last refurbished in 2010 and needs upgrading. However, the stakeholder is struggling to fund an upgrade or further refurbishment of the boiler, as shown in Figure 3-6. Additionally, the server room, located outside the building, is cooled by three further air conditioning units.

The workshop section, located beside the KD building, has more office space and provides heat for the area where ambulances are maintained via a wet heating system. The workshop office space is smaller, with an occupancy of around 24 during the day and 6-8 people at night, requiring 24/7 heating. This building and work area have an additional plant room housing a gas boiler, which was refurbished in 2010 and is now in need of upgrading. The plant room, located on the ground floor with outside access, is larger than KD's, as shown in Figure 3-7.

Table 3-5 summaries both heating systems:

Table 3-5: SAS heating system summary

Heating equipment	Manufacturer and Model	No. Units installed	Capacity	Operating Temperatures (Flow and Return)
Gas Boiler (KD)	Clyde Combustion	1	65 kW	80 Supply
Gas Boiler (Workshop)	ACV International	1	67 kW	82 Supply

Figure 3-6: King Duncan House boiler

Figure 3-7: Ambulance Workshop boiler

3.8 Police Scotland - Old Perth Road

Police Scotland's main office in Inverness is located on Old Perth Road. The main building was constructed in the 1990s, with a second building added a year later pictured in Figure 3-8. The primary function of these buildings is office space. Certain areas of the building are heated 24 hours a day, 7 days a week. A Building Management System (BMS) with weather compensation is installed to control the space heat demand, which is met by two different plant rooms. The first plant room, located in the main building, consists of three gas boilers, supported by an Andrews water heater installed in 2020. The second plant room, located in the second building, contains a single gas boiler and an 800L Domestic Hot Water (DHW) cylinder. It was noted that there is ample opportunity to install insulation on the pipework in the plant room to increase energy efficiency.

Figure 3-8: Police Scotland Entrance

The resilience of power and heat for this building is of the highest importance. To facilitate this, there is a back-up diesel generator that provides heating when the main system is not functioning. This generator has approximately 8 to 10 hours of running fuel. Due to the high importance of security at this building, any connection to a future heat network would require a secure access point.

3.9 HIE – Golden Bridge

The Golden Bridge was identified early in the study as a potential crossing point for the heat network to overcome the constraint posed by the A9, which separates the east and west of the Raigmore area. As an asset owned by HIE, it provides a clear passage from the high-demand area of Raigmore Hospital to the UHI/HIE campus. Therefore, it was deemed necessary to examine its specific location and size to determine if it could support a heat network pipeline.

As shown in Figure 3-9, the Golden Bridge arches over the A9 from its two banks. The space on its underside, illustrated in Figure 3-10, suggests that it could accommodate pipework, allowing the heat network to cross the A9 via the underside of the bridge. The structural assessment would of course be required to ensure this suitability.

Figure 3-9: Underside of the Golden Bridge

Figure 3-10 Golden Bridge

3.10 Site Visit Summary

The Raigmore site visit provided valuable insights into the condition of the proposed building connections for the heat network. Most buildings operate on a high-temperature regime (~80°C) and use gas boiler heating technology as their main heat source. It is assumed that these buildings would be ‘heat network ready’ for connection at the point of heat network installation. A few buildings already have low carbon technology installed; in these cases, it is assumed they will connect to the heat network after the end of their current low carbon technology's lifecycle.

Key findings include the identification of the Golden Bridge as a crucial crossing point for the heat network, overcoming the constraint posed by the A9. This bridge provides a clear passage from high-demand areas like Raigmore Hospital to the UHI/HIE campus, making it essential to assess its suitability for supporting a heat network pipeline. Alternatives, including a dedicated crossing, could be considered but these would drive up the cost of interconnection.

The site visit highlighted the necessity for resilient heating systems in critical buildings. For example, the police station requires continuous power, making the reliability of its power and heating systems crucial. Due to the high security needs of the police station, a secure access point must be identified, and dependable resilience must be integrated into the network's heating technologies.

5 Energy Demand Assessment

Section Outcomes

This section provides details on the buildings which were identified as potential connections to the Raigmore Heat Network. This covers the buildings considered throughout the project, as the network structure developed.

Key elements addressed include:

- Potential building connections – longlist to shortlist
- Heat demand assessment
- Linear Heat Density (LHD) carried out to identify a potentially suitable heat network opportunity in line with the FNA threshold of 4MWh/m/year.

5.1 Building Connection Longlist

In accordance with the LHEES, a comprehensive heat demand assessment was conducted for the entire Raigmore area. This assessment resulted in an initial longlist, identifying potential buildings which could be connected to a heat network. The buildings considered in the longlist are shown in Figure 5-1.

Figure 5-1: Longlist buildings

To understand the viability of their connection, BH, ZWS and THC contacted the relevant building stakeholders and requested pertinent information such as metered data, building asset registers and billing information. From this, BH either received the metered energy data or other information to support heat estimates, such as the floor area, or capacity of their heating plant. Additionally, the level of engagement at this stage provided an indication of the likelihood for the building connecting to the heat network. The longlist of building connections is provided in Appendix B.

5.2 Heat Demand Assessment

Accurate half-hourly (HH) gas and electricity usage data was utilised to estimate heat demands wherever available. In cases where this data was not accessible, monthly energy usage figures were employed. If no consumption data was available, standard industry benchmarks were applied to determine heat demand. For detailed information on the energy data received, please refer to Appendix B.

The buildings in this study were divided based on their location relative to the A9. They were categorised into those situated east and west of the A9 to better analyse the distinct heat opportunities on either side. Additionally, buildings were classified as either anchor or non-anchor loads. An anchor load is defined as a building with an annual heat demand greater than **500 MWh/year** [4]. Within the study boundary, there are 9 anchor loads located on the east side and 9 anchor loads on the west side.

5.2.1 East Demand Assessment

Figure 5-2 provides a visual representation of the proportion of the total 17 GWh heat demand on the east of the network, broken down by data source for the potential connections:

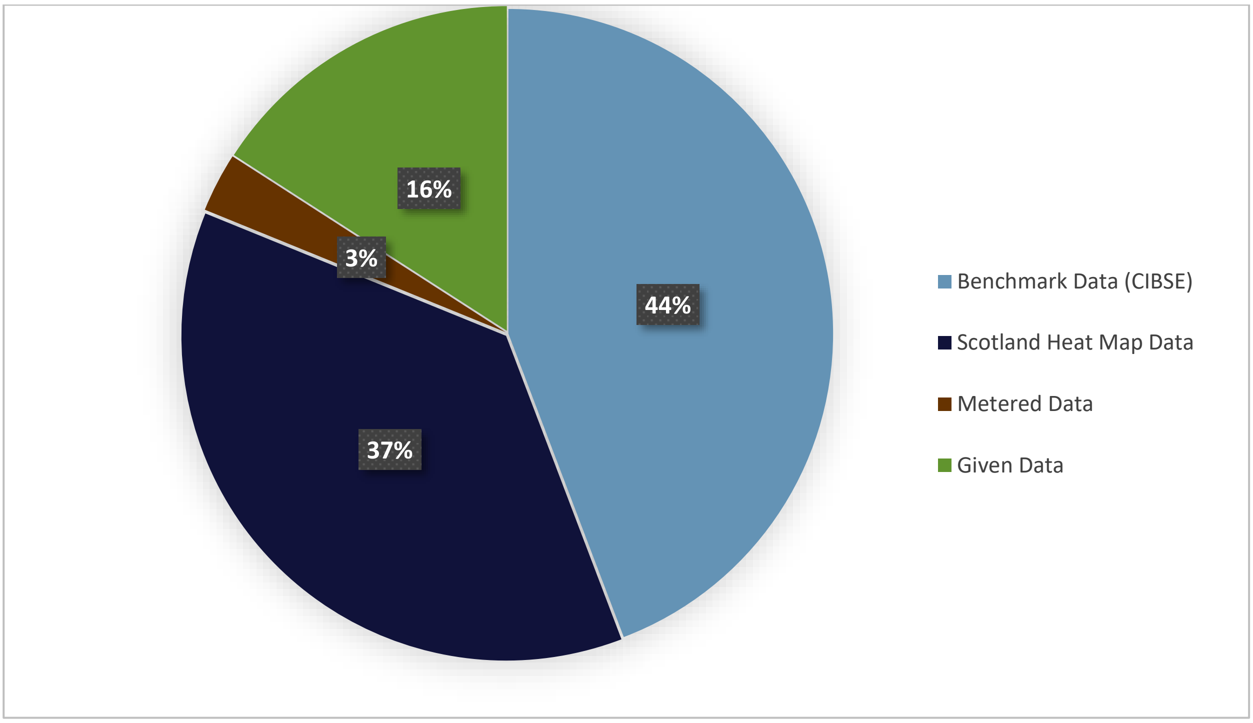

Figure 5-2: Proportion of data received for the east of Raigmore

[4] www.Gov.scot. First National Assessment of Potential Heat Network Zones, April 2022. URL: First National Assessment of Potential Heat Network Zones (www.gov.scot) Accessed 10/11/2024.

A significant portion of the total annual heat demand from east of the A9, 44%, was derived from benchmark data which is attributed to the business park found within the northeast area of Raigmore. Heating demands were based on floor area and CIBSE benchmarks[5] and accounted for 6 GWh, representing a substantial load on the network. Building consumption data, including metered half-hourly data or monthly/annual billing data provided by building connection stakeholders, constituted only 2% of the demand. The remaining building demands which made up the remaining 23% were determined using one of the following methods:

- **Scottish Heat Map-Derived Data (SHM)** This tool designed to assess heat demand and supply opportunities across Scotland
- **Given Data**: Representing estimated annual consumption quoted directly from a building connection.

5.2.2 West Demand Assessment

Figure 5-3 provides a visual representation of the proportion of the total 30 GWh heat demand on the west of the network, broken down by data source for the potential connections:

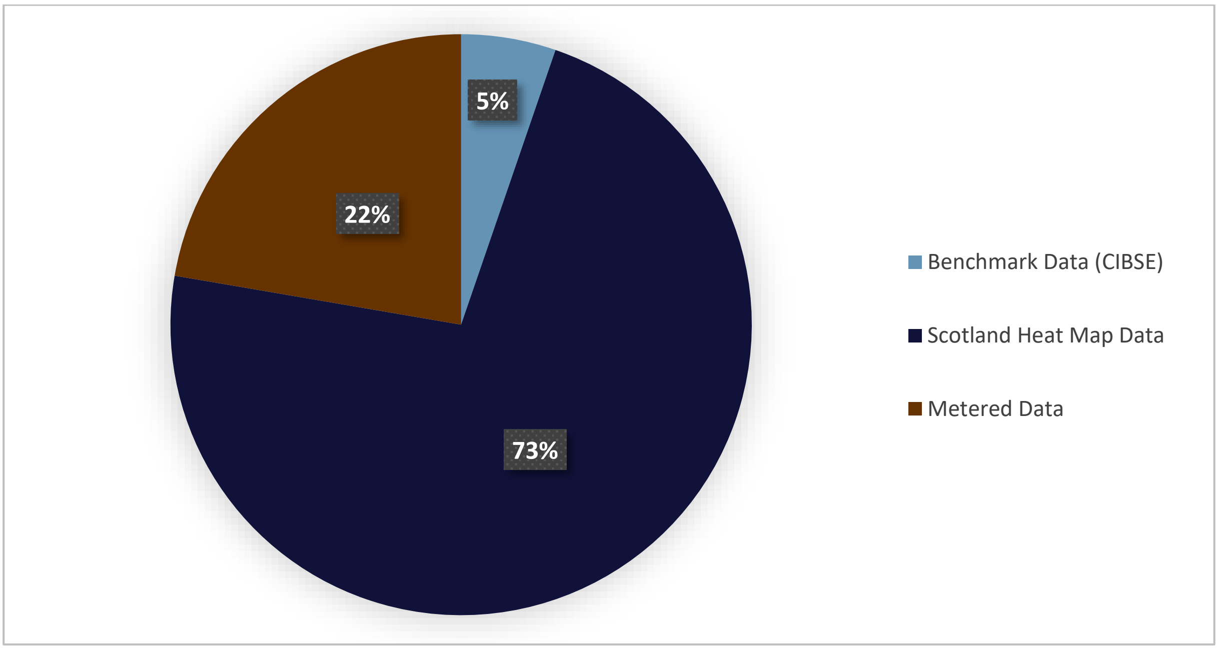

Figure 5-3: Proportion of data received for the west of Raigmore

A significant portion of the total annual heat demand on the west, 73%, was derived from the Scottish Heat Map (SHM) data. This is primarily due to the Raigmore Hospital's heat demand, which was based on SHM data and accounted for 10 GWh, representing a substantial load on the network. Building consumption data, including metered half-hourly data or monthly/annual billing data provided by building connection stakeholders, constituted approximately 22% of the demand. The remaining building demands which made up the remaining 5 % were determined using CIBSE Benchmarks as described above.

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[5] Energy Benchmarking Dashboard

5.3 Annual Heat Demand

5.3.1 East Annual Heat Demand

Figure 5-4 and Figure 5-5 show the calculated annual demands for building connections on the east side of the A9, along with the anchor load threshold separated out into high and low demands.

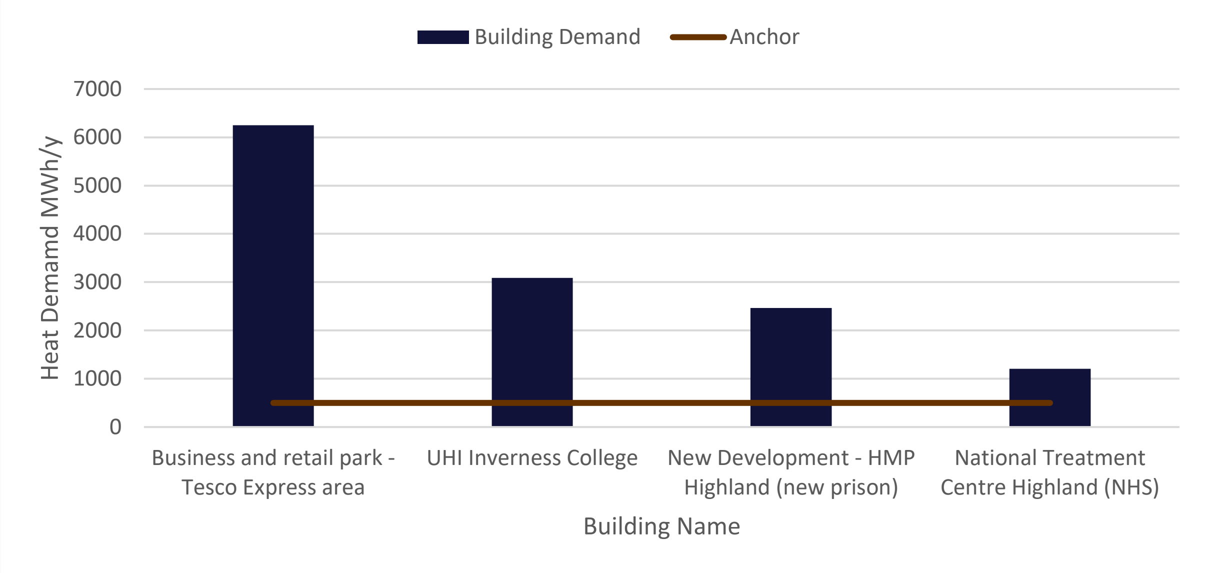

Figure 5-4: Annual Heat Demand for Higher-Demand Buildings East of A9

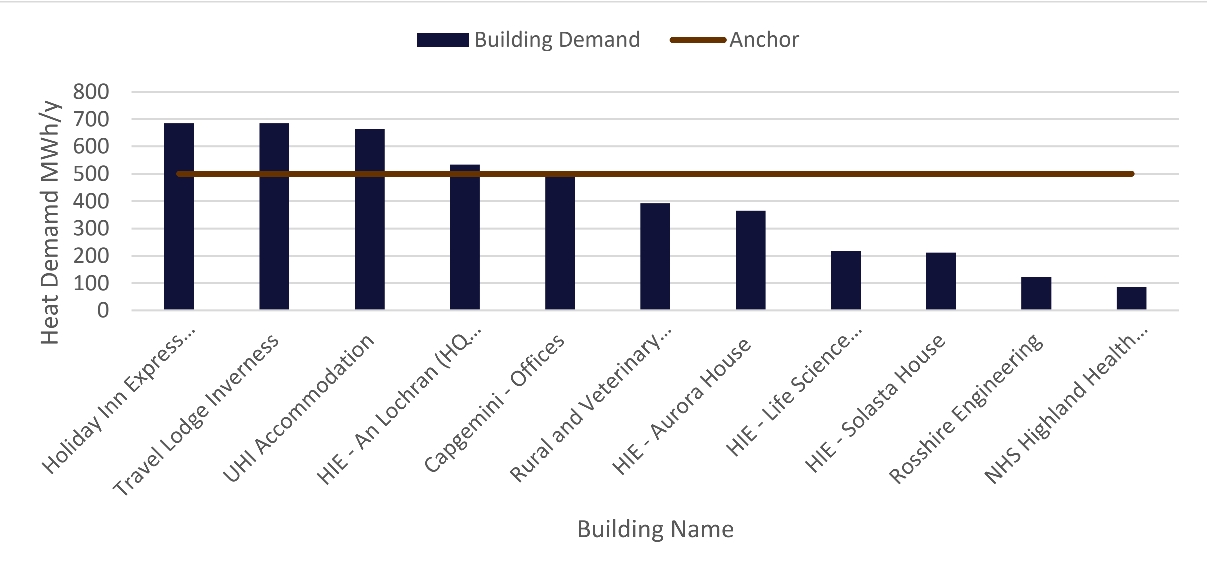

Figure 5-5: Annual Heat Demand for Lower-Demand Buildings East of A9

5.3.2 West Annual Heat Demand

Figure 5-6 and Figure 5-7 show the calculated annual demands for building connections on the west of the A9, along with the anchor load threshold separated out into higher and lower demands.

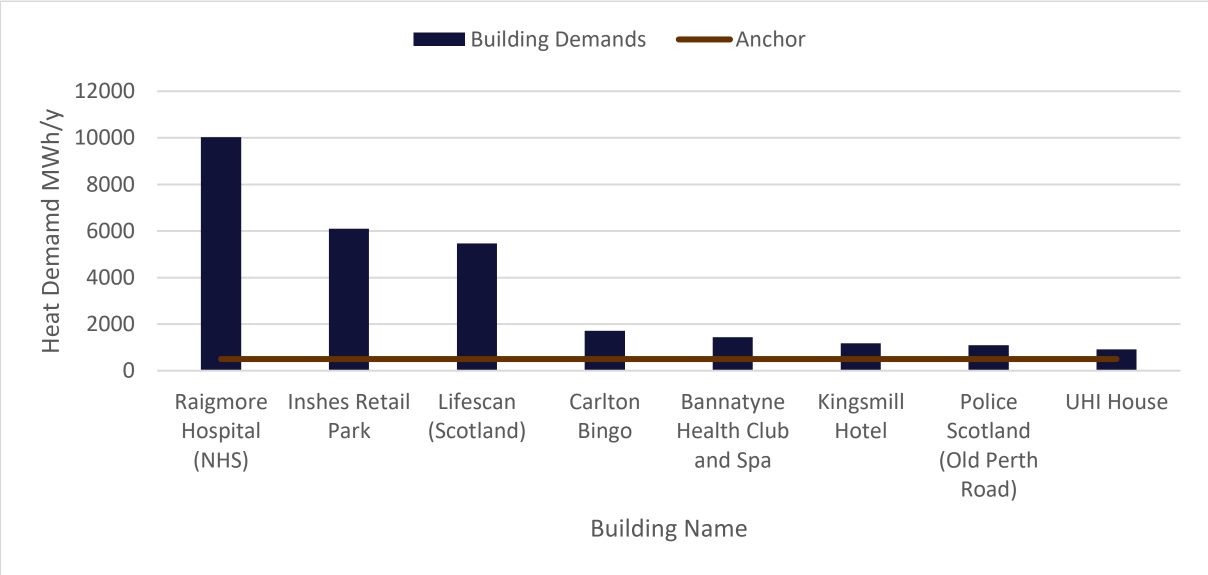

Figure 5-6: Annual Heat Demand for Higher-Demand Buildings West of A9

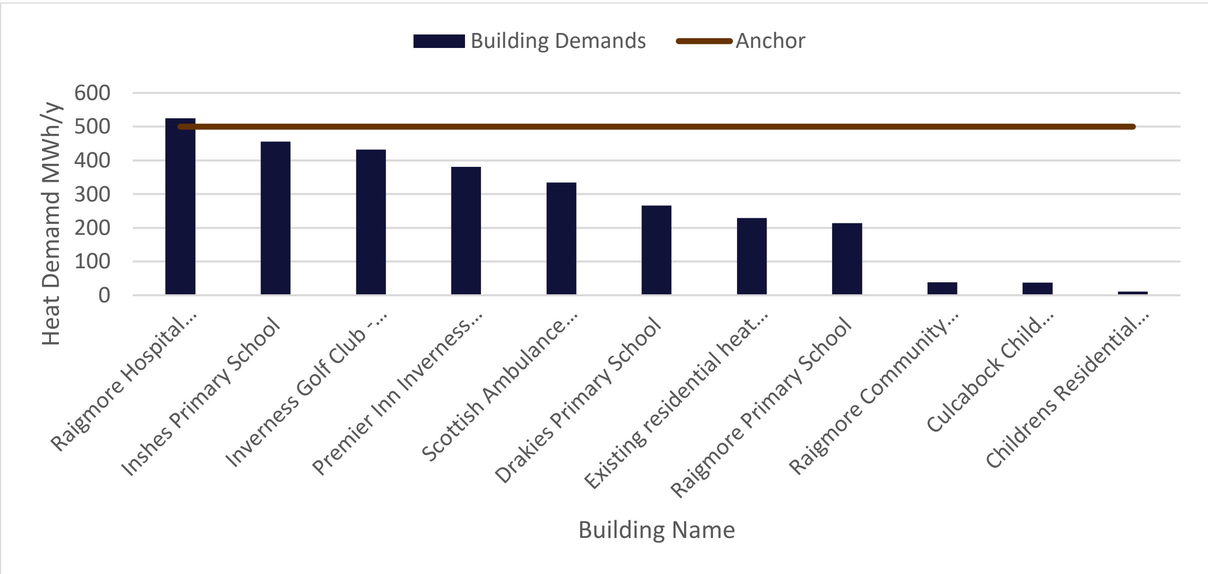

Figure 5-7: Annual Heat Demand for Lower-Demand Buildings East of A9

5.4 Peak Heat Demand

The total undiversified peak heat demand for the buildings considered on the east of Raigmore was 8.2 MW and 11.6 MW for the west. The undiversified peak heat demand represents the sum of the individual building connections' peak heat demand. When designing the network, consideration is given to diversification of the peak demand; this factors in the peaks not being coincident and the potential for the building design peak being higher than the observed peak. A breakdown of the peak heat demands for the building connections is provided in Appendix B.

5.5 Linear Heat Density Assessment

Linear heat density (LHD) is a means of relating annual heat demand to the network trench length; LHD is expressed as annual heat demand per meter of pipe trench. LHD is used to highlight potential heat network opportunities and has been used in this feasibility study to help to identify the shortlist of connections for the network.

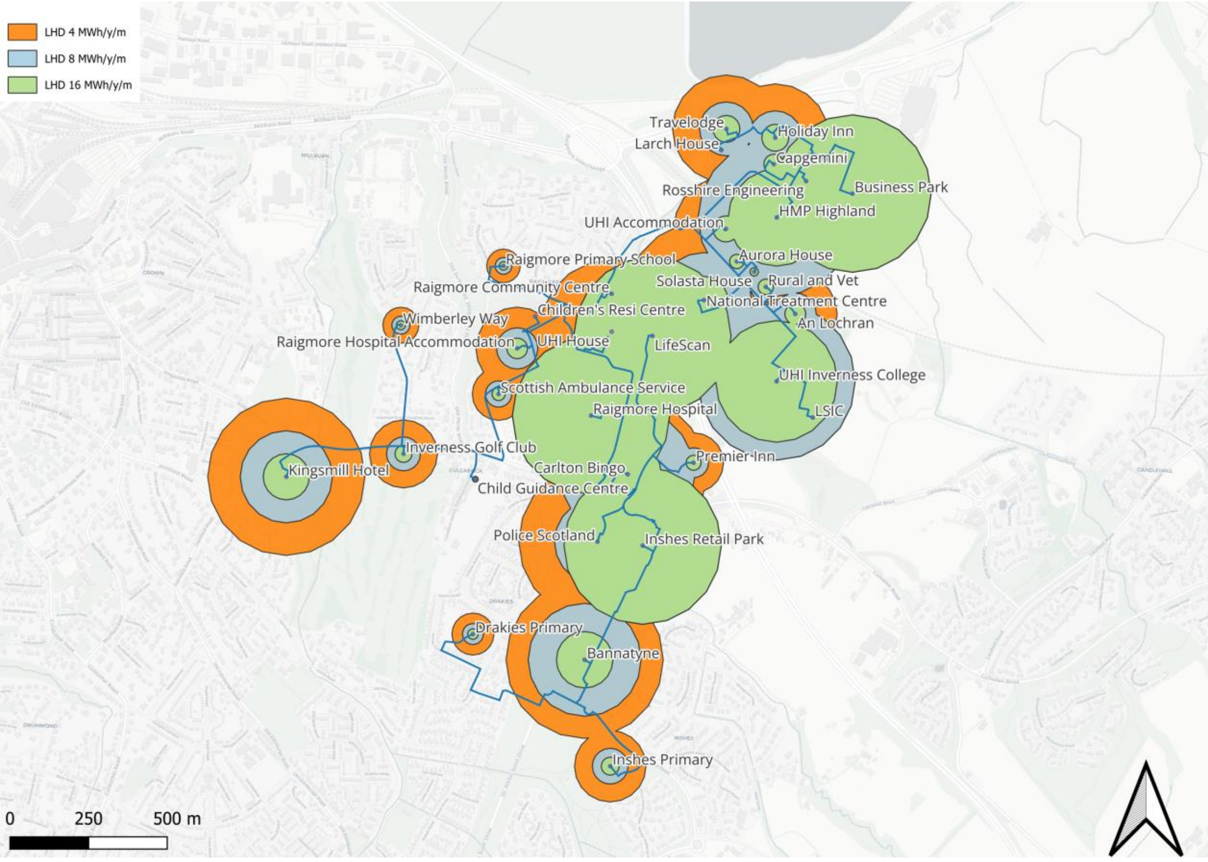

Figure 5-8: Linear Heat Density Analysis

A LHD analysis was considered for the longlist of building connections, as shown in Figure 5-8. In line with the First National Assessment [6], the LHD assessment has been completed with consideration for the screening criteria provided. The Baseline screening criteria is set at 4 MWh/y/m, with the Stringent screening criteria of 8 MWh/y/m included. Higher LHD values result in shorter connection distances and therefore provide a more stringent screening of potential. An additional 16 MWh/y/m analysis has also been included to give greater context.

The LHD highlights the connections which should be excluded from the analysis further. The connections listed below do not fall within the main cluster for the LHD analysis:

- Kingsmill Hotel
- Inverness Golf Club
- Child Guidance Centre
- Wimberley Way (existing residential heat network).

[6] Glossary - Potential heat network zones: first national assessment - gov.scot

5.5.1 Freeport Connections

As the study progressed, THC expressed their preference to evaluate the heat network, incorporating the Freeport development. An indicative master plan of the area, provided in Figure 5-9, along with the indicative floor areas which are detailed in Appendix B, informed this assessment.

The masterplan was subsequently divided into 8 different sections based on the typology of the building which included six commercial clusters, one academic cluster, and one hotel cluster. Each cluster's central point served as the connection point, and the combined floor area was used alongside the CIBSE TM46 benchmarks to estimate the annual heat demand for the heat network feasibility assessment. Figure 5-9 illustrates the suggested arrangement of the different Freeport areas.

Figure 5-9: Freeport Development Connections

Using this data, the demand for each area and the total Freeport development was estimated and can be found in Table 5-1.

Table 5-1: Freeport Demand Summary

Annual Demand (MWh/yr)	Peak demand (kW)
3,800	4,600

5.5.2 A9 Consideration

The A9 runs through the centre of the red line boundary considered for the heat network. The viability of crossing the A9 to develop a heat network connecting all the buildings within the boundary could introduce complications. The option to consider crossing the A9 via the Golden Bridge would require a structural assessment to ascertain the viability of the bridge supporting the pipework. Alternatively, the option for directional drilling could also be assessed as a means of connecting the network. Both options would introduce complications and increase the capital expenditure for the network development. As such, following discussions with THC and ZWS, the decision was made to progress with two distinct networks, one to the east and one to the west of the A9. The full network arrangement, which was discounted at this stage, can be found in Appendix B.

Part of the reason for not furthering considering connecting the two sides of the A9 was the lack of a large low-cost low carbon heat source – of a suitable scale for heating the full network extent. If a very low-cost low carbon heat source becomes available on one side of the A9, it would likely be the factor that drives the interconnection. Although the heat source assessment did not identify any such opportunities, the ongoing development in Inverness related to hydrogen and Scottish Water Horizons waste heat activity may realise such a heat source. Section 6 summarises the heat sources identified.

5.6 Heat Network Routing

5.6.1 East A9

An initial proposed heat network routing was constructed for the east of the A9, running through the HIE/UHI campus and extending to the northeast of Raigmore. This route connects the campus to anchor loads such as the prison and the business park. The network route is illustrated below in Figure 5-10. A summary table can also be found in Table 5-2.

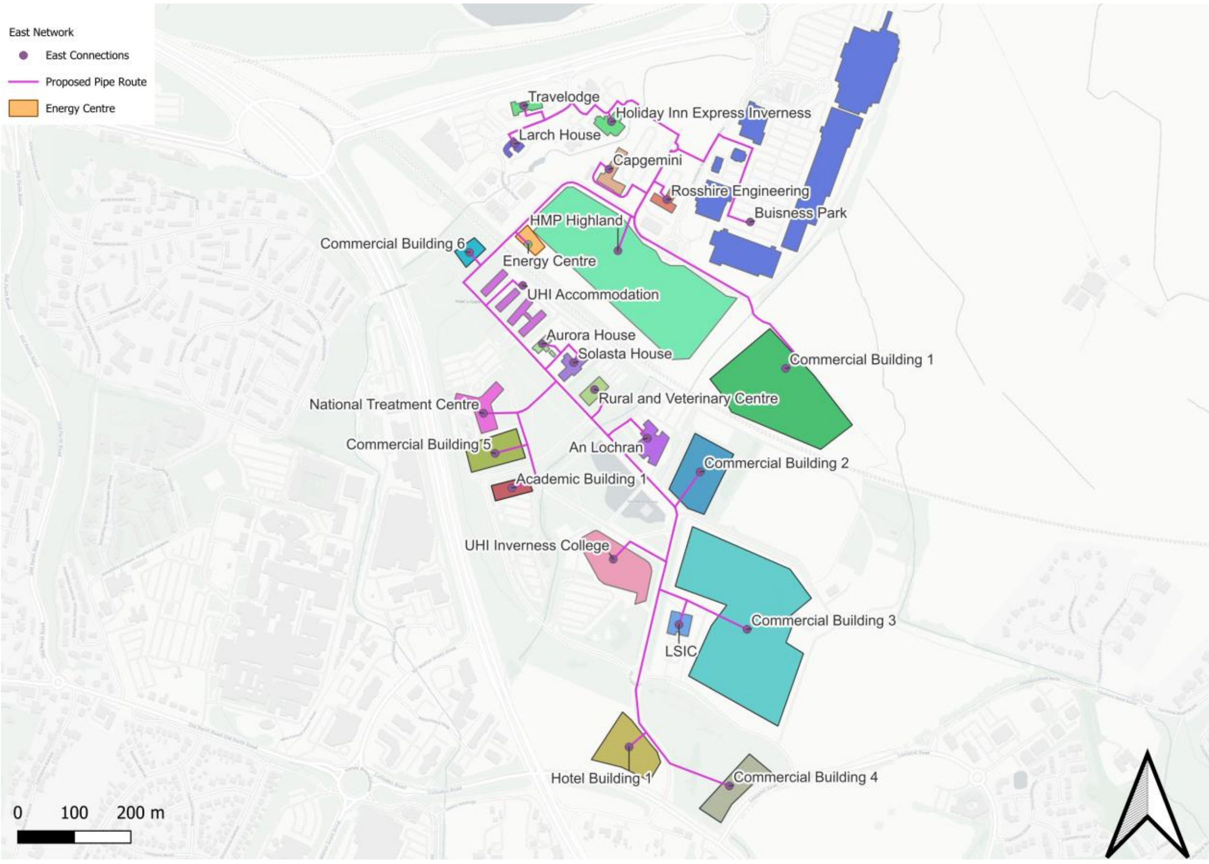

Figure 5-10: East Heat Network

Table 5-2: East A9 Summary

	East A9 HN
Annual heat demand (MWh/y)	20,750
Trench length (m)	4,500
Linear heat density (MWh/y/m)	4.6

5.6.2 West A9

An initial heat network route was proposed for the west side of the A9. This route focuses on connecting Raigmore Hospital to high anchor loads in the area, such as Lifescan and the Inches Retail Park, which includes the Bannatyne Spa facility. The network also extends to the council-owned primary schools in the north and south of the area. Figure 5-11 below highlights the proposed route, and Table 5-3 summarises the network.

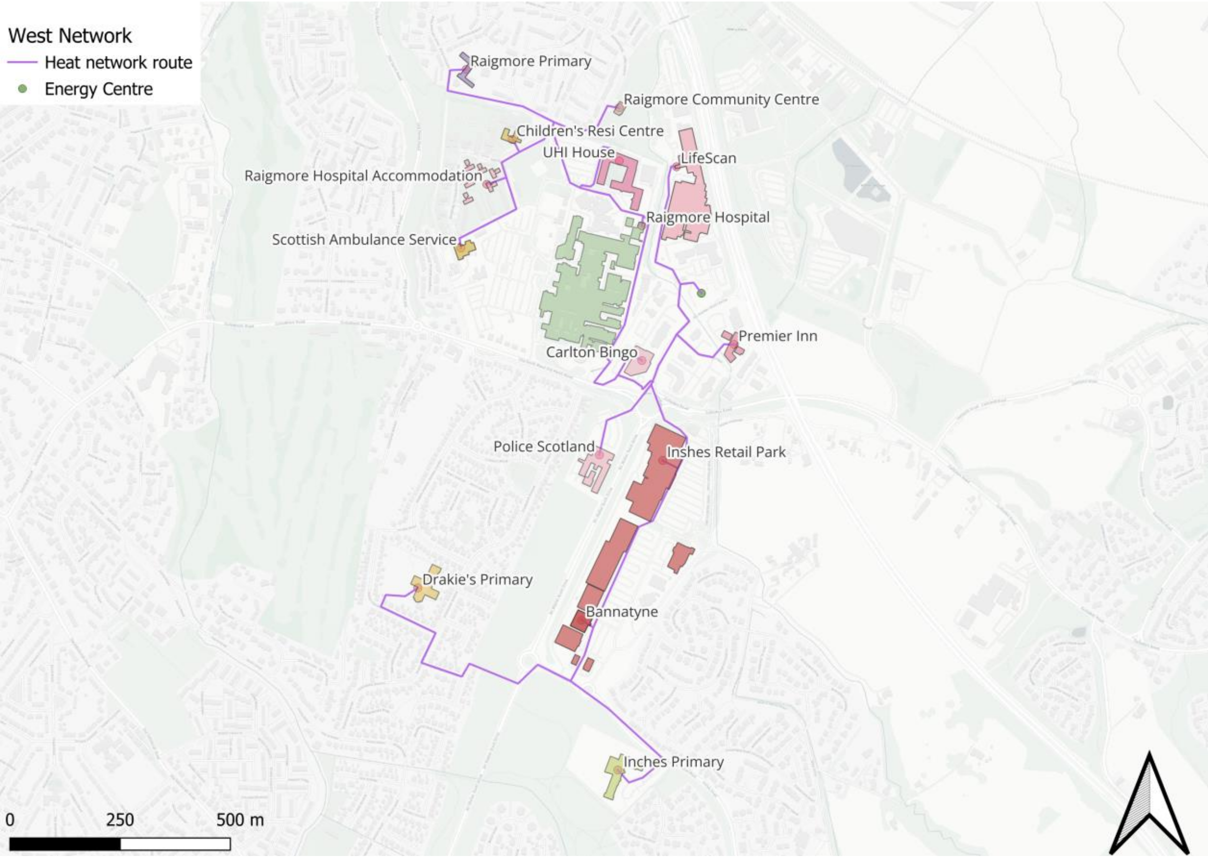

Figure 5-11: West Heat Network

Table 5-3: West A9 Heat Network Summary

	West A9 HN
Annual heat demand (MWh/y)	28,000
Trench length (m)	5,220
Linear heat density (MWh/y/m)	5.4

5.7 Section Summary

This section outlines the various buildings assessed in this study, including their ownership, annual demands, and peak demands. These assessments were used to conduct an LHD analysis of the area. Additionally, the section explains a key constraint posed by the A9 and the demands of the future Freeport development situated in the UHI/HIE campus. Two different heat networks were proposed for the east and west sides of the A9, addressing this major constraint.

The following key elements have been established:

- The east side of the A9 has an annual heat demand of 17 GWh, excluding the freeport development, while the west side has 30 GWh
- The east side peak demand is 8.2 MW excluding the freeport connections, whereas the west side peak demand is 11.6 MW
- The freeport development is estimated, through benchmarks, to have an annual heat demand of 3.8 GWh and a peak demand of 3.5 MW
- Two proposed heat networks were shown, with the east LHD being 4.6 and the west LHD being 5.4.

6 Heat Supply Assessment

Section Outcomes

This section outlines the heating technology considerations for the Raigmore Heat Network.

Key elements addressed include:

- Suitability assessment of the different low carbon heating technologies based on the heat network drivers, and the credentials of the different technologies
- Suitability assessment of different top-up technologies
- A shortlist of the different technology options to consider in the techno-economic model.

6.1 Heating Technology Solutions Assessment

A qualitative technology appraisal was carried out to assess the suitability of different low carbon technologies for the Raigmore Heat Network. Technologies were assessed against various criteria, including:

- Resource availability – availability of local energy resource (specific site)
- Carbon reduction potential
- Commercial complexity and technology maturity
- Capital cost
- Operational cost
- Spatial requirements
- Planning considerations.

A heating technology suitability scoring table and resource availability assessment, aligned with the above criteria, is provided in Appendix C.

The technologies that performed most favourably against all criteria and are therefore considered as suitable options for the main low carbon heating technology for Raigmore were:

- Air source heat pumps (ASHPs)
- Ground source heat pumps (GSHPs) – closed loop
- Biomass
- Wastewater water source heat pumps (WSHPs).

Regarding peaking / back-up technologies, gas boilers were identified as the most economical solution for the Raigmore Heat Network, with lower associated operational and capital cost. Additionally, the analysis indicated that thermal storage was an attractive option to assist in meeting the heat demand for the network.

At Raigmore Hospital, there is an existing heat network in operation. The source of heat for this network is biomass boilers, utilising wood pellet as the fuel source. Raigmore Hospital is the largest hospital in the NHS Highland Health Board. The DH network onsite comprises 950 kW Pyrtec wood pellet boiler, thermal storage (2 x 10,000 l), and back-up oil boilers (2 x 900 kW).

6.3 Low Carbon Heating Technology

Closed Loop Ground Source Heat Pumps

Closed loop GSHPs utilise the thermal energy stored in the surface of the Earth. The ground is heated by exposure to sunlight. The ground maintains a relatively consistent temperature profile over the year. Closed loop GSHPs have particularly high efficiencies all year round (3 – 4 COP), which can assist in reducing operational costs.

To the east of the A9, there is considerable space available to instate a borehole array. Additionally, there is an upcoming development within the UHI / HIE campus; the buildout of this could align harmoniously with the implementation of a borehole array. Subject to ground condition testing, closed loop ground source heat pumps are a viable low carbon option to consider for Raigmore.

The effectiveness of GFSHPs depends on the soil composition, land availability and underground temperature. The underlying geology in Raigmore is expected to have reasonable thermal conductivities to extract heat from a closed loop system. The geology is made up of mostly sandstone, with borehole depths of 150 m recommended to abstract sufficient heat at consistent low-grade temperatures (~10°C). Despite closed loop borehole arrays being expensive to install, closed loop circuits require little maintenance and once instated do not impact aesthetics of the installed location. i.e., green space or car parks. Due to this, coordination with the upcoming developments could minimise any disruption but still allow for maintenance and access to be achieved for the boreholes.

Air Source Heat Pumps

ASHPs can be installed in a wider variety of locations compared to the heat pump units utilising ground or water as the low-grade source of heat. ASHPs utilise heat from the outdoor air, giving these systems flexibility in design, which has led to their large-scale deployment. ASHPs are an increasingly popular technology, which can be implemented centrally to supply a heat network or distributed on a unit-by-unit basis.

The spatial requirement for centralised ASHP units is quite considerable, due to the footprint associated with the dry air cooler units. These external fan units can either be roof-mounted or ground-mounted.

The relative efficiency of ASHPs is typically less than that of a ground-source heat pump solution, leading to an increase in the associated operational cost. Moderate climate conditions are preferred to increase system efficiency. Given Raigmore's location, the efficiency of an ASHP in Raigmore can be expected to be less than that of other locations in the UK with warmer weather conditions.

For built-up areas, noise can be an issue for the implementation of an ASHP. However, for Raigmore, the UHI / HIE campus has considerable land available. Hence, the noise associated with their operation is not of high concern. Additionally, given the proximity to the A9, the concern of noise associated with the ASHP presents as less of an issue. For the west of the A9, the space available is more limited. The use of the Raigmore Hospital car park has been identified as unfeasible, given the existing constraints on car parking space. However, overall ASHPs present as a viable low carbon heating solution for Raigmore.

Wastewater Water Source Heat Pumps

Sewer heat recovery utilises the thermal energy present in wastewater flowing through sewer networks. In these systems, wastewater is extracted from a mains sewer line before reaching the wastewater treatment works. There are different potential abstraction arrangements for these systems, depending on the chosen abstraction point and screening level.

Wastewater WSHPs (WWHPs) extract low-grade heat from wastewater, including sewage, by channelling the waste liquid through a heat exchanger integrated within the piping system. This low-grade heat is subsequently captured and upgraded to a higher grade using a heat pump.

WWHPs can represent a substantial capital investment due to the extensive infrastructure required (should a wet well need to be instated). Their operation can be complex and is primarily suitable for low-temperature heating systems. Nevertheless, the consistently high temperature of sewage (12°C) throughout the year offers an opportunity of high system efficiency, which can lead to significant reduced operational costs and reduced carbon emissions.

Implementing this technology in Raigmore appears promising, due the high flow rates indicated adjacent to the new HMP development site. The opportunity to extract heat from this sewage point is promising. Should the indicative flow rate (287 l/s) be observed, the potential heat recovery is far in excess of the heat demand for the network to the east of the A9. At present, the flow rates are indicative values and further engagement with Scottish Water would be required to accurately measure onsite flow rates.

6.4 Top-Up Technology

Gas Boiler

Gas boilers are readily available, low capital cost solutions for heating. They are a proven and compact technology. Gas boilers require limited space in the energy centre and offer a reliable source of heat.

Gas boilers are a fossil fuel-dependent technology and therefore do not assist in working towards net zero targets, as they are not a low-carbon solution. However, gas boilers can act as a top-up solution for a heat pump-led energy centre. The result of which is reduced capital and operational expenditure. Hence, for a budget-constrained scheme, gas boilers present an attractive solution to avoid the heavy capital cost associated with large heat output heat pump units. Additionally, the running costs associated with a gas boiler, compared to that of electric boiler are reduced, given the reduced cost of gas in comparison to electricity.

Electric Boiler

Electric boilers are a useful option for many developments moving away from natural gas. Electric boilers can replace gas boilers and still produce hot water via a ‘wet’ heating system. The operational costs associated are high for electricity, but the boilers are relatively low cost versus heat pumps and are compact in design.

However, this technology is not a cost-effective solution if significant electrical infrastructure upgrades are expected. Due to their lower efficiencies than heat pumps, electric boilers can result in significant demand on the local grid network, which can come at a cost. Nevertheless, this low carbon technology is a promising solution to be considered for top-up and heating back-up when heat pumps are not available, as long as major grid upgrades are not required.

6.5 Thermal Storage

Integrating large thermal storage with heat pump technologies offers multiple operational benefits for a heat network. Thermal stores are an effective way of storing and managing renewable heat until it is required by the network. This allows management of the difference in time between when heat is available and when it is needed.

Large thermal stores can be used to meet short-lived peak heating demands such as instantaneous hot water. In turn, this reduces the heat pump size and electrical requirements. Thermal storage is essential for effective utilisation of heat pumps, extending the run hours and preventing frequent start-stop cycling, which would otherwise reduce efficiency and overall life span of the heat pumps.

Large thermal storage can optimise the operational cost of a heat pump. When the heat pump capacity is more than the network demand the thermal storage can be charged. Additionally, the thermal stores can be charged during periods of low electricity rates, then discharged to meet the demand during periods of higher tariffs; this will optimise the operational strategy for the network.

The thermal storage considered for this study is sized based on water as the storage medium. Water storage has been considered in the first instance as it is a traditional, proven technology, which presents as a low-risk option.

6.6 Potential Energy Centre Locations

The energy centre will house the low carbon heating plant, network ancillary equipment, and back-up plant for the network. The selected location should be close to the low-grade heat source and network anchor loads. It is preferable to place the energy centre on council-owned or stakeholder land and away from residential dwellings. When considering the full Raigmore area, multiple potential energy centre locations were identified. Figure 6-1 highlights each potential energy centre location.

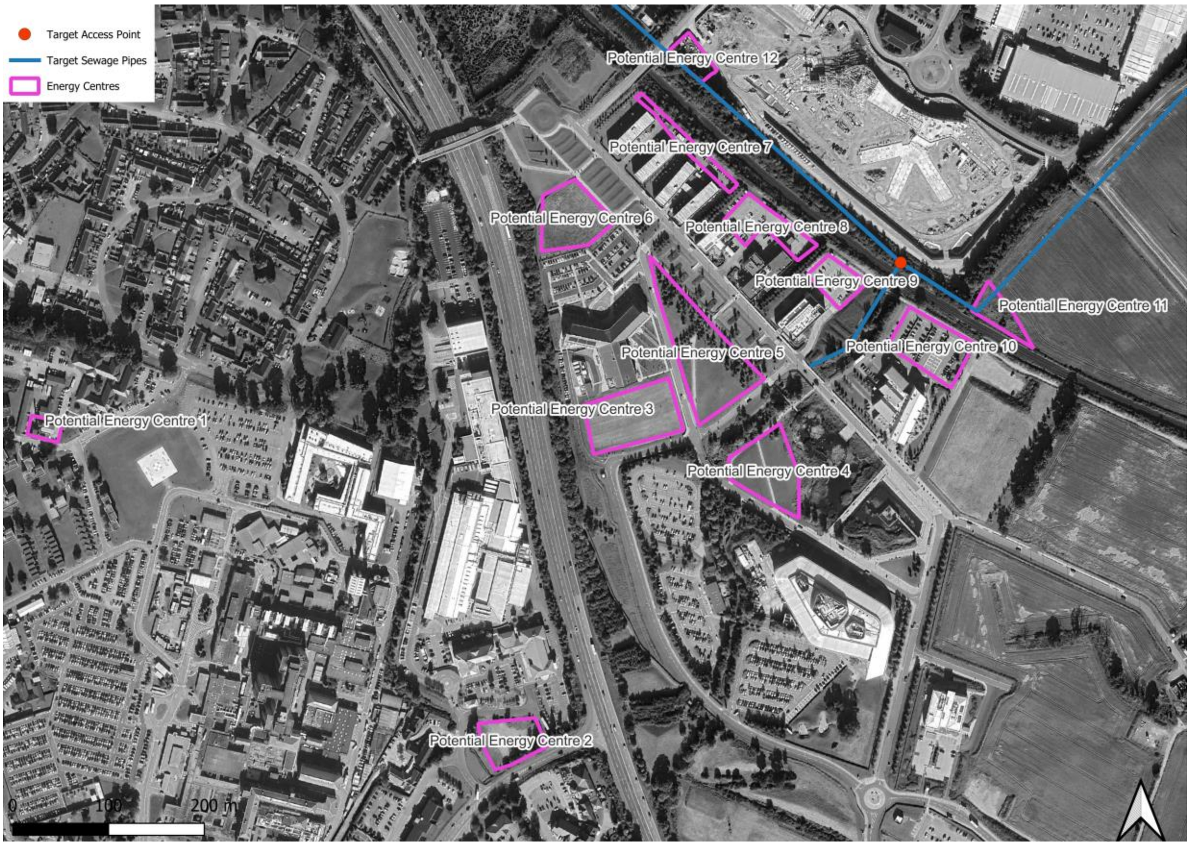

Figure 6-1 Potential energy centre locations

To the west of the A9, Location 2 emerged as the best option for an energy centre. This was due to its proximity to anchor loads such as Lifescan, Raigmore Hospital, and UHI House. Additionally, this location offers ample open space for the necessary equipment.

Looking to the east of the A9, there was an abundance of space for an energy centre, including the opportunity for boreholes to serve a potential ground source heat pump around the UHI/HIE campus. Additionally, a sewage pipeline running along the north side of the train line, highlighted by the blue line, was targeted for a wastewater option. For the east network, Location 12 offered the best solution due to its proximity to the identified anchor loads, access to the wastewater sewage pipe, and being on stakeholder land. It was also further away from student accommodation, mitigating noise pollution near residential areas which can be an issue when operating an ASHP.

6.7 Final Technology Shortlist

Following the technology assessment, a shortlist of low carbon technology scenarios was established; this list details the technologies which were progressed to the initial techno-economic modelling stage.

- Scenario 1: Centralised ASHP heat network with back-up gas boilers. Network established to the west of the A9
- Scenario 2: Centralised biomass heat network with back-up gas boilers. Network established to the west of the A9
- Scenario 3: Centralised (closed loop) GSHP with back-up gas boilers. Network established to the east of the A9
- Scenario 4: Centralised ASHP with back-up gas boilers. Network established to the east of the A9
- Scenario 5: Centralised WSHP (using wastewater as the low-grade heat source) with back-up gas boilers. Network established to the east of the A9.

Four low-carbon heating technologies were progressed to the interim techno-economic assessment. A high-level quantification of the potential heat available / low-grade heat requirement for each of these low carbon heating solutions is provided in Appendix C.

7 Techno-Economic Modelling

Section Outcomes

This section outlines the methodology employed, assumptions used, and results of the initial techno-economic analysis carried out for the Raigmore Heat Network study. The purpose of the initial techno-economic assessment was to determine the preferred low carbon heating solution.

Key elements addressed include:

- Key inputs and assumptions made for the Raigmore Heat Network
- Counterfactual cost of heat and heat sales price
- Revenue streams for the heat network
- Net Present Value (NPV) for the different Raigmore Heat Network scenarios at 40 years
- Calculated Internal Rate of Return (IRR) for each of the heat network scenarios at 40 years
- Selection of preferred low carbon heating technology for the main plant in the energy centre.

7.1 TEM Methodology

Each scenario suggested for the proposed network was assessed for financial viability with a techno-economic appraisal. This estimates the return on investment and net present values (NPV) over the lifetime of the project (40 years) using several inputs. The model calculates the energy consumption of the network, the capital expenditure (CAPEX), operational expenditure (OPEX), replacement expenditure (REPEX) and income from heat sales over the lifetime of the project. Within the techno-economic model, the connection fees have been included as an additional revenue stream, incurred in Year 1 (or year of connection for the phased buildings). The process is summarised in Figure 7-1. With regards to the sensitivity analysis, this was only performed on the preferred low carbon heating solution.

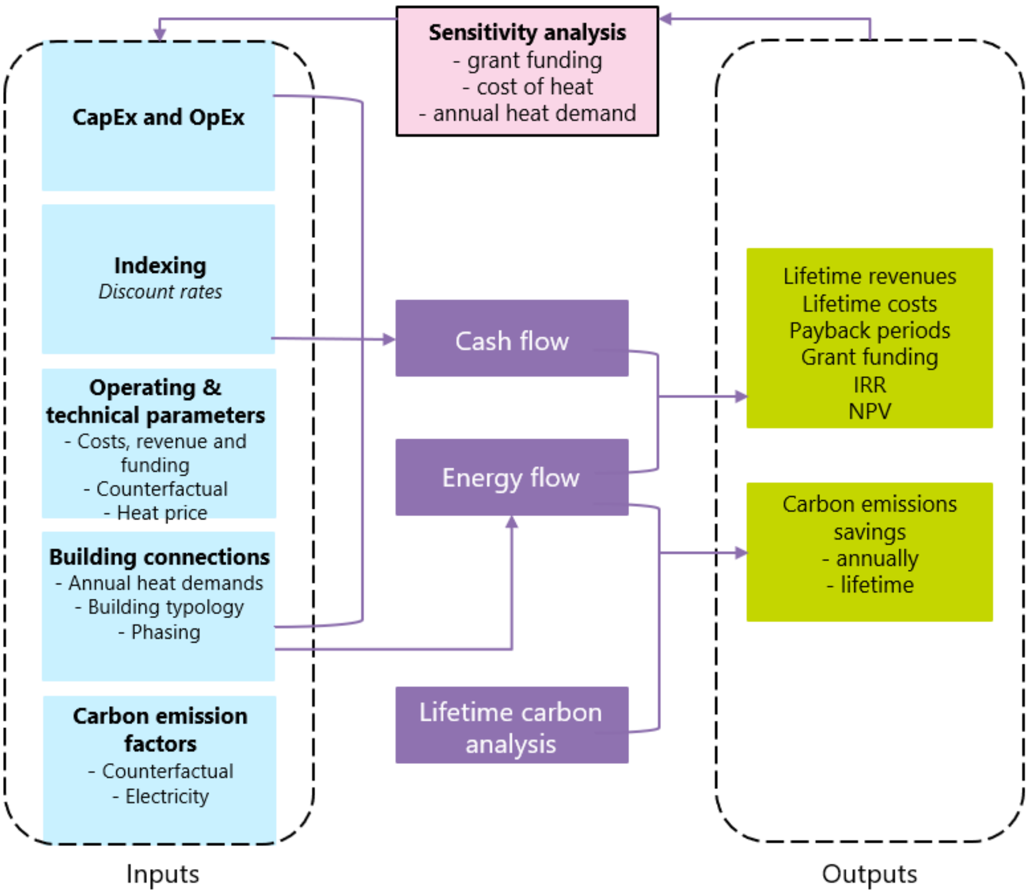

Figure 7-1: TEM methodology

The two main financial outputs calculated are:

a **Net present value (NPV)** – the cumulative present value of net project cash flow over a period
b **Internal rate of return (IRR)** – the discount rate at which the project NPV is equal to zero at the end of the project lifetime.

In the first instance, the financial viability of the heat network was considered for several potential low carbon heating technologies. For the network to the west of the A9, ASHP and biomass were considered as potential low carbon heating solutions. For the east of the A9, ASHP, closed loop GSHP, and wastewater WSHP were considered as potential heating solutions. As such, a total of 5 scenarios were modelled, as detailed below:

- Scenario 1: Centralised ASHP heat network with back-up gas boilers. Network established to the west of the A9
- Scenario 2: Centralised biomass heat network with back-up gas boilers. Network established to the west of the A9
- Scenario 3: Centralised (closed loop) GSHP with back-up gas boilers. Network established to the east of the A9
- Scenario 4: Centralised ASHP with back-up gas boilers. Network established to the east of the A9
- Scenario 5: Centralised WSHP (using wastewater as the low-grade heat source) with back-up gas boilers. Network established to the east of the A9.

7.1.1 Key Assumptions

In conducting the initial techno-economic analysis, several key assumptions were made, as detailed in Table 7-1.

Table 7-1: Key TEM assumptions

Parameter	Input	Description
Time period	40 years	40-year scheme period starting with a capital investment in 2027. Date agreed with The Highland Council.
Carbon offsetting costs included?	No	The UK Government Green Book does include carbon costs, but these were not integrated.
Heat network losses	10%	Assumed following guidance in Heat Network Code of Practice 1.
Pumping electricity requirement	2%	Parasitic losses applied for heat network fluid circulation.
Discount rate	3.5%	Green Book 2022 for Local Authority projects.
Connection charges	£7.3m	This is a one-off payment made in Year 1 (or year of connection for phased buildings) paid by the building connections. This reflects the avoided cost for the buildings by not having to install an alternative low-carbon system by connecting to the heat network. The connection cost is based on the capital cost associated with the counterfactual.
Natural gas carbon emissions factor ($kgCO_2e/kWh$)	0.184	DESNZ published carbon emissions factor. Unchanging throughout the model.

Parameter	Input	Description
Electricity carbon emissions factor ($kgCO_2e/kWh$)	0.072	DESNZ published carbon emissions factor, indexation for grid electricity projections[7].
Low carbon plant capacity	30% of diversified network peak	For the initial techno-economic modelling, the low carbon plant was sized to 30% of the diversified network peak. This plant capacity was assumed to deliver 85% of the annual network heat demand.

7.2 Cost

7.2.1 Fuel Cost

The proposed start date for the heat network is 2027. The fuel import prices in the model, used as the import cost to the energy centre, are displayed in Table 7-2. These prices are reflective of the DESNZ published 2025[8] retail prices for commercial / public sector consumers. To account for future cash flows, these prices have been indexed to most recent forecasted fuel prices, in line with the Green Book projections on retail electricity and gas prices.

Table 7-2: Fuel costs

Parameter	Import fuel price (p/kWh)	Description
Electricity	18.82	2025 – Green Book, commercial / public sector
Natural gas	4.84	2025 – Green Book, commercial / public sector

7.2.2 Revenue

For the energy centre, there are multiple revenue streams to be considered over the lifetime of the scheme, shown in Figure 7-2. The cost of heat to the buildings includes both a variable and fixed element.

The basis for cost of heat charged to the building connections is the counterfactual heating technology. For the Raigmore Heat Network, the counterfactual for the building connections is an individual ASHP heating solution at each building, where the ASHP meets the full demand of the building connection. In developing the techno-economic model, the heat sales tariff has been set equal to the counterfactual cost of heat. This is the upper limit for the heat sales price.

- **Variable rate (p/kWh)** is the price paid per unit of heat consumed by each customer, usually based on the fuel cost to deliver a kWh of heat, with consideration for the efficiency of the heating technology
- **Fixed tariff (£/kW)** is a flat rate paid to the heat network operator for connection to the network. This cost considers the plant OPEX & REPEX, metering and billing costs, and gas and electricity standing charge

[7] *https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal*
[8] https://www.gov.uk/government/statistical-data-sets/gas-and-electricity-prices-in-the-non-domestic-sector

- **Connection charge** is a one-off payment, made in Year 1 (or year of connection), paid by the building connections. The value is representative of the avoided cost of not having to install an alternative low carbon system by connecting to the heat network.

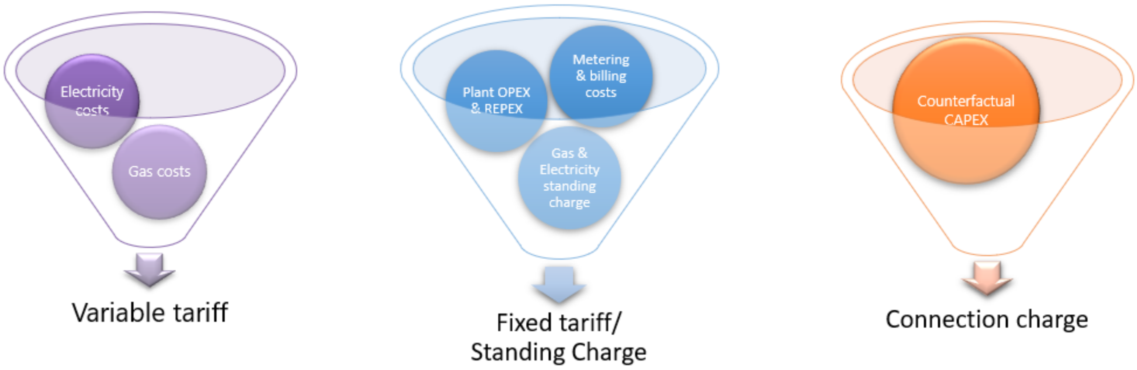

Figure 7-2: Revenue streams

The variable and fixed tariff for the cost of heat charged to the building connections is detailed below:

- **Variable rate (commercial, existing)**: 11.82 p/kWh
- **Variable rate (commercial, new build)**: 12.08 p/kWh
- **Fixed rate (commercial):** 68.07 £/kW.

The connection charge is based on the capital cost associated with the alternative low carbon heating solution. The total income from connection charges is phased across the project lifetime, in line with the buildings connecting to the network. The connection charges are detailed in Table 7-3.

Table 7-3: Connection charges

	Connection charge (£m)
Phase 1	3.59
Phase 2	2.23
Phase 3	0.82

7.2.3 Capital Cost

Capital costs have been developed through consultation with manufacturers, industry reference data and previous Buro Happold experience of similar projects. The assumptions for the “Additional Costs” can be found in Appendix D. A visual representation of CapEx for each of the scenarios considered is given in Figure 7-3.

Figure 7-3 Phased CAPEX, by scenario

Scenario 3 was the most expensive option due to the additional costs associated with network ancillaries, including the drilling of boreholes for the ground source heat pump.

7.2.4 Operation and Maintenance Cost

Fuel costs, operation & maintenance (O&M), REPEX and staff costs were applied to each network option, based on the rates provided in Appendix D.

7.3 Lifetime Costs

A comparison of the lifetime costs associated with each network scenario was completed to give an indication of the overall costs associated with each solution. The lifetime costs consider CAPEX, fuel costs, operation and maintenance costs, and REPEX. The costs are modelled over a 40-year project lifetime. The results are displayed in Figure 7-4.

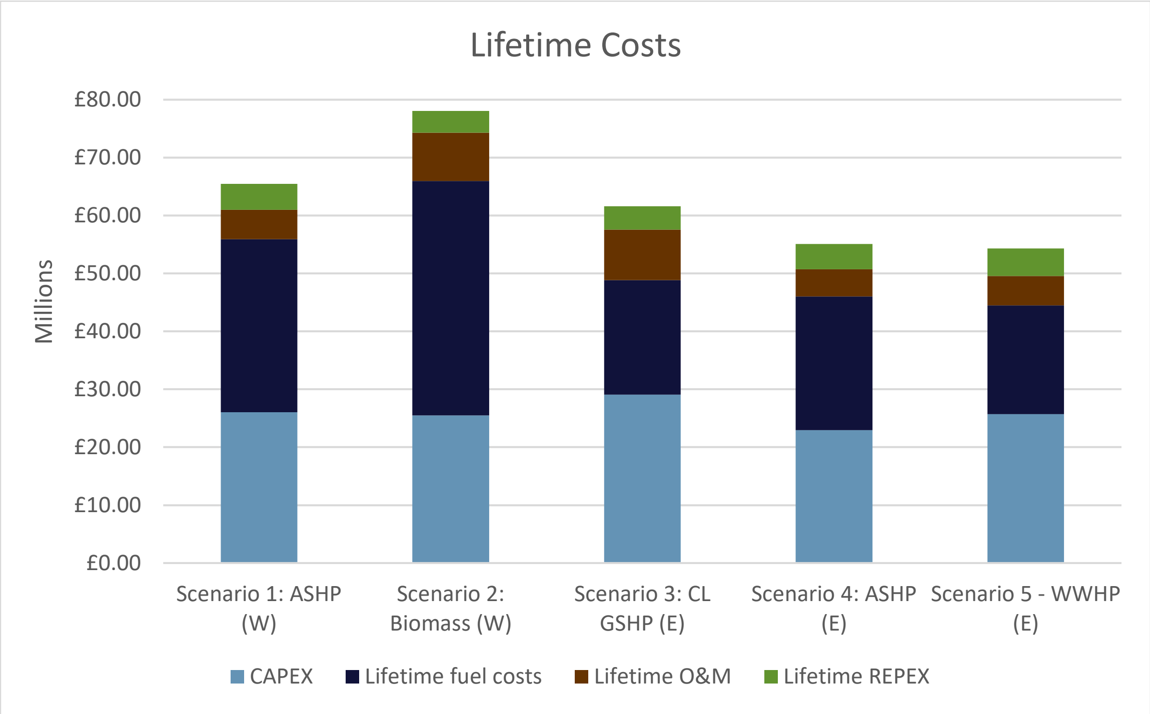

Figure 7-4: Lifetime costs

Scenario 2 has the greatest lifetime costs of the five scenarios considered. The greatest proportion of the costs for this option are associated with the fuel costs.

7.4 Levelised Cost of Heat

The levelised cost of heat (LCOH) represents the heat tariff required for the scheme to demonstrate profitability. LCOH considers the lifetime capex & repex, operation and maintenance costs, and fuel costs. For each option, the LCOH is displayed in Figure 7-5. Of the 5 options, the lowest levelised cost of heat is Scenario 1: 12.62 p/kWh.

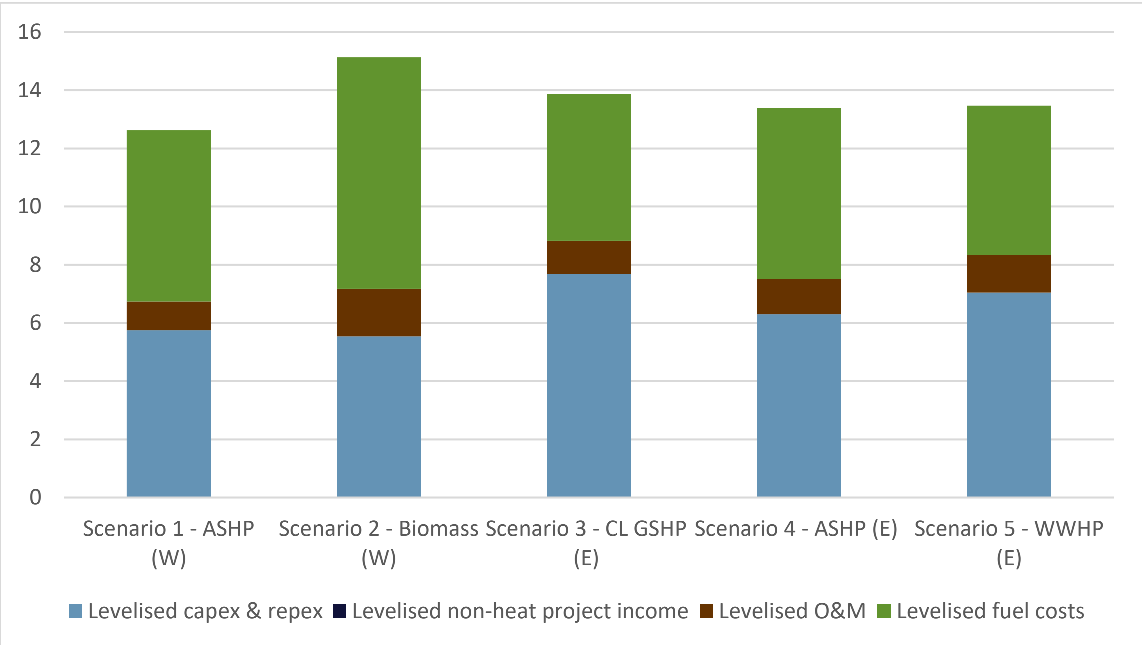

Figure 7-5: Split of key items behind the LCOH for the five scenarios.

The levelized heat tariff represents the tariff charged to the network connections, amalgamating the variable and fixed tariffs to provide a single p/kWh figure. This is detailed in Table 7-4.

Table 7-4: LCOH and the levelized heat tariff

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
LCOH (p/kWh)	12.62	15.12	13.87	13.39	13.46
Levelised heat tariff (p/kWh)	10.92	10.92	11.64	11.64	11.64

7.5 Low Carbon Technology: Results

The results of the initial techno-economic analysis are detailed in Table 7-5; these values are reflective of full network build-out. These network scenarios are unfunded. Of the scenarios modelled, a positive NPV is not achieved for any option.

The best performing network on an IRR and NPV basis is Scenario 4: ASHP (East).

Table 7-5: TEM results

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
NPV @ 40 years (£m) – unfunded	-2.5	-15.3	-2.8	-1.0	-1.3
IRR (%) at 40 years – unfunded	2.7	N/A	2.6	3.1	3.0

7.5.1 Summary

The initial techno-economic modelling has considered 5 scenarios for the Raigmore Heat Network. The best performing network is Scenario 4: ASHP (East). This option was selected as the preferred solution for the Raigmore Heat Network and progressed to the more detailed techno-economic analysis.

8 Energy Modelling and Heat Supply Equipment

This section outlines the approach taken to energy modelling for the Raigmore Heat Network, as well as the plant sizing strategy. The energy modelling was completed for the preferred heat network scenario only. As identified by the initial techno-economic model, this was the ASHP heat network for the East of the A9.

8.1 Operating Temperatures

Network temperatures have decreased over time, shifting from steam (first generation) to lower temperature (fourth generation) networks (Figure 8-1).

Most existing heat networks in the UK are third generation (3G) and operate at higher temperatures, which allow connection to existing building heating systems (e.g., conventionally sized radiators). This is without the requirement of any enabling works to the building heating system (e.g., replacement of heat emitters).

Low carbon heat technologies, such as heat pumps, achieve efficient performance at lower temperatures on 4G systems. The CIBSE CP1 Heat Network Code of Practice are encouraging designers to move towards a preferred 70/40°C approach for HN systems for new buildings. However, for existing buildings to connect to a 4th Generation HN, enabling works are often required. This may include replacing heat emitters such as radiators and fan coil units.

As the proposed temperature regime for the Raigmore Heat Network is 3G, the assumption is that the buildings will be ready to connect to the heat network without enabling works. For the Raigmore Heat Network, a 5G HN was not considered due to the lack of cooling demand on the network.

Given that the operating temperature for many of the potential HN building connections is high (~80°C), particularly in the early phases of the network, the proposed heat network generation for Raigmore is **third generation**. This design consideration was made on the basis that the additional cost associated with the enabling works required for operation of a lower temperature network could negatively impact the economic performance of the scheme.

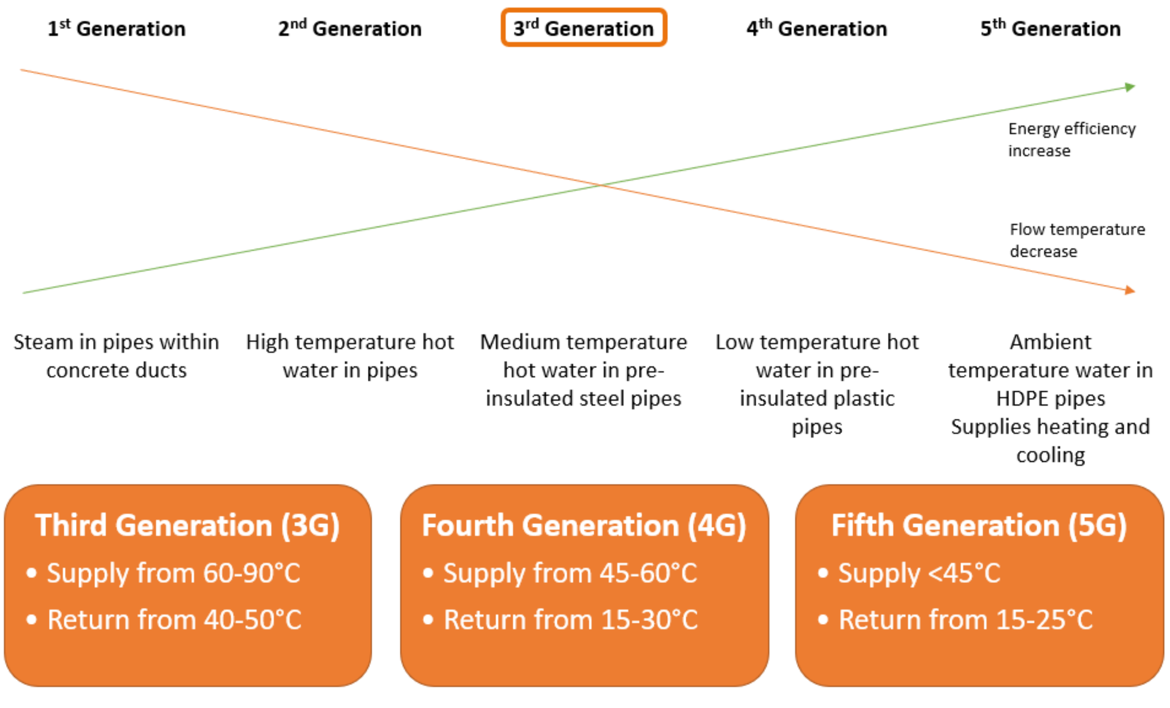

Figure 8-1: Overview of heat network generations

Table 8-1: Heat network generations

Generation	Flow and return temperature (°C)	Description
3G network	Flow: 60-90 Return: 40-50	Higher flowrates – larger pipework Low efficiency for heat pumps and associated heat loss Suitable for existing and new heat networks serving buildings operating at temperatures around 80°C
4G network	Flow: 45-60 Return: 15-30	Lower flows and higher efficiency Minimal heat loss Building heat emitter upgrades required for buildings operating at higher temperatures Suitable for new building developments where buildings are designed to work at lower temperatures

8.2 Energy Modelling

Heat demand modelling was carried out using a combination of EnergyPRO (EPRO) software and Excel modelling.

To size the required heating plant, an annual demand profile was generated for the whole HN; this considers the heating demand of each connection and network losses of 10% of the annual demand. To achieve this, a combined approach was employed. For the connections where HH data was received from the RFI process, this yearly profile was utilised. The profiles were weather corrected to align with current temperatures in Inverness.

For those buildings without HH data, the building's annual heat demand was distributed across a yearly profile based on a typical week's hourly profile for that building typology.

The modelling considers the ambient air temperature using historical weather data and predicts when heating is required. This process is shown in Figure 8-2.

Figure 8-2: Heat demand profiling approach.

The annual heat demand is met by a combination of the low carbon heat supply (ASHP) and the peaking boiler plant.

8.3 Plant Sizing

The heating plant within the energy centre has been sized to meet the demand of the network, without oversizing the equipment and incurring unnecessary capital cost. Key modelling inputs which have been accounted for in the plant sizing include:

- >85% heat fraction met by heat pump for all phases
- Minimum turndown ratio of 30%
- 95% availability on the heat pumps each year for equipment to carry out maintenance work (conducted in summer)
- 10% network heat losses (CIBSE CP1).

To maximise the generation from the low carbon technology solution, the following have been considered:

- Using a modulated heat pump solution, where, instead of relying on a single larger unit, 4 smaller heat pumps have been considered. Such a solution will have a lower turndown ratio, enabling a greater range of heat demand to be met. This solution also offers some resilience in the system, as there is more than one heat pump unit, so if one fails, the demand met by the low carbon heating technology does not fall to zero
- Prioritisation of the heat pumps, over the boilers, so that if the demand is within the capacity of the heat pump, it will be met by the low carbon technology. The boilers will only be used to reach peak demands and demands below the turndown ratio of the heat pump
- Strategically planned maintenance period to coincide with the summer season when heat demand is low. The is coordinated across the heat pumps to minimise downtime
- Thermal storage used to bolster the heat output generated by our low carbon technology. This technology allows the storage of excess heat for use during periods of high demand, ensuring a reliable energy supply and maximising low carbon technology generation.

The sized equipment at each phase is indicated in Table 8-2. For the full network build out, the COP of the ASHP is modelled at 2.44, and the number of ASHPs is four.

Table 8-2: Plant sizing

	Phase 1	Phase 2	Phase 3
Diversified peak (kW)	6,500	9,000	9,800
Low carbon technology (kW)	2,500	3,500	3,500
Boiler plant capacity (kW)	9,000	12,000	12,000
Thermal storage (m^3)	150	150	200
Low carbon heat fraction (%)	90%	89%	87%

8.4 Resilience Strategy

The heat network must demonstrate resilience to ensure a reliable and continuous supply of thermal energy to the buildings. This is done by introducing mitigation measures in the event of reduced equipment availability e.g., maintenance and repair. The resilience strategy employed is outlined below:

- **Modular heat pumps** to improve heat reliability by using multiple heat pumps and to easily provide heat during periods of low demand (low turndown ratio). The use of modular heat pumps ensures that there is not a time where planned maintenance would result in zero heat supply from low carbon technology
- **Modular back-up** boilers to reduce risk of insufficient top up
- **Additional capacity in the back-up plant –** the boiler plant has been sized to cover the diversified peak of the network, with additional capacity to ensure there is resilience should one of the heat pump units fail.

8.5 Section Summary

This section outlines the heat network design for the Raigmore Heat Network. Key findings are:

- The Raigmore Heat Network will operate as a 3G high temperature network to ensure the heat demand is reliably met for all connections. This also mitigates the need for potential enabling works which could require the Council to add an additional expense and to seek additional funding for building-side works
- The HN has a diversified peak heat demand of **9.8 MW**, at full build out of all phases
- Plant sized to maximise heat pump heat generation and achieve >85% heat fraction
- The plant sizing strategy for the full build-out includes:
  - 3 No. 1 MW and 1 No. 500 kW heat pumps will work in tandem to efficiently meet the heating needs of the network
  - 12 MW back-up boiler capacity is integrated to complement the heat pumps when necessary, ensuring consistent heat supply. Additional capacity is also incorporated into the boiler plant to offer resilience
  - 200 m³ thermal storage system is incorporated to enhance system flexibility and maximise low carbon technology
  - 87% of the heat demand is met by low-carbon technology heat pump.

9 Spatial Coordination

This section provides insight into spatial coordination of the energy centre and its electrical consideration, leading onto the development of the proposed heat network route.

Key considerations include:

- Energy centre layout and electrical considerations
- Proposed heat network route.

9.1 Energy Centre Location

An optioneering assessment was carried out to identify the location for a new energy centre. Which was discussed in section 5.5.

The location is situated in the northwest corner of the HMP development and is highlighted as potential energy centre location 12 in Figure 6-1, on a parcel of land close to the initial Phase 1 network connections, offering over 1,000 square meters of space. Currently, the location has no specific function. However, relevant stakeholders, including the prison, will need to be consulted further if this study is to be advanced.

9.1.1 Energy Centre Layout

An initial outline for the energy centre was prepared for the ASHP scenario. This design considers the spatial, access, and maintenance requirements, as shown in Figure 9-1. The total footprint area for the standalone building is anticipated to be approximately 500 m^2 (20 m by 25 m), as depicted in Figure 9-1.

The high-level design accounts for the spatial requirements of the key components of the energy centre, including allowances for general access and maintenance zones. At this stage, it is assumed that the building will be a single-floor standalone structure with the heat pump evaporator units located on the roof. Future designs can be adapted to two-storey buildings if footprint space needs to be minimized; however, the selected location has ample room for additional extensions. To save on civil works costs, the thermal stores, which require significant space, are to be located outside the energy centre building.

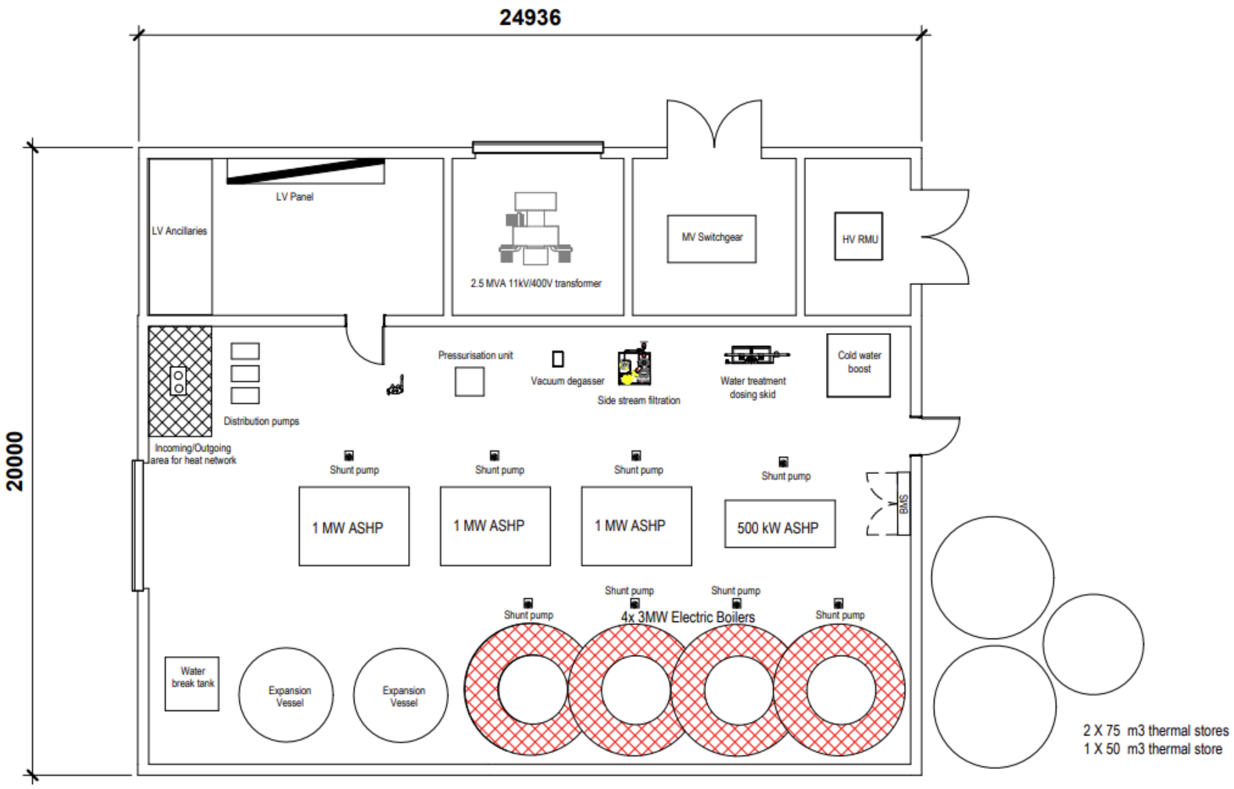

Figure 9-1 Energy centre layout

9.1.2 Electrical Considerations

Engagement took place with Scottish & Southern Electricity Networks (SSEN) to develop a strategy for supplying power to the equipment within the energy centre. The targeted substation is currently constrained. However, planned reinforcement works are to take place at this substation, with completion in August 2029.

The SSEN network operates at 11kV. To step down the voltage from 11kV to 400V within the energy centre, a transformer is necessary. This transformer has been sized based on a preliminary equipment schedule, which includes power requirements for mechanical equipment, small power, and lighting within the energy centre. High voltage electric boilers were chosen to minimise the need for multiple transformers, as they would incur significant costs and require a large floor area. Consequently, MV switchgear was incorporated into the energy centre designs to distribute the high voltage throughout the facility.

9.2 Pipe Sizing

For the preferred heat network route, identified at the Interim Stage of this project, utility coordination and pipe network sizing were undertaken, as detailed in Section 0.

The proposed heat network route for the preferred scenario is detailed in Figure 9-2.

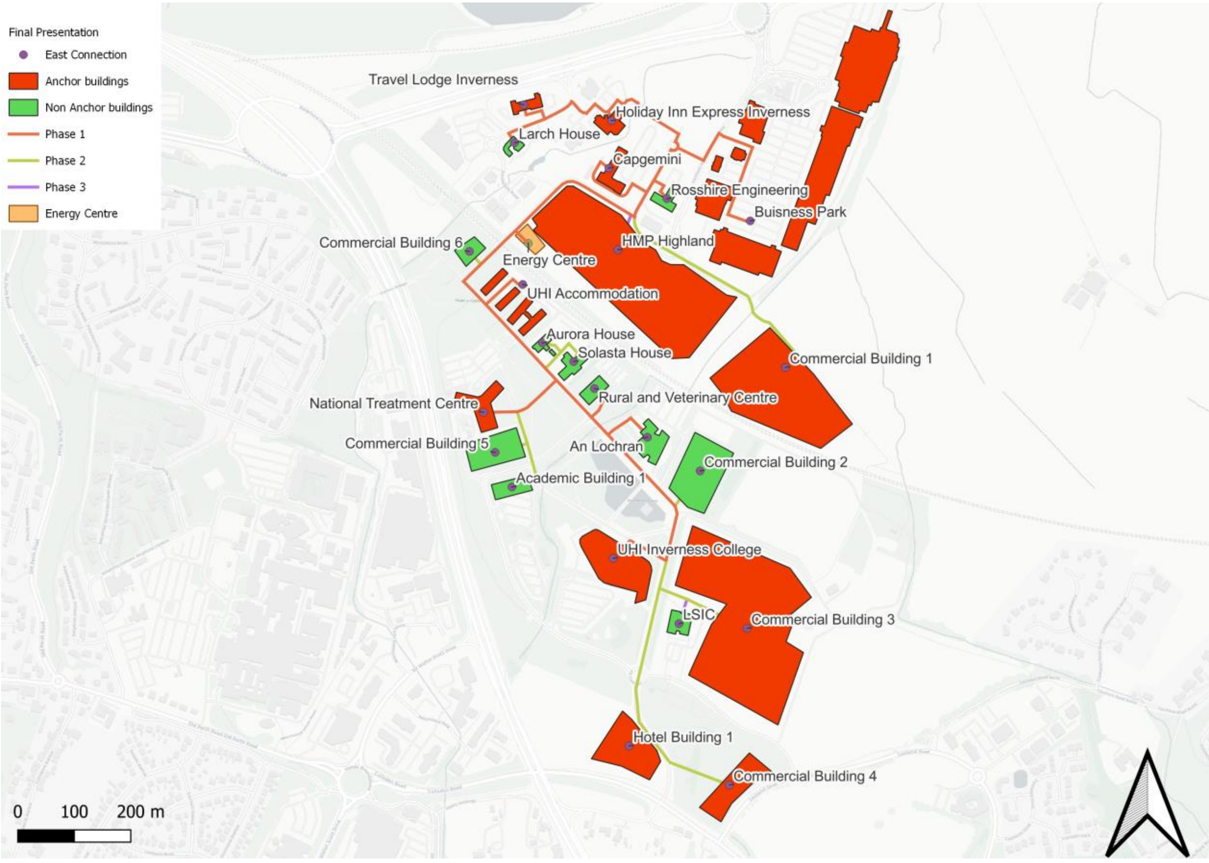

Figure 9-2 Heat network route

Pipe sizing for the proposed heat network was conducted. The total pipework length is ~ 4,510 m. This includes 2,785 meters in Phase 1, 1,615 meters in Phase 2, and 110 meters in Phase 3. It should be noted that where the pipework extended into the Free Port construction zone, the trench dig was assumed to be soft. A detailed table of pipe sizes, trenching type and lengths for Phase 1, Phase 2, Phase 3 and the full build-out is provided in Appendix E.

A summary of this network is shown in Table 9-1. The LHD, 4.6 MWh/y/m, is higher than the reference Baseline (4 MWh/m/yr)[9].

Table 9-1 Summary table of proposed network

Metric	Unit	Value
Heat demand (incl. DHN Losses)	MWh/yr	20,750
Heat network trench length	m	4,508
Linear heat density	MWh/y/m	4.6
Largest pipe diameter	DN (mm)	250

[9] www.Gov.scot. First National Assessment of Potential Heat Network Zones, April 2022. URL: First National Assessment of Potential Heat Network Zones (www.gov.scot) Accessed 31/03/2023

9.3 Section Summary

This section presented the preferred location for a new energy centre from which heat can be supplied to Raigmore Heat Network, as well as the considerations around electrical infrastructure required to provide heat. Floor plans of potential equipment arrangements within the energy centre for the preferred scenario were also presented. Similarly, the development of a preferred heat network route has also been presented here.

The following key elements have been established:

- The preferred energy centre is in the northwest corner of the HMP development, on a parcel of land close to the initial Phase 1 network connections, offering over 1,000 square meters of space
- The proposed heat network route is composed of:
  - **Phase 1:** 2,785 m of pipework
  - **Phase 2:** 1,615 m of pipework
  - **Phase 3:** 110 m of pipework
- Energy centre floor area:
  - **Preferred Scenario: ASHP + gas boiler/electric boiler back-up/top-up**
    - Total floor area required: 500 m^2.

10 Techno-Economic Results – Preferred Solution

Section Outcomes

This section outlines the results of the techno-economic analysis carried out for the preferred Raigmore Heat Network scenario: *ASHP heat network to the east of the A9.*

Key elements addressed include:

- Key inputs and assumptions made for the Raigmore Heat Network
- Counterfactual cost of heat and heat sales price
- Net Present Value (NPV) for the different Raigmore Heat Network scenarios at 40 years
- Calculated Internal Rate of Return (IRR) for each of the heat network scenarios at 40 years
- An assessment of the most appropriate peaking technology in the energy centre
- A sensitivity analysis, considering the scheme's performance against varying parameters
    - Grant funding considerations
    - Variation in heat sales price
- Heat network recommendations.

Grant funding has been considered within the techno-economic model. The grant funding looks at funding for the heat network's capital expenditure. The funding considered is up to 50% of the capital costs associated with the network, excluding any non-low carbon plant (e.g., gas boilers).

10.1.1 Limitations

The techno-economic model (TEM) is a pre-tax model used to give an initial indication of costs, revenues, and potential cash flows over time.

This TEM is different from a financial model, which is usually prepared at the Outline Business Case (OBC) stage and refines information such as heat sales tariffs.

A TEM is not to be taken as financial advice – it is to be used as part of the feasibility study to identify project opportunities worth progressing to a deeper level of detail at the next project stage.

Costing presented in this report is indicative only. It is based on information from manufacturers and project experience. Costing has been reviewed by an external Quantity Surveyor cost consultant.

10.2 Counterfactual Cost of Heat

Following the initial techno-economic assessment, the counterfactual cost of heat was refined. Within the techno-economic model, consideration has been given to the business-as-usual (BAU) heating technology and the counterfactual, in addition to the heat network scenarios. The assumptions are detailed in Table 10-1.

Table 10-1: BAU and counterfactual

Building connection	Business-as-usual (BAU)	Counterfactual
Business and retail park (Tesco Express area)	Gas boiler	ASHP
UHI Inverness College	Gas boiler	ASHP
HMP Highland (new prison)	GSHP	GSHP
National Treatment Centre Highland	Gas boiler	ASHP
Holiday Inn Express	Gas boiler	ASHP

Building connection	Business-as-usual (BAU)	Counterfactual
Travel Lodge Inverness	Gas boiler	ASHP
UHI Accommodation	Gas boiler	ASHP
HIE – An Lochran	Gas boiler	ASHP
Capgemini	Gas boiler	ASHP
Rural and Veterinary Innovation Centre	Gas boiler	ASHP
HIE – Aurora House	ASHP	ASHP
HIE – Solasta House	ASHP	ASHP
Rosshire Engineering	Gas boiler	ASHP
NHS Highland – Larch House	Gas boiler	ASHP
Freeport connections	ASHP	ASHP

Largely, the BAU heating technology is gas boiler; most existing connections have not yet transitioned to a low carbon heating solution. For those connections with an existing low carbon heating solution, the current heating technology is taken as both the BAU and counterfactual.

10.3 TEM Inputs

A summary of the different fuel cost and revenue items used in the economic modelling is provided in Table 10-2.

Table 10-2: Summary of cost assumptions for fuel, and the heat sales price and the fixed charge to customers.

Parameter	Value	Description
Electricity	18.82 p/kWh	2025 – Green Book, commercial / public sector
Natural gas	4.84 p/kWh	2025 – Green Book, commercial / public sector
Heat sales price – commercial existing	12.33 p/kWh	Based on the counterfactual heating technology
Heat sales price – commercial new build	11.05 p/kWh	Based on the counterfactual heating technology
Fixed charge	73.1 £/kW/yr	Based on the counterfactual heating technology Fixed charge is taken annually.

10.3.1 Connection Charge

The connection charge is based on the capital cost associated with the alternative low carbon heating solution, which is an ASHP/GSHP mix for the Raigmore Heat Network connections. The total income from connection charges is phased across the project lifetime, in line with the buildings connecting to the network. The connection charges for each phase of the proposed heat network per building are summarised in Table 10-3.

Table 10-3 Connection charges

Connection	Connection charge Phase 1 (£m)	Connection charge Phase 2 (£m)	Connection charge Phase 3 (£m)
Business and retail park - Tesco Express area	1.53		
UHI Inverness College	0.74		
HMP Highland (new prison)			0.63
National Treatment Centre Highland (NHS)	0.34		
Holiday Inn Express Inverness, an IHG Hotel	0.19		
Travel Lodge Inverness	0.11		
UHI Accommodation	0.14		
HIE - An Lochran (HQ building)	0.20		
Capgemini – Offices	0.3		
Rural and Veterinary Innovation Centre	0.10		
HIE - Aurora House		0.17	
HIE - Life Science Innovation Centre			0.07
HIE - Solasta House		0.10	
Rosshire Engineering	0.10		
NHS Highland Larch House	0.03		
Freeport connections		2.77	
Total	3.76	3.04	0.70

10.4 Capital Cost

Capital costs for the preferred solution have been developed through consultation with manufacturers, industry reference data and previous Buro Happold experience of similar projects. An independent QS check was completed by Thomson Bethune to verify the capital expenditure used in the model.

Figure 10-1 provides an insight to the phased capital costs for the network.

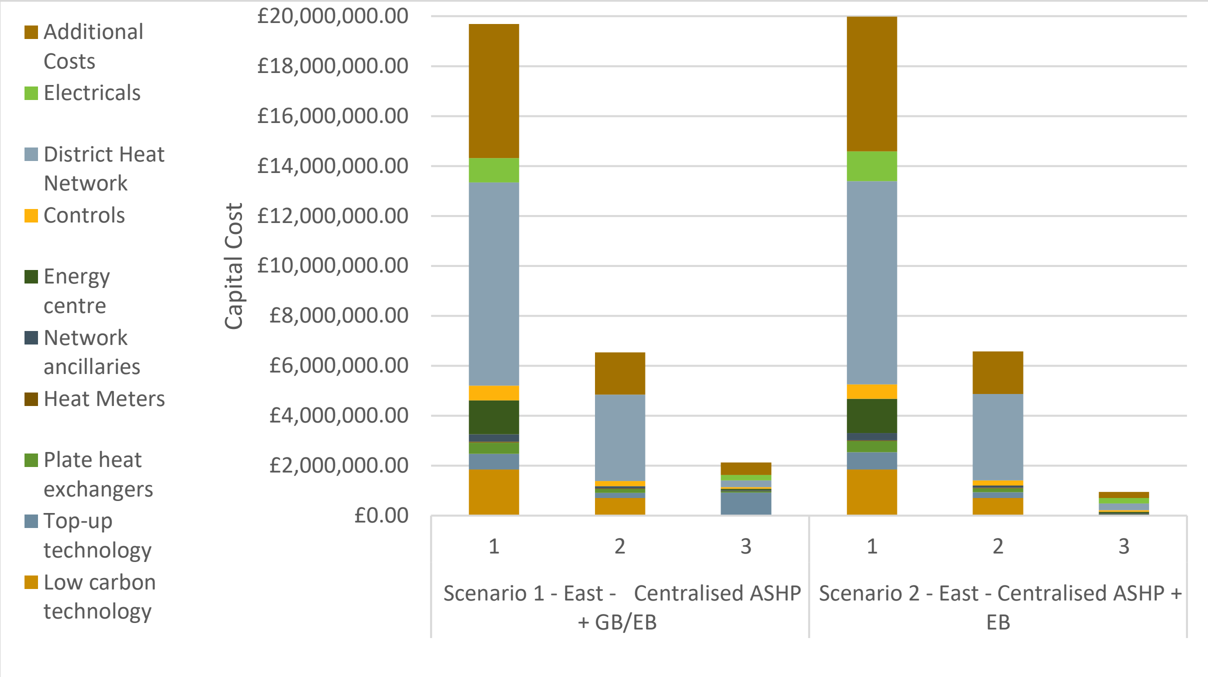

Figure 10-1 Phased capex per scenario for the East of the A9 network.

In Scenario 1, the initial capital costs for gas boilers in Phases 1 and 2 are slightly lower compared to Scenario 2. However, by Phase 3, the capital costs become higher. This increase is due to the switch from gas to electric boilers, which incurs additional costs. As a result, Scenario 1 has the highest overall capital costs. Within the techno-economic model, REPEX has not been included for the gas boiler plant in Scenario 1, due to the full replacement of plant in Phase 3.

10.5 Results

For this more detailed techno-economic model, four scenarios have been considered, as below:

1 Raigmore Heat Network – East A9 – ASHP / gas boiler
2 Raigmore Heat Network – East A9 – ASHP / electric boiler
3 Counterfactual – combination of building level ASHP and GSHP
4 Business-as-usual – existing heating technology (gas boiler, building level ASHP, building level GSHP).

10.5.1 Lifetime Costs

To understand the overall costs associated with each heat network option, the lifetime costs have been compared to the counterfactual and BAU heating solutions. The lifetime costs are displayed in Figure 10-2. The most expensive scenario over the modelled project lifetime (40 years) is the ASHP / electric boiler heat network (£64.8m) and the least expensive is the BAU. The BAU heating solution is largely gas boiler and as such does not represent a viable low carbon heating solution.

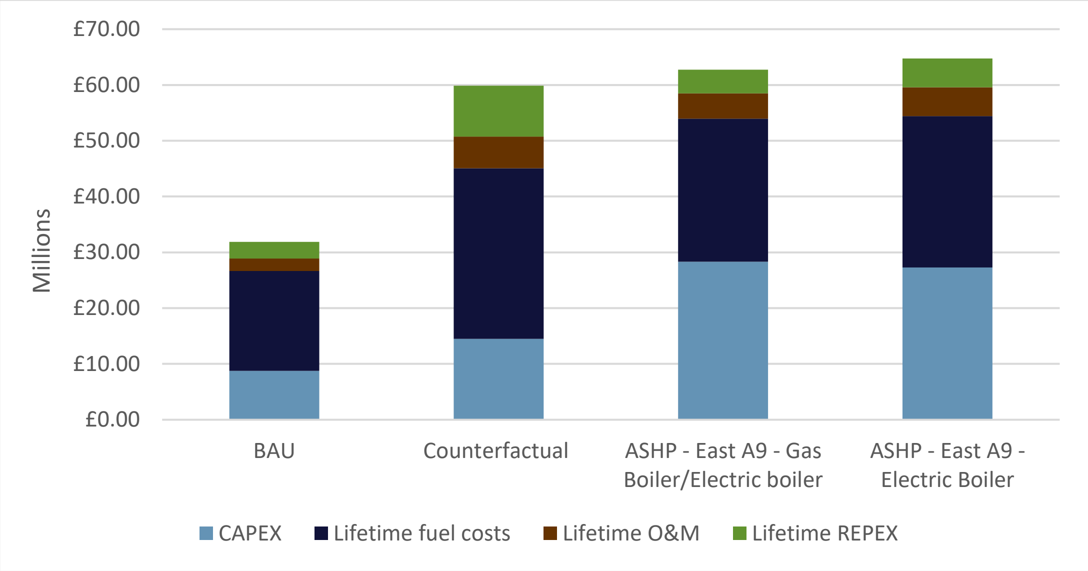

Figure 10-2: Lifetime costs for the East A9 network – full feasibility compared to BAU and counterfactual – unfunded

The assessment of the counterfactual solution has been considered in less detail compared to the heat network options. Given that the focus of this study is on the assessment of a heat network solution, there are limitations around the counterfactual assessment within the confines of this study. A complete assessment of the electrical upgrade and connection requirements, and their associated costs has not been conducted within this model. Additionally, the capital cost has only considered the heat pump unit and no further costs for any changes to the building. Hence, although the lifetime costs reflected indicate that this solution is superior to the heat network options, the counterfactual assessment is less comprehensive. Therefore, it is warranted to pursue the heat network opportunities further, at this stage.

10.5.2 Levelised Cost of Heat

The levelized cost of heat represents the heat tariff required for the scheme to demonstrate profitability. This considers the lifetime capex & repex, operation and maintenance costs, and fuel costs. As displayed in Figure 10-3, the ASHP / Electric Boiler heat network has the highest associated levelized cost of heat to the customer (15.86 p/kWh). This can be attributed to higher fuel costs present for operating electric boilers compared to gas boilers.

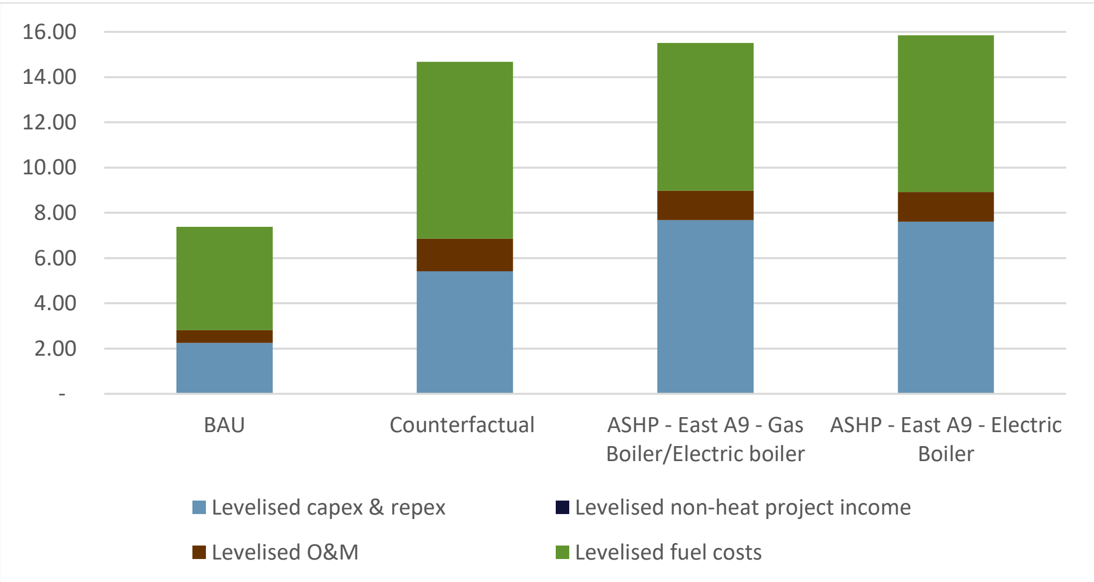

Figure 10-3: Levelised cost of heat for East A9 network – full feasibility compared to BAU and counterfactual – unfunded

The levelized cost of heat for the BAU is significantly lower than the low carbon solutions, as detailed in Table 10-4. This is largely due to the fuel for most of the BAU being gas compared to the electric counterfactual.

Table 10-4: Levelised cost of heat for East A9 network – full feasibility compared to BAU and counterfactual – unfunded

	BAU	Counterfactual	ASHP / Gas Boiler	ASHP / Electric Boiler
Levelised cost of heat (p/kWh)	7.39	14.67	15.52	15.86

10.6 Cash Flow

The results of the techno-economic analysis are illustrated in the cash flow curves for each scenario, showing revenue streams, operational expenditure and the NPV line.

10.6.1 ASHP / Gas Boiler

Figure 10-4 shows the cash flow for the ASHP / gas boiler without funding. The year-on-year revenues exceed cost, resulting in a positive gradient of the NPV line; however, the scheme does not achieve a positive NPV at the end of the modelled period (-£4.2m).

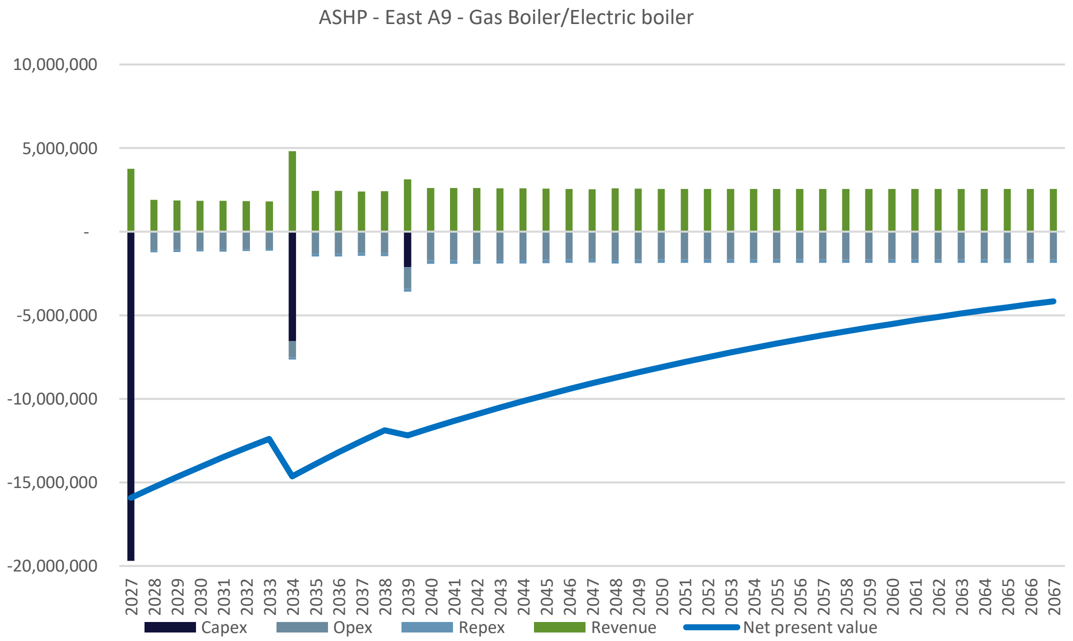

Figure 10-4: Cash flow – ASHP / gas boiler – unfunded

Figure 10-5 shows the cash flow curve for the ASHP / gas boiler network, with 50% capital funding. The 50% capital funding reflects the maximum funding available for the heat network schemes. With the maximum funding, the scheme does achieve a positive NPV at the end of the project lifetime (£12m). This illustrates the scheme's dependence on grant funding.

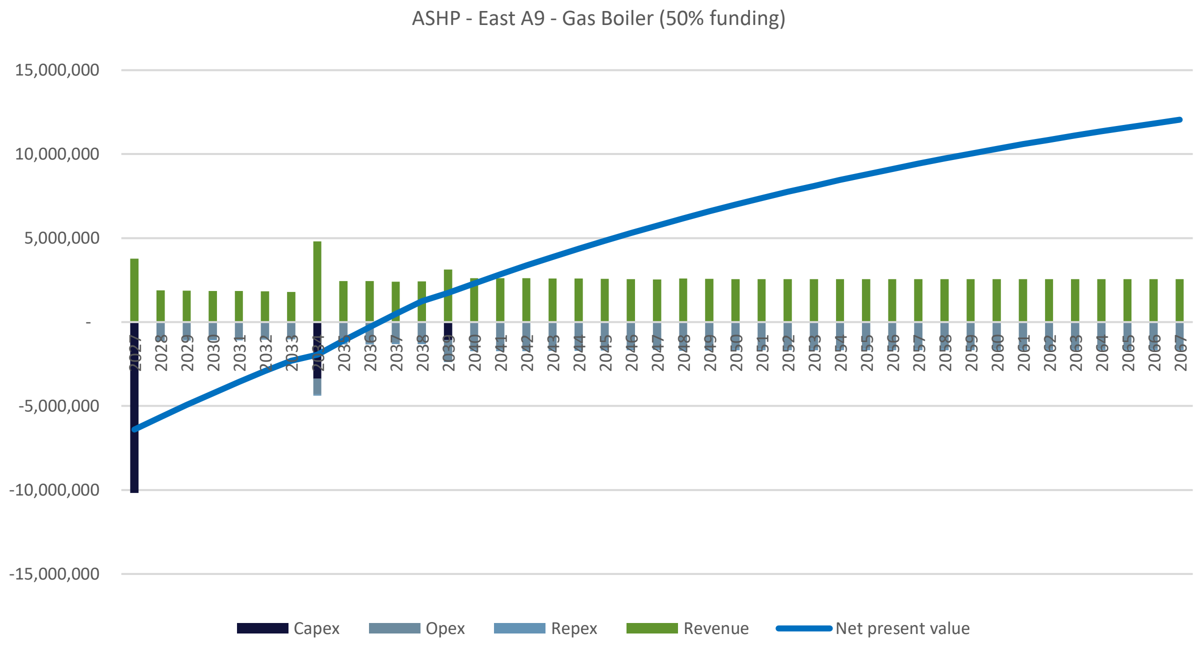

Figure 10-5: Cash flow - ASHP / gas boiler (50% CAPEX funding)

10.6.2 ASHP / Electric Boiler

Figure 10-6 shows the cash flow for the ASHP / electric boiler without funding. The year-on-year revenues exceed cost, resulting in a positive gradient of the NPV line; however, the scheme does not achieve a positive NPV at the end of the modelled period (-£6.3m).

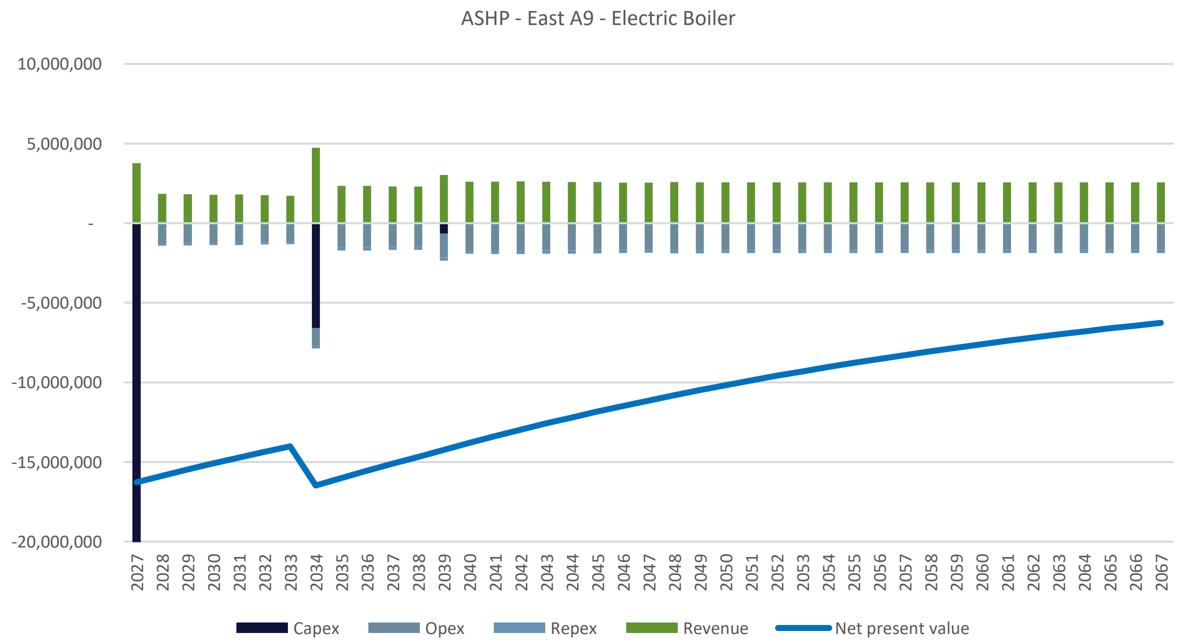

Figure 10-6: Cash flow - ASHP / electric boiler – unfunded

Figure 10-7 shows the cash flow curve for the ASHP / electric boiler network, with 50% capital funding, which is recognised as the maximum funding available for the heat network scheme. The scheme achieves a positive NPV at the end of the project lifetime (£10.4m), with the introduction of grant funding. This illustrates the scheme's dependence on grant funding.

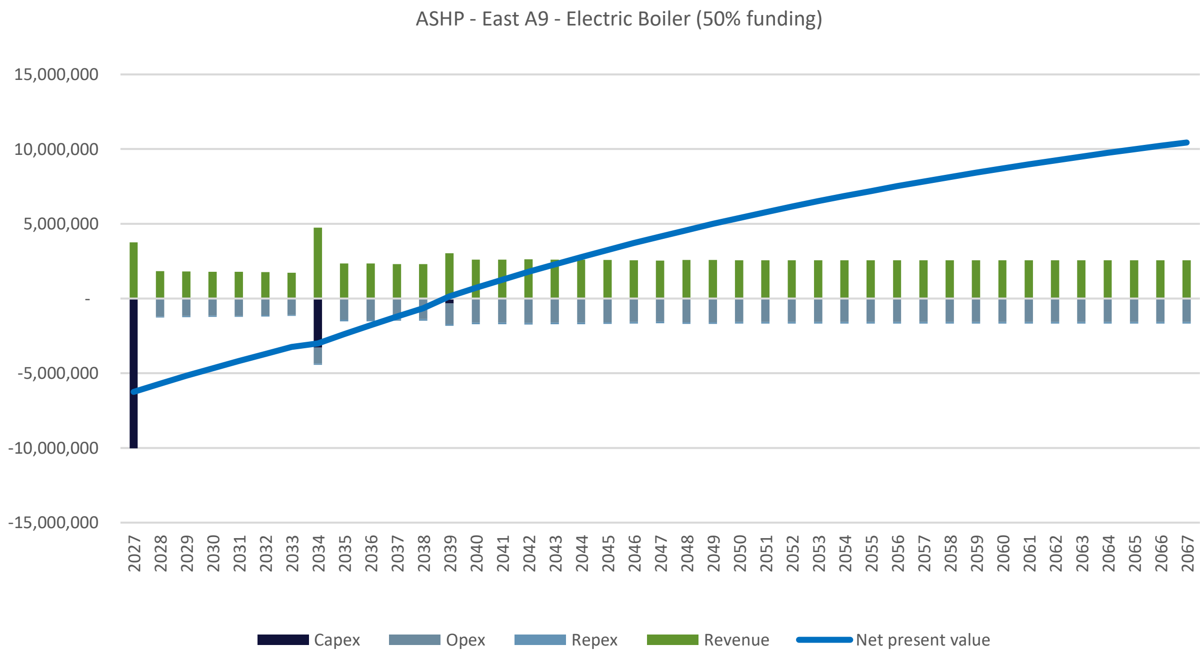

Figure 10-7: Cash flow - ASHP / Electric Boiler - (50% CAPEX funding)

10.7 Sensitivity Analysis

Within the techno-economic model, a sensitivity analysis is included, which tests the heat network's robustness to multiple parameters. The results of the analysis for the two network scenarios are depicted in Figure 10-9 and Figure 10-10, below.

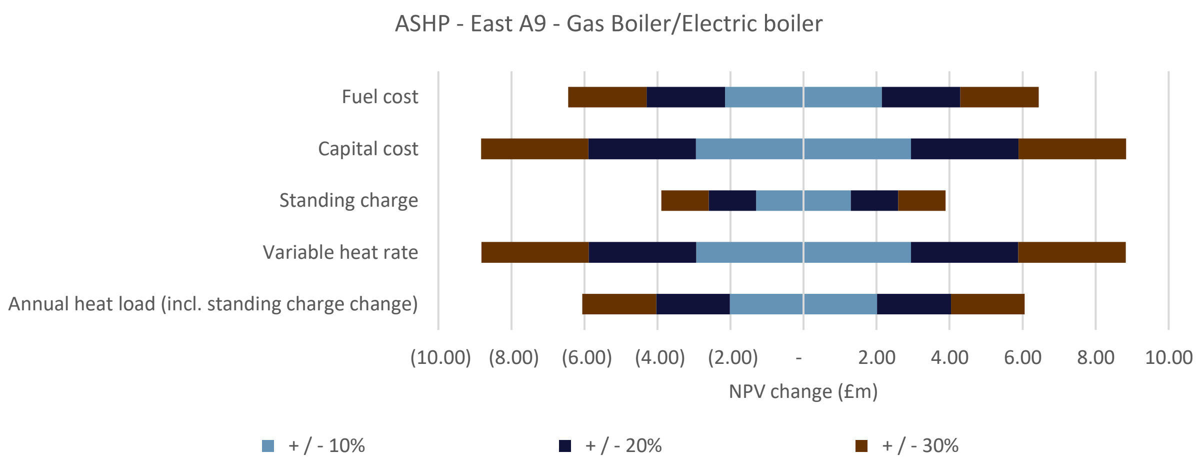

Figure 10-8: Sensitivity analysis - ASHP / Gas boiler network

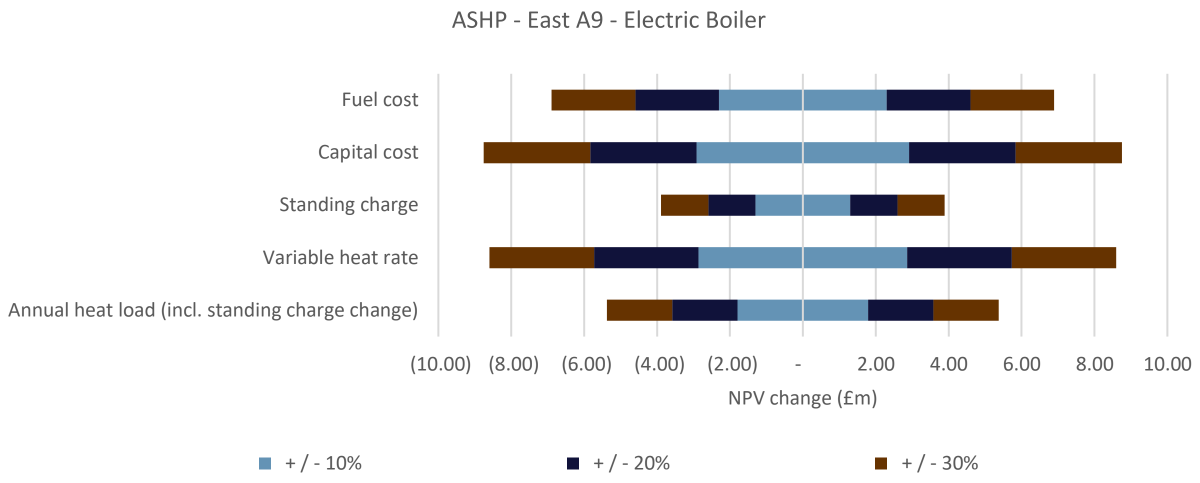

Figure 10-9: Sensitivity analysis - ASHP / Electric boiler network

In both instances, the performance of the heat network is most sensitive to capital cost and the variable heat sales price. Within the TEM, the variable heat rate is set equal to the counterfactual cost of heat, which can be recognized as the upper limit for the heat sales price. The capital costs would be further refined at the next stage of design, and would be further verified by independent, external assessment.

10.7.1 Grant Funding

As highlighted in Figure 10-5 and Figure 10-7, both heat network options will require grant funding to achieve a positive NPV at the end of project life. Within the TEM, the level of grant funding required for different IRR targets was explored, considering potential commercial arrangements.

The following options were explored:

- 6% IRR – reflective of a council-operated network
- 12% IRR – if seeking to attract a potential commercial partner.

Table 10-5 details the results of this analysis.

Table 10-5: Grant funding assessment

IRR consideration (%)		6%	12%
Scenario 1 – ASHP network – Gas boiler	Funding (£m)	8.0	11.9
	% of CAPEX	29%	43%
Scenario 2 – ASHP network – Electric boiler	Funding (£m)	10.0	13.5
	% of CAPEX	38%	51%

It is evident that for Scenario 1, there is scope to achieve the commercially attractive 12% IRR target, within the limits of potential grant funding available. For Scenario 2, the grant funding requirement exceeds the 50% for the 12% target. Given the level of accuracy around the capital costs at this stage, and the contingency consideration, the grant funding opportunity would require further exploration. However, at this stage, the results indicate that a commercially attractive IRR could be achieved within the limits of the grant funding available.

10.8 Carbon

Figure 10-10 shows the carbon emissions per scenario compared to the BAU and counterfactual cases across the 40-year project duration. The comparison is against the BAU to demonstrate the magnitude of carbon reduction potential. The rise in BAU emissions corresponds to the addition of building connections within Phase 2 and 3.

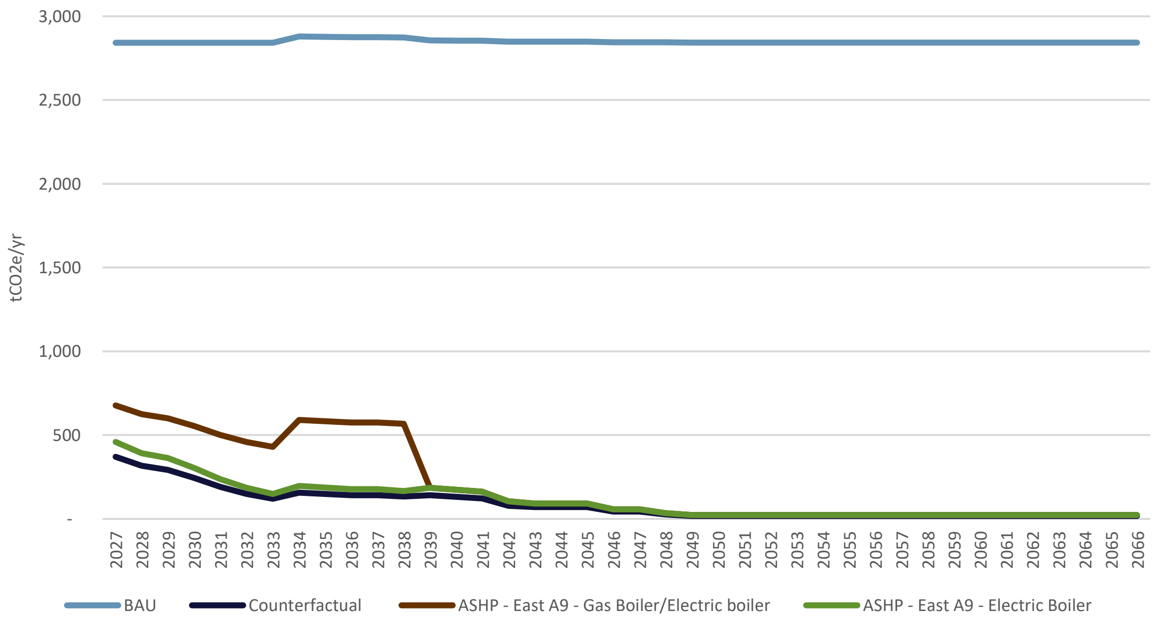

Figure 10-10 Carbon emissions across the different scenarios

The counterfactual scenario leads to significant carbon savings compared to the BAU scenario, as well as Scenarios 1 and 2. Scenario 1 initially has higher carbon emissions due to the gas boiler peaking plant, but these emissions decrease as it is replaced by an electric boiler in Phase 3, eventually aligning with the carbon emissions of Scenario 2.

Additionally, the counterfactual scenario offers greater carbon savings compared to the associated ASHP options. This is because of the system's higher efficiency due to the fact no electric boiler peaking plant is in place, which results in lower electricity consumption and, consequently, reduced carbon emissions.

10.9 TEM Summary

For both heat network scenarios, the NPV achieved at the end of the project lifetime (40-years) is less than £0, without funding. However, with the introduction of grant funding, at 50% of the capital expenditure, the NPV in both cases is positive. The NPV and IRR achieved for each network arrangement is detailed in Table 10-6.

Table 10-6: TEM Summary

Parameter	ASHP / Gas Boiler Heat Network	ASHP / Electric Boiler Heat Network
NPV @ 40 years (unfunded) - £m	(4.2)	(6.3)
NPV @ 40 years (50% CAPEX funding) - £m	12	10.4

Parameter	ASHP / Gas Boiler Heat Network	ASHP / Electric Boiler Heat Network
IRR @ 40 years (unfunded)	1.9%	1.2%
IRR @ 40 years (50% CAPEX funding)	12.9%	11%

The ASHP/ gas boiler heat network achieves an IRR of 12.9% with 50% grant funding, which would generally be considered commercially attractive.

11 Risk Mitigation

In development of the heat network solution for Raigmore, the key risks associated with development of the network have been identified throughout the study process. These risks should be considered with alongside the supplementary risk register. Key risks and mitigation measures are detailed below:

Stakeholder Engagement and Heat Demand Estimates

- The proposed heat network is sensitive to annual heat load
- Where stakeholder engagement has not been possible / has been limited, benchmarks and SHM data has been used to estimate heat demand. There is uncertainty around this heat demand, compared with use of metered data
- To mitigate the risk of inaccurate heat demand estimates, further stakeholder engagement should be pursued. This will give the opportunity to receive metered data.
- Additionally, further stakeholder engagement will provide an understanding of the likelihood of the demands joining the network.

Freeport Connections

- The nature of the Freeport connections is not fully understood and is currently in the 'Masterplan' stage
- The heat demands have been benchmarked based on the existing information available but are subject to change should the proposal for the site change
- The progress of the Freeport development should be monitored, and engagement should be sustained throughout to ensure the heat network opportunity is well understood by the developers
- The alignment of the development of the heat network with the Freeport development is crucial to ensure cost saving opportunities are achieved and the opportunity to connect these new buildings is not missed.

Low Carbon Technology on Network

- There are some connections with existing low carbon plant in the area. These connections will have less incentive to connect to the network as they do not require a decarbonization solution
- To incentivize connection to the network, the network's heat cost must be competitive with the low carbon buildings' cost of heat
- The counterfactual cost of heat has been set as the upper limit for the heat network's variable rate.

Pipe Routing

- Further investigation alongside careful coordination and engagement with Network Rail will be required to ensure the safe crossing over the railway via the bridge located next to UHI accommodation
- Further investigation will need to be undertaken to understand the nature of any buried gas pipelines within the UHI/HIE campus.

Financial

- Risk of obtaining funding. The unfunded heat networks do not present as a commercially attractive heat network opportunity
- Gas boilers would not receive funding. This would need to be factored in as a cost for the network
- Within the current techno-economic model, the gas boilers have been considered as a cost to the network.

Capital Cost

- The proposed heat network is sensitive to capital costs
- The cost estimates will need to be further refined at the next stage of design and developed through engagement with manufacturers to reduce the uncertainty around pricing
- A high-level Quantity Surveyor cost review has been carried out. Future coordination with a QS should be carried out as part of a detailed cost assessment.

Electrical Supply

- The electrical supply within the area is constrained which poses a risk to this heat network
- This is somewhat lowered as grid reinforcements in the area already taking place, with completion in August 2029 estimated
- Continued engagement with SSEN is required to ensure that sufficient capacity is available and to finalise estimated capital costs.

13 Conclusions and Next Steps

The Raigmore Heat Network Feasibility Study indicates that with consideration of grant funding opportunities available, there is scope to develop a heat network in Raigmore. The study identified opportunities to develop heat networks both to the east and west of the A9 in Raigmore. A single heat network opportunity to the east of the A9 was progressed; this option was favoured due to the uncertainty around the data available for the hospital on the west. The hospital is a significant anchor load on the west, and as such, greater confidence in the data would be favourable for pursuing this opportunity. Additionally, the future development of the free port in the east, which offers significant heat demand potential, makes the east network the more favourable option.

The proposed heat network arrangement considers an air source heat pump (ASHP) heat network solution, with gas boiler back-up / peaking technology. This heat network considers building connections to the east of the A9, with notable anchor loads including UHI Inverness College, the business and retail park area, National Treatment Centre, and the HMP Highland prison development.

The proposed Raigmore Heat Network would be developed over three phases. The phasing strategy has been established based on the status of the existing heating plant in the buildings selected for the network. The buildings with existing low carbon heating plant are to be phased in line with the expiration of their current low carbon plant. Additionally, the selected network for Raigmore includes new developments (as part of Inverness Campus Phase 2). The intention is for these buildings to connect to the Raigmore Heat Network once constructed.

The proposed Raigmore Heat Network is depicted in Figure 13-1.

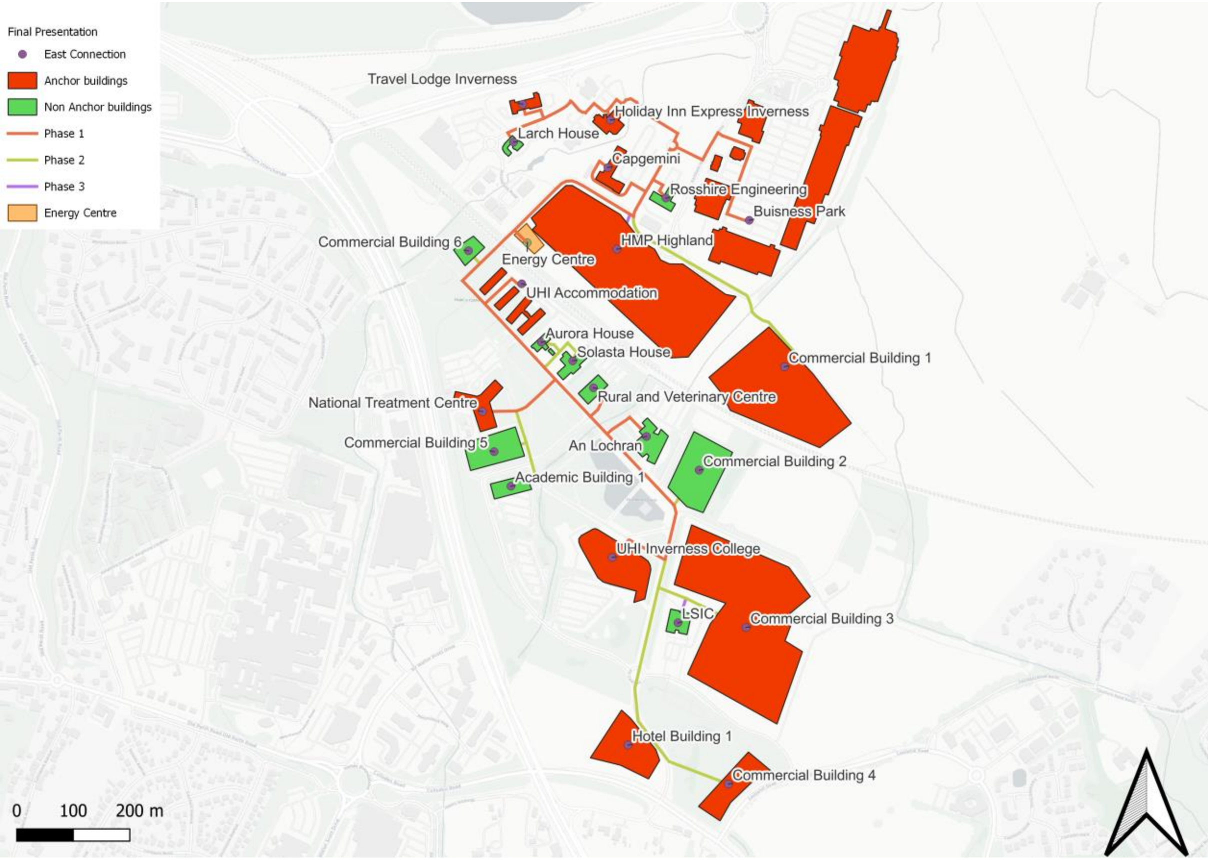

Figure 13-1: Raigmore Heat Network

The overall heat demand for the full build-out heat network is 20,750 MWh/y (excluding losses). The key anchor loads for the core heat network are:

- UHI Inverness College

- HMP Highland prison development
- National Treatment Centre Highland (NHS).

Key parameters of the proposed network extension are presented in Table 13-1.

Table 13-1: Key network parameters

Parameter	Value
Annual heat demand (MWh/a)	20,750
Heat network trench length (m)	4,500
Linear Heat Density (MWh/a/m)	4.6
Baseline LHD (MWh/a/m)	4.0

Energy Centre and Heat Network

The proposal for the energy centre for the Raigmore Heat Network considers:

- Centralised ASHP as the main low carbon heating technology at the energy centre
- Energy centre located adjacent to the HMP Highland prison development
- Equipment at the energy centre:
  - Main heating technology: 3 x 1 MW ASHPs and 1 x 500 kW ASHP
  - Back-up heating technology: gas boilers. Total capacity: 12,000 kW
  - 200 m^3 thermal storage
- Heat network:
  - 3G network – a third-generation heat network has a traditional centralised topology with the energy centre supplying heat outwards to buildings. The heat supply is ~ 90-60°C, with return temperatures of ~ 50-40°C
  - Total trench length: 4.5 km.

Capital Cost

A breakdown of the capital costs of the proposed heat network was developed from consultation with manufacturers, industry reference data and previous project experience at Buro Happold. The capital cost assessment carried out has been independently assessed by cost consultants, Thomson Bethune.

The total capital cost, **estimated at £28.3m**, includes:

- Energy centre and heat supply equipment (ASHP, thermal stores, top-up gas boilers, and ancillary equipment)
- Buried network pipework (~ 4.5 km) – trenching and pipe costs considered
- Electricals
- Building connection costs (heat substations, heat meters) – any upgrades required to secondary side systems for the buildings have not been included in the model
- Complex crossing considerations.

Additional costs considered include contingency (10%), prelims (15%) and design fees (10%). For the proposed heat network pipe route, there is the requirement to cross the railway by the HMP Highland development. An additional cost has been added in for this within the capital cost schedule. Within the techno-economic model, the assumption is that at the point of connection, the buildings will be ready to connect to the heat network, with any building enabling works having been carried out separately; hence, these costs have not been factored into the model.

Heat Sales Tariff and Connection Charges

The cost of low carbon heat for a building connected to the network is likely to be higher than the cost of the Business as Usual (BAU) heating, which is largely reflective of fossil fuel heating technology. For this study, the heat sales tariff for the heat network customers is the same as the counterfactual cost of heat. The counterfactual represents the alternative low carbon heating technology which would be instated in the absence of a heat network.

The selected counterfactual for the building connections is building-level ASHP, except for the HMP Highland development, which has a GSHP heating solution. This reflects the movement in the direction of heat decarbonisation, away from fossil fuels over time, as detailed in Table 13-2.

Table 13-2: Calculated BAU and counterfactual heat tariff structures

Metric	Variable tariff (p/kWh)	**Fixed tariff (£/kW)**
BAU – commercial existing	5.7	39.6
BAU – commercial new build	11.05	39.6
Heat network – commercial existing	12.33	73.1
Heat network – commercial new build	11.05	73.1

Connection charges are estimated based on the avoided costs of installing building-level, individual ASHPs. These are included in the techno-economic model, from the perspective of the organisation that owns and operates the heat network. One-off connection charges are estimated at approximately **£7.3m** for the full Raigmore Heat Network.

Techno-Economic Analysis Results

For the ASHP heat network with gas boiler back-up technology, a negative NPV (-£4.2m) is anticipated at the end of the project lifetime (40 years), in the absence of grant funding. This is reflective of an IRR of 1.9%. In terms of network operation, this is unlikely to be a commercially attractive IRR and grant funding would be required to achieve a desirable IRR for a project partner. To achieve an IRR of 12%, the ASHP heat network with gas boiler back-up technology requires £11.9 million in funding, which represents 43% of the total network CAPEX. Given that the maximum available funding is 50% of the total network CAPEX, there is sufficient funding for this solution to reach the 12% IRR, which is a positive outcome.

Carbon Savings

Significant carbon savings, compared to the BAU, are to be observed over 40 years. The lifetime savings are estimated at 2,075 tCO_2e/yr (average). Buildings that connect to a heat network are considered to have low and zero emissions heating systems.

Risk Mitigation

Risk mitigation measures have been considered for the Raigmore Heat Network.

A key risk to mitigate for the Raigmore Heat Network is to coordinate the pipe network route with crossing the railway line by HMP Highland prison development. This will require engagement with National Rail to ensure the network does not interfere with operation of the railway. In this techno-economic model, an allowance for making crossing has been included as an additional cost.

The selected heat network includes Freeport development connections. The heat demand associated with these connections has been benchmarked based on information available in the Masterplan documentation. Given the high-level nature of the information available, continued engagement with the site developers should be sought after to ensure the heat demand estimates are accurate. Moreover, within the heat demand assessment, the heat demand for several of the building connections has been derived from Scotland Heat Map (SHM) data; this data is typically less reliable than metered data. As such, with the performance of the heat network being reliant on the heat demands, accurate metered data would need to be obtained at the next stage of assessment for this network.

Additionally, in the absence of grant funding, the Raigmore Heat Network does not present as a commercially attractive heat network opportunity. Hence, securing grant funding is paramount to progressing the heat network opportunity. The gas boilers would not receive grant funding, so this would need to be considered as a cost for the network. Within the techno-economic model, the grant funding has excluded the gas boiler element of the capital expenditure.

The final key risk to mitigate is the electrical capacity requirement. At present, the local Raigmore primary substation is constrained. There are reinforcement works planned; however, engagement with SSEN will be required to understand the headroom available for the energy centre connection. The reinforcement works have a planned completion date of August 2029; this date is ahead of the transition to full electric boiler back-up plant. As such, the initial selection of gas boiler plant is favourable from an electrical capacity requirement.

Key Next Steps

Further consideration should be given to the commercial arrangement that is sought for development of a heat network in Raigmore. Without funding, the Raigmore Heat Network does not present as an attractive option for a project partner. However, results of the techno-economic assessment indicate that an IRR of 12% can be achieved for the heat network, within the limits of the 50% CAPEX funding available. Hence, there is scope to progress this opportunity further, in line with Scottish Government's approach to heat network development.

When considering a Joint Venture or Partnership approach in the delivery model and commercialisation, the IRR target should be considered further, this could potentially reflect:

c Public ownership type (targeting IRR of approx. 6%)
d Commercial ownership type (targeting IRR of approx. 12%)

There is scope to progress the Raigmore Heat Network to the next stage in project development, which could be Outline Business Case (OBC) with consideration of grant funding. To progress to this more detailed level of study, further review should be given to the following:

- Engagement with SSEN to understand the network constraints in the Raigmore region and ascertain the cost for connection and any potential reinforcement works
- Engagement with the Freeport development site to understand the progress of the development and to determine their appetite for connection to a heat network. Early engagement will ensure an alternative low carbon heat supply is not established for the sites
- Stakeholder engagement – for the building connections where benchmarked or SHM data has been used for the heat demands, further stakeholder engagement should be conducted to acquire more accurate metered data
- The Raigmore Feasibility Study is supplementary to the Inverness City Strategic Heat Networks Study. The strategic piece has identified that, although this study considers the heat network only to the east of the A9, there is still potential to consider the area as a whole. This can be attributed to the increased interest of the hospital following the study, which derisks the west network. As part of this work, there will be further assessment of the development of heat networks in Inverness, as well as the approach to different network delivery models.

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Heat Network Support Unit

Raigmore Heat Network Feasibility Study

Appendices

Prepared by: Buro Happold

Date: March 2025

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Disclaimer

Heat Network Support Unit is a collaboration between the Scottish Government, Scottish Futures Trust and Zero Waste Scotland aiming to support heat network projects across Scotland through the pre-capital project development stages.

www.heatnetworksupport.scot

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Contents

1 Appendix A – Context

1.1 Scotland's Heat Network Support Unit

Scotland's Heat Network Support Unit (HNSU) is a collaboration of organisations (The Scottish Government, Scottish Futures Trust, and Zero Waste Scotland) focused on supporting heat network project development in Scotland[1]

The HNSU is part of the Scottish National Public Energy Agency and its Centre of Expertise. It aims to support the growth of heat networks by working with the public sector to address key challenges and build capacity through advice, expertise and financial support.

Heat networks are a key strategic technology for reducing emissions from heating homes and buildings. A lack of skills, knowledge and resource pose significant challenges at the pre-capital stage of heat network project development in Scotland. The HNSU is designed to help overcome these challenges and rapidly develop the heat network pipeline. The HNSU works with the public sector to identify, support and develop heat network projects to capital readiness through expert advice and grant funding. The HNSU also builds capacity and expertise across the public (and private) sector in Scotland to develop and run successful heat networks.

The HNSU can offer support and expertise on interpreting the LHEES and available resources towards potential heat network area designation. Additionally, the HNSU can assist with developing detailed feasibility studies and Outline Business Cases (OBC), through the provision of guidance and steering.

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[1] https://www.heatnetworksupport.scot/#:~:text=The%20Heat%20Network%20Support%20Unit%20%28HNSU%29%20aims%20to,SUPPORT%20UNIT%20Aims%20and%20functions%20of%20the%20unit [Accessed 2023]

2 Appendix B – Energy Demand Assessment

2.1 Building Connection Longlist

Below is a longlist of the buildings considered within this study.

Table 2—1: Building connection longlist

Building	Ownership	A9 Relation
Bannatyne Spa	Bannatyne Fitness Limited (Private)	West
Holiday Inn	IHG Hotels & Resorts (Private)	East
Inshes Retail Park	Inshes Retail (Private)	West
Business park	Inverness Retail Park (Private)	East
LifeScan	Platinum Equity (Private)	West
Rosshire Engineering	Rosshire Engineering Limited (Private)	East
Travelodge	Travelodge (Private)	East
Premier Inn	Whitbread (Private)	West
Capgemini	Capgemini (Private)	East
Carlton Bingo	Carlton Bingo Limited (Private)	West
Inverness Golf Club - Club House	Inverness gold club	West
Kingsmill Hotel	Kingsmill Hotel Limited	West
Children's Residential Centre	THC (Council)	West
Drakies Primary School	THC (Council)	West
Inshes Primary School	THC (Council)	West
Raigmore Community Centre	THC (Council)	West

Building	Ownership	A9 Relation
Raigmore Primary School	THC (Council)	West
Culcabock Child Guidance Centre	THC (Council)	West
An Lochran	HIE (Public)	East
Aurora House	HIE (Public)	East
HMP Highland	HMP (Public)	East
Larch House	NHS (Public)	East
LSIC	HIE/UHI (Public)	East
National Treatment Centre	NHS (Public)	East
Police Scotland	Police Scotland (Public)	West
Raigmore Hospital	NHS (Public)	West
Raigmore Hospital Accommodation	NHS (Public)	West
Rural and Veterinary Innovation Centre	SRUC (Public)	East
Scottish Ambulance Service	NHS (Public)	West
Solasta House	HIE (Public)	East
UHI Accommodation	UHI (Public)	East
UHI House	UHI (Public)	West
UHI Inverness College	UHI (Public)	East
Wimberly Way HN	MOD (Public)	West

2.2 Energy Demand Assessment

Table 2—2 shows how each buildings heat demand was estimated within this study.

Table 2—2: Energy demand assessment summary

Building	Fuel (electricity, gas, other)	Year	Data Type (Half-hourly, monthly, benchmark)
Bannatyne Spa	Bannatyne Fitness Limited (Private)	West	SHM
Holiday Inn	IHG Hotels & Resorts (Private)	East	SHM
Inshes Retail Park	Inshes Retail (Private)	West	SHM
Business park	Inverness Retail Park (Private)	East	SHM
LifeScan	Platinum Equity (Private)	West	Monthly
Rosshire Engineering	Rosshire Engineering Limited (Private)	East	SHM
Travelodge	Travelodge (Private)	East	SHM
Premier Inn	Whitbread (Private)	West	SHM
Capgemini	Capgemini (Private)	East	SHM
Carlton Bingo	Carlton Bingo Limited (Private)	West	SHM
Inverness Golf Club - Club House	Inverness gold club	West	Benchmark
Kingsmill Hotel	Kingsmill Hotel Limited	West	Benchmark
Children's Residential Centre	THC (Council)	West	Monthly
Drakies Primary School	THC (Council)	West	Monthly
Inshes Primary School	THC (Council)	West	Monthly
Raigmore Community Centre	THC (Council)	West	Monthly
Raigmore Primary School	THC (Council)	West	Monthly

Building	Fuel (electricity, gas, other)	Year	Data Type (Half-hourly, monthly, benchmark)
Culcabock Child Guidance Centre	THC (Council)	West	Monthly
An Lochran	HIE (Public)	East	Monthly
Aurora House	HIE (Public)	East	SHM
HMP Highland	HMP (Public)	East	Quoted
Larch House	NHS (Public)	East	SHM
LSIC	HIE/UHI (Public)	East	Benchmark
National Treatment Centre	NHS (Public)	East	Benchmark
Police Scotland	Police Scotland (Public)	West	Monthly
Raigmore Hospital	NHS (Public)	West	SHM
Raigmore Hospital Accommodation	NHS (Public)	West	SHM
Rural and Veterinary Innovation Centre	SRUC (Public)	East	Benchmark
Scottish Ambulance Service	NHS (Public)	West	Annual
Solasta House	HIE (Public)	East	SHM
UHI Accommodation	UHI (Public)	East	SHM
UHI House	UHI (Public)	West	Monthly

Building	Fuel (electricity, gas, other)	Year	Data Type (Half-hourly, monthly, benchmark)
UHI Inverness College	UHI (Public)	East	SHM
Wimberly Way HN	MOD (Public)	West	SHM

2.3 Peak Heat Demand

2.3.1 East Peak Heat Demand

Figure 2—1 and Figure 2—2 show the calculated peak demands for building connections on the east side of the A9, separated into higher and lower peaks for visual clarity.

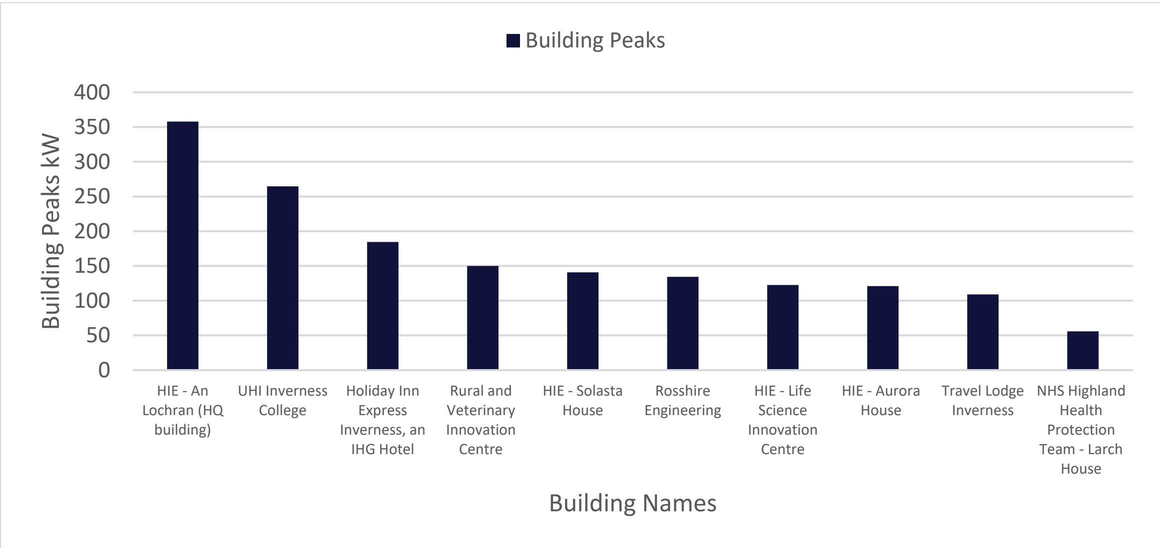

Figure 2—1: Buildings with higher peak demand on the East of the A9

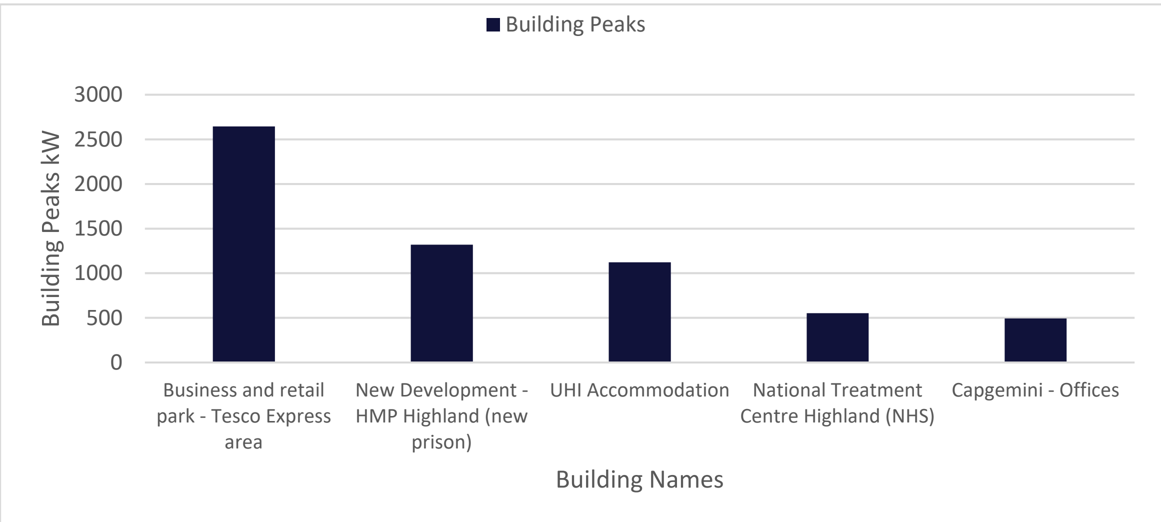

Figure 2—2: Buildings with lower peak demand on the East of the A9

2.3.2 West Peak Heat Demand

Figure 2—3 and Figure 2—4 show the calculated peak demands for building connections on the east side of the A9, separated into higher and lower peaks for visual clarity.

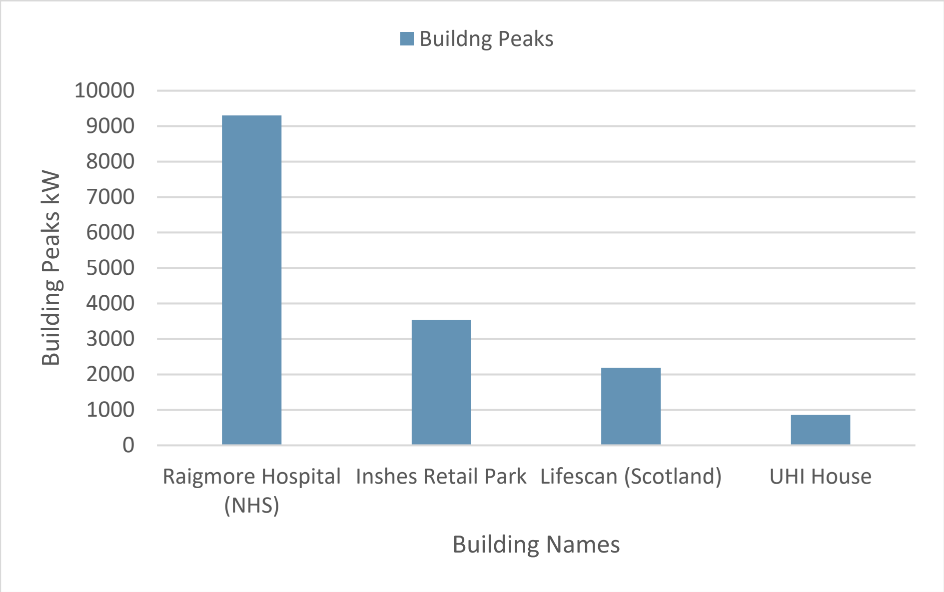

Figure 2—3: Buildings with higher peak demand on the West of the A9

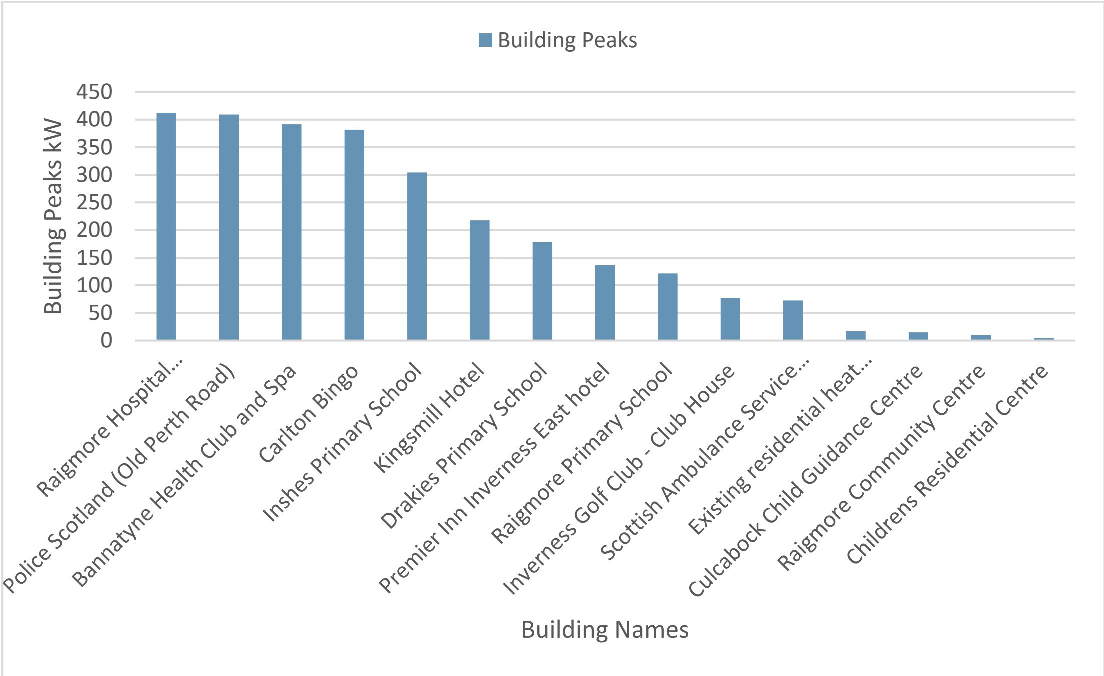

Figure 2—4: Buildings with lower peak demand on the West of the A9

2.4 Freeport Heat Demands

The different sections were treated as new buildings with distinct typologies. The commercial sections were assigned an office typology, based on the existing commercial buildings in the area being available for business growth as office spaces. The academic clusters were given a university building typology, while the hotel section was assigned a hotel typology.

Table 2—3: Summary of Freeport building demands and peaks

Building Name	Annual Demand (MWh/yr)	Peak Demand (kW)
Commercial 1	582	803
Commercial 2	248	342
Commercial 3	880	1,214
Commercial 4	826	1,139
Commercial 5	244	336
Commercial 6	83	115
Hotel 1	802	448
Academic 1	128	174
Total	**3,792**	**4,570**

2.5 Full Heat Network Arrangement

This section presents the complete network connecting both east and west demands via the Golden Bridge. Below, Figure 2—5 illustrates the network route, and Table 3—1 summarizes the route's annual demand, trench length, and LHD.

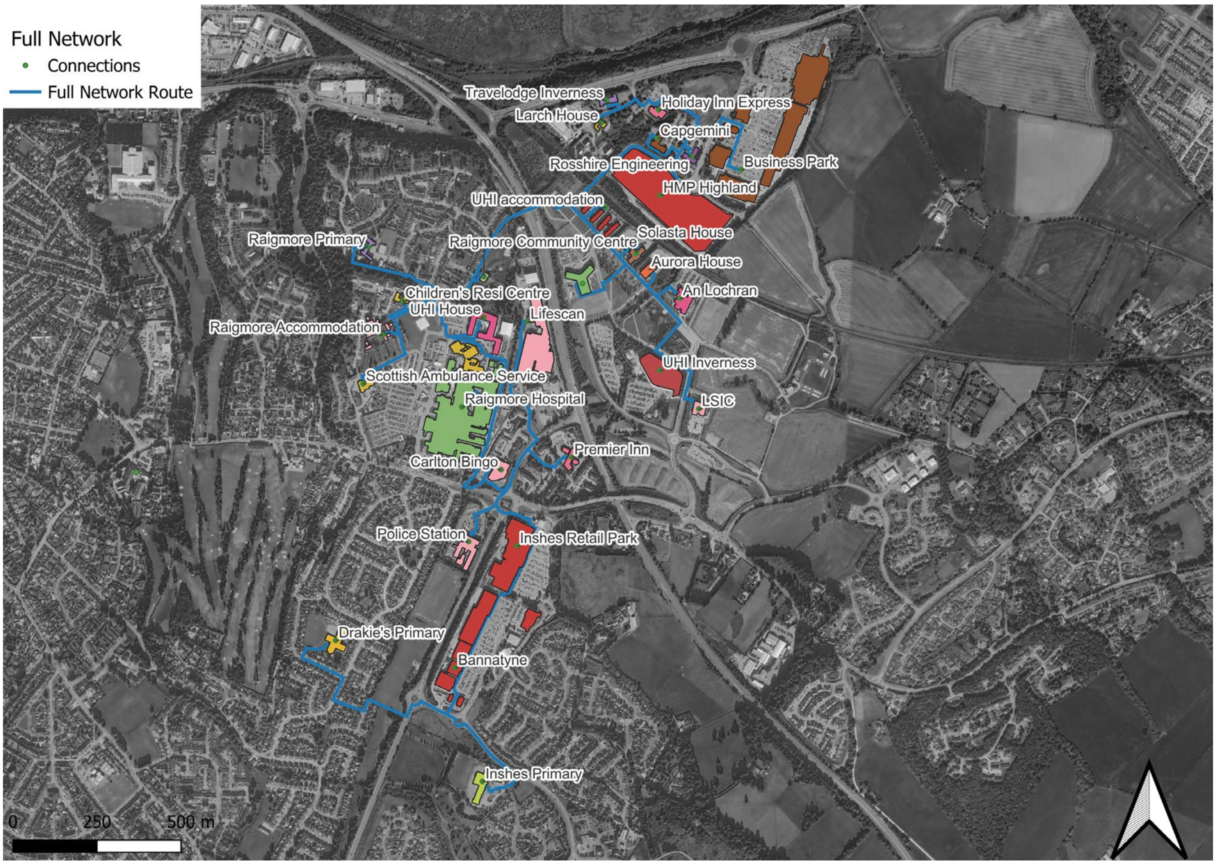

Figure 2—5: Full network route

3 Appendix C – Heat Supply Technologies

3.1 Closed Loop GSHP

Closed loop ground source heat pumps were considered as a potential heating technology for Raigmore.

To understand the potential heat available from this heat source, a high-level assessment of the local geology was completed. Utilising the data available on the British Geological Survey (BGS) GeoIndex map[2], the bedrock geology was identified as sandstone, as shown in Figure 3—1.

Table 3—1 Full network summary

	Full Network Build out
Annual heat demand (MWh/y)	45,520
Trench length (m)	7,290
Linear heat density (MWh/y/m)	6.2

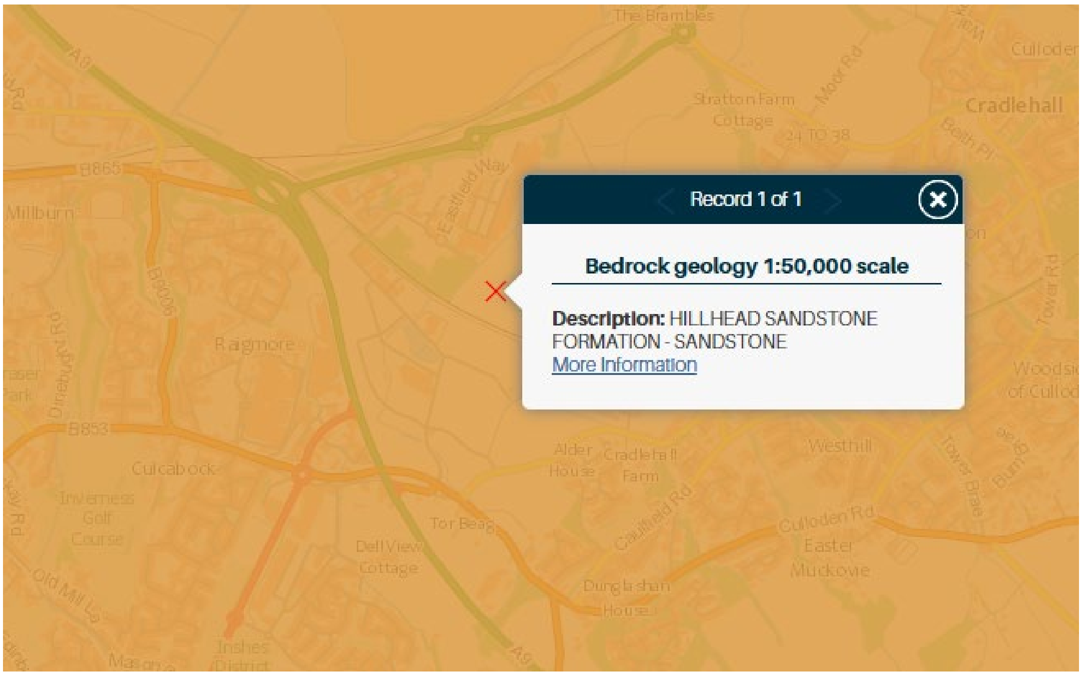

Figure 3—1: Raigmore geology

For this geology type, a specific heat extraction of 55 W/m was assumed. For the nominal heat pump output of 3,000 kW, and assuming a borehole depth of 150 m, approximately 81 boreholes would be required. Based on a borehole separation of 9m, the total area required would be approximately 6,600 m2. As shown in Figure 3—2, the total area considered is 18,300 m2. Hence, for locations east of the A9, there is scope to instate a borehole array large enough to meet the network heat demands.

[2] GeoIndex - British Geological Survey [Accessed 2024]

Figure 3—2: Potential borehole locations

3.2 Wastewater Water Source Heat Pump

To estimate the potential heat available from the sewage network in the area, the Scottish Water data was available. This data is indicative flow data, which provides an indicative flow rate for the sewage lines.

For the Raigmore Heat Network study, the target sewage lines are shown in Figure 3—3. As shown below, at the target access point, the indicative flow rate is 287 l/s.

For modelling purposes, 50% of this flow was assumed to be available for abstraction. As such, the modelled heat available from the wastewater system at the intersection point is 38,200 MWh/y. This is based on a COP of 3.2 for the heat pump and a dT for the sewage of 5°C.

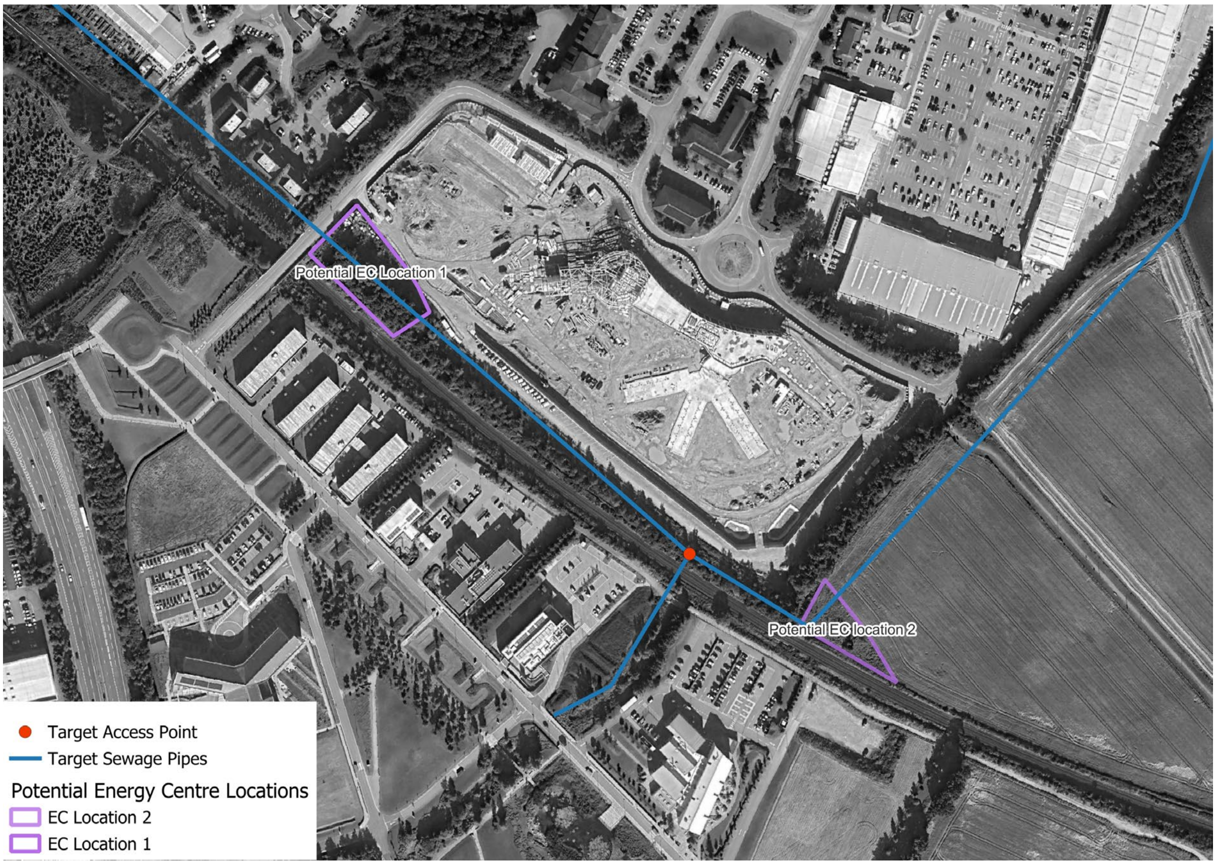

Figure 3—3: Targeted sewage lines

4 Appendix D – Techno-Economic Modelling

4.1 Additional Costs

Parameter	Input	Description
Contingency	10%	For uncertainty of feasibility level costing
Overheads and prelims	15%	Site-specific overheads of the project
Design fees	10%	Future contractor design services
Installation	0%	Cost associated with installation of network equipment. This cost is accounted for within the equipment costs.
Testing and commissioning	0%	Final construction stage of the project where the network system is tested. This cost is accounted for within the equipment costs.

4.2 Phasing Strategy

The proposed phasing strategy for the Raigmore Heat Network considers 3 phases.

The proposed dates for the phases considered are as below:

- Phase 1: 2027
- Phase 2: 2035
- Phase 3: 2040.

Table 4—1 Phasing strategy summary

Building	Typology	Annual Heat Load (MWh/m2)	Estimated phase of connection
Business and retail park - Tesco Express area	General retail	2,640	Phase 1
UHI Inverness College	University campus	1,220	Phase 1
HMP Highland (new prison)	Emergency services	1,320	Phase 3
National Treatment Centre Highland (NHS)	Clinic	550	Phase 1
Holiday Inn Express Inverness, an IHG Hotel	Hotel	310	Phase 1
Travel Lodge Inverness	Hotel	180	Phase 1
UHI Accommodation	General accommodation	250	Phase 1

Building	Typology	Annual Heat Load (MWh/m2)	Estimated phase of connection
HIE - An Lochran (HQ building)	General office	320	Phase 1
Capgemini – Offices	General office	490	Phase 1
Rural and Veterinary Innovation Centre	University campus	150	Phase 1
HIE - Aurora House	General office	280	Phase 2
HIE - Life Science Innovation Centre	Laboratory or operating theatre	120	Phase 3
HIE - Solasta House	General office	170	Phase 2
Rosshire Engineering	Laboratory or operating theatre	170	Phase 1
NHS Highland Larch House	General office	60	Phase 1
Freeport connections	Hotel / Academic building / Office space	3,500	Phase 2

4.3 Capital Cost Breakdown

4.3.1 Scenario 1

Table 4—2: CAPEX breakdown including all equipment, cost source and capacity for scenario 1

		Cost source	Capacity	Capacity Unit	Cost	Cost Unit	Scenario 1 ASHP with GB total cost
Heating Equipment							
	Centralised air source heat pump	OPEX CAPEX Database	3,500	kW	705	£/kW	2,546,222
	Communal Gas Boiler	OPEX CAPEX Database	12,000	kW	77	£/kW	843,335
	Electric boiler	OPEX CAPEX Database	12,000	kW	68	£/kW	924,000
Energy Centre/Plant Room							
	Energy centre building	Previous Project	500	m2	2,200	£/m2	1,149,132
	Thermal store with insulation	Previous Project	200	m3	1,385	£/m3	286,279
Energy Centre Equipment							
	DHN Distribution Pumps	Previous Project	9,860	kW	15	£/kW	152,322
	Expansion Pressurisation unit	Previous Project	2	No	7,000	£/unit	14,625
	Water treatment	Previous Project	1	No	5,000	£/unit	5,223
	Dirt separator and deaerator	CAPEX database	1	No	25,000	£/unit	26,117
	EC Controls	CAPEX database	9,860	kW	85	£/kW	863,157
	Other energy centre M&E	Thomson Bethune			-	20 % allowance	212,289
Pipe costs (including trenching)							
	Total Hard dig	CAPEX database		£/m			10,181,661
	Total Soft Dig	CAPEX database		£/m			1,754,437
Connection costs							
	Heat meters	Previous Project	23	No	2,500	£/units	58,728
	Substation PHX	Previous Project	9,860	kW	65	£/kW	660,061

		Cost source	Capacity	Capacity Unit	Cost	Cost Unit	Scenario 1 ASHP with GB total cost
Network Costs							
	Earthing	Previous projects	1	No	50,000	£/EC	52,233
	LV Switch Board	Previous projects	1	No	200,000	per unit	208,933
	LV Cabling	Previous projects	1	No	120,000	£/system	125,360
	Transformer	Previous projects	2.5	MVA	130,000	£/MVA	339,516
	MV Switchgear	Previous projects	1	No	240,000	£ per cubicle	250,720
Grid connection cost							
	Budget quote	SSEN Estimate, 2025	1	No	216,500	£/quote	216,500
Special Works							
	Railway crossing	SSEN Estimate, 2025	1	No	200,000	£/quote	208,933

4.3.2 Scenario 2

Table 4—3 CAPEX breakdown including all equipment, cost source and capacity for scenario 2

		Cost source	Capacity	Capacity Unit	Cost	Cost Unit	Scenario 2 ASHP with EB total cost
Heating equipment							
	Centralised air source heat pump	OPEX CAPEX Database	3,500	kW	705	£/kW	2,546,222
	Communal Gas Boiler	OPEX CAPEX Database			77	£/kW	-
	Electric boiler	OPEX CAPEX Database	12,000	kW	68	£/kW	924,000
Energy centre/plant room							
	Energy centre building	Previous Project	500	m2	2,200	£/m2	1,149,132
	Thermal store with insulation	Previous Project	200	m3	1,385	£/m3	286,279
Energy Centre Equipment							
	DHN Distribution Pumps	Previous Project	9,860	kW	15	£/kW	152,322
	Expansion Pressurisation unit	Previous Project	2	No.	7,000	£/unit	14,625
	Water treatment	Previous Project	1	No.	5,000	£/unit	5,223

		Cost source	Capacity	Capacity Unit	Cost	Cost Unit	Scenario 2 ASHP with EB total cost
	Dirt separator and deaerator	CAPEX database	1	No.	25,000	£/unit	26,117
	EC Controls	CAPEX database	9,860	kW	85	£/kW	863,157
	Other energy centre M&E	Thomson Bethune				20 % allowance	212,289
Pipe costs (including trenching)							
	Total Hard dig	CAPEX database	0	£/m		Total hard dig	10,181,661
	Total Soft Dig	CAPEX database	0	£/m		Total soft dig	1,754,437
Connection costs							
	Heat meters	Previous Project	23	No	2,500	£/units	58,728
	Substation PHX	Previous Project	9,860	kW	65	£/kW	660,061
Network Costs							
	Earthing	Previous projects	1	No	50,000	£/EC	52,233
	LV Switch Board	Previous projects	1	No	200,000	per unit	208,933
	LV Cabling	Previous projects	1	No	120,000	£/system	125,360
	Transformer	Previous projects	3	MVA	130,000	£/MVA	339,516
	MV Switchgear	Previous projects	1	No	240,000	£ per cubicle	250,720
Grid connection cost							
	Budget quote	SSEN Estimate, 2025	1	No	216,500	£/quote	216,500
Special Works							
	Railway crossing	SSEN Estimate, 2025	1	No	200,000	£/quote	208,933

4.4 Operation and Maintenance Costs

Description	Rate	Unit	Reference
OPEX: Heat Supply Equipment			
Air source heat pump	4%	% of heat pump CAPEX	Previous Buro Happold projects
Ground source heat pump	4%	% of heat pump CAPEX	Previous Buro Happold projects
Water source heat pump	4%	% of heat pump CAPEX	Previous Buro Happold projects
Back-up boiler	5%	% of boiler CAPEX	Previous Buro Happold projects
OPEX: Network and Connection Equipment			
Plate heat exchangers	5%	% of PHEX CAPEX	Previous Buro Happold projects
Heat meters	150	£/unit	Previous Buro Happold projects
Heat network	0.1	p/kWh	Previous Buro Happold projects
Metering and billing – bulk	500	£/connection/year	Previous Buro Happold projects
Business costs – staff costs	20,000	£/year	Assumption – based on previous BH projects
REPEX			
% REPEX cost incurred	80%	This is instated in the model as a sinking fund, charged annually.	Assumed

4.5 Connection Charges

Connection	Connection charge Phase 1 (£m)	Connection charge Phase 2 (£m)	Connection charge Phase 3 (£m)
Business and retail park - Tesco Express area	1.53		
UHI Inverness College	0.74		
HMP Highland (new prison)			0.63
National Treatment Centre Highland (NHS)	0.34		
Holiday Inn Express Inverness, an IHG Hotel	0.19		
Travel Lodge Inverness	0.11		
UHI Accommodation	0.14		
HIE - An Lochran (HQ building)	0.20		
Capgemini – Offices	0.3		
Rural and Veterinary Innovation Centre	0.10		
HIE - Aurora House		0.17	
HIE - Life Science Innovation Centre			0.07
HIE - Solasta House		0.10	
Rosshire Engineering	0.10		
NHS Highland Larch House	0.03		
Freeport connections		2.77	
Total	3.76	3.04	0.70

5 Appendix E - Heat Network

5.1 Heat Network Pipe Sizing

The heat network pipework has been sized using in-house Buro Happold hydraulic pipe sizing tool. The pipe sizing analysis utilised the following hydraulic assumptions presented in Table 5—1.

Table 5—1: Pipe sizing assumptions

Parameter	Value	Unit
Material selection	BS EN 253 Steel Pipes	-
Flow temperature	70	°C
Return temperature	40	°C
Specific heat capacity of water	4.18	kJ/kg/K
Pipe roughness factor	0.05	mm
Water density	1,000	kg/m3
Trunk pipe maximum allowable flow velocity	3	m/s
Trunk pipe maximum allowable pressure gradient	150	Pa/m
Connection pipe maximum allowable flow velocity	1.5	m/s
Connection pipe maximum allowable pressure gradient	300	Pa/m
Temperature differential	20	K
Kinematic viscosity	4.09x10-7	m^2/s

The total network length was calculated at 4,508 m with pipework dimensions ranging from DN 40 to DN 250. Table 5—2 summarises the pipe schedule.

Table 5—2: Pipe size summary

Pipe Size (DN)	Phase 1	Phase 2	Phase 3	Total Pipe Length (m)
25	-	-	-	-
32	-	-	-	-

Pipe Size (DN)	Phase 1	Phase 2	Phase 3	Total Pipe Length (m)
40	-	144	44	188
50	173	61	-	234
65	204	312	-	516
80	463	429	-	892
100	271	615	-	886
125	115	52	66	233
150	902	-	-	902
200	625	-	-	625
250	32	-	-	32
Total	2,785	1,613	110	4,508

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