Agenda Item	**9**
Report No	**CIA/19/25**

The Highland Council

Committee: **City of Inverness Area**

Date: **19 May 2025**

Report Title: **Potential Heat Network Development in Inverness**

Report By: **Assistant Chief Executive - Place**

1 Purpose/Executive Summary

1.1 The report provides an update on the Inverness city-wide heat network opportunity.

2 Recommendations

2.1 Members are asked to **note** progress to date.

3 Implications

3.1 **Resource** – The development of heat networks project in Inverness has been led by internal resource dedicated to deliver the Heat Networks Project within Our Future Highland Delivery Plan 2024-2027 and Local Heat and Energy Efficiency Strategy (LHEES) and its delivery.

Burro Happold acts as the technical consultant to assess the practicality of developing a heat network in Inverness. The technical piece of work is now completed.

Addleshaw Goddard acts as the legal consultant to inform the Council of the most appropriate model which could be adopted to unlock heat network deployment.

The Council receives advisory support from the Heat Network Support Unit, which is sponsored and managed by the Scottish Government, with partners Scottish Futures Trust (SFT) and Zero Waste Scotland (ZWS).

3.2 **Legal –** The report contributes to the Local Heat and Energy Efficiency Strategies (Scotland) Order 2022, which places a statutory duty on local authorities to prepare, publish and update a Local Heat and Energy Efficiency Strategy (LHEES) and Delivery Plan.

As part of the Council's statutory obligations to develop LHEES, the Council is required to identify areas of potential for heat networks.

3.3 **Risk** - There are no direct implications arising from this report.

3.4 **Health and Safety (risks arising from changes to plant, equipment, process, or people)** - There are no direct implications arising from this report.

3.5 **Gaelic** – There are no Gaelic implications arising from this report.

4 Impacts

4.1 In Highland, all policies, strategies or service changes are subject to an integrated screening for impact for Equalities, Poverty and Human Rights, Children's Rights and Wellbeing, Climate Change, Islands and Mainland Rural Communities, and Data Protection. Where identified as required, a full impact assessment will be undertaken.

4.2 Considering impacts is a core part of the decision-making process and needs to inform the decision-making process. When taking any decision, Members must give due regard to the findings of any assessment.

4.3 This is an update report and therefore an impact assessment is not required.

5 Background

5.1 **Local Heat and Energy Efficiency Strategy (LHEES) and Delivery Plan**

5.2 The Local Heat and Energy Efficiency Strategies (Scotland) Order 2022 places a legal duty on all 32 Scottish local authorities to prepare a local heat and energy efficiency strategy and delivery plan by the end of December 2023 - (LINK)

5.3 The Council published the first iteration of the Strategy and Delivery Plan in December 2023 - (LINK). An updated LHEES and Delivery Plan is to be published at internals of no more than 5 years after the date of publication of the previous LHEES and Delivery Plan.

5.4 The Strategy underpins the Highland-based approach to improving energy efficiency and achieving heat decarbonisation across domestic and non-domestic buildings in the region. The Delivery Plan is built on opportunities outlines in the Strategy which provides a useful baseline of local priorities and drivers for domestic and non-domestic properties.

5.5 The work carried out by the Highland Council as part of its LHEES includes a requirement to identify areas likely to be particularly suitable for the construction and operation of a heat network. This requirement is set out in the LHEES Guidance and are aligned with the area review duty set out within the Heat Networks (Scotland) Act (2021) - (LINK)

5.6 The first iteration of LHEES identifies indicative Heat Network Zones (HNZs) to understand the scale of potential and initial areas of focus. Three potential HNZs were identified in Inverness. The potential zones present theoretical and technical potential only at a strategic level, prior to any site level feasibility study alongside funding availability to progress them.

6 Inverness Castle and West Bank Heat Networks Feasibility

6.1 In 2021, two pre-feasibility assessments of proposed heat networks have been completed for the West Bank of River Ness and Inverness Castle. A combination of supplied data and industry benchmarks allowed for the energy demand of the networks to be assessed and a heat network solution to be evaluated. The study concluded that there is a promising heat network opportunity in both study areas.

6.2 In 2022, the Council secured the grant funding from the Heat Network Support Unit (HNSU), which covered up to 100% of a detailed feasibility study up to a value not exceeding £50,000 (LINK) to undertake the heat network feasibility in the Castle and West Bank areas of Inverness. The purpose of the heat network feasibility studies was to inform the Highland Council of the opportunity for a heat network in the Inverness Castle and West Bank study areas. (LINK, Item 7)

7 City-Wide Heat Network Feasibility

7.1 In 2024, the Highland Council successfully secured the Strategic Heat Network Support funding from the HNSU to conduct a city-wide feasibility study, explore delivery models and identify interested parties to get a full understanding of what an Inverness-wide heat network would entail. The study explores the potential for developing heat networks across several strategic areas within the city: City Centre, Longman, West Bank and Raigmore. The HNSU funding covers up to 90% of the costs (capped at £150,000), requiring a 10% contribution from the Highland Council.

7.2 This piece of work has been split into two work packages - technical and delivery models.

7.3 The purpose of the technical work is to produce technical information to inform and support the Highland Council to understand the commercial and financial analysis of the heat network opportunity for the whole of Inverness. The outputs of this work will inform the development of an Outlines Business Case (OBC) and identify a suitable delivery model(s) to the project. The technical work is now completed, and the reports can be accessed by Members in **Appendix 1** and **Appendix 2**.

7.4 The purpose of the delivery models work is to help determine the optimum delivery model the Council should adopt to unlock deployment of long-term and large-scale heat networks in Inverness and the wider local authority area; to equip the Council to develop an Outlines Business Case (OBC) for the procurement of a delivery partner. The delivery models work is currently ongoing and aimed to be completed this summer.

7.5 Effective engagement with both internal and external stakeholders is vital. The Council has been actively engaging stakeholders using various methods including site visits, meetings, emails, and workshops. This comprehensive approach aims to ensure stakeholder interests are considered in decision-making and to foster collaborative relationships.

7.6 Key stakeholders include internal Council colleagues, elected members, High Life Highland, NHS Highland, UHI, HIE, Lifescan, HMP Highland, SSE, Scottish Water Horizons, Eden Court, Police Scotland, Scottish Episcopal Church, Scottish Ambulance and Inverness Ice Centre.

7.7 The Council held the technical findings workshop with internal colleagues and High Life Highland in March. The workshop presented a review of the Raigmore, West Bank, Longman and City Centre areas focusing on characteristics, opportunities and risks. The workshop also provided a demonstration of the multi-criteria analysis (MCA) tool for interrogating different opportunities, strategic overview providing an integrated vision to aid initial prioritisation of different opportunities.

7.8 The delivery models workshop led by Buro Happold was held in March. The aim of the workshop was to provide the internal project team with an overview of options for delivery models linking to each heat network feasibility area.

7.9 The delivery models workshop hosted by Addlehaw Goddard was held in April. The aim of this workshop was to inform the senior leadership team of various delivery models and commercial structures which facilitate heat network development.

7.10 The delivery models' workshop with external stakeholders is planned to be hold in May. The aim of this workshop is to introduce various delivery models to key stakeholders and consider their interest in the project. This gives the Council the opportunity to identify interested parties, understand their priorities, concerns and potential impact. This will enable more informed decision-making.

8 Benefits to Inverness

8.1 Heat networks are vital to making Net Zero a reality in Inverness. The majority of Inverness in on the gas grid, and in high density areas such as Inverness, they can often offer the lowest cost and low carbon heating option.

8.2 The Inverness heat network feasibility studies have identified the opportunity to develop a low carbon heat options to support heat decarbonisation and statutory Net Zero obligations. The development of the decentralised, high efficiency heat network(s) capable of serving public assets, commercial partners, and existing and future residential developments will deliver significant economic, environmental and social benefits to Inverness and wider local authority area, including, but not limited to:-

- **Accelerate Net Zero Delivery**: Reduce operational emissions across the Council estate and local commercial footprint by transitioning away from fossil-fuelled heat systems, in line with Scotland's 2045 Net Zero commitment and the Council's Our Future Highland Delivery Plan.
- **Maximise Energy Efficiency**: Implement a system-level approach to heat supply that eliminates redundancy, maximises performance through economies of scale, and supports ongoing decarbonisation of the built environment.
- **Establish Energy Sovereignty and Security**: Reduce reliance on volatile global energy markets by harnessing local renewable and low-carbon sources - including biomass, heat pumps, and industrial waste heat recovery - tailored to the Highland energy landscape.
- **Stimulate Local Green Growth**: Deliver high-value green jobs and supply chain investment through the design, construction, and operation of the network, positioning Inverness as a clean heat innovation hub for the Highlands.
- **Support Energy Affordability**: Extend tariff equity and predictability to consumers - particularly vulnerable households - by avoiding the commodity-linked pricing of traditional gas supply and offering localised, index-controlled alternatives.

- **Air Quality and Public Health:** Transitioning away from gas and oil-based systems will reduce local air pollutants, contributing to improved public health outcomes across the city.
- **Community Confidence and Engagement:** A publicly backed energy network delivers visible, tangible climate action that enhances civic pride and strengthens public trust.

9 Next Steps

9.1 The next steps in developing a heat network project in Inverness involve:-

- **Delivery Models Options Appraisal:** Evaluate different delivery model options for the Council, ensuring the most suitable and effective approach is chosen. It involves identifying and assessing various delivery models, considering their desirability, viability, and ultimately recommending the preferred option.

- **Continuous stakeholder engagement:** Engage with key stakeholders in Inverness to understand their interest and identify potential opportunities and barriers related to the development of heat networks in Inverness.

- **Market testing**: Establish the level of market interest in the development of heat networks in Inverness. This will also allow the Council to inform potential suppliers about upcoming procurement opportunities.

Designation:	Assistant Chief Executive - Place
Date:	1 May 2025
Author:	Ruta Burbaite, Project Manager Neil Osborne, Climate Change & Energy Team Manager
Background Papers:	None
Appendices:	Appendix 1 – Raigmore Heat Network Feasibility Report and Appendices Appendix 2 – Inverness Strategic Heat Network Report

Heat Network Support Unit

Raigmore Heat Network Feasibility Study

Final Report

Prepared/published by: Buro Happold

Author/s for crediting: Laura Carter, Fraser Gilvray

Date: March 2025

ZERO WASTE SCOTLAND

Scottish Government
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SCOTTISH FUTURES TRUST

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

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

[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.

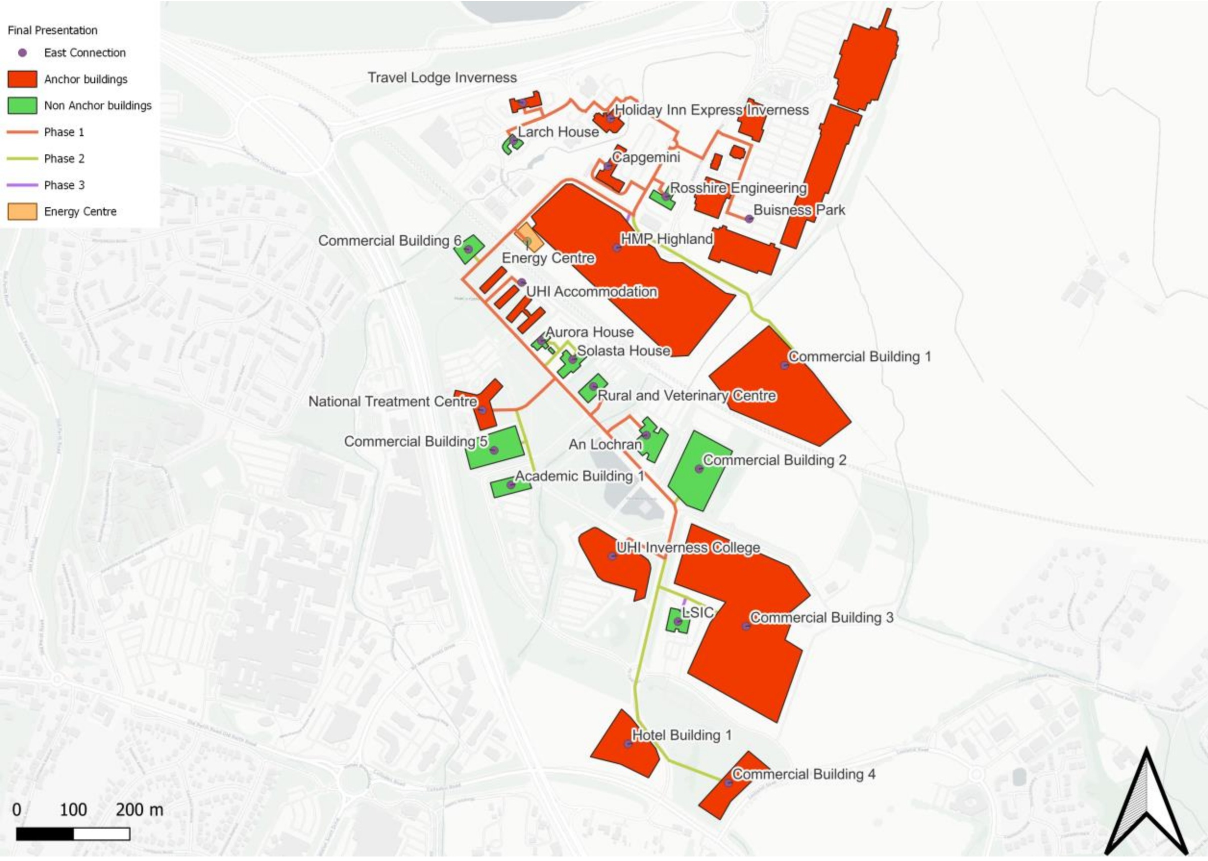

Figure 0-1: Raigmore Heat Network

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

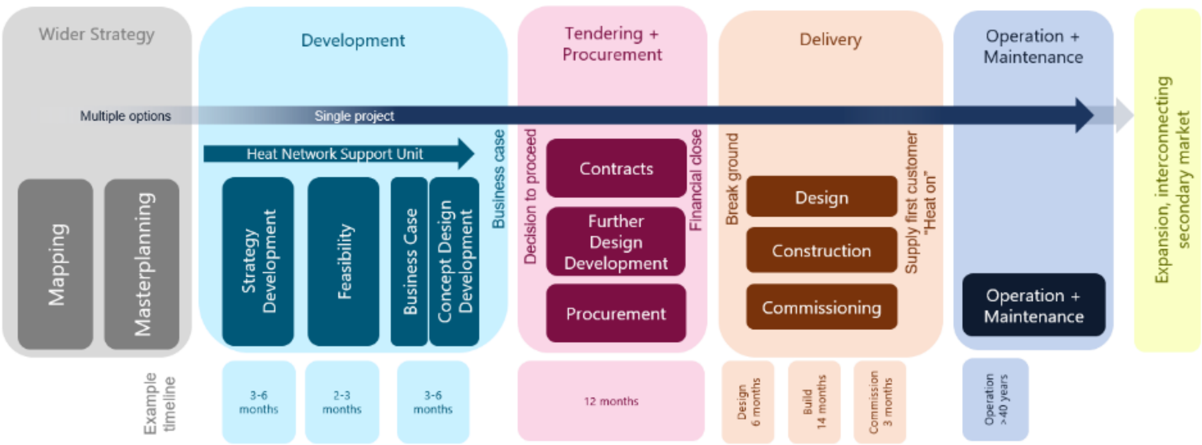

Figure 1-1: Heat Network Project Delivery Steps

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.

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[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.

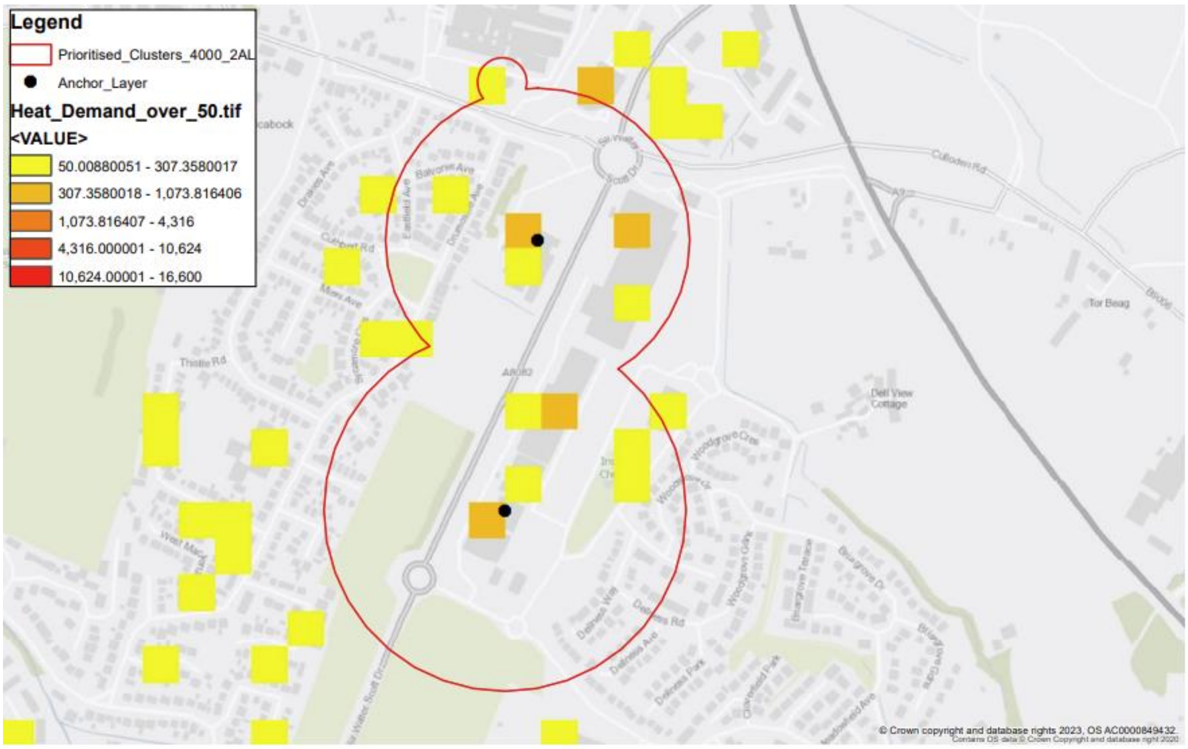

Figure 2-1: LHEES Inverness 3 Potential Heat Network Zone

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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.

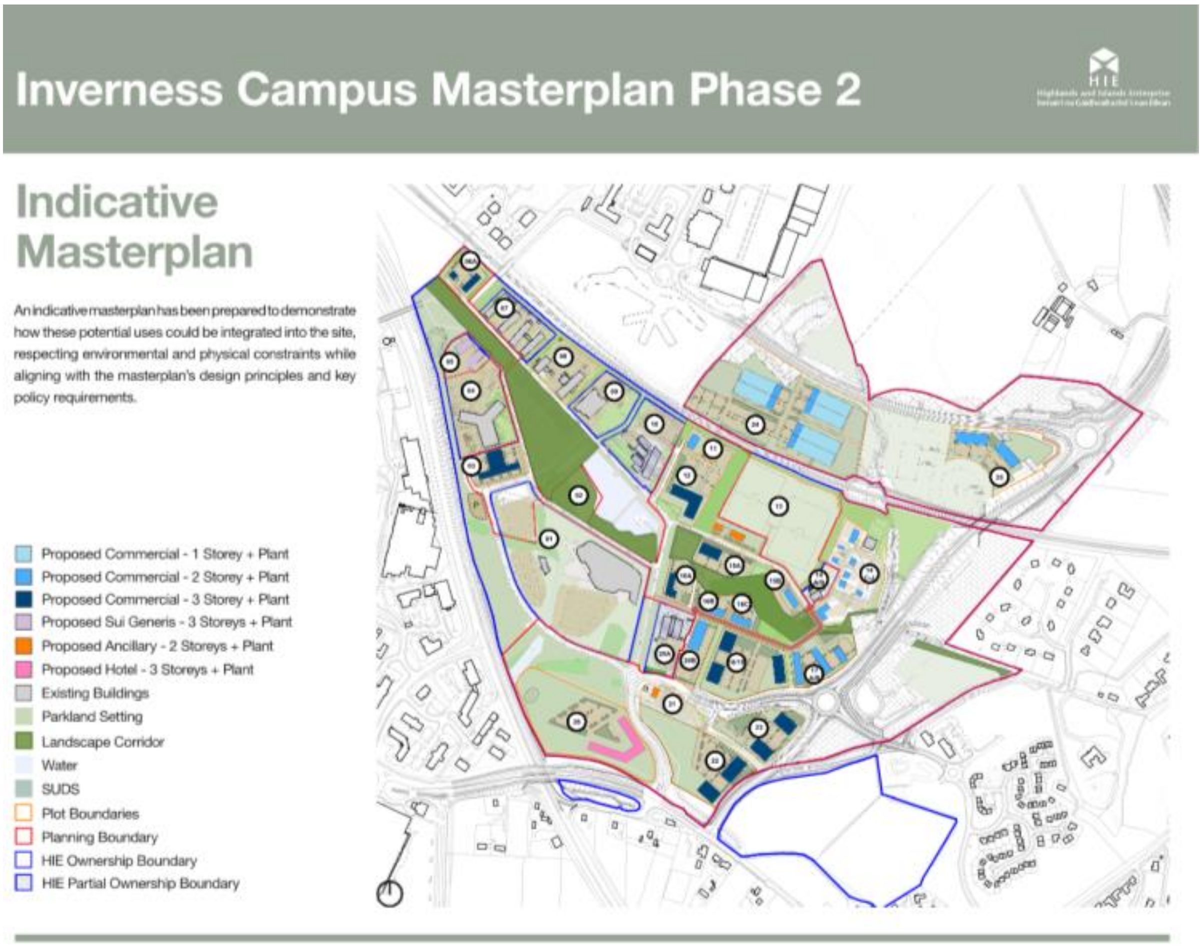

Figure 2-2: Freeport Masterplan

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

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.

Figure 3-2: 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)

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.

Figure 3-3: LSIC ASHP plant

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:

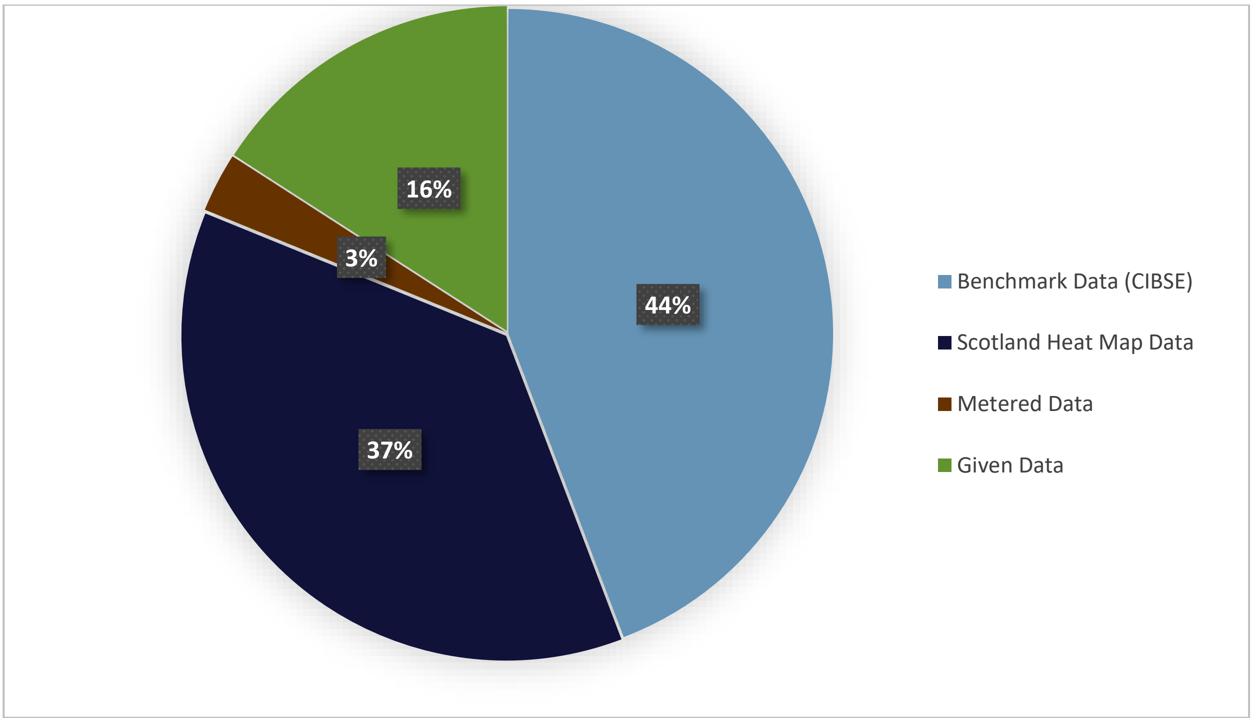

Figure 5-2: Proportion of data received for the east of Raigmore

[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:

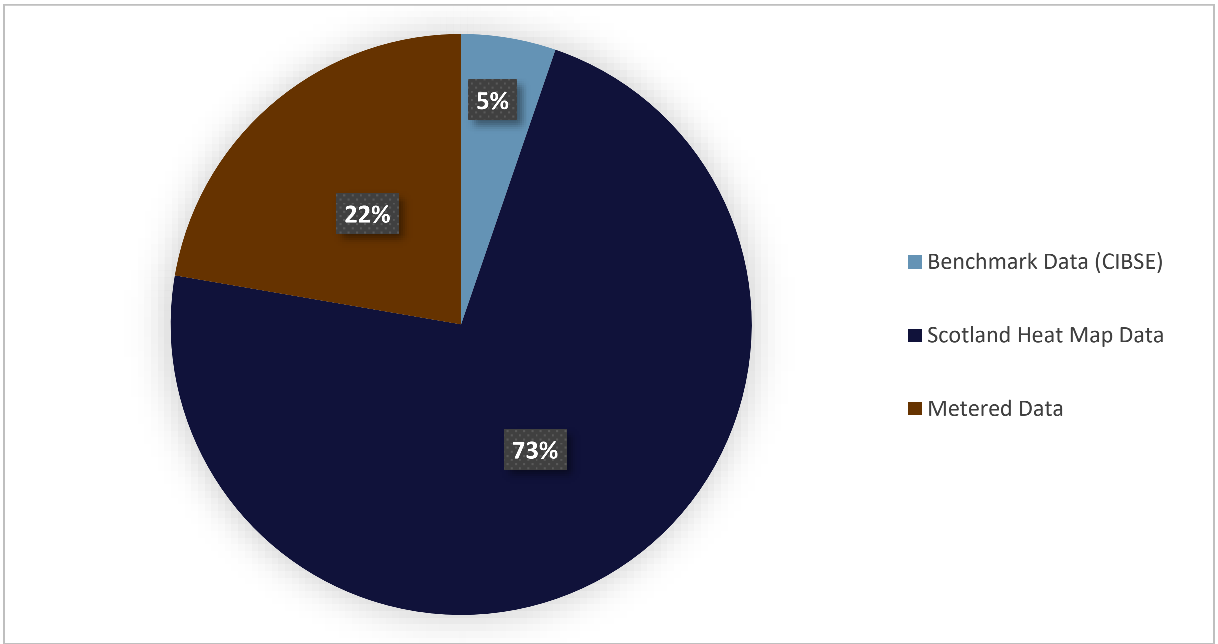

Figure 5-3: Proportion of data received for the west of Raigmore

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.

[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.

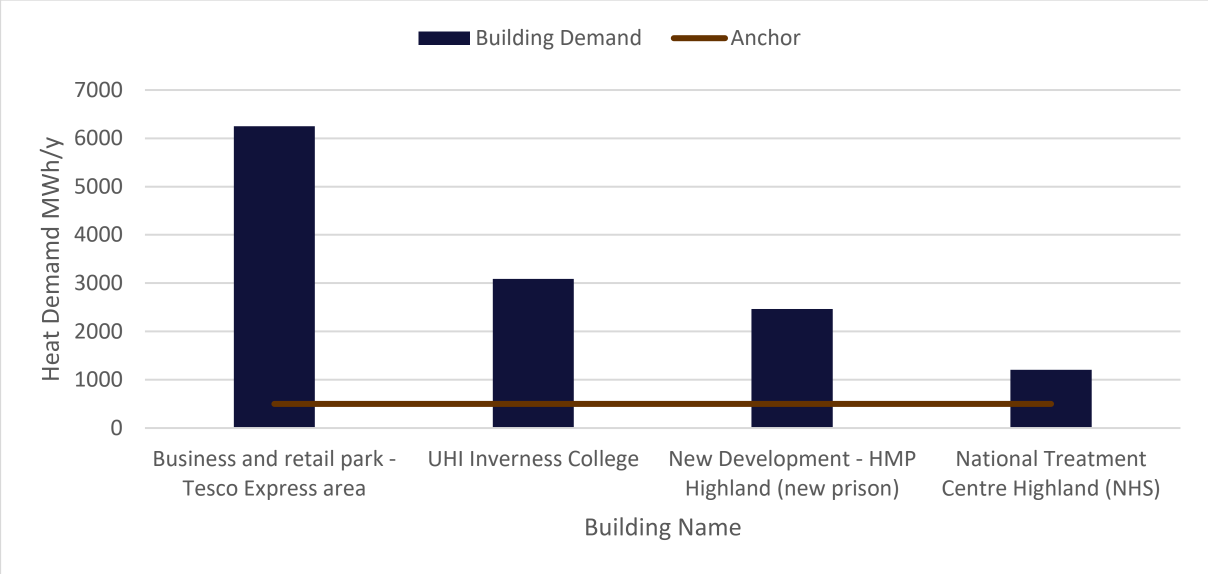

Figure 5-4: Annual Heat Demand for Higher-Demand Buildings East of A9

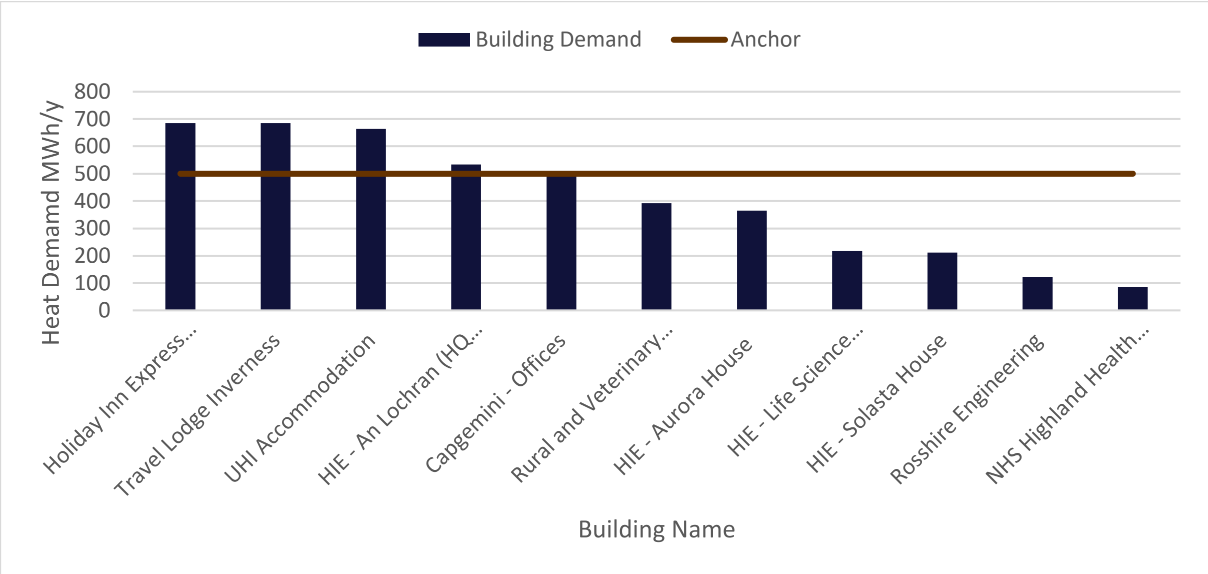

Figure 5-5: Annual Heat Demand for Lower-Demand Buildings East of A9

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.

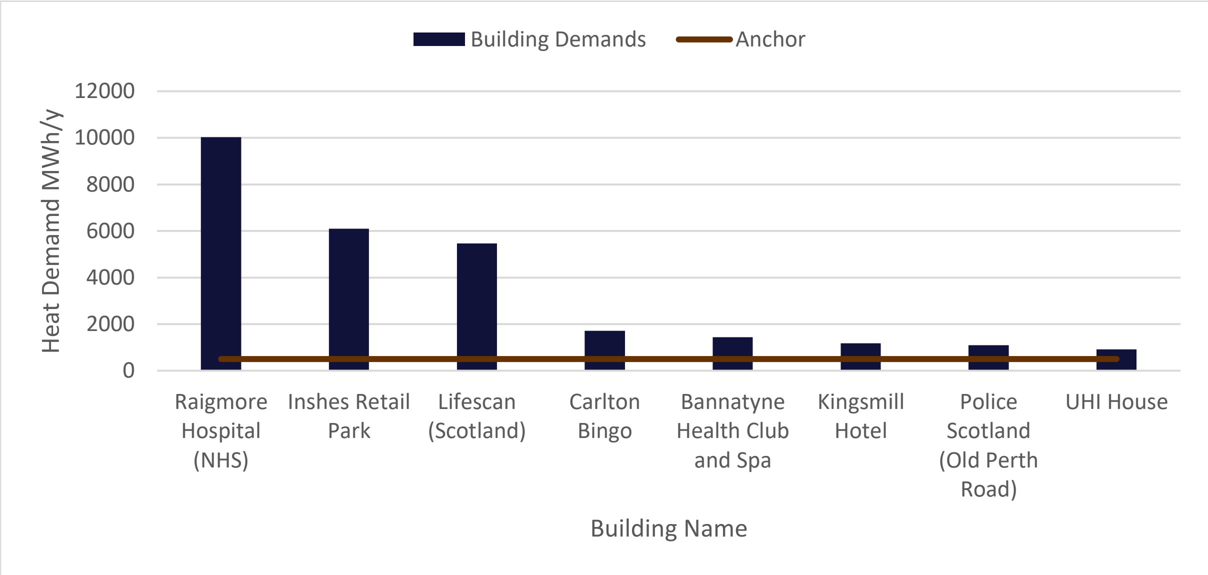

Figure 5-6: Annual Heat Demand for Higher-Demand Buildings West of A9

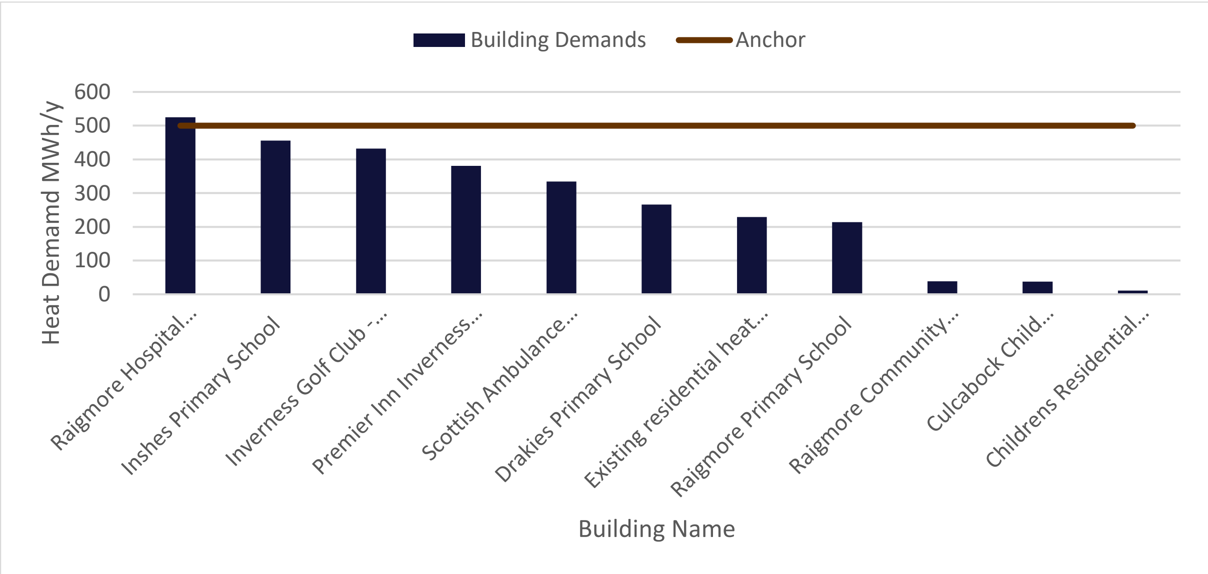

Figure 5-7: Annual Heat Demand for Lower-Demand Buildings East of A9

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.

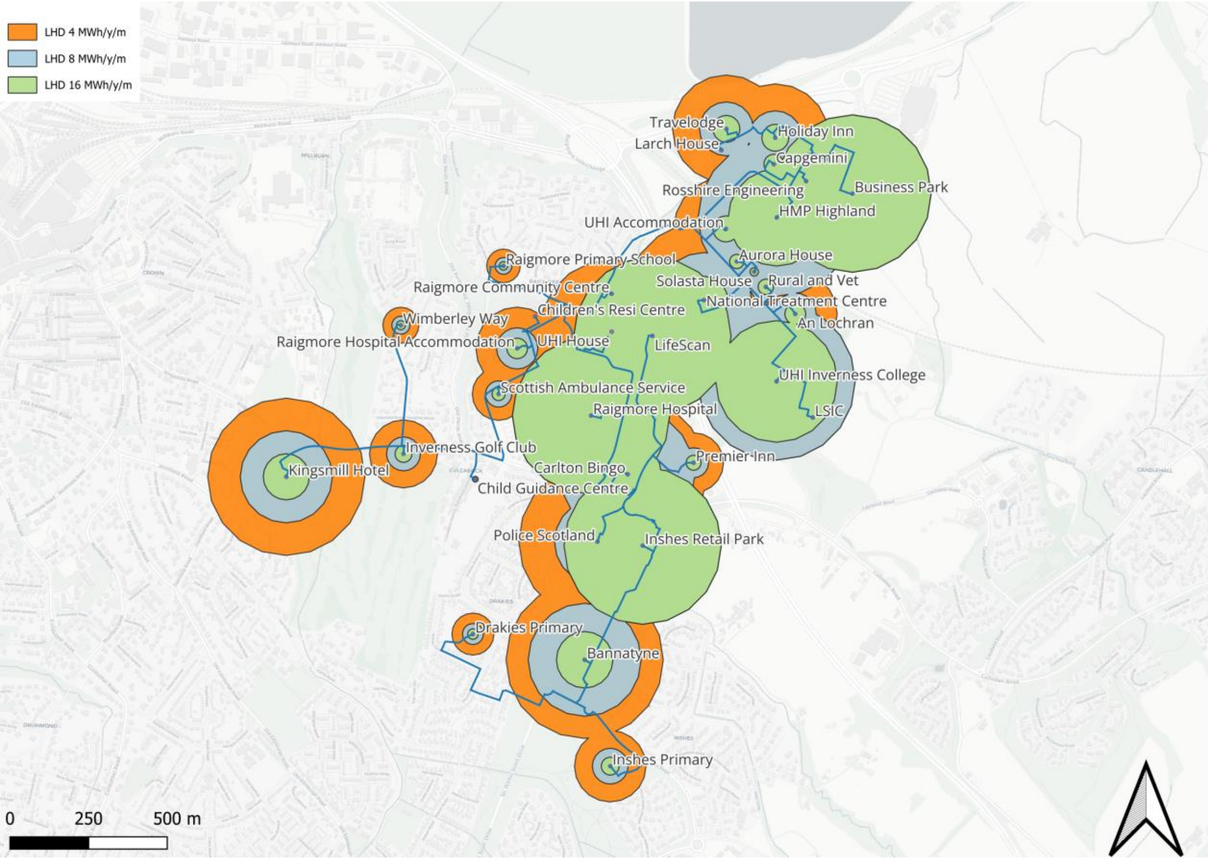

Figure 5-8: Linear Heat Density Analysis

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.

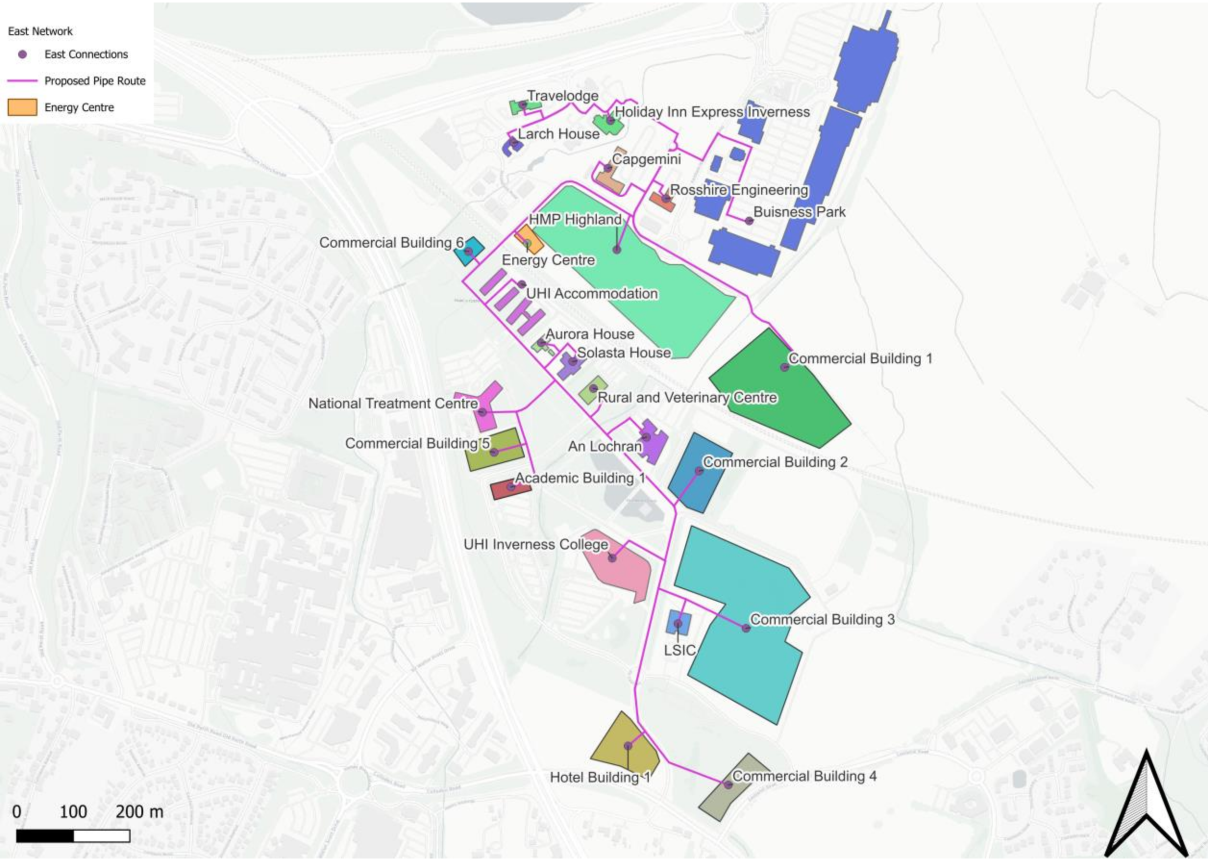

Figure 5-10: East Heat Network

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.

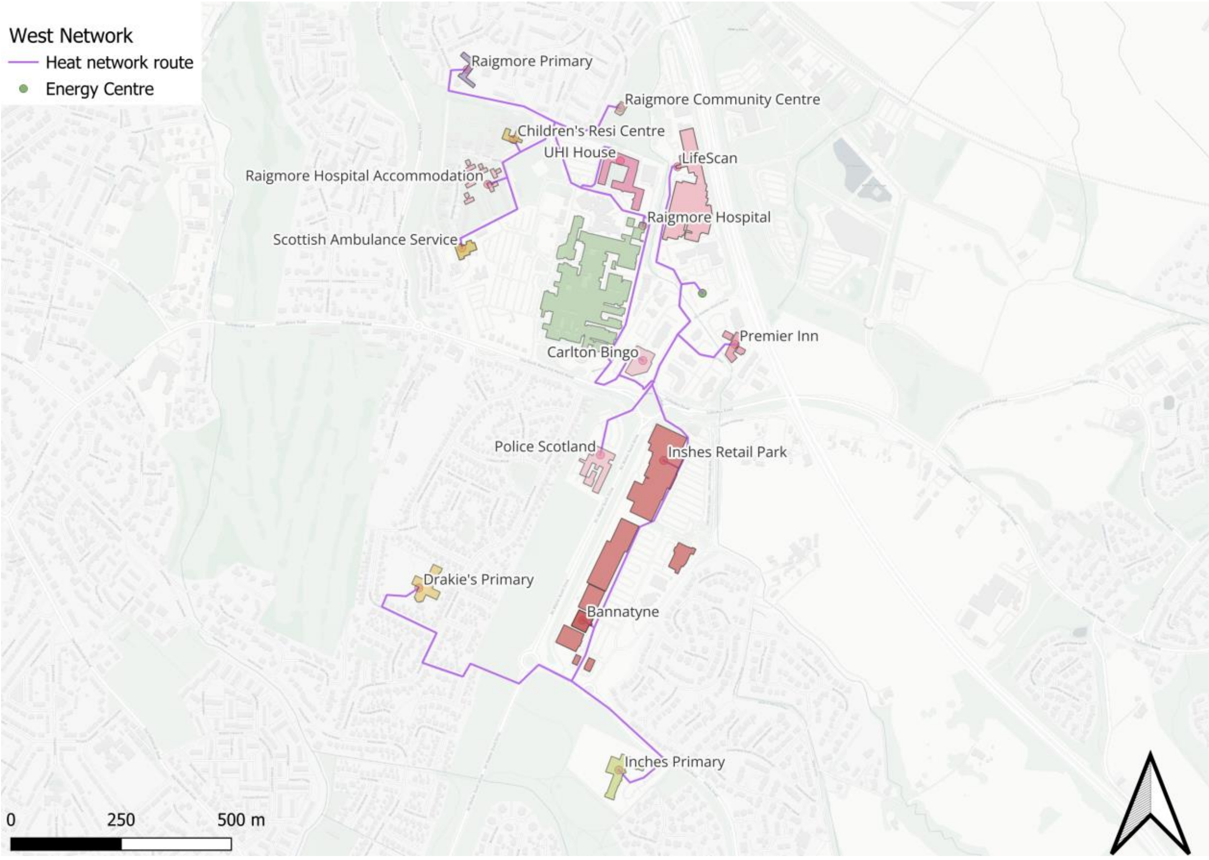

Figure 5-11: West Heat Network

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.

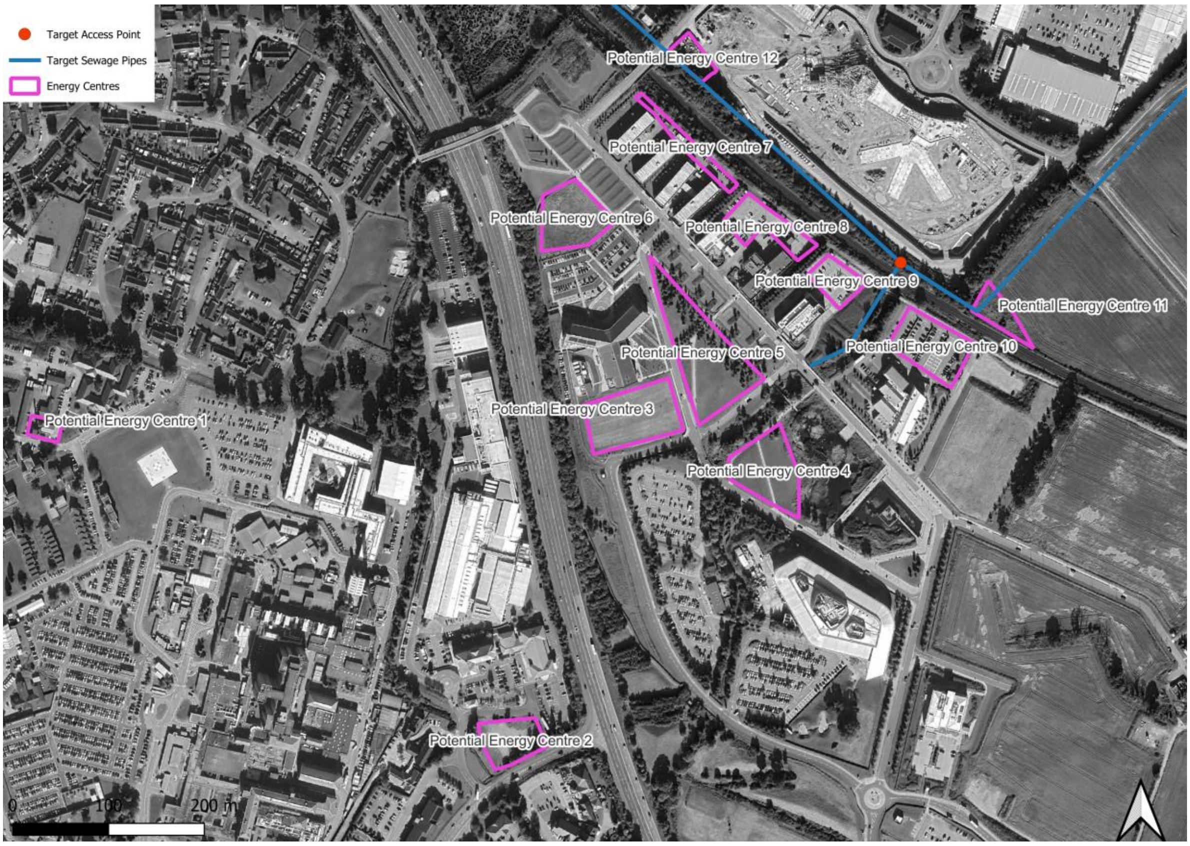

Figure 6-1 Potential energy centre locations

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.

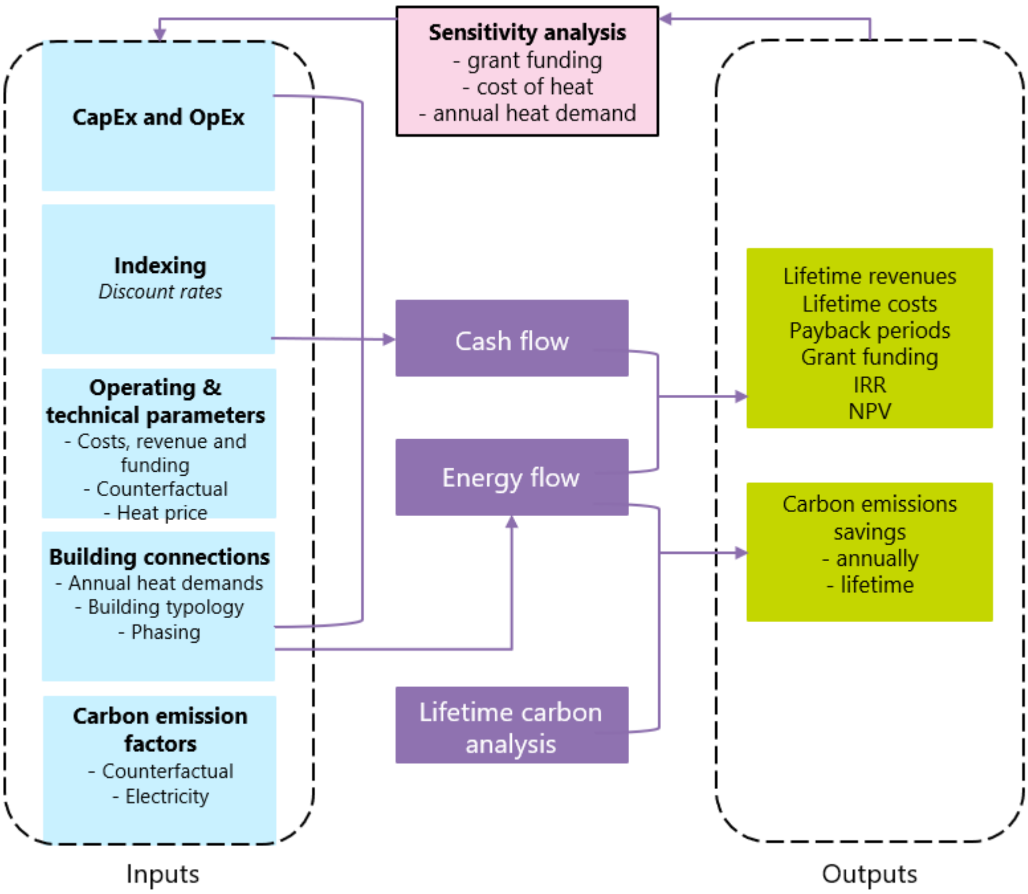

Figure 7-1: TEM methodology

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 (kgCO2e/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.

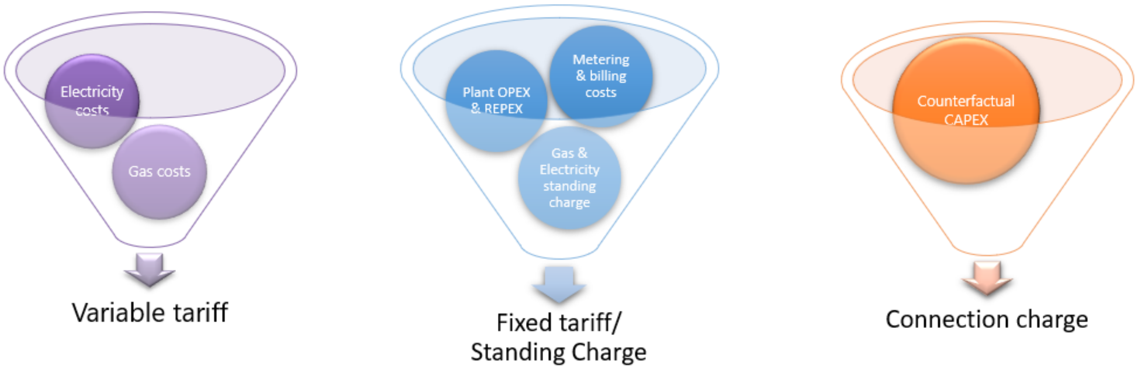

Figure 7-2: Revenue streams

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.

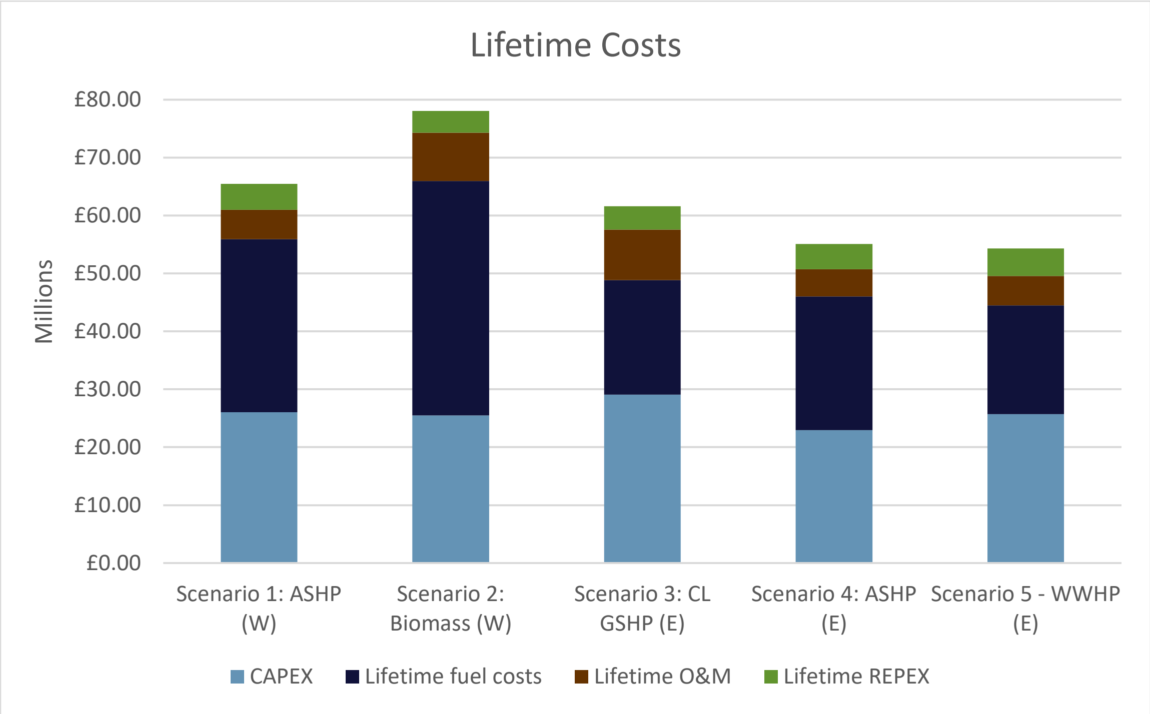

Figure 7-4: Lifetime costs

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.

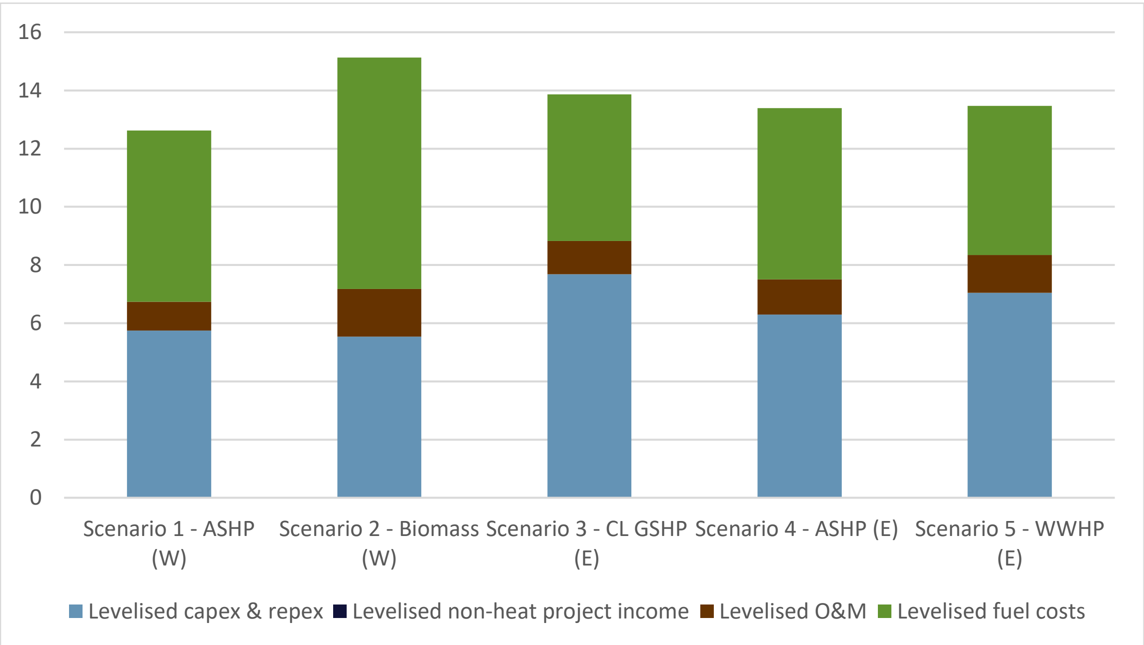

Figure 7-5: Split of key items behind the LCOH for the five scenarios.

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.

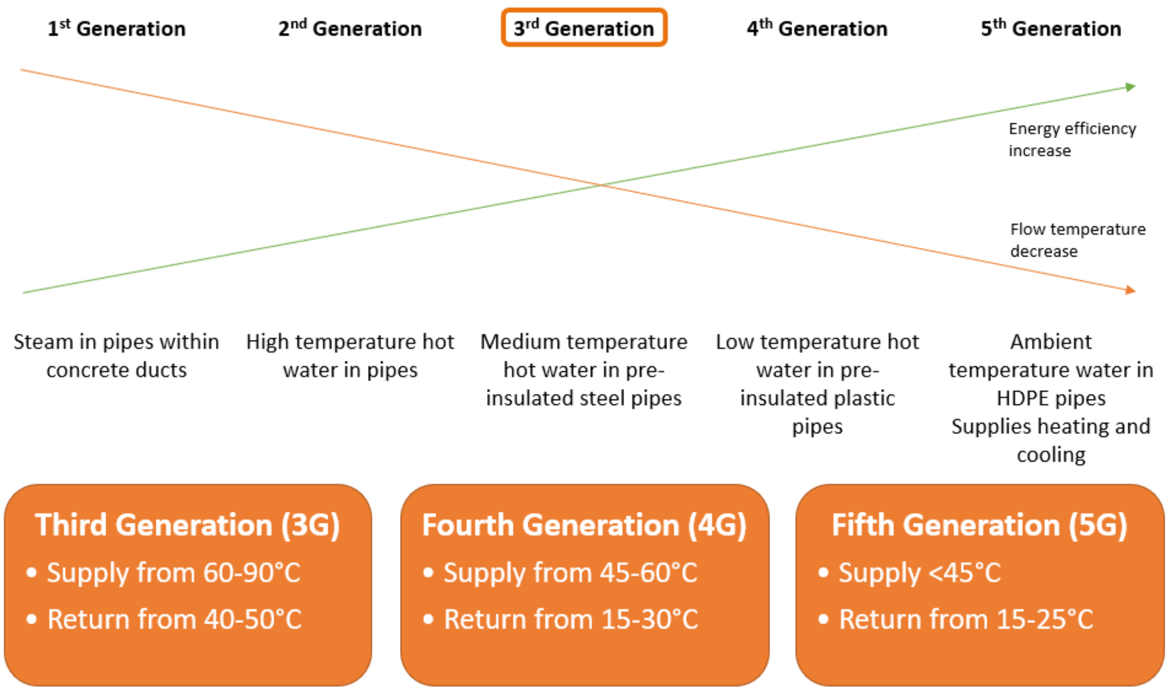

Figure 8-1: Overview of heat network generations

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 m^3 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.

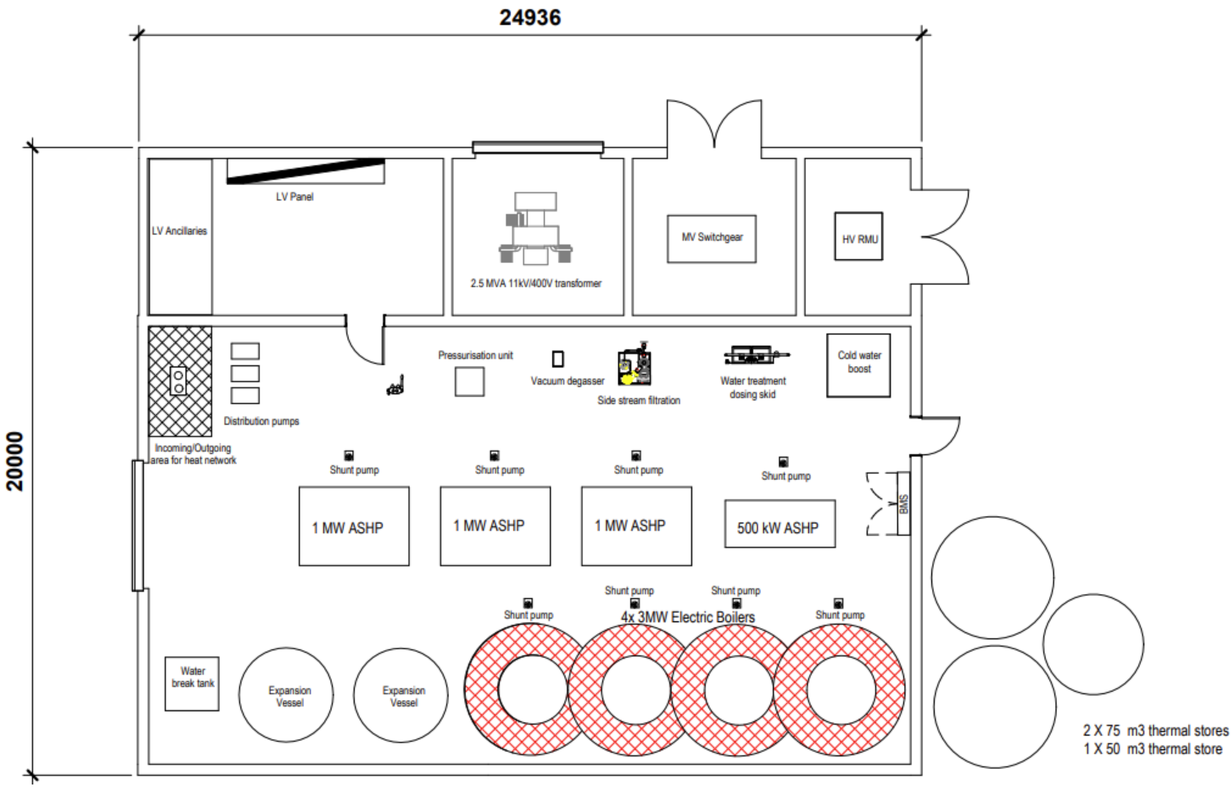

Figure 9-1 Energy centre layout

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.

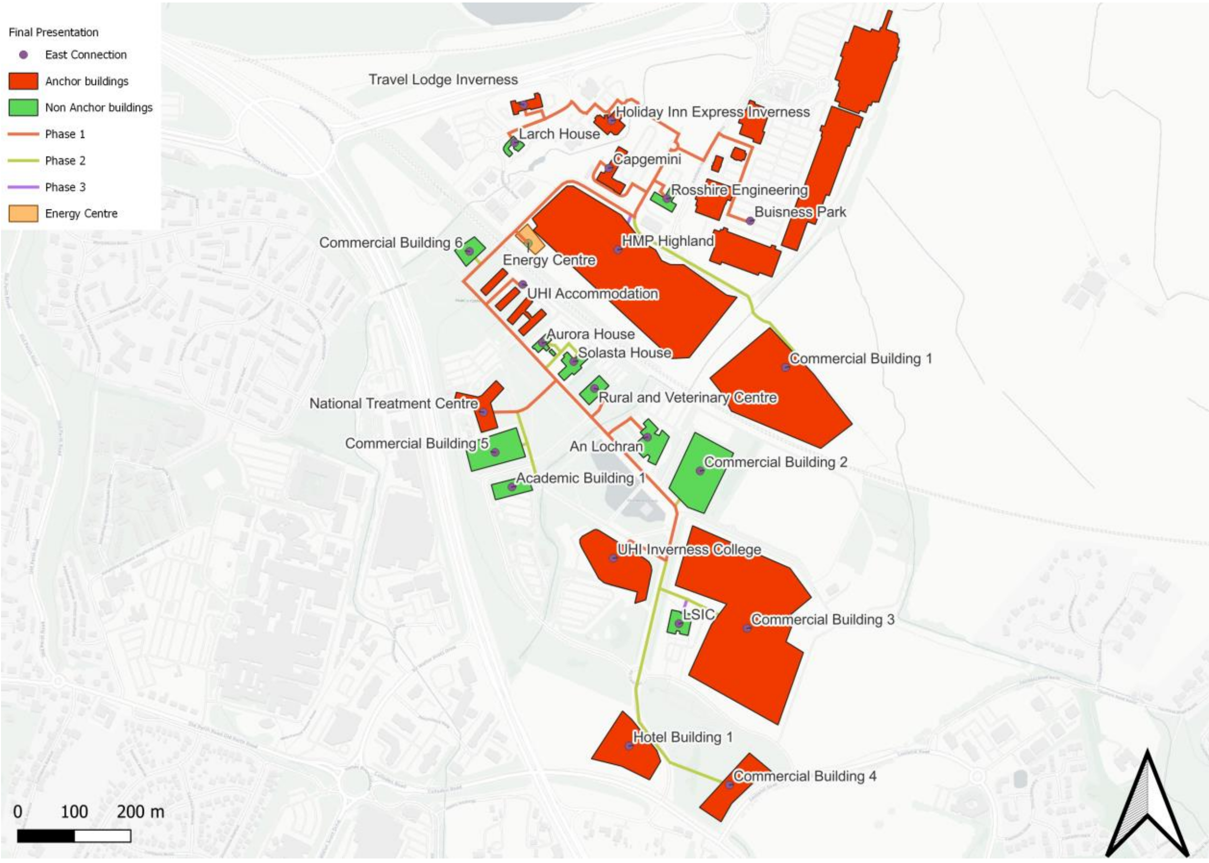

Figure 9-2 Heat network route

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.

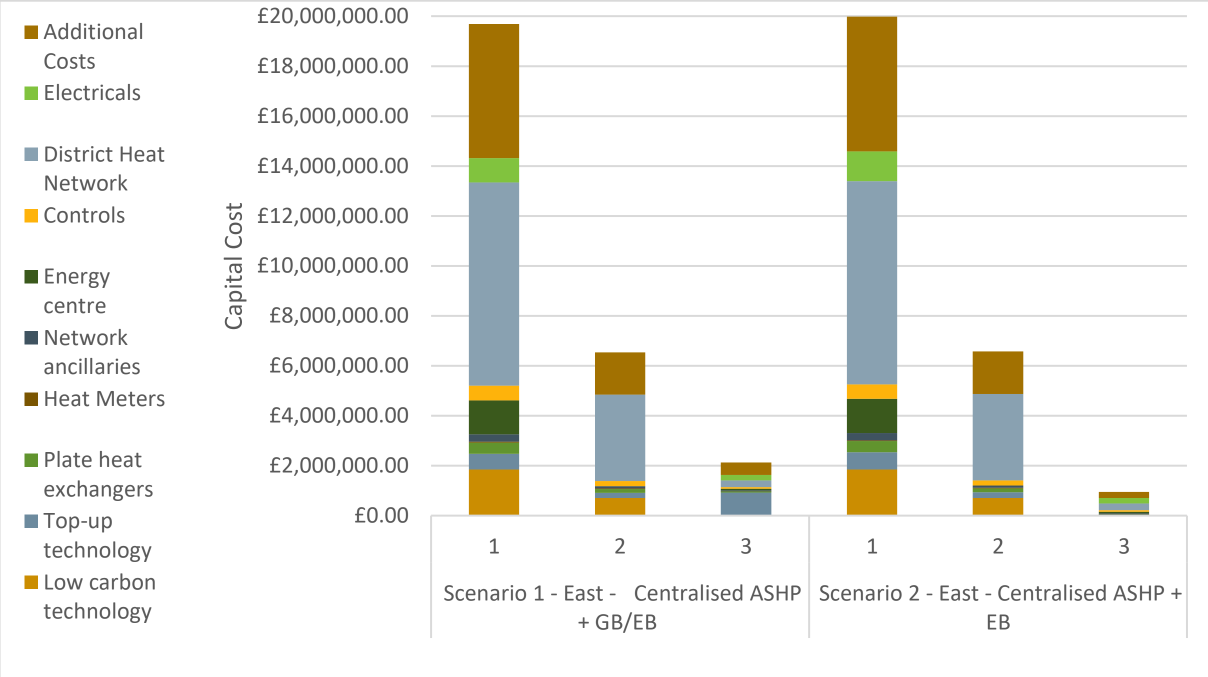

Figure 10-1 Phased capex per scenario for the East of the A9 network.

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.

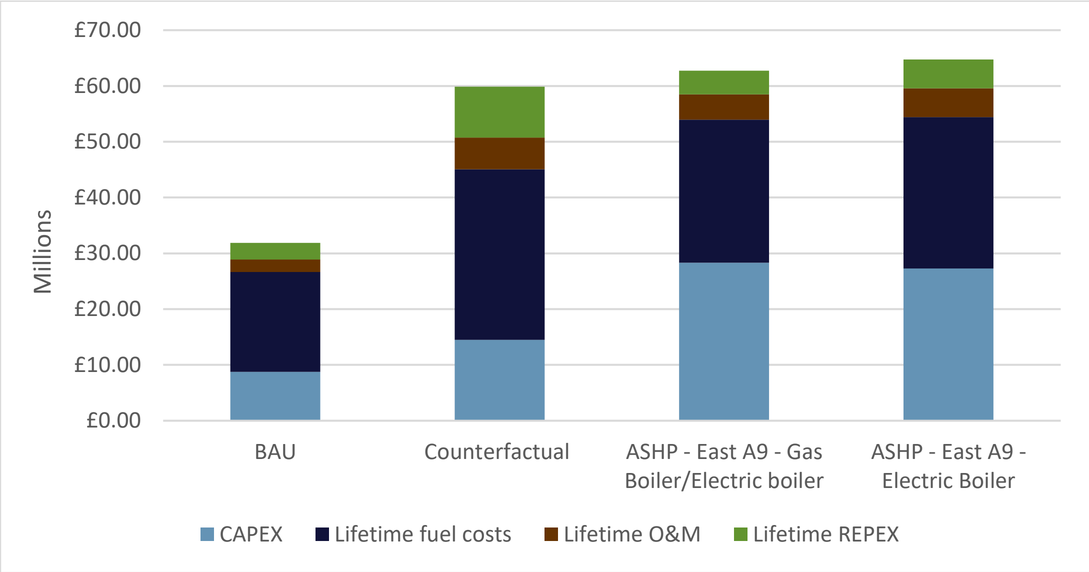

Figure 10-2: Lifetime costs for the East A9 network – full feasibility compared to BAU and counterfactual – unfunded

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.

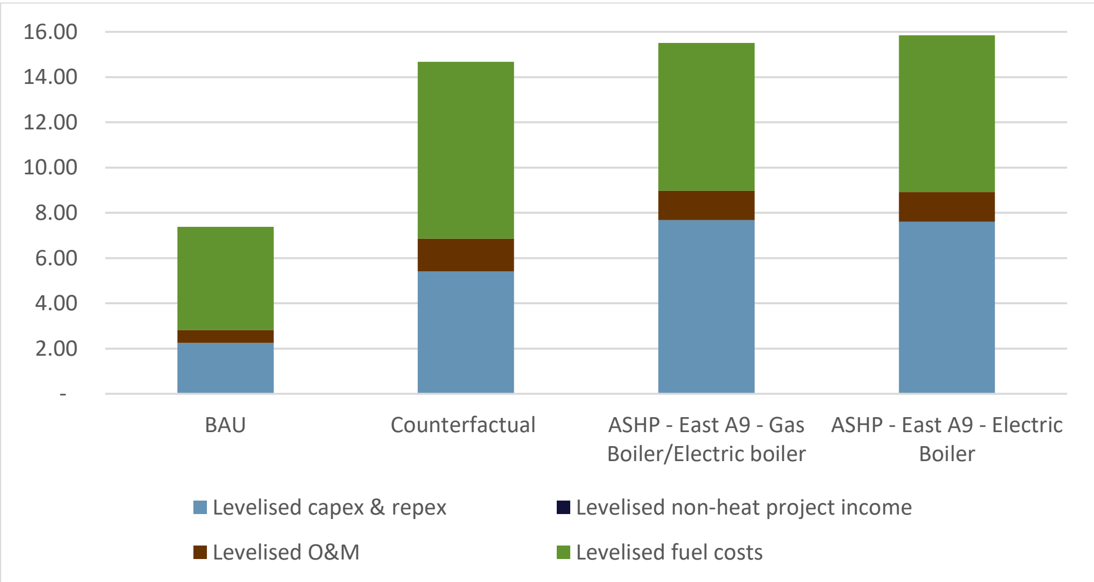

Figure 10-3: Levelised cost of heat for East A9 network – full feasibility compared to BAU and counterfactual – unfunded

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).

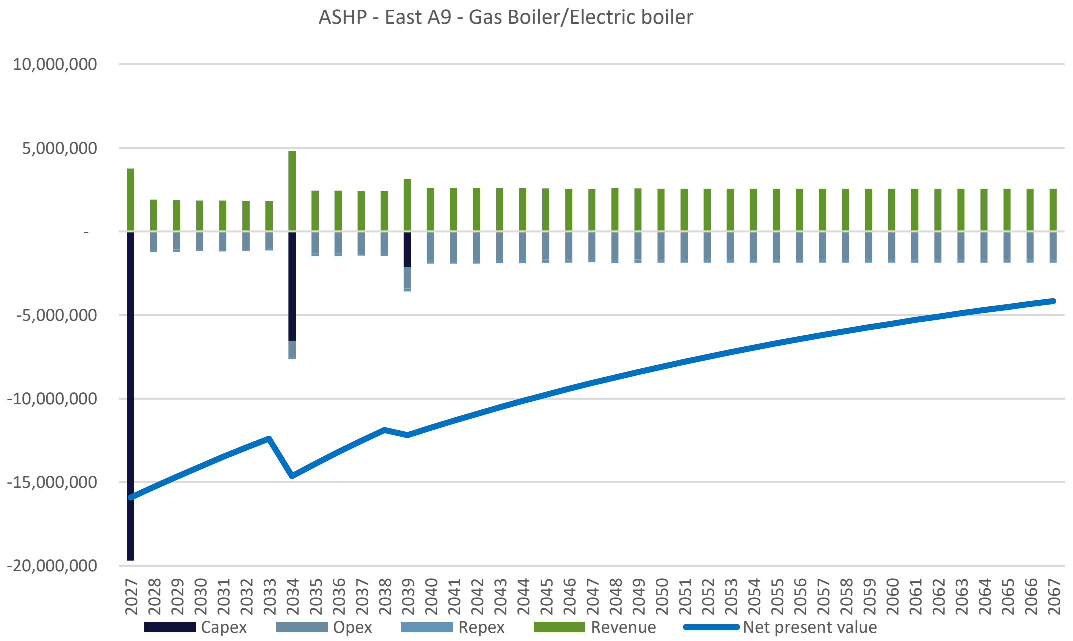

Figure 10-4: Cash flow – ASHP / gas boiler – unfunded

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).

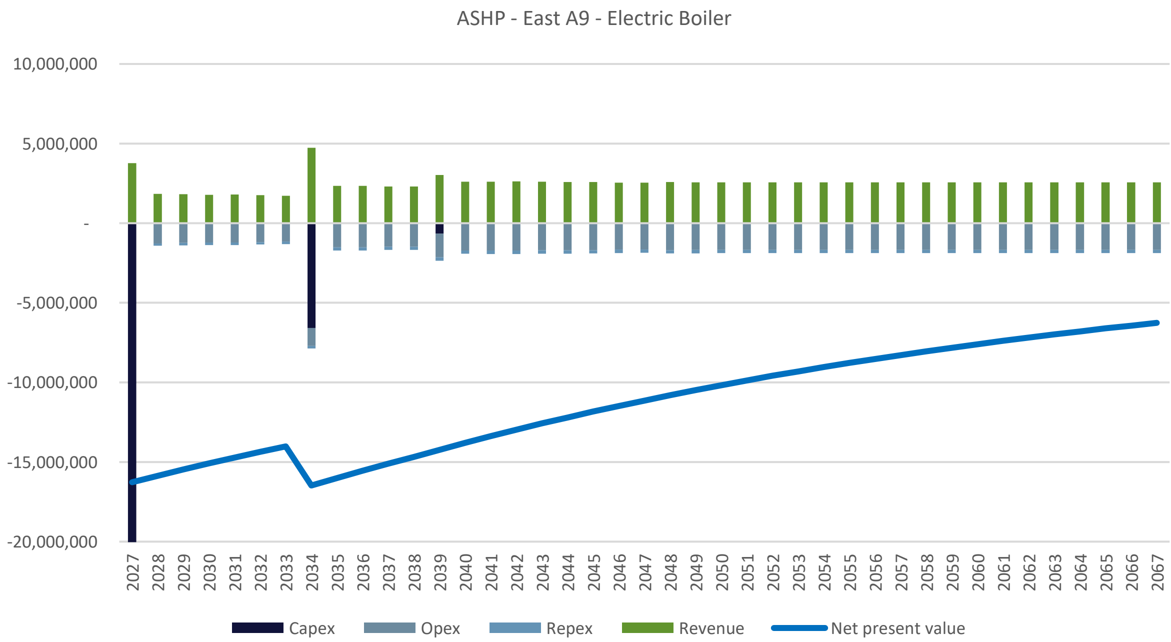

Figure 10-6: Cash flow - ASHP / electric boiler – unfunded

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.

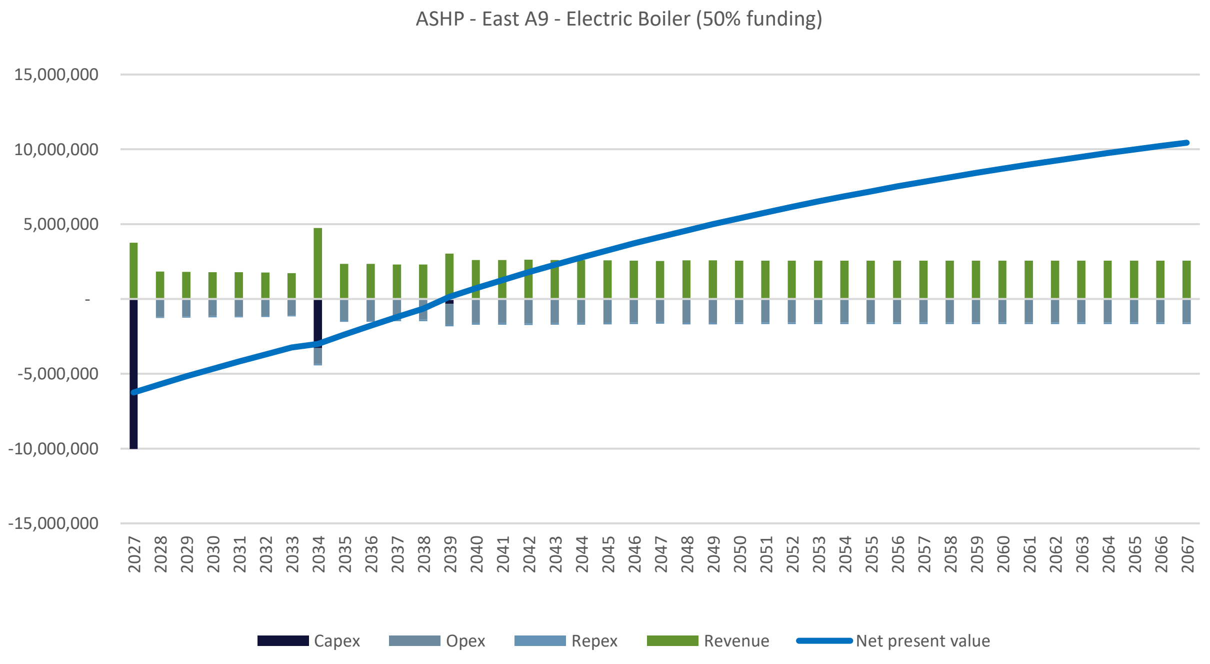

Figure 10-7: Cash flow - ASHP / Electric Boiler - (50% CAPEX funding)

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.

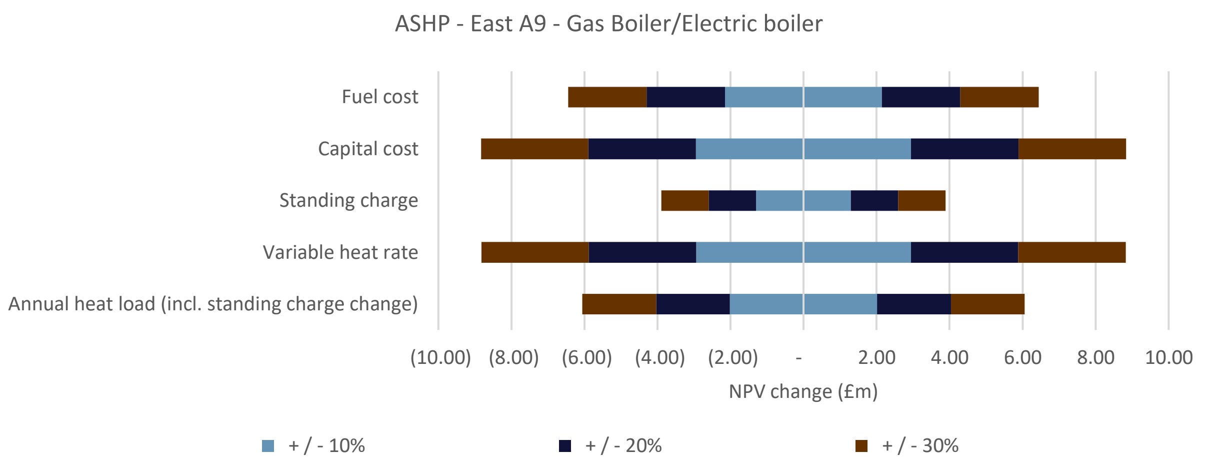

Figure 10-8: Sensitivity analysis - ASHP / Gas boiler network

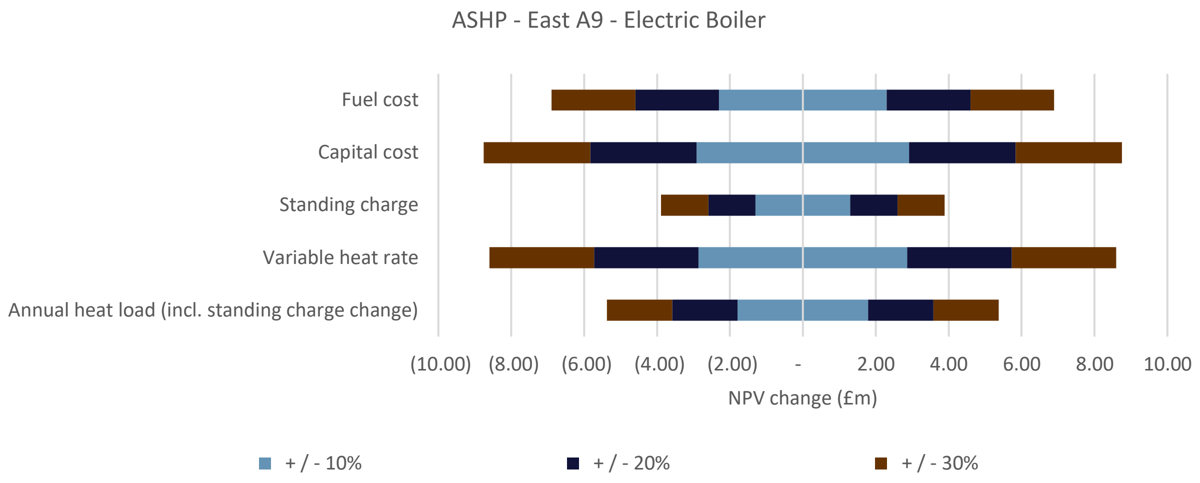

Figure 10-9: Sensitivity analysis - ASHP / Electric boiler network

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.

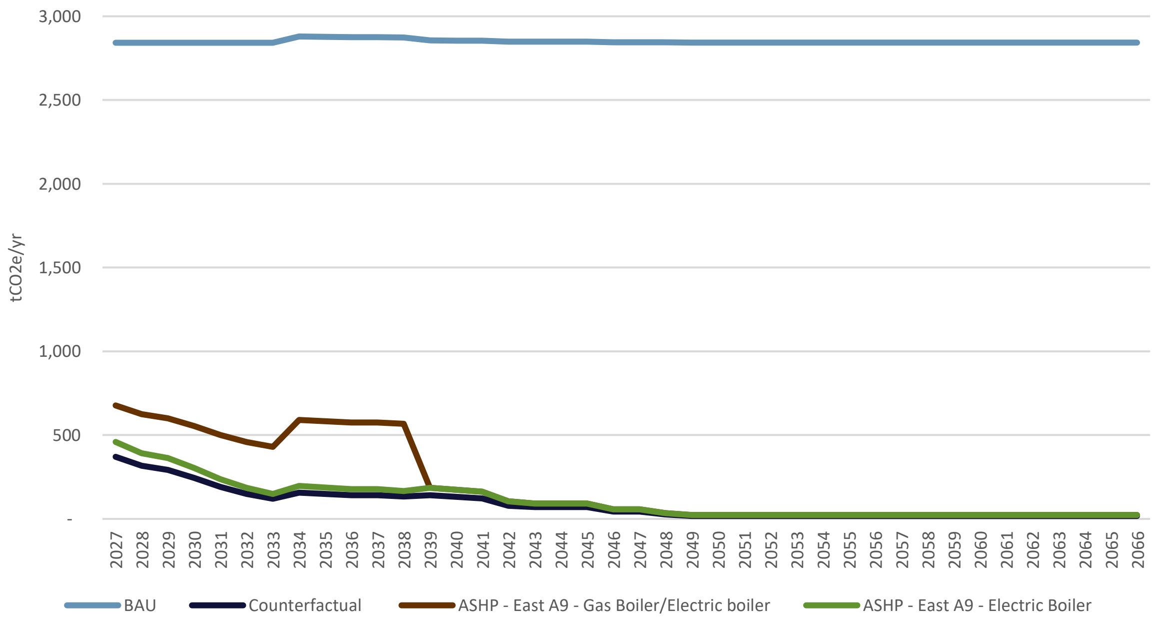

Figure 10-10 Carbon emissions across the different scenarios

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.

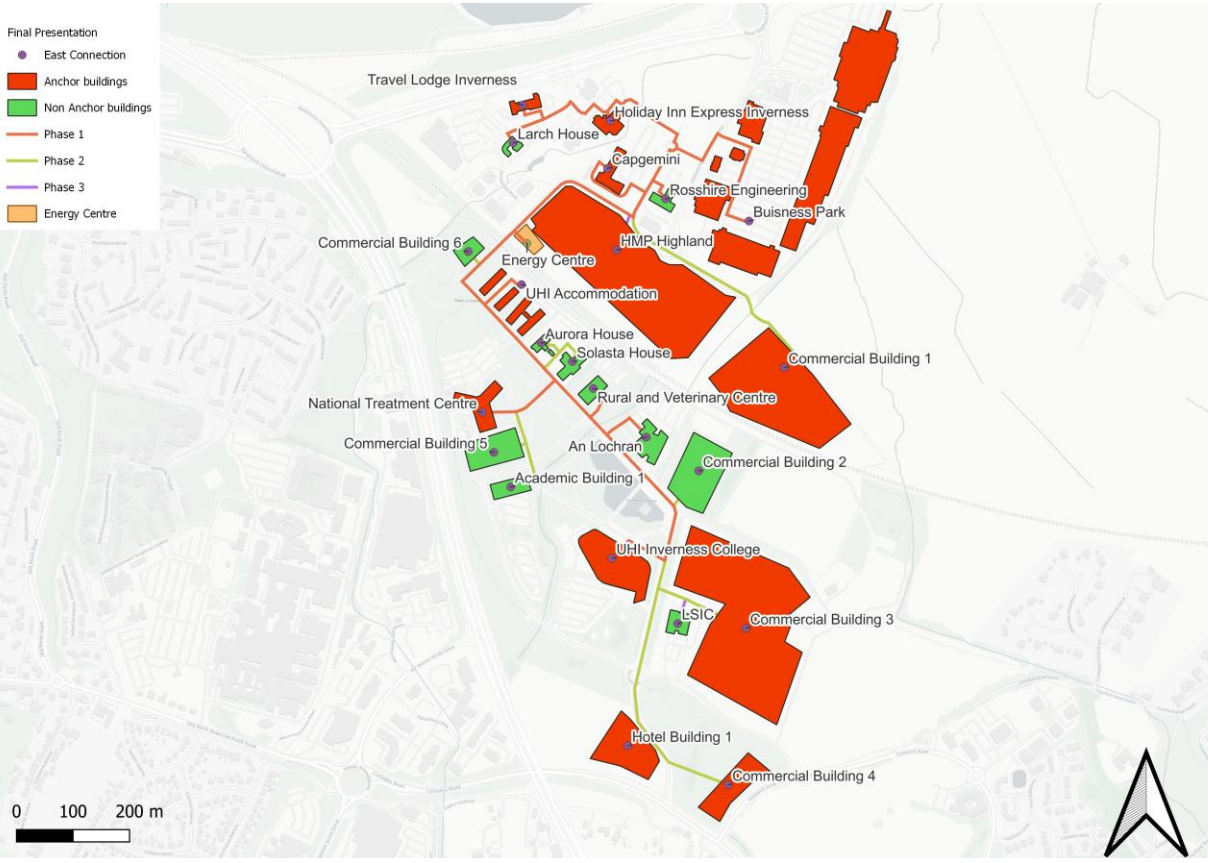

Figure 13-1: Raigmore Heat Network

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

Authors for crediting: Laura Carter, Fraser Gilvray

Date: March 2025

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

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.

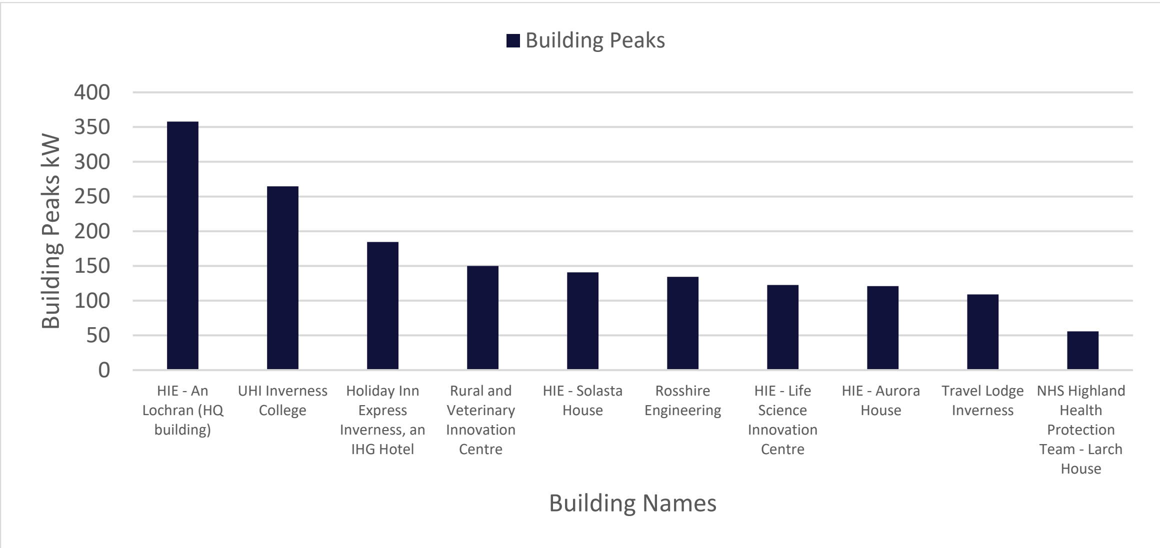

Figure 2—1: Buildings with higher peak demand on the East of the A9

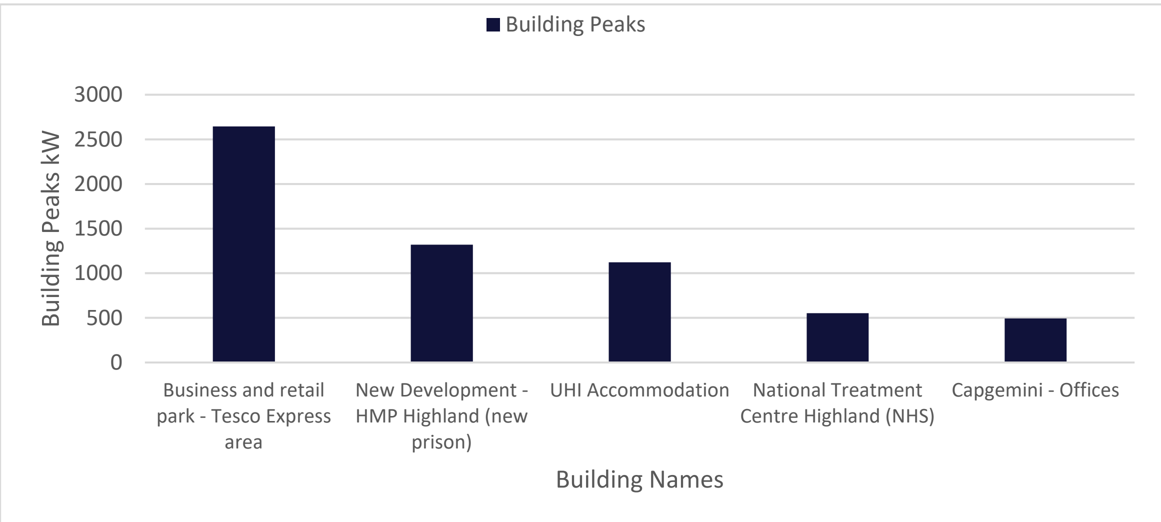

Figure 2—2: Buildings with lower peak demand on the East of the A9

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.

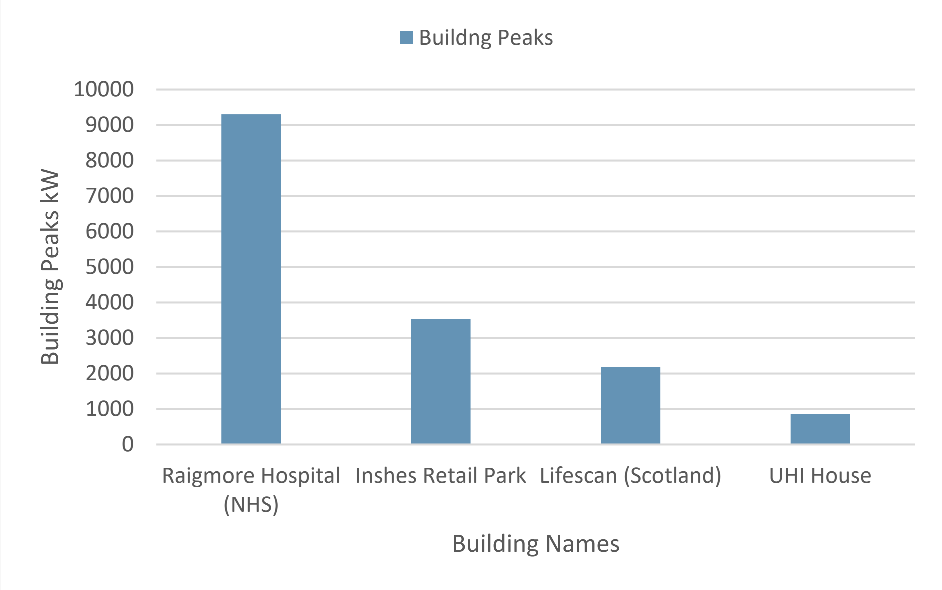

Figure 2—3: Buildings with higher peak demand on the West of the A9

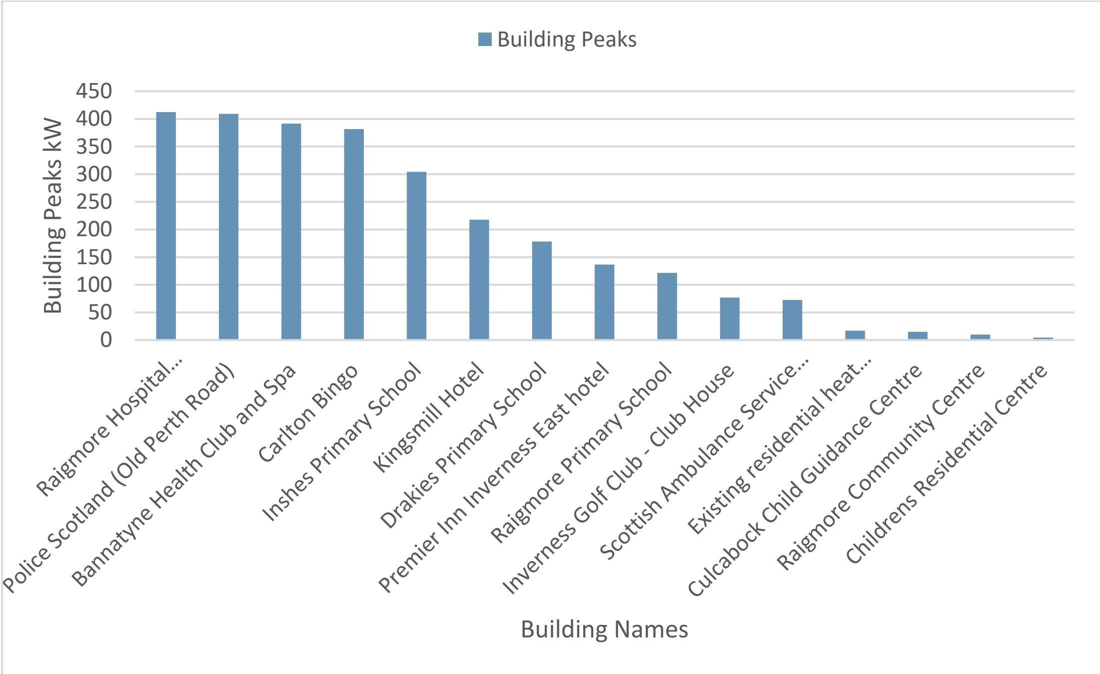

Figure 2—4: Buildings with lower peak demand on the West of the A9

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.

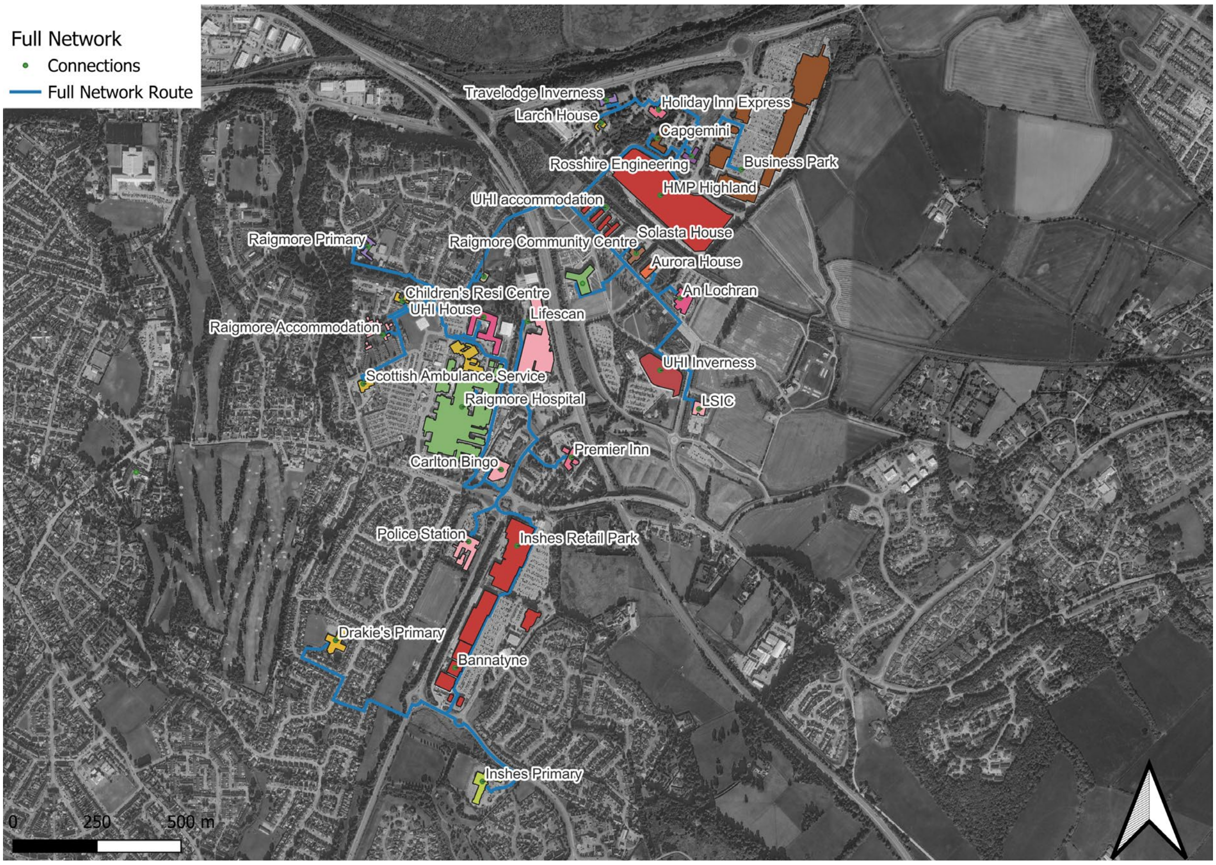

Figure 2—5: Full network route

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 map2, 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

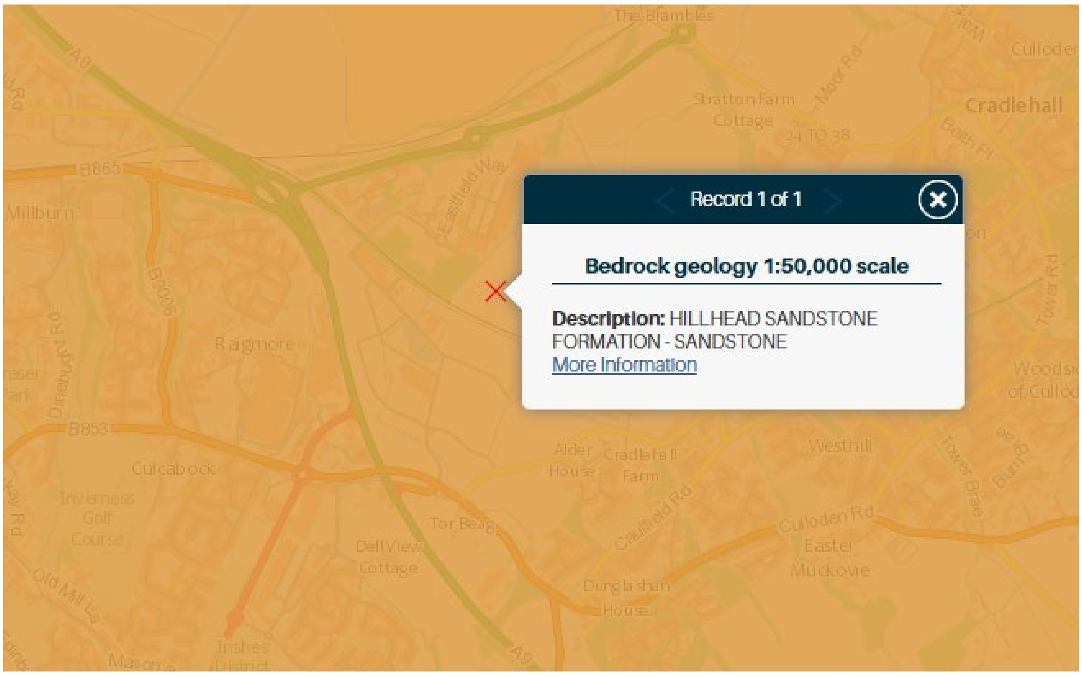

Figure 3—1: Raigmore geology

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.

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[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.

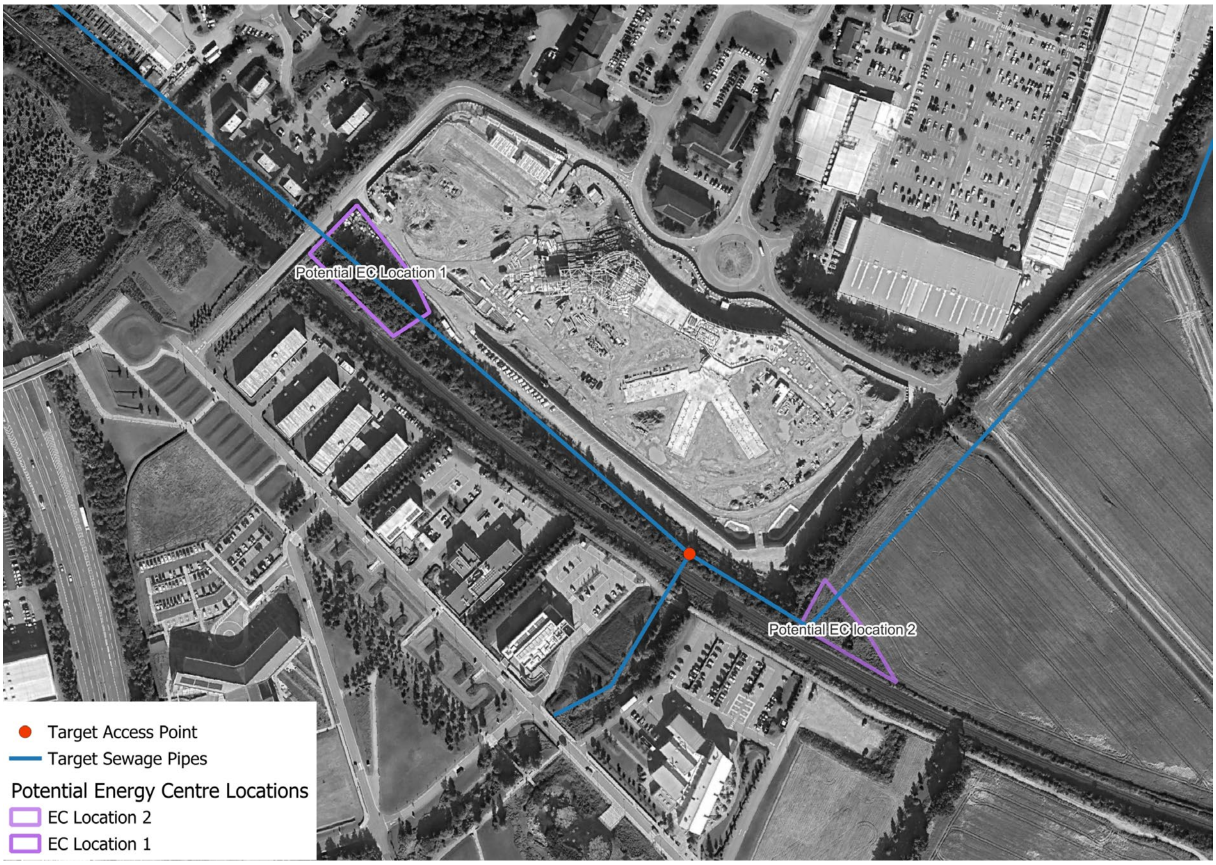

Figure 3—3: Targeted sewage lines

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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Heat Network Support Unit

Inverness Strategic Heat Network Support

Summary report

Prepared/published by: Buro Happold

Authors for crediting: Andrew Commin and Soma Mohammadi

Date: 18 April 2025

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

Glossary

Term	Definition
ASHP	Air Source Heat Pump
BAR	Building Assessment Report
BAU	Business As Usual
BGS	British Geological Survey
CAPEX	Capital Expenditure
CHP	Combined Heat & Power
CNPA	Cairngorm National Park Authority
CoP	Coefficient of Performance
CO_2	Carbon Dioxide
DESNZ	Department for Energy Security and Net Zero
dT	Temperature Difference
EC	Energy Centre
EfW	Energy from Waste
EST	Energy Saving Trust Company
FME	Feature Manipulation Engine processing tool
GHiGs	Green heat in Greenspaces
GHG	Green House Gas Emissions
GSHP	Ground Source Heat Pump
GSP	Grid Supply Point
HIE	Highlands and Islands Enterprise

Term	Definition
HMP	His Majesty's Prison
HN	Heat Network
HNZPP	Heat Network Zoning Pilot Program
HP	Heat Pump
IMFLDP	Inner Moray Firth Local Development Plan
KPI	Key Performance Indicator
LCITP	Low Carbon Infrastructure Transition Programme
LDP	Local Development Plan
LHEES	Local Heat and Energy Efficiency Strategies
LHD	Linear Heat Density
MCA	Multi-Criteria Analysis
NHS	National Health Service
NPF4	National Planning Framework 4
OPEX	Operational Expenditure
OS	Ordnance Survey Maps
RAG	Red- Amber-Green also known as a traffic light report
RFI	Request for Information
SEPA	Scottish Environment Protection Agency
SHM	Scotland Heat Map
SSEN	Scottish and Southern Electrify Network

Term	Definition
SW	Scottish Water
SWH	Scottish Water Horizon
THC	The Highland Council
TOID	Topographic Identifier
WSHP	Water Source Heat Pump
UHI	University of Highlands and Islands
UPRN	Unique Property Reference Number
ZWS	Zero Waste Scotland

Executive Summary

Through the Heat Network Support Unit (HNSU) funding Zero Waste Scotland (ZWS) commissioned Buro Happold (BH) to undertake a strategic appraisal of heat network opportunities in Inverness for The Highland Council (THC). Alongside this strategic work a feasibility study was carried in parallel for the Raigmore area of Inverness, insights from this fed into this strategic analysis. Being a high level analysis this report should not be treated as an economic assessment but rather a strategic indicator of heat network suitability and viability for further investigation.

Heat network vision statement

The first element of the study was to capture Highland Council's heat network vision for Inverness, which was agreed as follows:

As a cornerstone of the Highland Council's decarbonisation strategy, we envision developing and expanding heat networks to deliver sustainable, affordable, and efficient energy solutions – providing the lowest cost low carbon heating option. Thereby, supporting Scotland's Net Zero goals by 2045 and providing social, economic, and environmental benefits to the region.

Through LHEES and aligned with national policies, the Council envisions a number of heat network zones across Inverness. These zones will reduce reliance on fossil fuels, decrease carbon emissions, and support energy resilience. The Council recognises that the heat network can deliver further benefits including:

- **Carbon emissions reduction:** By transitioning to low-carbon and renewable energy sources, heat networks significantly reduce greenhouse gas emissions which is essential for achieving the Highland Council's ambitious Net Zero emissions target by 2045.
- **Tacking fuel poverty:** Heat networks can provide consistent and reliable heating and hot water on demand. Providing affordable heat particularly in areas with a high proportion of older, less energy-efficient homes.
- **Creating job and economic growth:** The development and operation of heat networks stimulate local economies by creating jobs and supporting the growth of a skilled workforce. This economic boost can contribute the overall prosperity of the region.
- **Energy Security and Resilience:** By diversifying energy sources and localising heat production, heat networks enhance energy security and resilience. This approach reduces dependence on imported fuels and mitigates the impact of global energy price fluctuations.
- **Environmental Sustainability:** Heat networks facilitate the integration of various renewable energy sources, such as geothermal, solar, and biomass, promoting environmental sustainability and contributing to cleaner air quality in urban areas.

By embracing these benefits, the Highland Council can ensure that the development of heat networks in Inverness not only addresses environmental concerns but also delivers tangible social and economic advantages to the community.

Heat network areas

Inverness is the largest and most heat dense area of Highland and was the focus for this strategic work. Four areas were examined for heat network potential in Inverness, these are outlined in Figure 0—1, alongside some key strategic elements of the areas (please note the background THC areas indicate land rather than building ownership).

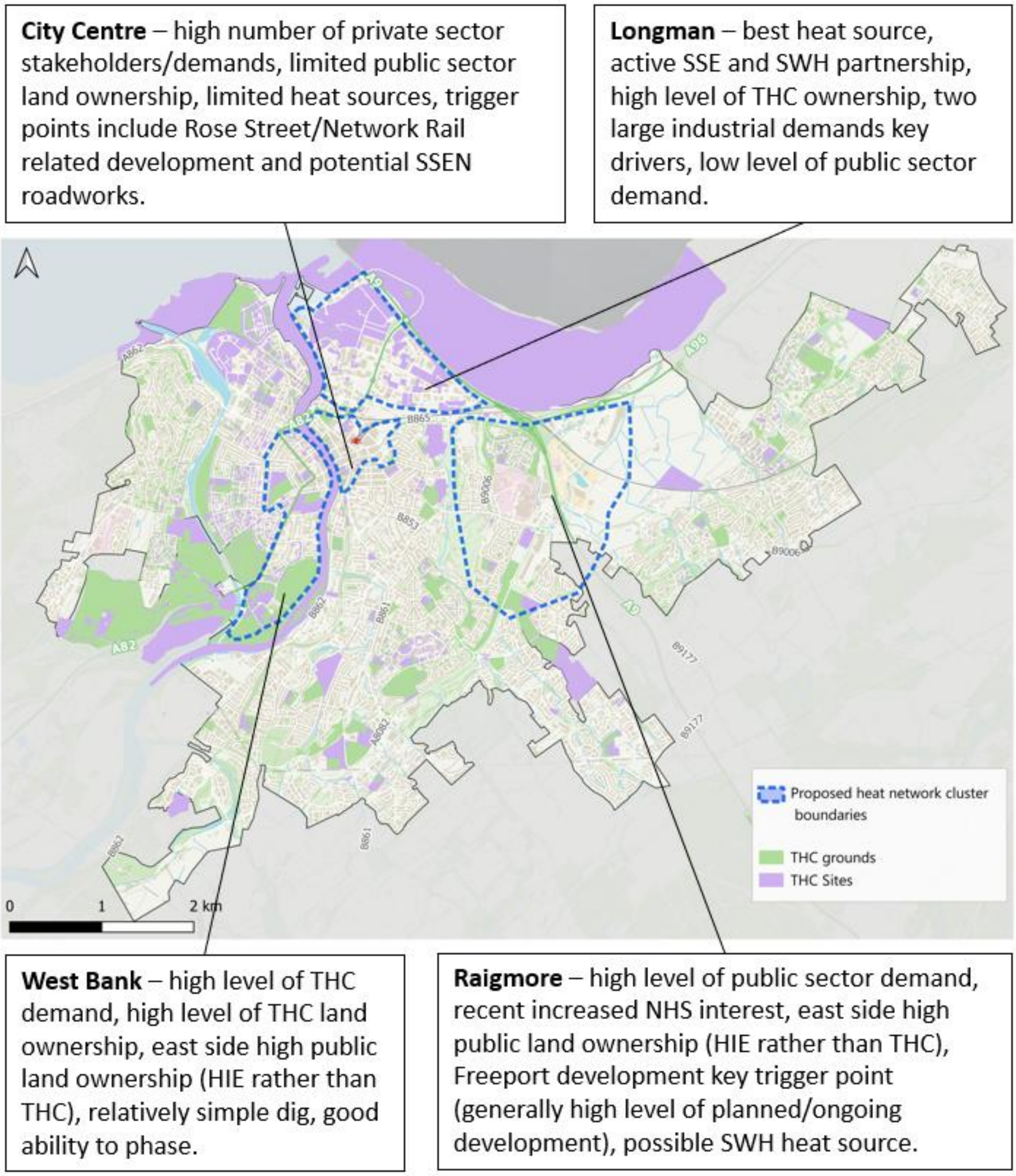

Figure 0—1 High level summary of some key strategic items the four heat network areas examined.

The **West Bank** area was found to present a promising heat network opportunity. It has a high level of Highland Council land ownership and large Highland Council heat demands. The proposed network routing runs through Bught Park, offsetting a relatively low Linear Heat Density (LHD) of 4.6 MWh/yr/m, this would be improved by a more optimised network design. The CAPEX £/MWh/yr thermal[1] measure of 0.85 for the core connections scenario is indicative of economic viability at this

[1] This is a measure of capital cost compared to heat delivered. As this project is strategic rather than feasibility more detailed economic measures were not modelled. However, this provides an indicator of economic performance. A heat network at this level of study would be expected to achieve a CAPEX £/MWh/yr thermal figure of 0.7 to 1 (less than 0.7 is very unusual but would represent a very economically attractive network, whilst greater than 1 indicates a need for optimisation).

level of analysis. The area has multiple low carbon heat supply options, including air, ground and water (from the River Ness) source heat pumps, as well as future potential waste heat from a data centre that is in the early stages of planning.

A recently announced strategic partnership between Scottish Water Horizons (SWH) and SSE is seen as a key driver for a heat network in **Longman**. The area has the best low carbon heat source identified in any of the heat network areas in Inverness (a SWH pumping station), which improves the attractiveness of the area. THC being a key land owner in Longman could be a key enabler for heat network deployment. Without two large private sector industrial loads (Baids Maltings and a Tarmac plant) connecting the LHD and CAPEX £k/MWh/yr thermal indicators perform poorly for the area (2.4 and 1.5 respectively), highlighting the importance of private sector stakeholder engagement at an early stage. When Bairds Maltings is included it raises to a LHD of 10.2 and CAPEX £k/MWh/yr thermal value of 0.33, indicating a high level of attractiveness (these values are very high level and purely indicative – industrial loads are particularly challenging to model for heat networks). These values are all for the western area of Longman, which is identified as presenting the best heat network opportunity.

The **City Centre** presents a promising opportunity for a heat network, with a high demand density (an LHD of 7.8). However, the dig complexity (with a high level of hard dig) indicates that the cost of network construction will be high – planned cabling work by SSEN could help mitigate these costs by reducing the civils costs associated with digging up the roads. This could reduce the relatively high CAPEX £k/MWh/yr thermal value of 1.08. The heat network has little public sector influence in terms of land or demand ownership, increasing the complexity of stakeholder engagement. The planned development in the Rose Street area and planned work by National Rail creates an opportunity for constructing an energy centre in what is a spatially constrained area of Inverness. There is also potential to link with the Longman area, and its large waste heat sources, but this requires more detailed analysis; including the economics of such a connection and the amount of waste heat that will be used within the Longman area. If the majority of the heat is used in Longman (which is likely the case if the Maltings and Tarmac plant are connected) the quantity of low cost heat that can be supplied to the City Centre will reduce, reducing the benefit of interconnection. Within the City Centre there are no waste heat sources identified, air source heat pumps are considered the most likely local heat source (the River Ness is adjacent but in a challenging location from a likely heat network build out perspective).

The **Raigmore** area presents multiple promising heat network opportunities. The area is split by the A9 and in a feasibility study alongside this report a heat network covering the full area, just the West and just the East of the A9 were examined. The latter was selected to progress to full feasibility in the report. Engagement with the NHS, due to the large and strategically placed heat demand of Raigmore Hospital, will be key for driving a network to the West of the A9 where the LHD and CAPEX £/MWh/yr measures appear to be promising (5.4 and 0.93 respectively). On the East of the A9, the planned Freeport development will be key to driving a heat network, the LHD and CAPEX £/MWh/yr (4.6 and 1.24 respectively) indicate a slightly less favourable network. However, this is offset by a likely reduction in cost due to high dig costs being assumed in the area and the economic effectiveness of connecting a new site (the Freeport development). The accompanying feasibility study found the East option viable and suggested continuing to outline business case. For both sides of the A9 there are large number of public sector anchor loads, meaning engagement is likely to be straight forward if the option is taken to progress the heat network opportunities. On the East of the A9 the high level of ownership by HIE will further ease the engagement process. Sewer waste heat, ground source and air source heat pumps all have some potential in Raigmore, with the feasibility study taking air source heat pumps forward as the selected technology.

Interactions between heat networks

When considering large scale strategic interaction between heat network opportunities it is important to understand the key drivers for interaction. These can be broken down to push or pull factors:

- **Push factors** relate to a drive to export heat from an area or a low-cost heat source acting to push interconnection in the area itself. This will generally be a large-scale heat source which either exceeds the heat demand nearby or is an area which is not well suited to heat network deployment.
- **Pull factors** are those which drive import of heat to an area. This will often be related to a highly attractive heat dense area. At the strategic level another pull factor could be the lack of heat supply potential within the area to meet the heat network opportunity. Other pull factors could be societal indicators such as fuel poverty – prioritising these areas for the lowest cost source of heat.

These are summarised for the different areas in Table 0—1. In Inverness there is generally a stronger set of pull than push factors within zones, which would generally lead to a lack of interconnection.

Table 0—1 High level summary of push and pull factors for different potential heat network areas in Inverness.

Area	Push factors	Pull factors
West Bank	Very few, potentially some benefit from the River Ness but would require detail assessment to demonstrate superior economics to ASHP or GSHP. High level of THC land ownership would aid broader push of heat if suitable.	High level of THC demands key driver for heat networks in the area.
Longman	SW pumping station is the most promising heat asset identified in Inverness. Potential route for electrolysis waste heat from adjacent hydrogen production site in planning. High level of THC land ownership allowing effective push of heat from the area. Justice Centre well located for a strategic connection for any push to wider heat interconnection. Large amount of available land near heat source provides space for a large energy centre and the potential for associated thermal storage.	Two large industrial demands but otherwise relatively few pulls for heat to the area.
City Centre	Very limited push factors, no major heat sources and spatially constrained.	High heat demand density.
Raigmore	Some waste heat potential from the sewer was shown to perform in a similar manner to ASHP, ongoing SWH activity in Inverness may help drive down costs for this technology.	Large number of public sector anchor loads.

The Longman area is the only one with significant positive push factors out of the area. The geographic proximity to the City Centre, which would have the greatest difficulty generating heat locally, means that interconnection could be considered.

Challenges for this include the danger of a relatively low-density connection route through the Longman site to the City Centre. It will be important to maximise connections on this route (such as the Justice Centre) to help improve viability of the connection. The redevelopment in the Rose Street area of Inverness is also well located for any route connecting Longman and the City Centre, which would be important to consider in any detailed layout options for the network. There is increased complexity in strategic alignment over large, interconnected areas.

Both the West Bank and Raigmore areas are, based on the findings of this work, initially better placed to consider in isolation. They have suitable land and heat sources to supply their own potential networks and there are good local pull factors in terms of heat demands and land ownership. For

Raigmore although the feasibility study considered the East and West sides of the A9 separately it is still important to consider the area as a whole:

- The increased interest of the hospital since the feasibility study was completed helps derisk the West network.
- The large sewer main on the East side may become more attractive, with increased SWH work in the area potentially driving down costs – this heat supply could be the push factor required to connect the East and West sides of the A9.
- The larger total heat demand is likely to be more attractive to investors.

The scale of the heat demand in the four areas examined are broadly similar. With demand varying between 24 GWh/yr and 49 GWh/yr, depending on the areas and the modelling scenarios selected.

Sequencing and heat network trigger points

All of the areas examined in Inverness show potential for heat network deployment. All the potential heat networks have specific benefits and challenges and how these are balanced and consider impacts their attractiveness. This section captures key trigger points for each area, many of which have been discussed previously, in Table 0—2 to Table 0—5 and then goes on to discuss how these influence sequencing of potential heat network zones and activity.

Table 0—2 Key trigger points for the West Bank heat network area.

Key trigger points
• Planned work at the leisure centre. • Understanding of heat supply technology in anchor loads and core connections. The replacement of heating systems will be a trigger point for connection for many loads, with a heat network connection not being available it could mean connection is not viable until end of life for the new heating technology. • The potential data centre could be an important waste heat source. Ensuring compatibility with any energy centre design should be considered. This could drive the price of heat down and could be a trigger for network expansion (it is considered likely that a first phase of West Bank could progress ahead of the data centre deployment).

Table 0—3 Key trigger points for the Longman potential heat network area.

Key trigger points
• The ongoing collaboration of SSE and SWH has already acted as key trigger point for this area. This has progressed interest faster than may be expected based on the other heat demand (rather than source) led opportunities in inverness. • Shared trenching captures a number of key trigger points in Longman. This includes a potential hydrogen pipeline and waste heat transmission from the electrolysis site on the old landfill site. Another being shared trenching with a private wire from the PV site in Longman (based around the pumping station). Finally, planned SSEN upgrades in the wider area may drive Longman interconnection (this is discussed further for the City Centre). • The interest of the Tarmac and Bairds Maltings sites will be a key trigger for deployment, without these the heat network potential in the area appears marginal.

Table 0—4 Key trigger points for the City Centre potential heat network area.

Key trigger points
• The Rose Street redevelopment is a key enabler for allowing for the centralised infrastructure of an energy centre in the spatial constrained City Centre. • SSEN have planned cabling upgrades in the City Centre. They have already expressed initial interest of using this as an opportunity for heat network installation, reducing the cost of pipework.

• Understanding of key anchor load requirements and interest for heat network connection. Eastgate is the single largest demand identified in the City Centre and would create a strong network spine, with the route passing other key loads like the Royal Highland Hotel.

Table 0—5 Key trigger points for the Raigmore potential heat network area.

Key trigger points
• The Freeport developments are key to driving the heat network to the East of the A9. • Recent increased interest from the hospital and understanding of required timescales and onsite plans will be key to determining timings on the West. This should also consider the potential redevelopment of the Raigmore, which could be the required trigger for connection. • Planned electricity network upgrades in the area (focused in the West) could provide opportunity for shared trenching, acting as a trigger point for pipework deployment. • There is also understood to planned ongoing in the south of the area which could be a trigger point for connection to the Police Scotland site. It may be hard to align this with the likely rate of network deployment on the West. Thus, it is important to review the ambitions on the West side of Raigmore consider whether laying a pipe to futureproof for connection to the Police Scotland building.

These trigger points help inform key considerations for heat network sequencing in Inverness, these are summarised below:

- **West Bank** – suggested to be the first network to pursue, focusing on the area to the south of Bught Park. Planned activity in the area adds an element of time criticality. Key will be engaging the Ice Centre to understand the appetite for cooling, as this will influence energy centre design. The energy centre design will also have to consider future proofing for potential expansion across Bught Park. In terms of sequencing this expansion across Bught Park is considered to be most suitable at a later stage, focusing on early delivery in the south of the area to reduce complexity and ensure the time critical opportunities are not missed.
- **Longman** – understanding the full ambition of heat networks in the wider Longman and City Centre areas is key to sequencing. The potential interconnection and transmission of heat is key to ensuring pipes are suitably sized. Many items to determine the sequencing will be based on stakeholder engagement to understand the desire of demands to connect. Shared trenching opportunities during electricity network upgrades, may drive activity earlier than would normally be expected in a heat network with the characteristics and complexities of Longman and the City Centre. In terms of overall sequencing some early activity in Longman is considered likely, due to the drive of SWH and SSE, but wider strategy and realisation of the opportunity is likely to take longer. This could potentially align well with the potential additional waste heat supply from the electrolysis site going through planning.
- **City Centre** – the city centre has some of the greatest complexities and in terms of sequencing is thus likely to be slower to progress than the other opportunities in Inverness. The main driver for any early-stage activity in the area will be cable upgrades by SSEN, potential reducing pipework trenching costs. As discussed for the Longman area the laying of pipework ahead of guaranteed connections and strategy does create substantial risks in terms of upfront investment. The trigger point of the Rose Street redevelopment is going to be key for sequencing development in the City Centre area, understanding the heat demands that are likely to connect and their scale before the redevelopment is key to effective sequencing and heat network planning for the City centre.
- **Raigmore** – is an area with relatively simple stakeholders to engage (this was demonstrated during the feasibility study. The sequencing of the East is laid out in detail in the accompanying feasibility study. The Freeport connections are key to the network and the sequencing. In the West loads are more well established and a network could potentially progress more rapidly, the engagement of the hospital at the end of the study and their ambitions will be a key actor and driver of timings in the West.

Next steps

There are large number of potential actions for progressing the heat network opportunities in Inverness, THC are exploring other opportunities outside Inverness but Inverness was the focus of this work. Some suggested actions, a few of which are already ongoing, include:

- **Consideration of delivery models** – an introduction to the options for these were provided in a workshop by Buro Happold at the end of the strategic study. Separately, Addleshaw Goddard are providing support to decide on delivery models for the different opportunities in Inverness. This will help determine the different actions for THC in the different heat network opportunities and how to progress through zone designation and delivery and bringing the opportunity to market.
- **Decision on indicative heat network zone boundaries** – this is linked to delivery models. It is suggested that both West Bank and Raigmore should be individual zones. For West Bank its relative isolation and the high level of THC demand in the area would suggest a different delivery model to the other opportunity areas. For Raigmore even though the feasibility focused on the East there could still be potential to connect both sides of the A9, particularly as the hospital is now more engaged. Additionally, the full Raigmore area is more likely to be of interest to private investment as it is of a larger scale and having the option of different distinct areas and phases of development is likely to be of interest to developers. For the City Centre and the Longman area the decision needs to be as to whether the areas should be considered as one or two potential heat network zones. The available heat from the pumping station and the availability of waste heat from the potential hydrogen site are key influences. If it becomes apparent Longman has large volumes of cheap heat it become suitable to group the two areas, to help reduce deployment complexity. This increase in heat demand scale is also likely to increase the desirability for investors.
- **Building Assessment Reports** – the identification of key heat demands in the opportunity areas should be a driver for BARs. For West Bank in particular this is seen as a focus for THC activity, understanding the heating systems and likely replacement timetables for equipment is key to building a cogent strategy for the area.
- **More detailed analysis of West Bank** – this should initially be focused in the southern area of the network. This area has the most pressing trigger point with the work at the leisure centre being an opportunity for initial deployment. There are multiple actions, three being: a utility survey, greater understanding of a potential energy centre location, future proofing for expansion and connection of any additional heat sources (e.g. the potential data centre in the area), and appraisal of heat supply technologies (this could include more detailed consideration of the Ness as heat source including insights from the Glen Mhor project, GSHP, and engagement with SWH to ensure there is not sewer potential).
- **Stakeholder engagement** – each potential zone has key stakeholders to engage, some like SSEN are key for all (to ensure network capacity is available for low carbon heat) whilst others are more localised, some key ones being:
    - In Raigmore it is important to engage with the hospital in the West and in the East the Freeport stakeholders are important to engage as well as HIE and the new prison. More details of these and other stakeholders are provided in the feasibility study.
    - In the City Centre there are multiple private sector loads key to the network viability. For the energy centre location National Rail are willing to set aside land as part of the Rose Street development, based on conversations with THC. Continued engagement with SSEN is required to ensure opportunities align with planned cable upgrades.
    - For Longman the Maltings and Tarmac plant are key for driving a network in Longman. The potential waste heat from hydrogen is also key to monitor through stakeholder engagement (and align any pipework). SSE and SWH are already pursuing a heat network in the area and are as such the key stakeholders driving the heat network. Continued understanding of their ambition and strategy is key to the overall strategy for both Longman and the City Centre.

  - West Bank is the most dependent on internal stakeholders at the Council and related bodies like High Life Highland.

These key next steps form initial actions to help take these heat network opportunities forward in Inverness. The opportunity to align with other activity in Inverness is seen as a key driver for Highland as a local authority to progress with large scale strategic heat networks. This building of a supply chain and expertise in the area will help realise a wider heat network vision for Highland, attracting interest and helping the exploration of opportunities across the local authority as a whole.

1 Introduction

Through the Heat Network Support Unit (HNSU) funding Zero Waste Scotland (ZWS) commissioned Buro Happold (BH) to undertake a strategic appraisal of heat network opportunities in Inverness for The Highland Council (THC). Alongside this strategic work a feasibility study was carried in parallel for the Raigmore area of Inverness, insights from this fed into this strategic analysis.

The aims of this study can be broadly summarised as:

- Creating a better understanding of the potential heat network opportunities in Inverness and their scale.
- Agreeing a strategic vision for heat network ambition in Inverness.
- Understanding of how heat network opportunities in Inverness could be realised and progressed.

The key sections of this report are:

- **Heat Network Vision Statement and KPIs** – this outlines the ambitions of THC and can act as a standalone document for engaging and gaining buy-in from stakeholders.
- **Methodology** – summarises the analysis undertaken to inform the strategic vision and captures some high-level assumptions.
- **Heat network areas** – provides details of the four heat network areas examined in Inverness, including indicative pipe route layouts and an analysis of the different demands in each area.
- **Multi Criteria Analysis** – this provides an overview of key assessment criteria considered for heat networks. It also provides an overview of an accompanying Excel tool that can be used to interrogate the various heat networks, depending on which criteria are most important for the specific appraisal.
- **Strategic overview and summary and next steps** – this section provides a summary of the key criteria, discussed in the Multi Criteria Analysis section, for each heat network. It also gives a summary of key trigger points for development. Finally, it gives some suggestions for next steps.

2 Heat Network Vision Statement and KPIs

This section establishes the aspirations for heat networks in a Vision Statement for Highland Council and the key performance indicators (KPIs) that sit alongside this to ensure that strategic heat networks explored are accurately assessed against this vision and other key Council metrics. Figure 2—1 shows where these two items sit in creating an overall strategic vision.

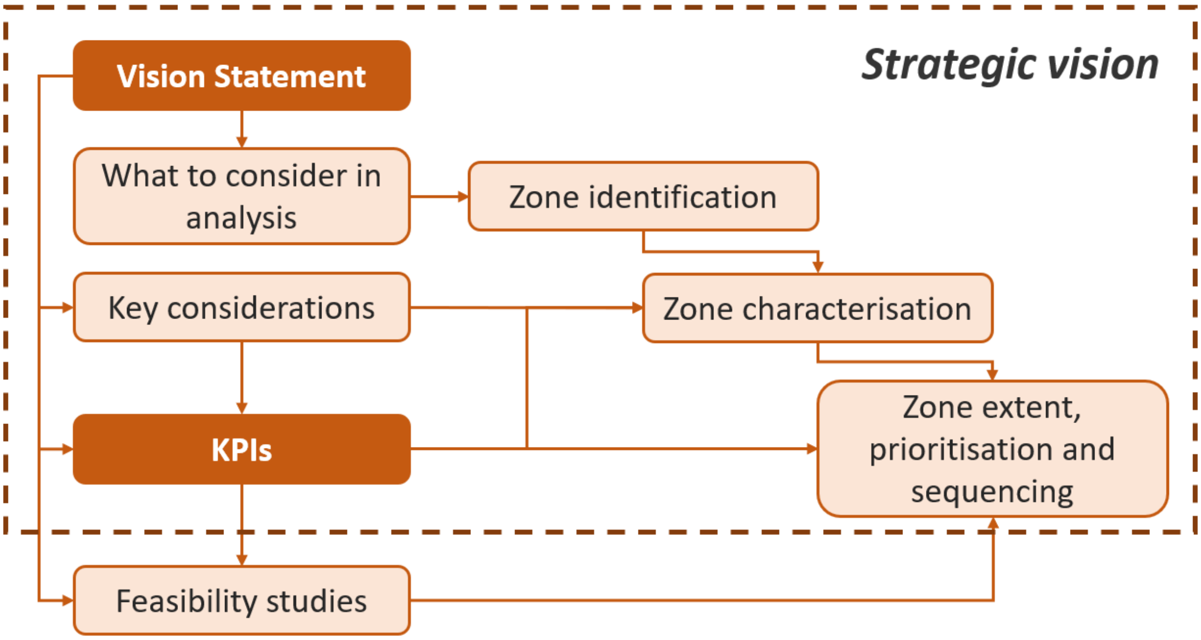

Figure 2—1 Summary of key elements of creating a strategic heat network vision.

2.1 Heat Network Vision Statement

The Heat Networks Vision Statement sets out the anticipated role that heat networks will play in the decarbonisation of heat across Inverness, and the position that the Highland Council expects heat networks to play in the delivery of broader policy outcomes and/or objectives. It draws on evidence compiled as part of Local Heat and Energy Efficiency Strategies (LHEES) and other heat network scoping activities carried out in Inverness. This statement can be used to introduce new internal and external stakeholders to heat networks opportunities in the area as well as helping to define the Key Performance Indicators (KPIs) and other consideration for the strategic assessment of heat network opportunities in Inverness.

2.1.1 Vision statement summary

As a cornerstone of the Highland Council's decarbonisation strategy, we envision developing and expanding heat networks to deliver sustainable, affordable, and efficient energy solutions – providing the lowest cost low carbon heating option. Thereby, supporting Scotland's Net Zero goals by 2045 and providing social, economic, and environmental benefits to the region.

Through LHEES and aligned with national policies, the Council envisions a number of heat network zones across Inverness. These zones will reduce reliance on fossil fuels, decrease carbon emissions, and support energy resilience. The Council recognises that the heat network can deliver further benefits including:

Carbon emissions reduction: By transitioning to low-carbon and renewable energy sources, heat networks significantly reduce greenhouse gas emissions which is essential for achieving the Highland Council's ambitious Net Zero emissions target by 2045.

Tacking fuel poverty: Heat networks can provide consistent and reliable heating and hot water on demand. Providing affordable heat particularly in areas with a high proportion of older, less energy-efficient homes.

Creating job and economic growth: The development and operation of heat networks stimulate local economies by creating jobs and supporting the growth of a skilled workforce. This economic boost can contribute the overall prosperity of the region.

Energy Security and Resilience: By diversifying energy sources and localising heat production, heat networks enhance energy security and resilience. This approach reduces dependence on imported fuels and mitigates the impact of global energy price fluctuations.

Environmental Sustainability: Heat networks facilitate the integration of various renewable energy sources, such as geothermal, solar, and biomass, promoting environmental sustainability and contributing to cleaner air quality in urban areas.

By embracing these benefits, the Highland Council can ensure that the development of heat networks in Inverness not only addresses environmental concerns but also delivers tangible social and economic advantages to the community.

2.1.2 Alignment with national legislation, Local Development Plans and strategy

There are multiple local and national policies which should be considered when developing a heat network strategy, key items include:

Heat Networks (Scotland) Act 2021: Mandates local authorities to designate Heat Network Zones, streamline permissions supporting the development of heat networks.

Heat in Buildings Strategy: Outlines Scotland's approach to reducing emissions from buildings, emphasizing the role of heat networks in achieving these goals. In April 2025 there has been an update on the future heat in buildings bill[2]. This includes creating particular requirements for large, nondomestic premises and including powers to require public sector buildings to connect to district heating when it is available.

The Inner Moray Firth Local Development Plan (IMFLDP2): sets out ambitions for low and zero carbon development, requiring new developments within identified Heat Network Zones to connect to existing networks or implement future-proofing measures.

The new Local Development Plan (LDP) - the Council is developing the new LDP for the whole of Highland excluding most of the Badenoch & Strathspey area for which the Cairngorm National Park is the Planning Authority (CNPA); (CNPA will likewise be developing a new LDP). The plan will set out how the land can be used by developers for the next twenty years and will be used alongside National Planning Framework 4 (NPF4) as a framework for planning of development and investment.

The Highland Council adopts a comprehensive approach to developing heat networks:

Identifying Potential Heat Network Zones: Through the LHEES, areas suitable for heat network development are identified, focusing on energy efficiency and heat decarbonisation.

Undertaking Feasibility Studies and Business Cases: Detailed feasibility studies and robust business cases ensure the viability of heat network projects, as evidenced by feasibility studies in Inverness Castle and Inverness West Bank.

Engaging with Stakeholders: Collaboration with communities, developers, energy suppliers, and investors is prioritised to ensure successful implementation.

[2] https://www.parliament.scot/api/sitecore/CustomMedia/OfficialReport?meetingId=16359

Securing Funding and Investment: Active pursuit of funding opportunities, including grants, loans, and private sector investment, supports heat network development.

The LHEES process identified three potential Heat Network Zones in Inverness. Recognising that the zones identified during LHEES are smaller than the Highland Council's ambition for heat networks. A more long-term strategic view is required. This approach considers wider opportunities, demands and connections, building on LHEES, previous feasibility studies and an ongoing study in areas like Raigmore. The strategic work will characterise and assess potential Heat Network Zones in Inverness. This will help sequence heat network deployment to increase interest and promote deployment.

By embracing these strategies, the Highland Council aims to ensure that the development of heat networks in Inverness not only addresses environmental concerns but also delivers tangible social and economic advantages to the community.

2.2 Drivers and KPIs

For heat networks to be developed they often require certain key drivers, alongside the legislative and policy frameworks (briefly explored above). These can include localised items related to the character of an area, or specific temporal factors – such as new developments. Many of these drivers can have a quantifiable element making them suitable to be used to characterise different potential heat network zones. Through a workshop with Highland Council various different drivers and measures were considered to establish an agreed set of KPIs against which to review the relative performance of different heat network zones, the KPIs fall within four key themes:

- **Economic** – assessment of how well a scheme is likely to perform as an economic proposition. As this is a strategic review detailed techno-economic modelling is not carried out. Instead the economic indicators are include linear heat density and estimated capital costs compared to heat supply.
- **Deliverability** – covers several factors such as alignment with broader strategy and linking to the ease of network deployment. This also includes capturing indicators relating to Highland Council influence. Key items considered include the number and size of Highland Council heat demands as well as
- **Decarbonisation** – reducing carbon emissions is a cornerstone of heat network and related policy and thus a key item to consider heat network performance against. The KPIs for this are based around the amount of carbon saved by switching to a heat network solution as well as the presence of low carbon heat sources for a heat network.
- **Social** – factors such as fuel poverty are a key concern in many energy strategies, including being an assessment area within LHEES, and understanding the context of these social factors in potential heat network zones were considered important KPIs to capture. The measures used are the average fuel poverty score in the potential heat network zones and the amount of social housing.

These KPIs are considered in the methodology, using tools to enable the necessary information to be gathered to assess potential heat network zones against them. The precise KPIs items captured and quantified are detailed and explored in the multi-criteria analysis in section 5.

The KPIs are used to understand how the different potential zones meet different Highland Council objectives. This will form a useful basis for identifying which delivery models are best suited to deliver these opportunities. Highland Council have commissioned a separate piece of work, which will be completed after this strategic study, to explore the different delivery models available to them. Linked to this a key ask of the KPI process is to be able to understand which zones are most suitable to a high level of Council involvement and which may better be pursued by a third party, with less direct Council participation. This is also considered at the multi-criteria analysis (MCA) level.

3 Methodology

3.1 Review of existing work

Several feasibility studies have been conducted in recent years to evaluate the potential heat network opportunities in Inverness:

- Inverness West Bank heat network feasibility study (2023): The study identifies an opportunity for a heat network in the West Bank area of Inverness. This network could connect various buildings including the Highland Council Headquarters, Inverness Leisure Centre, and Inverness Botanic Gardens. The study evaluates the open-loop ground source heat pumps fed by an alluvial aquifer, supplemented by top-up electric boilers. The estimated annual heat demand for the network was found to be 13,070 MWh, with a peak of 5,830 kW peak and estimated 2700 m pipe network. The study suggests assessing the feasibility of adding the Inverness High School connection considering its load and proximity to the Highland Council HQ. The Linear Heat Density (LHD) for the network identified is 4.8 MWh/yr/m and the Internal Rate of Return (IRR) for the network was indicated as 3.6% after 40 years. However, as well as the additional load of the high school, other non-domestic loads not captured such as the Royal Northern Infirmary, the main building at Eden Court and Inverness Cathedral could improve the performance.

- Inverness Castle heat network feasibility study (2023): The study explores the potential for a heat network near Inverness Castle. The heat network was identified as connecting buildings like Inverness Castle, North Tower, Inverness Town Hall, the Inverness Art Gallery & Museum and a new development. The study suggests using air source heat pumps (ASHPs) as the primary heating technology with electric boilers for backup. The estimated annual demand is circa 1,070 MWh, with a peak of 910 kW and estimated 188 m pipe network. The IRR is 3.6% and the LHD is 5.7 MWh/yr/m. There has been significant work in this area of Inverness since the feasibility. There are 11 ASHPS installed at the new energy centre for the heat network. They provide heat to the castle. There is also a connection where the energy centre can export excess heat to the Town House plant room. The gas boilers in the Town House can also provide heat to the Castle via the new energy centre. The gas CHP in the Town House has been removed and a new gas boiler installed to act as lead boiler for the Town House. The energy centre is not fully commissioned yet.

- Heat network feasibility near the Longman (2019): The study assesses the utilisation of waste heat from Scottish Water (SW) existing sewage network to supply nearby loads. The Bairds Malting Company factory was identified as the main anchor load due to their high process heat demand. Other buildings considered for connection are the SW regional office and laboratory. The annual heat demand is estimated to be 60,000 MWh with a peak of 17 MW peak. It was estimated that approximately 4,000kW_{th} of deliverable heat is available from the sewer heat.

- Raigmore heat network feasibility study (2025): A feasibility study for a heat network in Raigmore area is currently ongoing in parallel with this study. The report highlights that there are opportunities across the Raigmore area. The focus of the feasibility study was to the east of the A9. The full report should be read for completeness but the area examined had an LHD of 4.6 MWh/yr/m and a IRR of 12% with 50% capital funding. It was suggested that the opportunity is pursued to outline business case (OBC).

- Local and Energy Efficiency Strategies[3] (LHEES) (2023): The Highland Council (THC) has completed and published LHEES in 2023[4], outlining a strategy for long term decarbonisation with heat networks as a key element. The LHEES identifies three indicative heat network zones in Inverness:
    - Inverness 1: This zone encompasses Inverness High School and the Highland Council Headquarters with the combined annual demand of 1645 MWh.
    - Inverness 2: Located around the Justice Centre and Police Scotland buildings, this zone has a combined heat demand of 1431 MWh/yr.
    - Inverness 3: This zone is centred around Police Headquarters and Bannatyne Health Clubs, with a combined heat demand of 1956 MWh/yr. consistent heat demand that could be served by a heat network.

Figure 3—1 indicates the boundaries of the feasibility studies and highlights the LHEES heat network opportunities in Inverness.

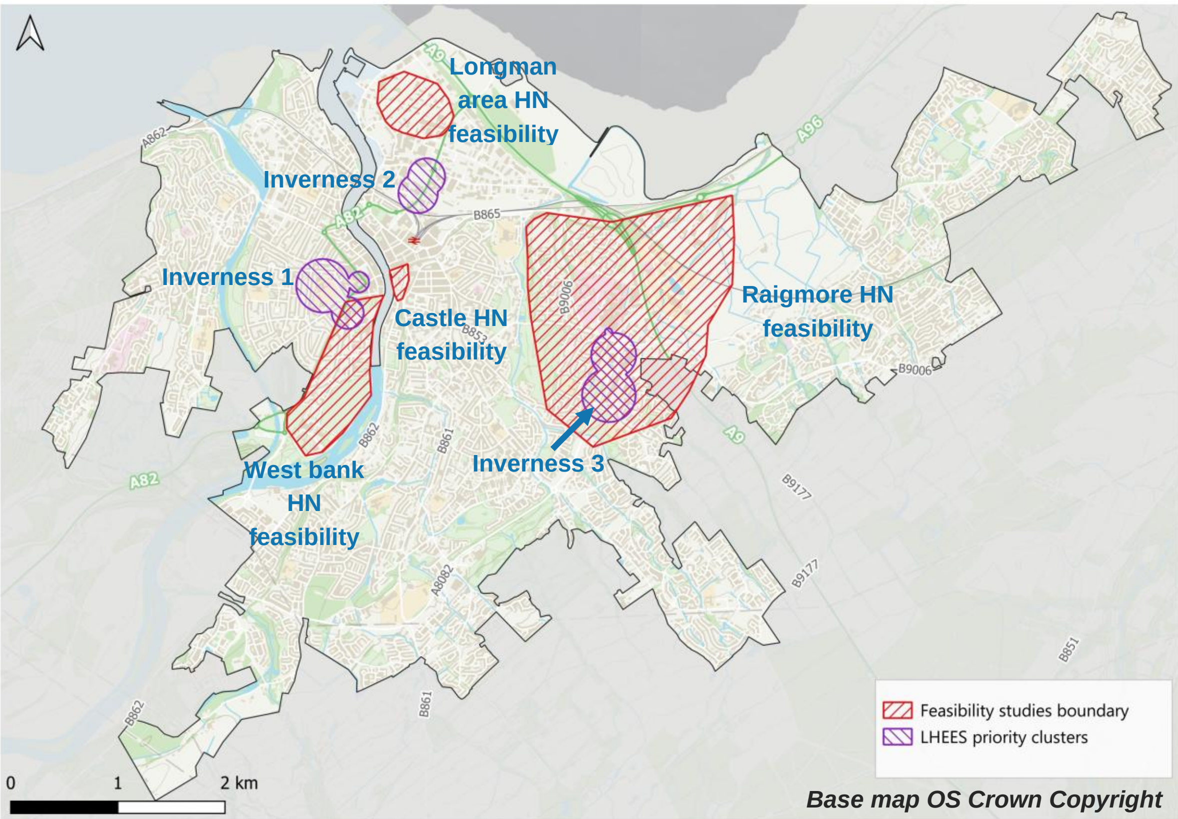

Figure 3—1 Feasibility studies boundaries and LHEES heat network opportunities

These studies demonstrates that Inverness has several viable opportunities for heat network development, utilising low carbon technologies such as ground source heat pump, air source heat

[3] Local Heat and Energy Efficiency Strategies (LHEES), mandated by the Heat in Buildings Strategy, are developed by local authorities to coordinate heat decarbonisation activities at the local level. The LHEES are designed to help meet Scotland's targets concerning energy efficiency and heat. A key element of the LHEES is the identification of potential heat network zones, informed by the First National Assessment and further refined by local authorities using their specific knowledge and datasets See: https://www.gov.scot/publications/local-heat-energy-efficiency-strategies-delivery-plans-guidance/

[4] https://www.highland.gov.uk/info/1210/environment/1097/the_local_heat_and_energy_efficiency_strategy

pump and water source heat pump, waste heat recovery. With the LHEES strategy in place, Inverness is positioned well to expand it heat networks.

Another heat network which is important to note alongside these wider studies is the Glen Mhor Heat Project[5]. The project was supported by a £1.6 million grant from the Low Carbon Infrastructure Transition Programme (LCITP) to commission and install a new energy centre housing a 1 MW water source heat pump, utilising water from the River Ness to supply heat to the Glen Mhor Hotel. There is potential for future connections, including a planned brewery, Visitor Centre Development, nearby social housing development and a nearby Church of Scotland. This project is on the east bank of the Ness, slightly to the south of the Castle HN feasibility marked in Figure 3—1.

3.2 Load assessment and new developments

For the heat demand analysis across Inverness, several datasets were used:

- **Scotland Heat Map (SHM)[6]**
  SHM consolidates various data sources available to the Scottish Government to provide estimates of the heat demand at both property and area level. It has been developed to identify opportunities to reduce carbon emissions in buildings. The datasets include: The Scottish Public Sector Energy Benchmarking Tool 2022, Local Authorities billing/procurement records, Energy Performance Certificates (EPCs), Energy Saving Trust's (EST) Home Analytics data, Scottish Assessors data and Ordnance Survey (OS) mapping data. When heat demand data is not available, estimates are derived using CIBSE TM46 benchmarks and Scottish House Condition.
- **Heat demands from feasibility studies**
  As detailed in section 3.1, Buro Happold has conducted several feasibility studies, some of which are ongoing. Where available, metered energy consumption has been used to determine the energy demand of the buildings in the study boundary. Where metered consumption data has not been available, industry standard benchmarks have been used in conjunction with relevant floor area data to assess forecasted energy demand.
- **The Highland Council energy benchmarking tool[7]**
  Developed by THC Climate Change and Energy Team, the tool provides a meaningful analysis of energy consumption, costs, and relative performance efficiencies for the non-domestic property estate.
- **Building Assessment Reports[8]**
  Under the Heat Networks (Scotland) Act 2021[9], owners of non-domestic buildings, initially in the public sector, are required to prepare Building Assessment Reports (BARs). These reports assess the suitability of these buildings for connection to a heat network, considering factors like heat demand and existing heat supply. This information will feed into review and designation of heat network zones and inform the development of heat networks within potential zones and supports a strategic approach to heat network planning.

To ensure the most reliable heat demand estimates, the following hierarchy was applied when prioritising data sources:

- Heat demand data from Buro Happold previous studies (covers key buildings near Inverness Castles, West Bank area and Raigmore area).
- Heat demand data collected from BAR (A BAR was available for two buildings in Inverness – with one of these being in the study areas).

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5 https://www.gov.scot/publications/low-carbon-infrastructure-transition-programme-capital-projects-march-2024/pages/16/
6 https://www.gov.scot/publications/scotland-heat-map-documents/
7 https://www.highland.gov.uk/info/1210/environment/276/energy_use_in_our_buildings
8 https://www.gov.scot/publications/building-assessment-report-bar-guidance/
9 https://www.legislation.gov.uk/asp/2021/9

- Heat demand from the Highland Council energy benchmark tool.
- Heat demand data from SHM.

The datasets listed above provide the demand data at the individual property level for each individual property across Inverness; in flats, for example this would multiple properties in one building. For this study, these demands were aggregated from individual property level to the building level. This was performed using the buildings' Topographic Identifier (TOID), as properties within same building have the same TOID, whereas each individual property is identified by a Unique Property Reference Number (UPRN). The demands reported throughout the report reflect the building level demand rather than individual property demand. To define the building typology where a building contains multiple uses (e.g., a mix of offices and retails), the dominant typology was assigned based on the property type with the largest share of the total demand.

Figure 3—2 provides an overview of building level heat demand across Inverness, highlighting the data sources used. The figure highlights the dominance of the SHM as a data source, aligning to the LHEES heat network methodology. It is also useful for highlighting areas with a high number of Highland Council buildings and previous feasibility studies – these are good indicators of buildings that are likely to connect to a heat network and where the demand data will tend to have a higher confidence level. Figure 3—3 shows the distribution of the loads with over 100 MWh annual heat demand across Inverness.

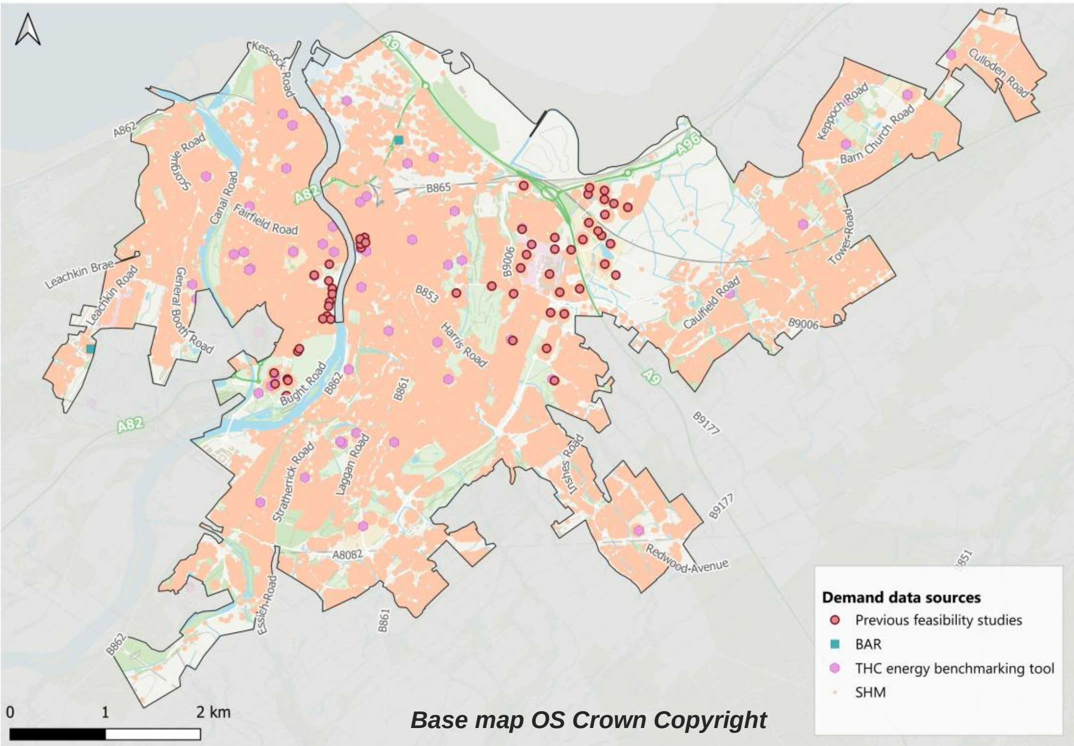

Figure 3—2 Building level heat demand across Inverness highlighting the data sources used.

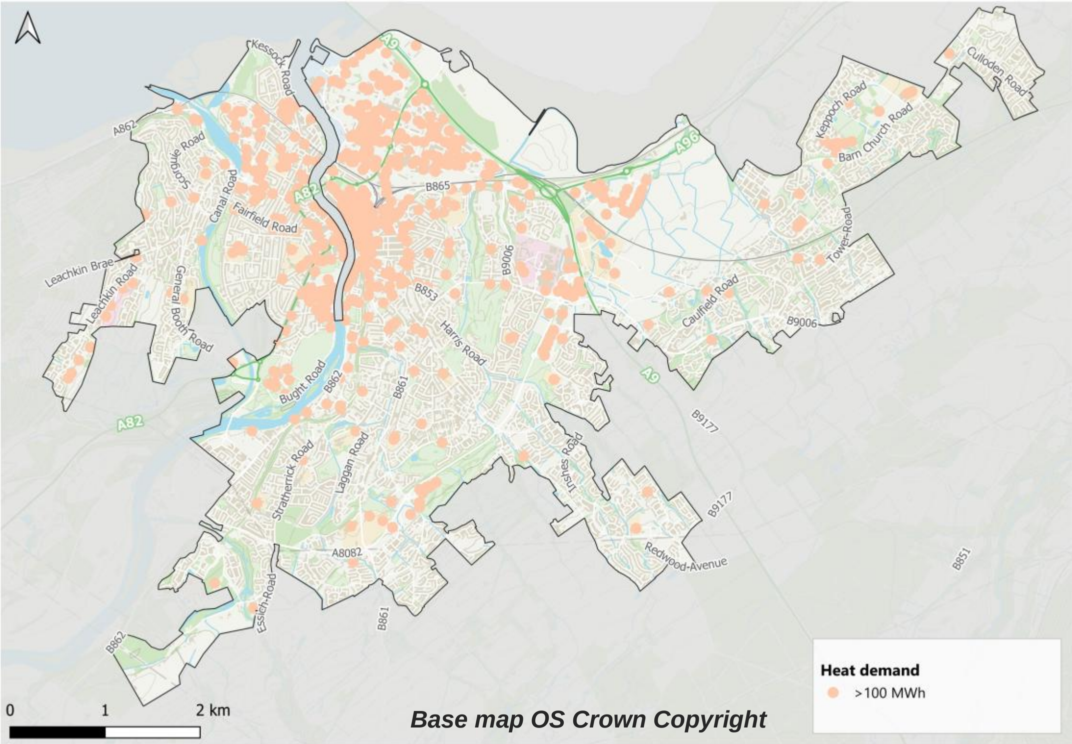

Figure 3—3 Inverness heat loads over 100 MWh/yr.

The allocations for adopted Local Development Plans (LDP) in Inverness according to the IMFLDP2[10] are presented in Figure 3—4. These are significant as they can act as drivers for heat networks in an area. Having a clear heat network strategy in an area can give confidence for the heat network system to be integrated into the building design. Understanding of LDP sites and their timings can be key to informing the temporal aspect of heat networks, as if the load is going to connect to the heat network it is important that there is a connection in place at the right time. Or if a network will not be available until after the LDP site is constructed, the heating system design is suitable for future heat network connection.

[10]https://www.highland.gov.uk/downloads/file/28837/inner_moray_firth_local_development_plan_2_strategy_and_general_policies

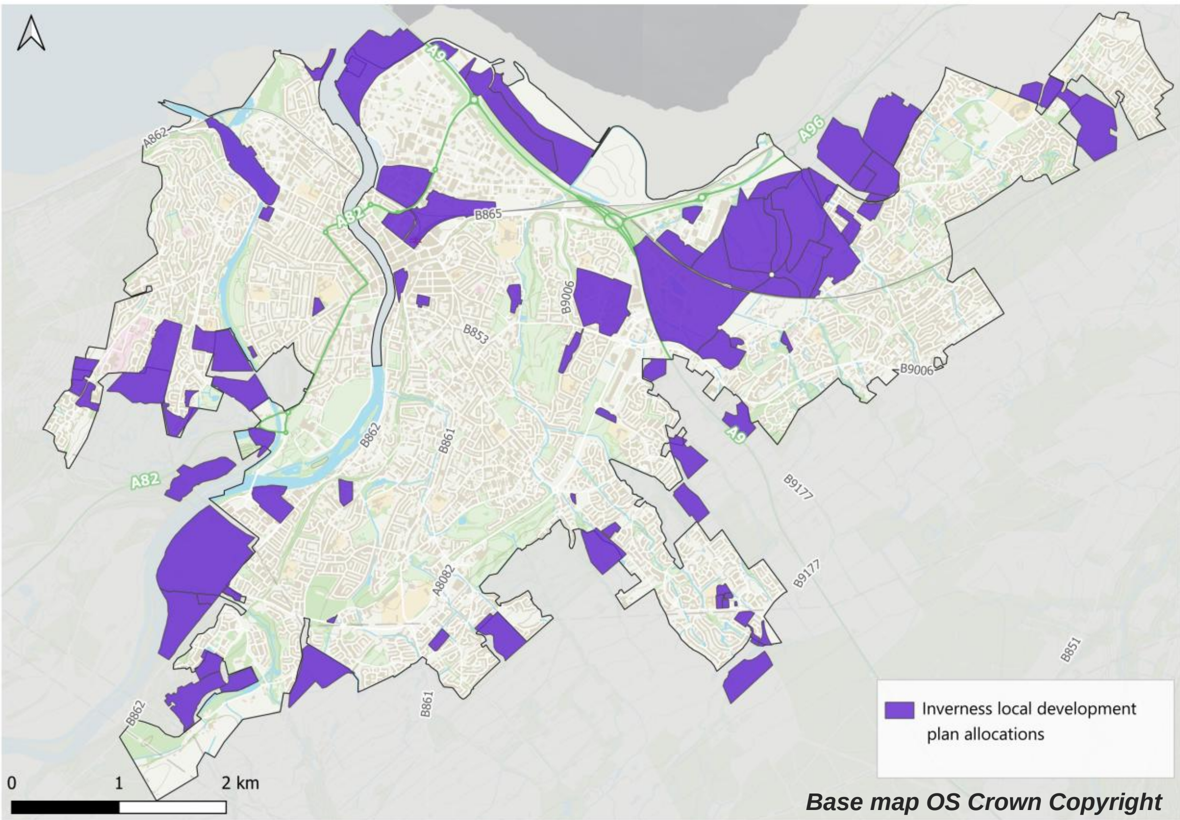

Figure 3—4 Inverness local development planned allocations

The planned development and redevelopment sites were noted but not modelled in the clustering analysis. While, they are not modelled, they remain important as potential trigger points for heat network development.

Some of key planned developments in Inverness are as follows:

- New prison – The new HMP Highland prison is being built in the Raigmore area to replace the previous HMP Inverness. It is scheduled for completion in 2026. The significance of this is discussed further in the Raigmore Feasibility Report.
- Freeport development - The Freeport development in Raigmore area represents the next phase for the University of Highlands and Islands (UHI) and Highlands and Islands Enterprise (HIE) campus, envisioned as a hub for education, research, healthcare, and innovation. Following discussion with THC, 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, tech, and renewables sectors, leveraging Green Freeport incentives. Again this is a significant element of the heat network feasibility study for Raigmore and one of the reasons for the focus on the East of the A9.
- Rose street development – as outlined in the IMFLDP2, a major redevelopment is planned in Rose Street, involving demolition of an existing car park and retail units to make way for a new hotel, retail and student accommodation. This is important for the City Centre potential heat network zone.
- Inverness railway station planned development as outlined in the IMFLDP2. Again this could present opportunities for the City Centre area.
- Longman landfill site phased redevelopment plan by THC. This includes the potential hosting of an electrolysis unit for hydrogen production just outside the site over the A9 on the old landfill site. This green hydrogen site could be a future source of waste heat for the Longman area.

- In additional to the green hydrogen site the Council are looking at several projects to produce energy, these can potentially link into the heat network strategy, providing local sources of electricity or shared utility routing. Some key examples are:
  - Solar PV Council Estate - optimise and expand solar PV across the Council's domestic and non-domestic, non-commercial, estate to supply green energy by direct wire; delivering a financial and carbon saving and protecting against future carbon tax liability.
  - Battery storage - collaborate with industry specialist to develop an investable model aligned to the Region's renewable energy potential.
  - Utility scale solar PV - develop a commercial solar farm at Longman. The project aims to sell generated electricity to the national grid, with future potential to provide direct energy sales to complementary developers on site.
  - Solar PV Commercial Estate - develop a Commercial PPA to generate income from the development of a solar portfolio.

New developments are noted for context rather than benchmarked. The exception for this is in the Raigmore area, where benchmarking of new developments was included as part of a feasibility study carried out in parallel to this work.

3.3 Linear heat density buffer analysis

To identify potential zones for heat network consideration, the LHEES stage 4[11] methodology is applied. This uses a radii-buffering approach is a deployed for identifying potential heat network zones. The buffers are defined using the linear heat density (LHD) metrics.

The LHD of a heat network is the total annual heat demand divided by the total length of the network. A higher LHD typically indicates better financial viability for a heat network. For instance, in areas where several high-heat demand buildings are clustered together, the required pipe length is relatively shorter, reducing capital expenses relative to the total connected loads.

LHD is used to determine a notional network length for each building based on its heat demand. Where buffer zones overlap, initial heat network clusters emerge, without considering the detail of a specific heat network layout. Figure 3—5 shows LHD buffering and connection distances for three heat demand points, assuming LHD of 4000 MWh/yr/m. The visualisation presents that the two properties on the left would be viable connections to each other due to their LHD 'buffers' overlapping, while the third property on the right is not viable for connection.

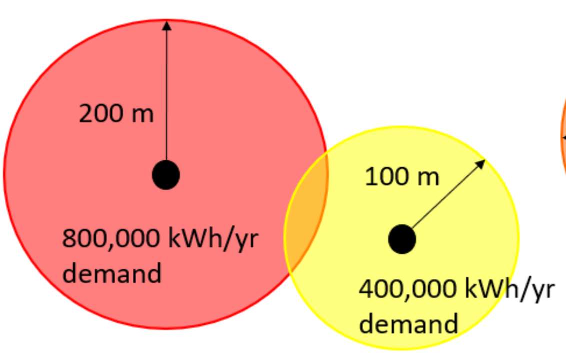

Figure 3—5 Example of LHD based buffering for 4000 kWh/yr/m, for three central points representing individual heat demands

To avoid very large buffers which could misleadingly suggest connection viability across whole towns or cities, the maximum buffer radius is capped at 250 m to restrict the maximum size of buffered

[11] https://www.zerowastescotland.org.uk/resources/lhees-methodology

circles. This also prevents heat demand points with low confidence level significantly influence the results.

The buffer radius is calculated for each building based on two LHD assumptions:

- 4000 kWh/yr/m (4 MWh/yr/m)
- 8000 kWh/yr/m (8 MWh/yr/m).

Although industry benchmarks for LHD tend to be higher, the 4000 kWh/yr/m LHD was selected to ensure potential heat networks are not excluded unnecessarily at the strategic stage. Figure 3—6 illustrates clusters formed at 4000 kWh/yr/m LHD and 8000 kWh/yr/m LHD clusters in Inverness, highlighting initial opportunities for heat network development.

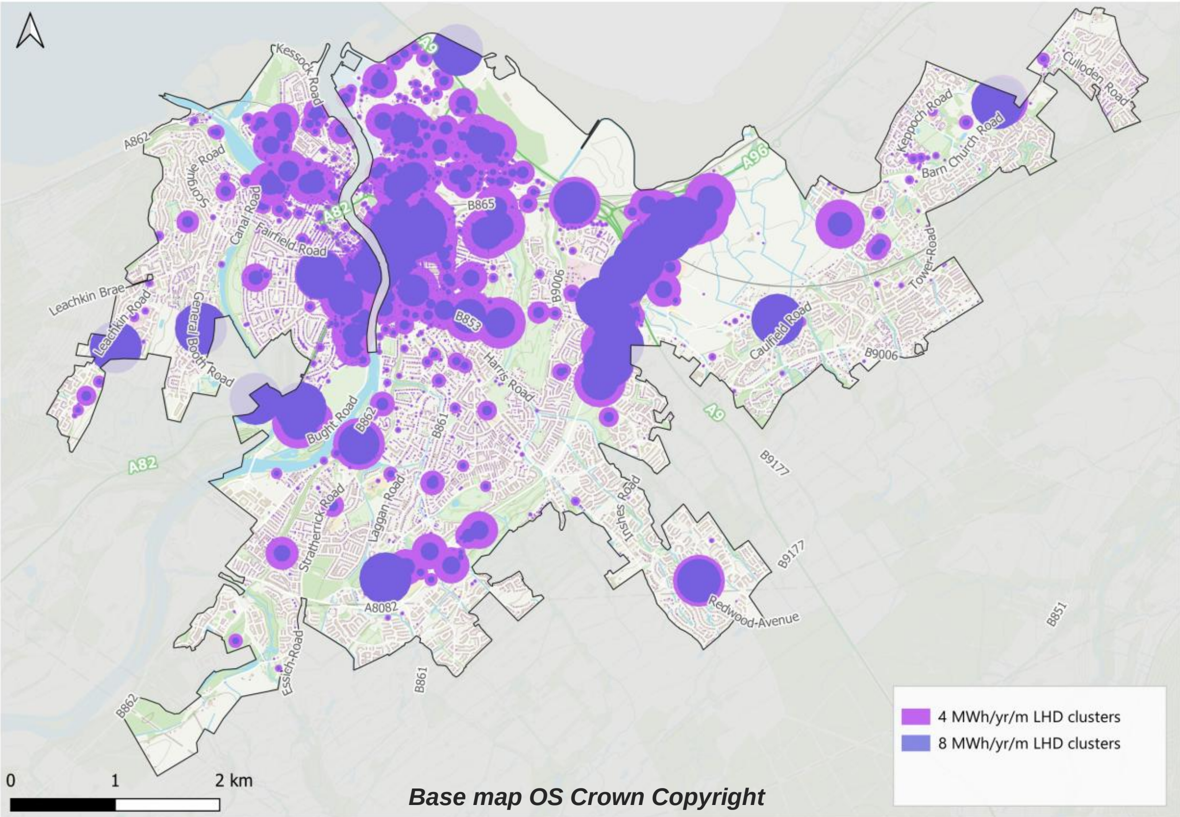

Figure 3—6 Clusters with LHD 4 and 8 MWh/yr/m

Anchor loads are high heat demand buildings and key connections on a heat network that usually drive project economics. These buildings often include public sector or local authority buildings, since these are typically easier to coordinate than private stakeholders in the early phases of heat network projects.

To prioritise clusters, a standard threshold of 500 MWh/yr is used to define anchor loads. Figure 3—7 presents clusters with at least 2 anchor loads, each with demand of over 500 MWh/yr. This highlights a number of potential heat network clusters in Inverness, including opportunities for heat network development in Raigmore (east of the Inverness), the City Centre, West bank and a few smaller areas around Longman. It is worth highlighting that the large Bairds Malting heat demand in Longman is not included in the map at this stage but is captured later in the analysis (see section 4.2.3.1). There are several reasons for this including distortion of the Longman heat network opportunity and the site not being properly captured in the SHM.

In addition to the anchor loads, other factors are considered when prioritising heat network clusters such as buildings tenure, planned developments, proximity to existing networks, deployment complexity.

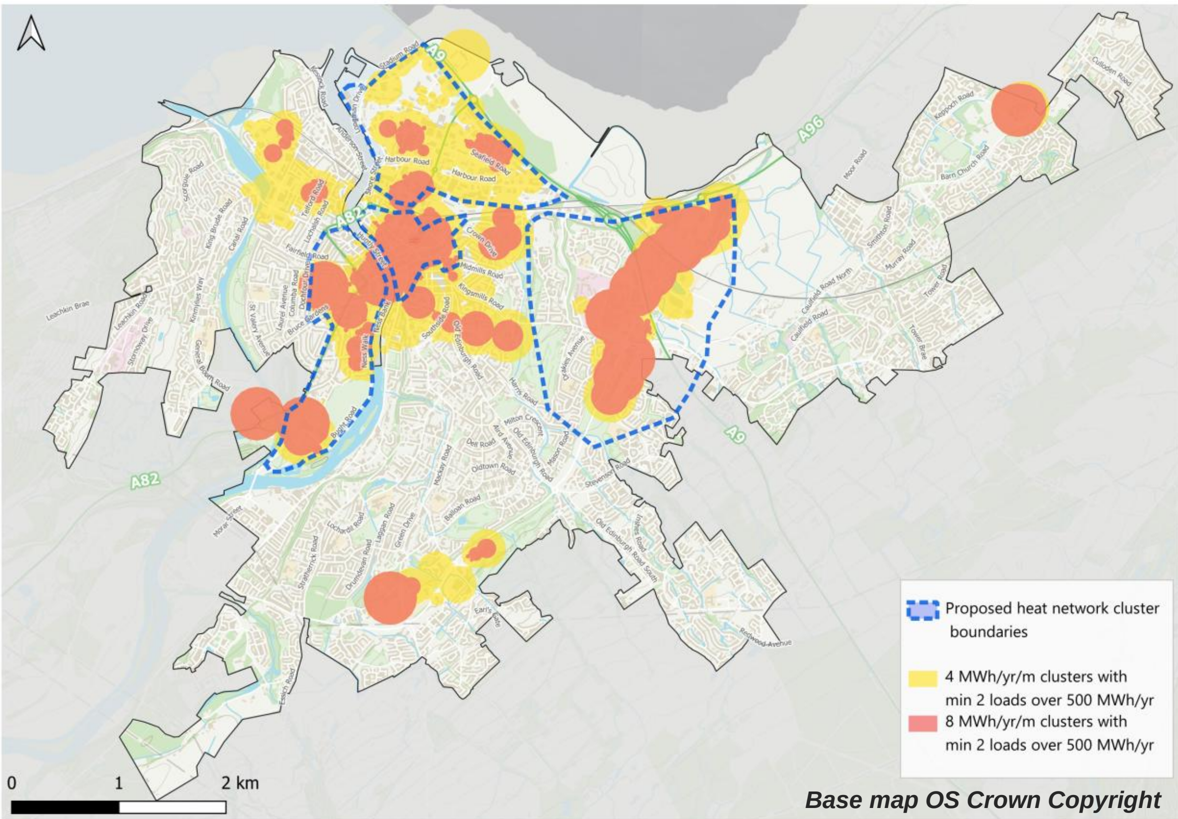

Figure 3—7 Clusters with LHD 4 and 8 MWh/yr/m with at least two anchor loads with over 500 MWh annual demand and the proposed boundary for the heat network clusters

This LHD buffering approach is used for cluster identification rather than assessment. The sections below describe the additional analysis to characterise and understand these potential heat network zones.

3.4 Heat source assessment

Alongside the LHD analysis, potential waste heat and low-carbon heat sources are identified. Waste heat refers to heat generated as a by-product of various industrial and commercial processes. Common sources include industries, Energy from Waste (EfW), electrical substations, wastewater treatment plants, data centres, hydrogen electrolysers and supermarkets refrigeration systems. Instead of being discarded, this heat can be captured through waste heat recovery and reused such as supplying it to a heat network. The feasibility of integrating waste heat into a heat network depends on several factors including the temperature grade of the waste heat sources, the scale of available heat, supply reliability and proximity to heat network. Additionally, some waste heat sources may require temperature upgrade to meet the heat network operational requirement.

Figure 3—8 highlights several potential waste heat and low-carbon heat opportunities in areas near the high LHD Clusters with estimated available heat exceeding 1 GWh.

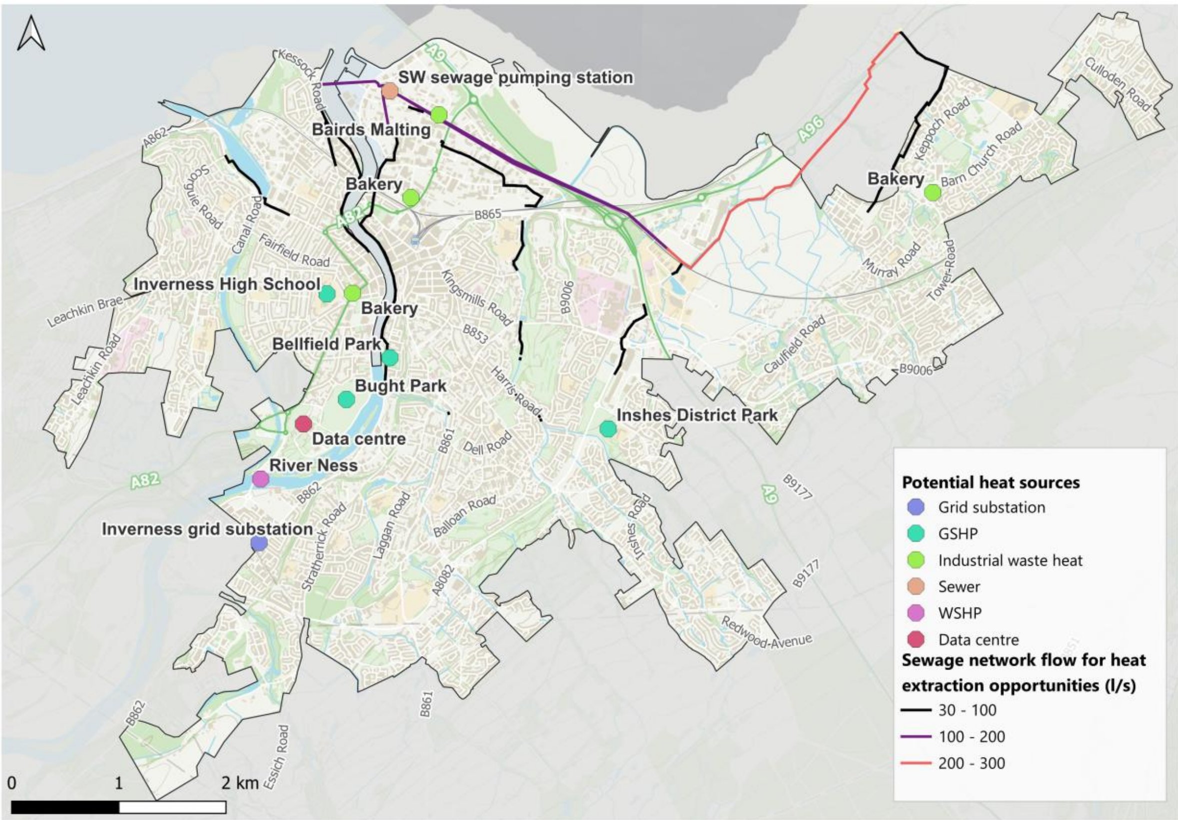

Figure 3—8 Waste heat opportunity map

In addition to the data provided by THC, the datasets outlined below were used to identify the potential heat sources in Inverness:

- **Scotland Heat Map (SHM)**
  It identifies potential sites including industries, electrical substations and supermarkets where excess heat could be repurposed for heating.

- **ReUseHeat database**[12]
  It maps the urban waste heat potential across Europe including heat from food retails, wastewater treatment plants, food production, tube stations, power plants, steam production, industrial site and data centres. The identified waste heat sources in Inverness are relatively small, primarily from food retails with available heat below 5 MWh.

- **Scottish Water Horizons (SWH) – Waste heat extraction opportunity map**
  It helps with the strategic identification of where wastewater could be a potential heat source. The key areas for heat extraction in Inverness include the sewage pumping station in North of Inverness in Longman with the sewage flow approximately 190 l/s and Raigmore area (East of A9) with the estimated sewage flow of circa 286 l/s.

- **ParkPower and Green heat in Greenspaces (GHiGs) Maps** (developed by Greenspace Scotland[13])
  It assesses the suitability of greenspace sites (e.g., public parks, gardens, playing fields and sport grounds) for low-carbon heating technology such as GSHP.

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[12] https://cordis.europa.eu/project/id/767429
[13] https://www.greenspacescotland.org.uk/project-dashboard

- **Hydrogeological** map British Geological Survey (BGS) [14]
  It indicates aquifer potential across the entire Inverness boundary, classifying it as moderately productive aquifer for low carbon heat technologies such as open loop GSHP (see Figure 3—9). This requires further investigation to assess the potential abstraction rate.

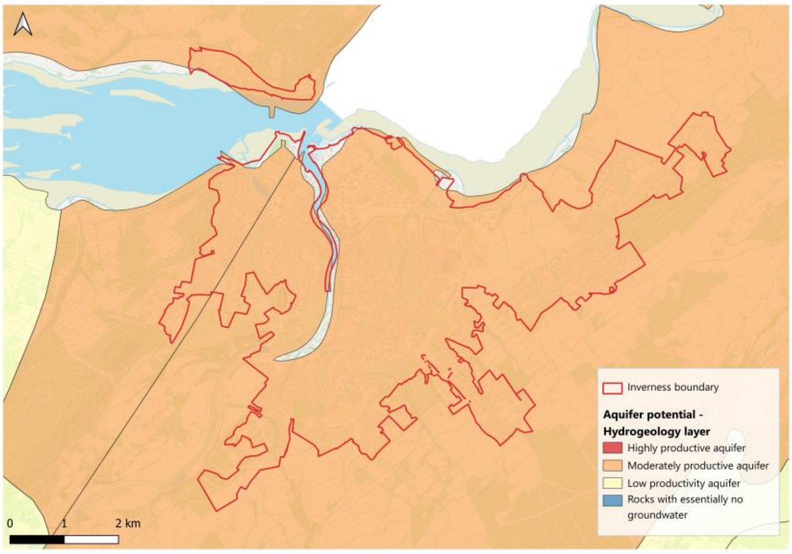

Figure 3—9 Aquifer potential in Inverness – Hydrogeology map

- **Additional datasets**
  Information gathered from THC and previous studies.

Table 3—1 provides an overview of the identified waste heat sources in Inverness including their type, temperature range and estimated waste heat potential.

Table 3—1 Potential heat sources summary

Name	Heat type	Estimated Temp °C	Potential heat MWh	Source	Note
Raigmore sewage network	Sewer	10 - 15	76000	Scottish Water Horizon Map	BH calculation (assumption: 286 l/s flow and 5 DT)
Sewage pumping station	Sewer	10 - 15	45000	Scottish Water Horizon Map	BH calculation (assumption: 190 l/s flow and 5 DT)
Bairds Malting	Industrial waste heat	50 - 100	Heat recovery from the kilning process		Malting also considered as a key heat off taker rather than source
Bught Park	GSHP potential	8 - 10	7300	GHiGs	
Bellfield Park	GSHP potential	8 - 10	1200	GHiGs	
River Ness	WSHP potential	5 - 20	Detailed value not available but heat availability is	National River Flow Archive and SPEA	Not enough data available to estimate the potential available heat

[14] https://www.bgs.ac.uk/datasets/hydrogeology-625k

			greater than the demand in the West Bank cluster	personal communication	but has been used successfully in Inverness in Glen Mhor (more information and site visit was sought but not available). SEPA were contacted and provided some indication of water depths.
Inverness grid substation	Grid substation	40 - 80	1400	SHM	New transformer with the uncertainty around the heat recovery potential and proven capacity
Bakery	Industrial waste heat	>120	5000	SHM	Relatively small and have technical challenges associated.
Bakery	Industrial waste heat	>120	1700	SHM	Relatively small and have technical challenges associated.
Data centre	Data centre	20 - 40		THC	Early discussion - 100MVA
Inverness High School	GSHP potential	8 – 10	3400	GHiGs	
Inshes district park	GSHP potential	8 - 10	10900	GHiGs	
Bakery	Industrial waste heat	>120	5000	SHM	Relatively small and have technical challenges associated.

It should be noted that, further investigation is required to confirm the practicality of using these waste heat sources including technical assessment, operational challenges and economic viability.

A summary of the long list of heat sources considered is provided in Appendix A.

3.5 Demand classification

The key heat demands to be considered for connection within a heat network cluster are categorised as core and Infill loads. This is defined based on the buildings' demand scale, and tenure. Generally, local authority and public sectors buildings are easier to engage early in heat network development, making them priority for core connections.

To align with the Scotland first national assessment[15], 73 MWh/yr is set as the minimum threshold for connections with all buildings of a demand lower than this being excluded from analysis. Building demands greater than 500 MWh/yr are typically defined as 'anchor loads' which usually drive project economics and the viability of a potential heat network.

Additional thresholds define core and infill connections:

- Demands above 500 MWh/yr: core connection regardless of tenure

[15] https://www.gov.scot/publications/first-national-assessment-potential-heat-network-zones/

- Demands between 250 MWh/yr and 500 MWh/yr: core connection if public buildings, council-owned buildings, buildings with existing communal heating and buildings with social housing/housing association tenures, otherwise infill connection
- Demands between 73 MWh/yr and 250 MWh/yr: infill connection regardless of tenure
- Planned development were not captured at a demand level (apart from Raigmore as this is a feasibility study) but were considered for context across the analysis,

Table 3—2 provides a summary of infill and core connection criteria. In some areas with a high concentration of private-sector properties (e.g., workshops, warehouses), the core connection threshold may be adjusted accordingly.

Table 3—2 Summary of connection approach

Connection group	Criteria
Core	Public and council buildings >=250 MWh/yr Buildings with existing communal/HN >=250 MWh/yr Housing Associations/social housing >= 250 MWh/yr Other tenure/non-domestic >=500 MWh/yr
Infill	Public and council buildings 73 MWh/yr to 250 MWh/yr Existing communal/HN 73 MWh/yr to 250 MWh/yr Housing Associations/social housing 73 MWh/yr to 250 MWh/yr Other tenure/non-domestic 73 MWh/yr to 500 MWh/yr (in areas dominated by private tenures such as warehouse, workshops, industrial buildings) this is adjusted to 250 MWh/yr to 500 MWh/yr

The core connections are the key driver of network viability and infill connections supplement the network and expanding coverage.

Buildings are assumed to be public if they fall into one of the categories below:

- Education
- Health
- Emergency services
- Place of worship
- Care homes
- Community and cultural centre

Buildings are assumed to be council-owned if they are run and controlled by the Council. These tenure data are provided through engagement with THC along with using land ownership data. If a building is on Council land but is listed as "Let to Third Party" or "Third Party," it is not considered as Council land.

3.6 Steiner analysis

Once heat network areas, key heat demands (core and infill), potential heat sources and energy centre locations are identified, a pipe network is modelled to establish the most efficient connections between heat demands and heat sources.

The pipe network is modelled:

- First for core connections only, to ensure the network economic viability. This routing forms the 'spine' of a network connecting typically the largest heat demands.
- Then for both infill and core connections, extending the network to other potential loads.

The routing methodology connects heat demand points to the chosen heat source/energy centre using the Steiner tree approach, which determine the shortest possible routes while following existing road networks. This method helps to minimise the network length and improve cost estimation. It is done using QGIS and an internal Feature Manipulation Engine (FME) processing tool. Figure 3—10 provides an example of the Steiner tree methodology for creating the pipe network. The process uses existing road networks (from OS) to give an indication of an optimised heat network routing.

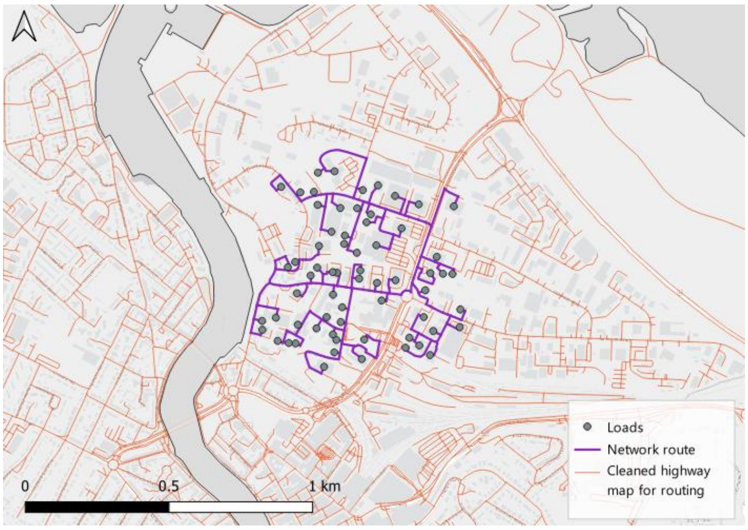

Figure 3—10 Example of heat network routing using Steiner tree analysis method

Following the generation of indicative heat network routes for heat network connection scenarios, the routes were manually inspected and validated to ensure accurate representation and to identify and rectify any routing anomalies.

Ground conditions and the surrounding environment could influence heat network trenching, dig type and cost of installation. Typical classification of dig types are as follows:

- **Soft dig:** Areas, such as footpath, greenspaces and parks, allow for low-disruption installation, resulting in the lower costs due to ease of excavation.
- **Suburban**: Suburban areas such as road, pavement or car parks in lower impact streets with moderate accessibility, involve coordination around private properties and existing utilities, resulting in mid-range costs depending on site complexity.
- **Hard dig**: Very urban environments, impacts busy routes, resulting in high disruption. They demand extensive planning and logistical requirements, leading to the highest costs.

These categories capture the variable dig types across Inverness. The Department of Energy Security and Net Zero (DESNZ) provides indicative costs for these dig types. Allowing a high-level differentiation to be used in creating an indicative capital cost for networks.

3.7 Contextual geographic analysis

In addition to demands and heat sources broader geographic and societal factors were captured and considered in the analysis. These were nominally fuel poverty, land ownership and the presence of existing heat networks/communal systems in the potential heat network areas. These are used in a multi-criteria analysis to further explore potential zones, this is detailed in section 5.

Fuel poverty

Figure 3—11 presents the properties where the probability that the property is in fuel poverty is over 50% (i.e. that the household's fuel bill represents more than 10% of its full income, after housing costs). This is obtained from EST Home Analytics database.

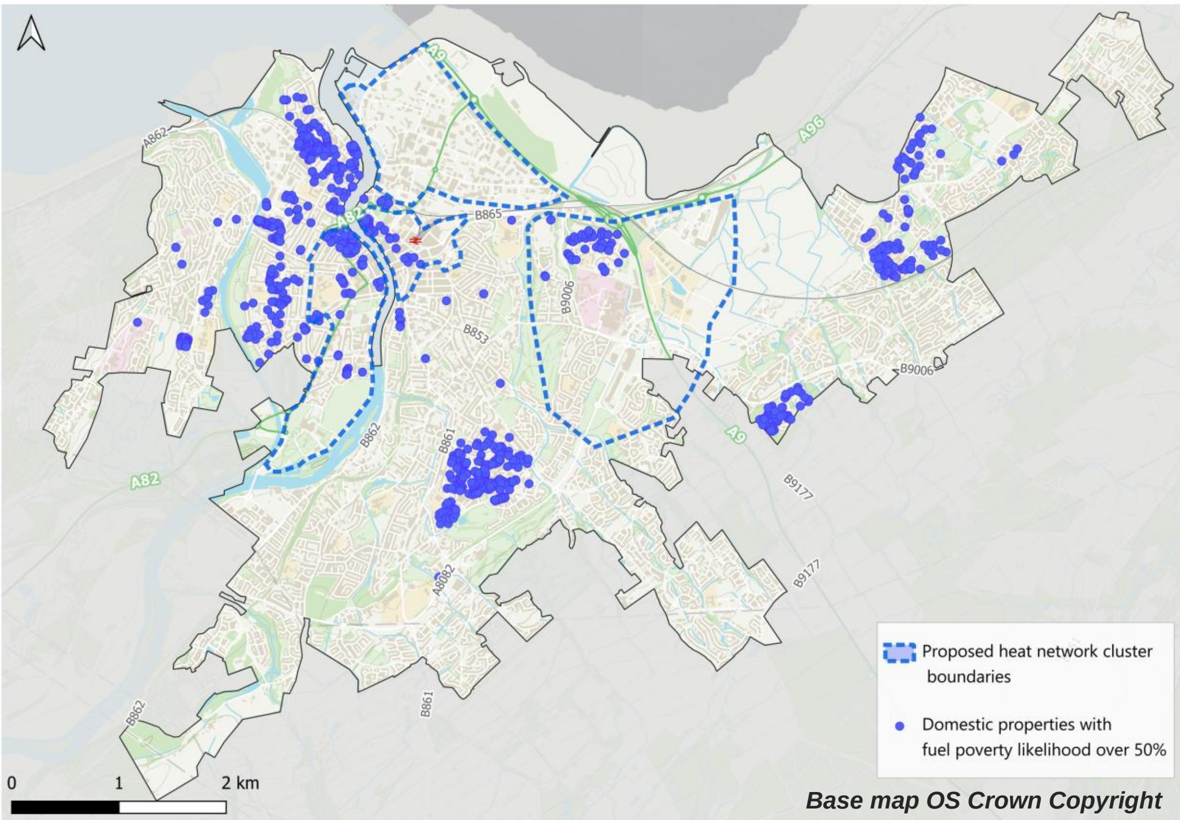

Figure 3—11 Domestic properties with fuel poverty likelihood over 50%

Land ownership

Figure 3—12 shows the council land ownership map. Some of these sites might be owned by the council and council pays the bills, but they might be managed by organisations such as High Life Highland. They can also be leased to industrial or commercial tenants. THC grounds show the sites where the grounds are maintained by the council.

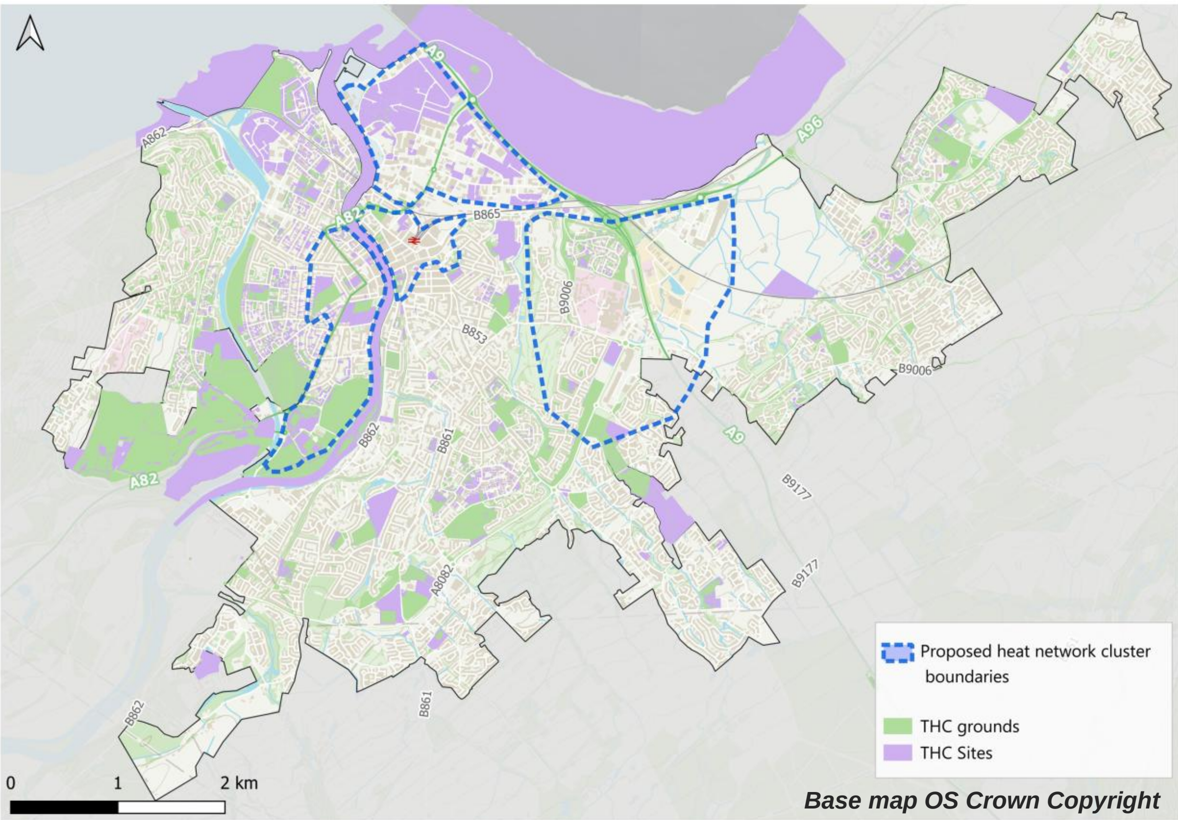

Figure 3—12 Council land ownership Map

Existing heat networks

The SHM data, along with the EST Home Analytics, were used to identify the existing heat networks in Inverness. It should be noted the existing heat network point data contained within the Scotland Heat Map captures network summary detail and not detail on connections at a property or building level. Additionally, EST Home Analytics was utilised to identify properties listed with communal heating, which could be part of communal or larger heat networks. Some discrepancies were identified between the two datasets; for example, a building shown with communal heating in EST Home Analytics is not recorded as a heat network in SHM and vice versa. Moreover, there are a few networks listed as district heat network in SHM, but further investigation proves them to be communal network where a number of properties are connected to central heating within one building.

Further data exploration shows no major heat network is recorded in Inverness except for the Wimberley way heat network, which is recorded as +1MW size, supplying heat to several Ministry of Defence domestic properties. The other networks recorded in SHM are rather small communal heat networks with a small number of connections. Figure 3—13 provides an overview of existing heat networks in Inverness. Existing networks are important to consider as they are generally likely to connect to larger heat networks (the Scottish Government are currently considering requirements for existing networks to connect with larger heat networks). Additionally, existing communal networks are one of the easiest ways to integrate domestic demands into heat networks. The lack of existing heat networks in Inverness means the opportunity for connecting smaller networks into a larger heat network is limited.

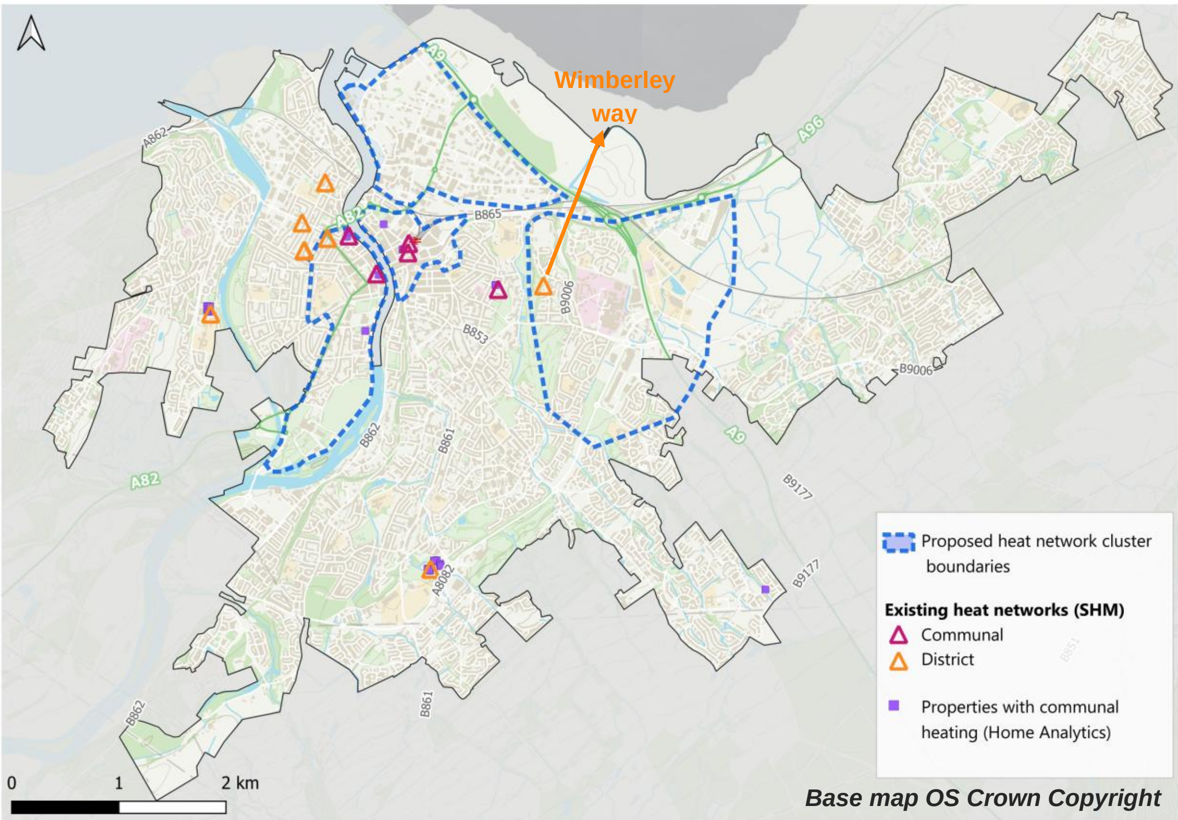

Figure 3—13 Existing heat networks (communal/district) in Inverness.

It should be noted that Inverness Castle and Glen Mhor are not captured by the SHM but are captured elsewhere in this report.

3.8 Stakeholder identification and screening approach

Stakeholders were considered throughout this strategic review. There is a particular focus in identifying areas where THC (or THC adjacent organisations like High Life Highland) are key stakeholders (such as in the West Bank) or where other public sector bodies have significant influence (such as Highlands and Islands Enterprise on the East side of Raigmore), as these can be key enablers for deployment; this can include owning land for the pipework to cross or being key demand that drive the economics of the heat network. Private sector stakeholders were also considered, with SSE and SWH being key to Inverness – particularly their recently announced ambitions to develop heat networks in the city with an initial focus on Longman.

In the feasibility study for heat networks in Raigmore carried out alongside this strategic study there was substantial stakeholder engagement undertaken. For the strategic work engagement was more limited but specific insights were gathered. For example, SEPA were engaged during the evaluation of the West Bank area, to better understand the potential of the River Ness as a heat source and any risks associated with its use. This engagement highlighted that SEPA do not hold detailed water depth information for the Ness in this area, temperature and the consistency of depth throughout the year were also not available. Further study is thus likely to be required. The successful WSHP project at Glen Mhor would provide useful insight to the tenability of a scheme on the Ness. Glen Mhor were engaged initial but due to various factors more detail could not be included during the time period of this study.

3.9 Cost analysis

A high level cost analysis was undertaken for this strategic work, adapting a simplified techno-economic model created by DESNZ for Heat Network Zoning Pilot Program (HNZPP). The model combines technical details of the network, such as CAPEX and OPEX, with revenue and cost inputs to generate annual cashflow. This allows for an assessment of viability and means of comparison between different heat network clusters.

Key input parameters include the heat network length, hard/soft dig proportions, obstacles on the heat network route, annual heat demand for connections (by building type), primary low carbon technology and the energy balance of the plants if there is more than one low-carbon technology. These inputs are also used to estimate the size and operation of the primary low carbon plant, as well as top-up/back up technology. Assumptions are then used to estimate the costs of the plant, network, and other associated costs to generate an estimate for the capital cost of the network. Table 3—3 provides a summary of the key cost assumptions.

An energy balance is generated from assumptions linked to the type of plant and the annual heat demand figures, which is used to generate a cash flow to derive the economic outputs. The model also generates an assessment of carbon emissions over a 40-year period, against a gas boiler counterfactual system.

It is worth highlighting that this is a high level analysis, enabling a comparative economic assessment of proposed heat network clusters within Inverness. However, a detailed feasibility study is required to further refine these estimates and provide a more comprehensive evaluation of the heat network economic viability. Additionally, the costs for grid reinforcement, if required, and for making the building compatible with heat networks, such as upgrading radiators, are not included in the CAPEX.

Table 3—3 Cost assumptions

Variable	Value	Unit	Lifetime (years)
Pipe work cost (suburban environment) Pipe work cost (dense urban environment) Pipe work cost (soft dig)	2 4 1	£m/km £m/km £m/km	60
Gas boiler	0.25	£m/MW	20
Heat pump - ASHP	0.75	£m/MW	15
Heat Pump – WSHP	1	£m/MW	20
Heat Pump – GSHP	1	£m/MW	20
Heat Pump – sewer source	1	£m/MW	20
Sever obstacles (e.g., single track railway crossing, canal crossing)	1	£m/obstacles	n/a
Major obstacles (e.g., river crossing, multi-track railway crossing)	5	£m/obstacles	n/a

4 Heat network areas

As outlined in section 3.3, the analysis of LHD 4 MWh/yr/m and 8 MWh/yr/m identifies a number of promising areas for further investigation as potential heat network clusters. Figure 4—1 is based on insights from these and shows the boundary of the proposed clusters.

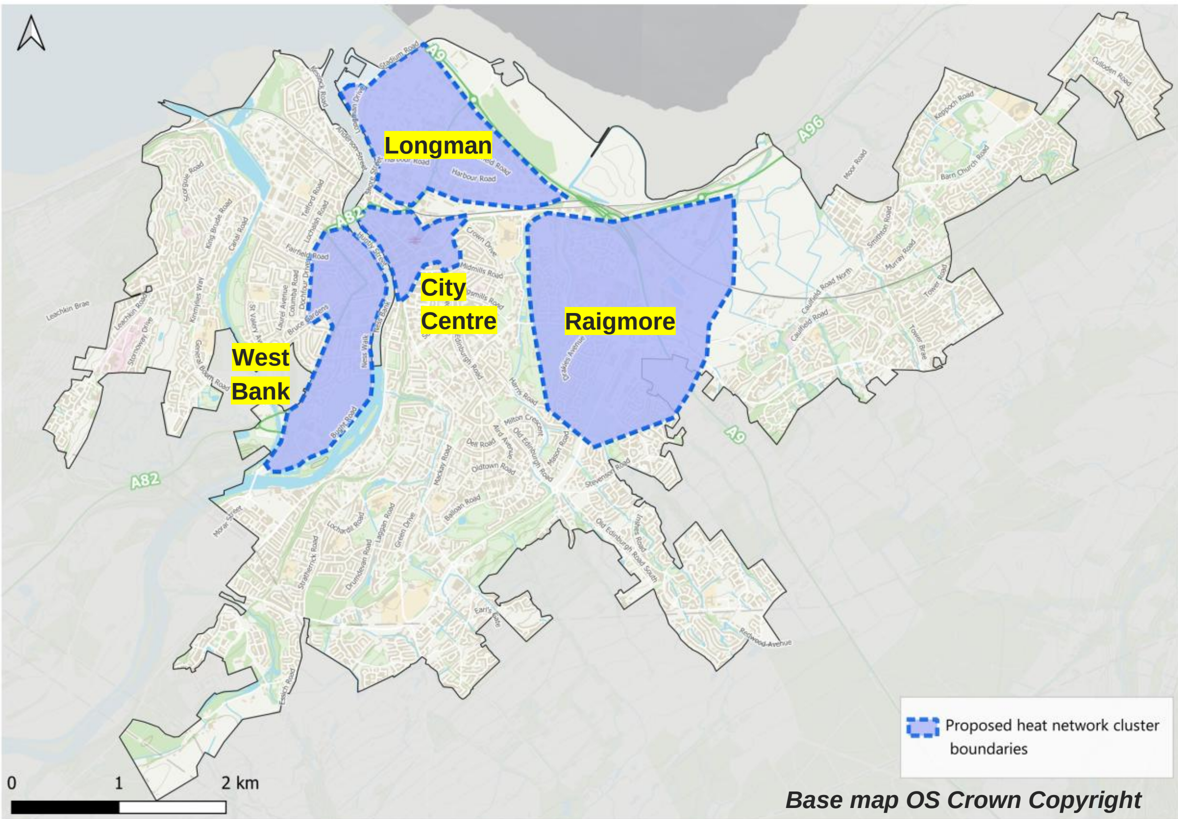

Figure 4—1 Inverness proposed strategic heat network clusters

Further details in each clusters including the area overview, the key demands, potential heat sources, proposed energy centre location, indicative capex, key risks and mitigations are provided in section 4.1 to 4.3 with higher level overview of Raigmore in 4.4, to avoid repetition of the parallel feasibility study.

4.1 West Bank

4.1.1 Area overview

The west bank area of the River Ness in Inverness has several buildings with high heating demands, and several council-owned and public buildings including the Highland Council Headquarters, Eden Court, Inverness Leisure Centre, Inverness Botanic Gardens and Inverness Ice Centre.

Buro Happold was commissioned to assess the opportunity for a heat network in West Bank area[16]. The study area is split geographically into north and south clusters with high heat demands, separated by stretches of land, mainly through Bught Park. Figure 4—2 provides the study boundary, key connections and the heat network route. The total annual heat demand for the combined north and south areas is estimated to be 13,070 MWh/yr. The southern area, near the leisure centre, has a LHD at 12.60 MWh/yr/m, compared to the northern area near the Council HQ, which has an LHD of 2.79 MWh/yr/m (as stated previously there are additional demands in the north which if connected would

[16] Inverness West Bank Feasibility Study 2023 Buro Happold

improve LHD). The proposed energy centre is adjacent to the Inverness Leisure Centre. The entire study area has an LHD of 4.80 MWh/yr/m, this means that for each meter of network length there is 4.8 MWh of heat demand per year. In areas with a low cost dig (which due to Bught Park West Bank is the case) a LHD of 4 MWh/yr/m is an indicative threshold, in more urban areas a LHD of 8 MWh/yr/m is a common threshold used in projects like LHEES.

Two scenarios were considered include a borehole closed loop GSHPs solution with initial CAPEX of £18.2M, and an alluvial aquifer open loop GSHPs solution with £14.9M initial CAPEX considered for heat sources with the energy centre adjacent to the Inverness Leisure Centre (these cost are for the whole area shown in Figure 4—2.

Figure 4—2 West bank feasibility study boundary, connections and heat network route [17]

4.1.2 West Bank Cluster

As outlined in section 3.3, the analysis of LHD 4 MWh/yr/m and 8 MWh/yr/m identifies the West Bank area as a prime opportunity for heat network development. This aligns with the findings of the previous BH feasibility study conducted in the West Bank, which also indicated potential for heat network development. However, the proposed area extends beyond the feasibility study boundary to include several additional large heat loads including Inverness High School, Central Primary School, St Joseph's Primary School, a number of hotels and buildings with existing communal heating system. The additional loads strengthen the network viability by increasing the heat demand density. Figure 4—3 presents the LHD clusters and the proposed West Bank cluster boundary. The River ness is considered as a natural boundary preventing to extend the network to river east. Additionally, crossing the river poses a major obstacle, which is why the West Bank and City Centre clusters are kept separate.

[17] Inverness West Bank Feasibility Study 2023 Buro Happold

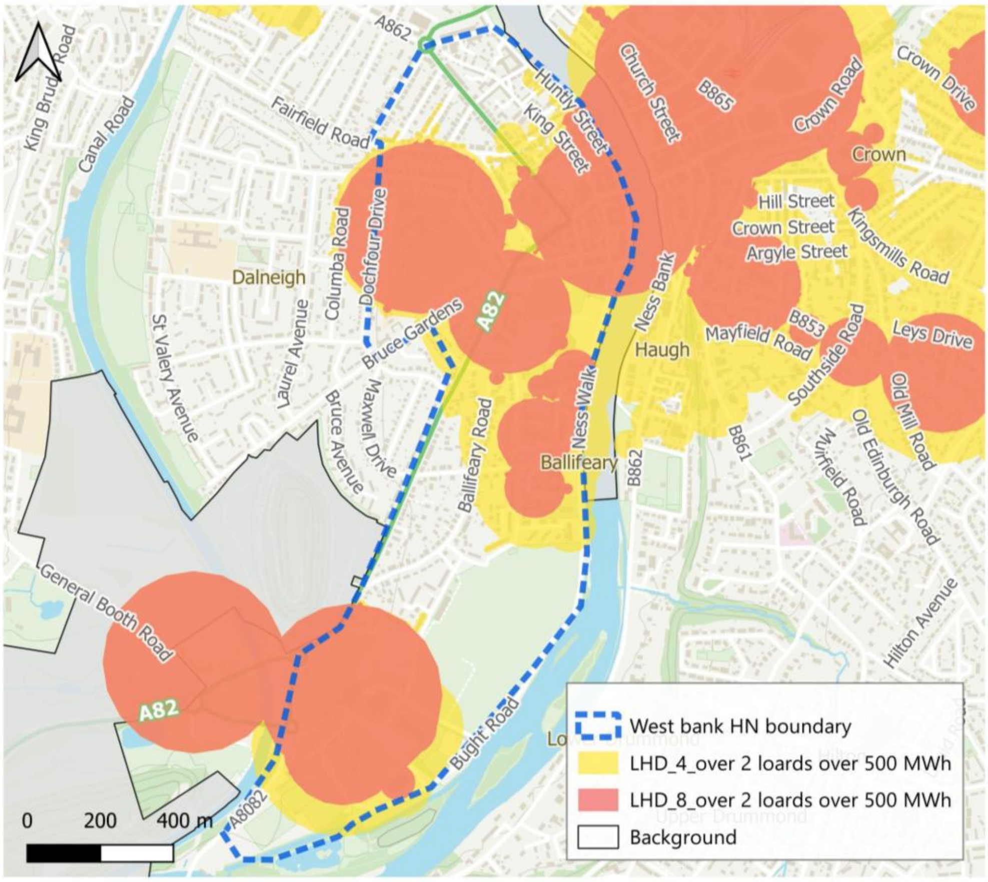

Figure 4—3 LHD 4 MWh/yr/m and 8 MWh/yr/m bubbles and West Bank proposed heat network boundary (***Base map OS Crown Copyright)***

The total heat demand in the proposed cluster is approximately 60 GWh/yr. This includes all buildings regardless of their typology or suitability for heat network connection, so the demand connected to a heat network would be lower than this 60 GWh/yr figure.

A significant proportion (over 46%) of the proposed cluster area consists of the council-owned land. Moreover, there are over 160 properties with the fuel poverty likelihood of exceeding 50%, which could benefit from heat network connection to alleviate fuel poverty. Additionally, the area contains 419 social housing properties. Having similar ownership would make connecting to the heat network less complex compared to privately owned housing.

The West Bank cluster includes 15 council owned buildings and 12 public buildings in the proposed cluster, each with demand over 73 MWh/yr. This makes the area strong candidate for a public-led heat network development benefiting from the streamlined decision making with fewer stakeholders. This is likely to be a key consideration in the heat network delivery model work Highland Council is undertaking with a legal consultant alongside this strategic study.

As explained in section 3.5, buildings are considered for heat network connection based on factors such as scale of heat demand, typology and tenure as core or infill connections. Two assessments were performed:

1) A heat network consisting of only core connections – focusing on the high demand buildings to establish financial viability of the network
2) A heat network consisting of the core and infill connections – where additional buildings are integrated to improve network utilisation and efficiency

Key features of the West Bank cluster are shown in Figure 4—4, where the left presents a heat network with only core connections. right presenting a heat network with both infill and core connections.

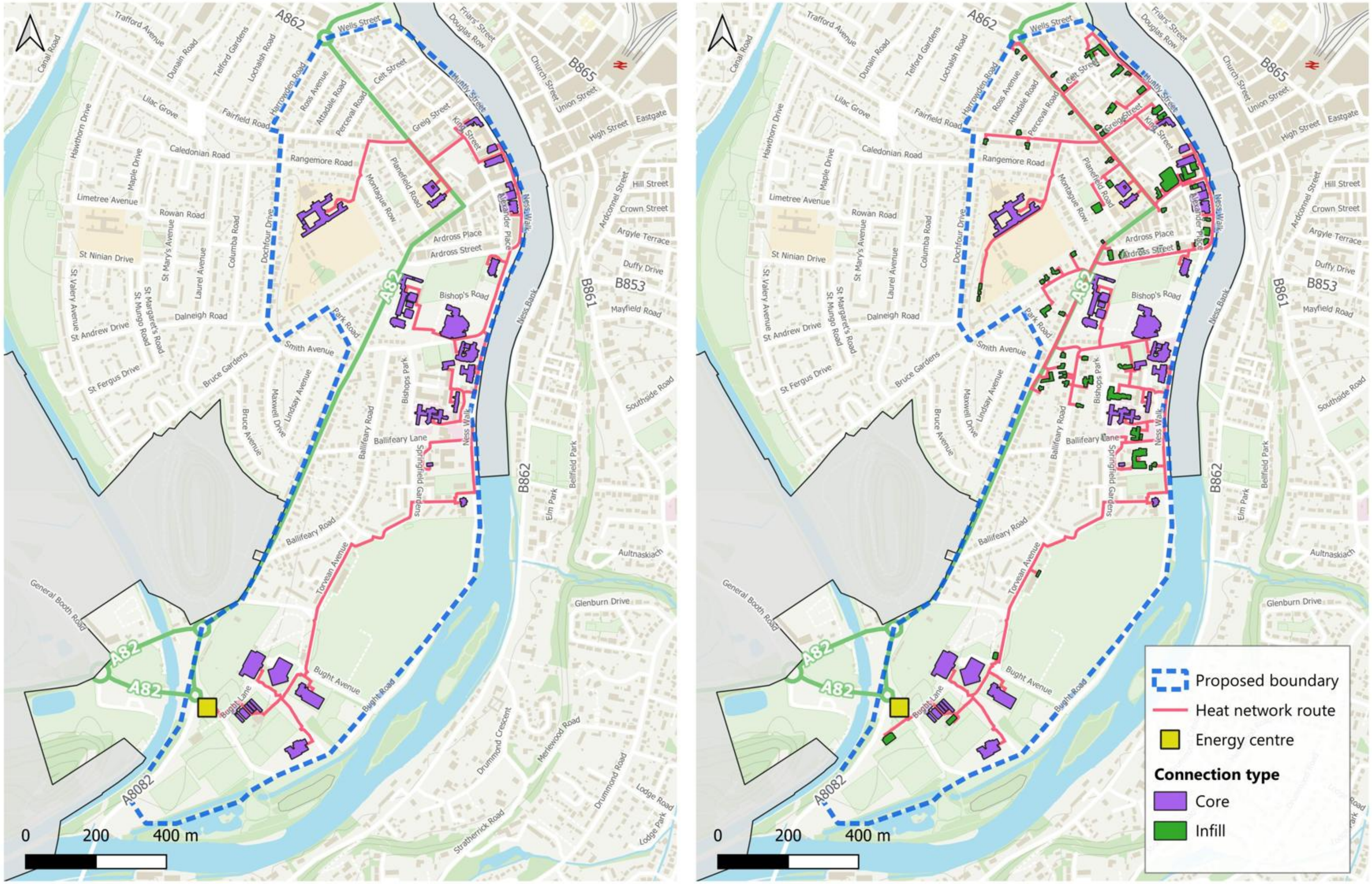

Figure 4—4 West Bank indicative heat network left only core connections and right: both core and infill connections (*Base map OS Crown Copyright*)

Further detail on the heat network key heat demands, heat sources and distribution network along with high level capex are provided in the subsequent sections. Moreover, the key risks and potential mitigations identified for successful development of the heat network are addressed in section 4.1.6.

4.1.3 Heat demand and key loads

Figure 4—4 shows the total annual heat demand and the distribution of this demand between different building categories. The total demand in the West bank cluster boundary is around 60 GWh/yr and the heat network with core connections would connect circa 24 GWh/yr of the demand and the heat network with the core and infill connections connect around 33 GWh/yr of heat demands.

In both network council-owned and public buildings form large share of the total heat demand with 75% in core connection heat network and 58% in core and infill connection network.

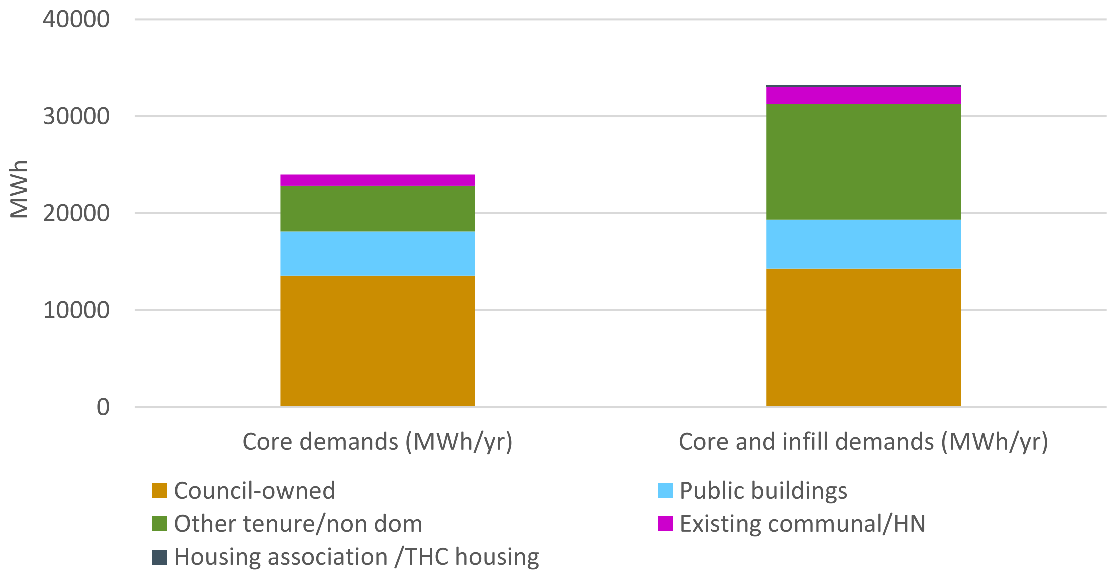

Figure 4—5 Heat demand based on the connection typologies defined in section 3.5

Inverness Leisure centre, Inverness High School, Council HQ office and Eden Court are among the largest demands in West Bank. Table 4—1 provides further details of the key heat demands.

Table 4—1 Key anchor loads in West Bank cluster

Building name	Building connection category	Building typology[18]	Annual heat demand (MWh)	Data source
Inverness Leisure Centre	Council-owned	Sports and recreation	6890	Previous feasibility study
Columba Hotel	Other tenure/non-domestic	Hotels	1924	SHM

[18] Some buildings might contain more than one typology, such as both domestic and non-domestic typologies. The building typology is defined based on the typology that has the largest share of the total heat demand in the building.

Inverness High School	Council-owned	Education	1882	THC benchmarking tool
Eden Court	Council-owned	Entertainment /Catering	1754	Previous feasibility study
Palace Hotel	Other tenure/non-domestic	Hotels	1546	SHM
Highland Council HQ	Council-owned	Offices	1360	Previous feasibility study
Botanic Gardens	Public buildings	Entertainment/ Catering	1230	Previous feasibility study
The Royal Northern Infirmary Hospital	Public buildings	Health/Hospital	835	SHM
The Edens Hotel	Other tenure/non-domestic	Hotels	670	Previous feasibility study
Inverness Ice Centre	Public buildings	Sports and recreation	590	Previous feasibility study
Premier Inn Inverness Centre	Other tenure/non-domestic	Hotels	585	SHM
Central Primary school	Council-owned	Education	574	THC benchmarking tool
University of Highlands and Islands	Public buildings	Education	500	Previous feasibility study

There is not any major new planned development planned in the cluster, the two items noted during the study being:

- A park kiosk is planned to be demolished, and a new pavilion is planned to be constructed in its place built following Passivhaus principles. The newbuild pavilion was originally planned to be heated using GSHP with a vertical borehole array. However, following a ground condition survey, the ground conditions were unsuitable for ground source heat pumps, so the decision was made to revert to air source.
- There are also plans to construct a new pavilion and clubhouse at the Bught Park stadium seating, both will be built in accordance with Passivhaus principles. Heating with GSHP in a plant room was originally planned. However, this is reverted to ASHP after ground condition survey conducted by THC.

Both of these new demands are relatively small and thus not considered to make a large difference to the overall routing and total demand connected. However, ongoing activity (particularly the stadium) could be a trigger point for encouraging deployment in this southerly part of the West Bank.

4.1.4 Heat sources and energy centre

Several potential waste heat sources are identified in the West Bank cluster as outlined in Table 3—1.

A key option for consideration is deployment of a GSHP in Bught Park. Both closed loop and open loop GSHP were assed in the previous feasibility study. With the finding indicating that the aquifer open-loop GSHP shows lower capital cost and better overall economic performance when 50% grant funding was factored in the economic model. However, a subsequent ground condition study conducted by THC found the ground condition unsuitable for GSHP deployment in Bught Park. Therefore, although GSHP was examined in the previous feasibility study, GHSP was not considered as a viable heat source option anymore.

Another potential heat source is a WSHP, which could extract heat from the River Ness, particularly near the Hydro Ness[19], taking advantage of the river depth. However, there are not sufficient data regarding the river temperature variations through the year, flowrate and depth variations, to assess the viability of WSHP deployment. Some engagement with SEPA has been made which indicates there could be some opportunity. More detailed studies are required to understand the feasibility for a WSHP and assess the practical limitations of installing equipment for processes such as water abstraction. The existing Glen Mhor WSHP the other side of the river does lend confidence to the viability of such a scheme but the increased distance of the energy centre from the heat demands as well as the lack of spatial constraint in the area meant this technology was not considered to be vital to make the scheme viable.

Therefore, a large centralised ASHP was identified as the primary low carbon heating technology for the West Bank cluster which offers lower capital cost and proven reliability and scalability for heat networks. Additionally the flexibility of location reduces the civils costs compared to the WSHP solution.

A potential location for the energy centre was proposed on council-owned land parking area adjacent to the Highland Rugby Club. This site was chosen due to proximity to key heat loads in the area, including Inverness Leisure Centre and Inverness Ice Centre. Additionally, the site’s closeness to Hydro Ness would be advantageous if water source heat pump deployment is determined in future. The Ice Centre produces waste heat from its cooling processes, which could be captured and integrated into the heat pump system. This would enhance the overall efficiency by improving the heat pump COP, lowering the energy demand and operating cost as well.

Other potential waste heat sources were also presented in Figure 3—8, but are not considered as main heat sources due to uncertainty around their proven capacity and heat recovery practicality.

Gas boiler is included for back-up and peaking plants due to their low cost, compact size, and rapid ramp up. However, to meet the long-term goal of full decarbonisation by 2045, gas boiler must be replaced by low-carbon alternatives, such as electric boilers. Electric boilers will have an elevated running cost compared to gas due to the relative difference in price and also require substantial headroom on the electricity network.

4.1.5 Heat network characteristics

Figure 4—4 presents the proposed network route for both options: the core connections (left) and the combined infill and core network (right). The proposed network has been developed using the Steiner tree methodology (as detailed in section 3.6), which determine the shortest possible routes while following existing road networks to minimise the construction complexity.

A key consideration in the network routing is the opportunity for soft dig within Bught Park, from Warrand Rd (North of the Bught Park) to the major heat loads in the southern part of the cluster, including Inverness Leisure Centre and Inverness Ice Centre. Soft dig costs will potentially be lower.

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[19] https://www.highland.gov.uk/info/1210/environment/971/hydro_ness/

The soft dig through the Bught Park was factored in the pipe routing cost estimates for the West Bank cluster, helping to reduce the overall capital cost and improve the viability of the heat network.

A summary of the key network parameters including the total heat demand, network length and LHD for both networks is provided in Table 4—2. Extending the network to the north of the West Bank cluster by incorporating both infill and core connections, would reduce the network LHD. However, this area has a large number of social housing (primarily council-owned stock), which could be integrated into the heat network. This could further improve the overall LHD, making it more economically viable. Additionally, given the current LHD of 4.6 MWh/yr/m for the core network, extending connections to additional buildings along this route could also be considered which increase the network efficiency and economic.

Table 4—2 West Bank cluster summary

	Core network	Core and infill network
Total demand (MWh/yr)	24015	33213
Network length (m)	5200	9500
LHD (MWh/yr/m)	4.6	3.5

As detailed in section 3.9, a simplified techno-economic model was utilised. The model incorporates the pipe length data (including soft dig/suburban/dense urban environment), major obstacles, the annual heat demand by building typologies. It creates a heating profile and annual load duration curve to size the low-carbon plant and back-up plant. The ASHP size is estimated to be around 5.9 MW for the core network and 7.8 MW for the core and infill network. In both heat network options, over 85% of heat demand is expected to be met by heat pump. Table 4—3 provides an indicative capital cost and estimated carbon savings compared to a gas boiler counterfactual for both networks.

Table 4—3 Indicative capital cost and carbon savings for West Bank

	Core network	Core and infill network
Capex £m	20.3	37.1
Carbon saving TCO2e over 40 years	158170	224750

It is worth noting that the indicative capex does not account for the electricity grid reinforcement if required.

The routes presented for both scenarios are not optimised, instead considering the potential full extent of the network. The best opportunity is likely to be based around the old feasibility study area (shown in Figure 4—2) but extended to include Inverness High School. Additional smaller demands could be connected along the route to help increase the LHD further and improve viability.

4.1.6 Key risks and mitigations

The table below outlines key risks, constraints and potential mitigations for the West Bank cluster heat network:

Table 4—4 Key risks and mitigations for West Bank

Risk / constraints	Mitigation
Road crossing	The West Bank network requires crossing the A82 main road. A study is needed to evaluate the feasibility of these crossing and reviewing the potential constraints presented by existing buried utilities. The final network may be able to minimize this with Inverness High School being the only key load the other side of the A82 from the other key loads in the area.
Proposed network route cost	The proposed network is following the existing road infrastructure. However, opportunities for cost reduction have been factored in including the soft dig opportunity through Bught Park, from Warrand Rd (North of the Bught Park) have been factored into cost estimates to reduce the CAPEX. Ground assessment should be carried out to confirm this.
Electricity network capacity	The nearest SSEN electrical substation (Inverness Substation, south of the cluster, across the river) is currently unconstrained. However, the Dalneigh substation is overloaded. Early engagement with SSEN is required as part of a full formal application in determining network capacity in the area.
Low Linear heat density in the heat network option with both infill and core connections	The North of the West Bank cluster includes a high portion of social housing (primarily council owned stock), which could be integrated into the heat network to improve the overall LHD, making it more economically viable. Additionally, given the current LHD of 4.6 MWh/yr/m for the core network, extending connections to additional buildings along this route could also be considered which further enhance the network efficiency and economic. The soft dig does offset some concerns of the relatively low LHD but enhancing the LHD will still help the economics of the network.
Non-optimised routings	Explore options for focusing on the most economic areas of the network, this is likely to limit the extent of the network (probably excluding the area to the north). The value of crossing Bught Park should also be assessed or whether two networks are more viable (due to the low dig costs this is indicated as viable although maybe not optimal in this analysis). Adding additional small loads along the northwest edge of the park will help building the case for connecting both sides of the network.
Buildings compatibility for heat network connection	For the new development, engagement with planned developments is required to ensure secondary systems are connection ready to DHN. For existing buildings, enabling works on the buildings that currently operate at high temperatures to ensure heating system compatibility. Enabling works may include design and contractor works to replace existing heat emitters (radiators and fan coil units) to operate at lower temperatures.
Land ownership and implications for energy centre locations	There is a risk that energy centre locations identified in this report may not be available and suitable for use for construction of an energy centre. Having a high level of THC land and influence helps de-risk this major aspect of development. A full energy centre location assessment should be conducted.
Heat demand and heating system data accuracy	There is a risk that the heat demand estimates may be inaccurate as some of them are benchmarked. Moreover, the key connections are assumed to be all gas boiler and technically suitable to join the heat network. A feasibility study with stakeholder engagement is required to validate and confirm the assumptions and address potential complexities. The previous feasibility study helps de-risk this element as does the high level of THC loads, this is more of an issue in the north of the area.
Missing alignment with broader activity	Aligning to ongoing activity is key, for example, if a heating system is being replaced soon it can create technology lock in for a period until the new system reaches the

	end of its life. The redevelopment of the leisure centre is a case in point, ensuring development links with this opportunity is key. Similarly, the likely replacement date of heating technology in other key THC assets and connections should be established to help understand the key timings for the network.

4.2 Longman

4.2.1 Area overview

The Longman area has a previous feasibility for a heat network focusing on linking the SW pumping station with the Bairds Maltings site. The area is important strategically for Inverness, representing the best area in terms of heat source, with the SW pumping station and also being a potential key route for waste heat from a hydrogen electrolysis which is going through planning (the site is in the old landfill area the other side of the A9).

The area has a very high level of THC land ownership. Making the Council a key enabler for any activity in the area.

Most significantly for providing impetuous for a heat network in the area is the recent announcement of collaboration between SWH and SSE in the area to develop a heat network.

4.2.2 Longman Cluster

The Longman area generally has a low heat demand density, based on the SHM, than the other areas examined. This is shown by a relatively small amount of the area being covered by the 8 MWh/yr/m LHD in Figure 4—6.

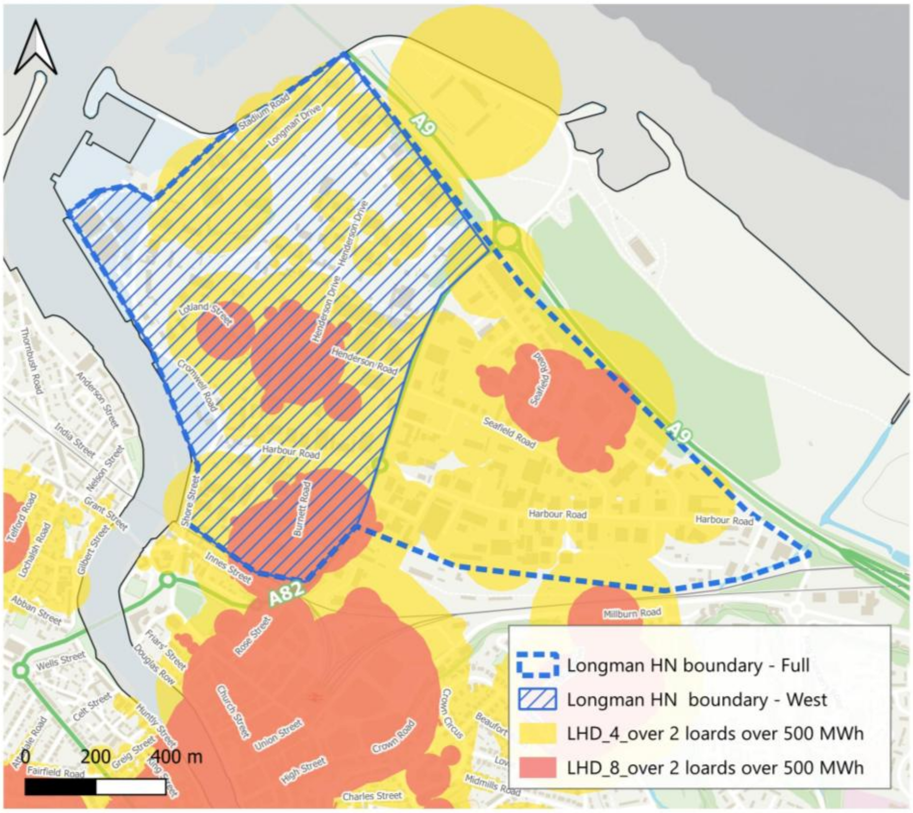

Figure 4—6 LHD 4 MWh/yr/m and 8 MWh/yr/m bubbles and Longman proposed heat network boundary (*Base map OS Crown Copyright)*

As shown in Figure 4—6 for Longman two different scales of heat network area are examined. The largest blue boundary is for the whole Longman area, indicative connection and pipe routings for this area are provided in Figure 4—7. A smaller area just covering the west of Longman is also examined, this area has the highest heat density areas (as shown in Figure 4—6), indicative pipe routings are provided in Figure 4—8. This is in part due to the two largest heat demands in the area being poorly captured in the SHM, due to being industrial in character. This is discussed in 4.2.3.

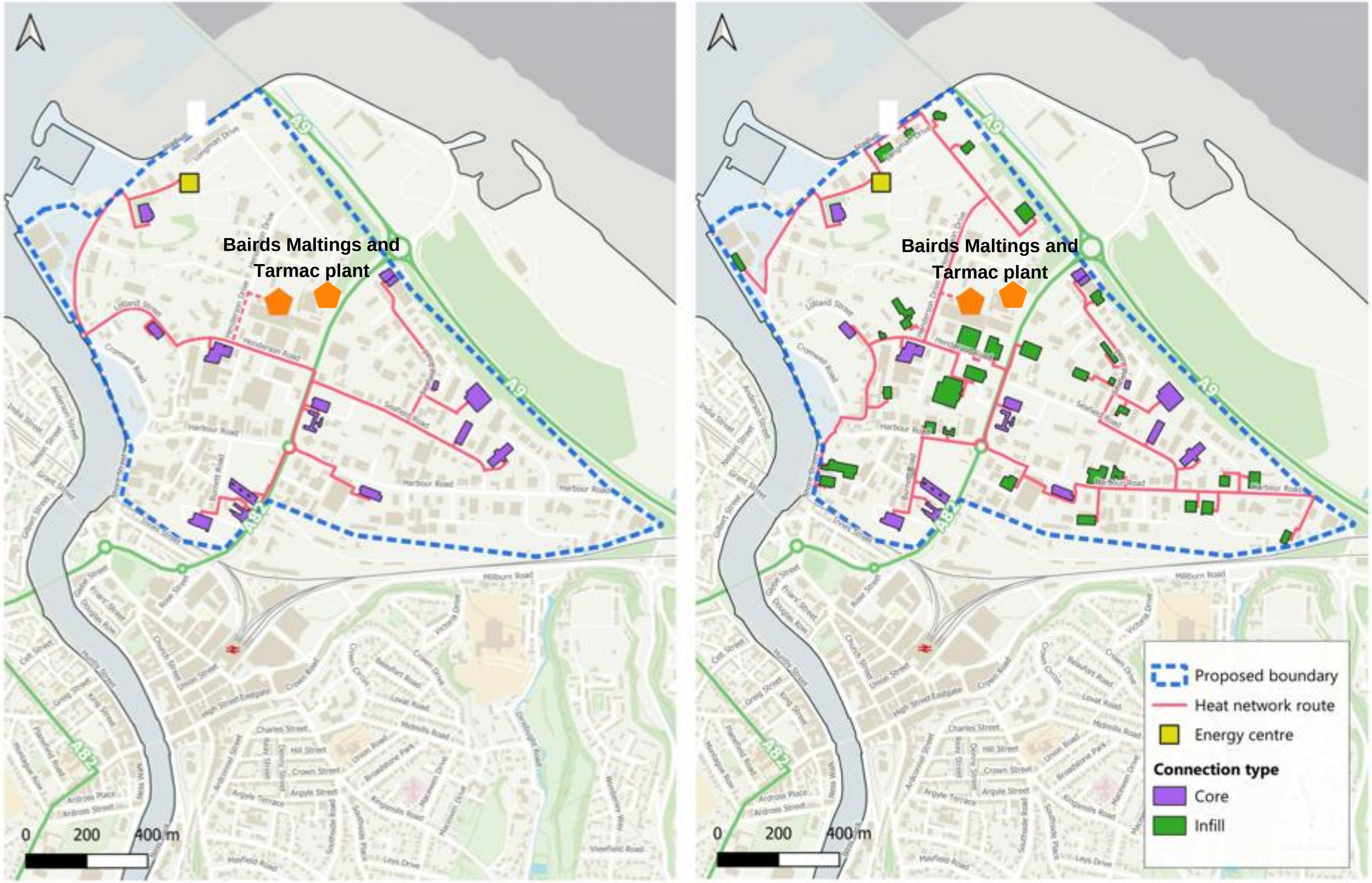

Figure 4—7 Full Longman area indicative heat network left only core connections and right: both core and infill connections (*Base map OS Crown Copyright*)

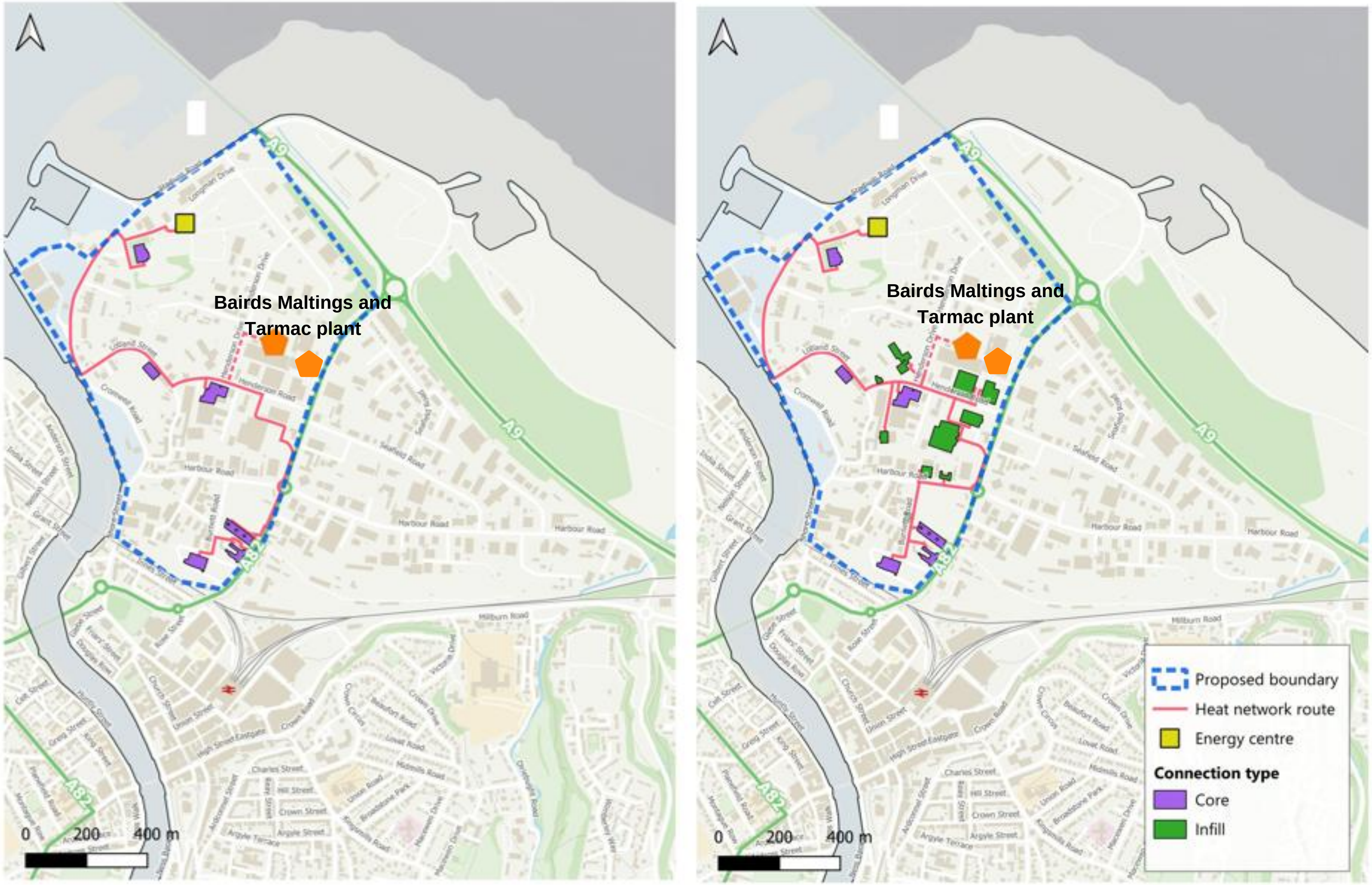

Figure 4—8 West Longman area indicative heat network left only core connections and right: both core and infill connections (*Base map OS Crown Copyright*)

4.2.3 Heat demand and key loads

The majority of demands in the Longman area are industrial units. These generally require a high level of validation compared to benchmarking of SHM, which can sometimes lead to large overestimations in heat demand. This is important to note in the context of Figure 4—9 which summarises the demands in the Longman area.

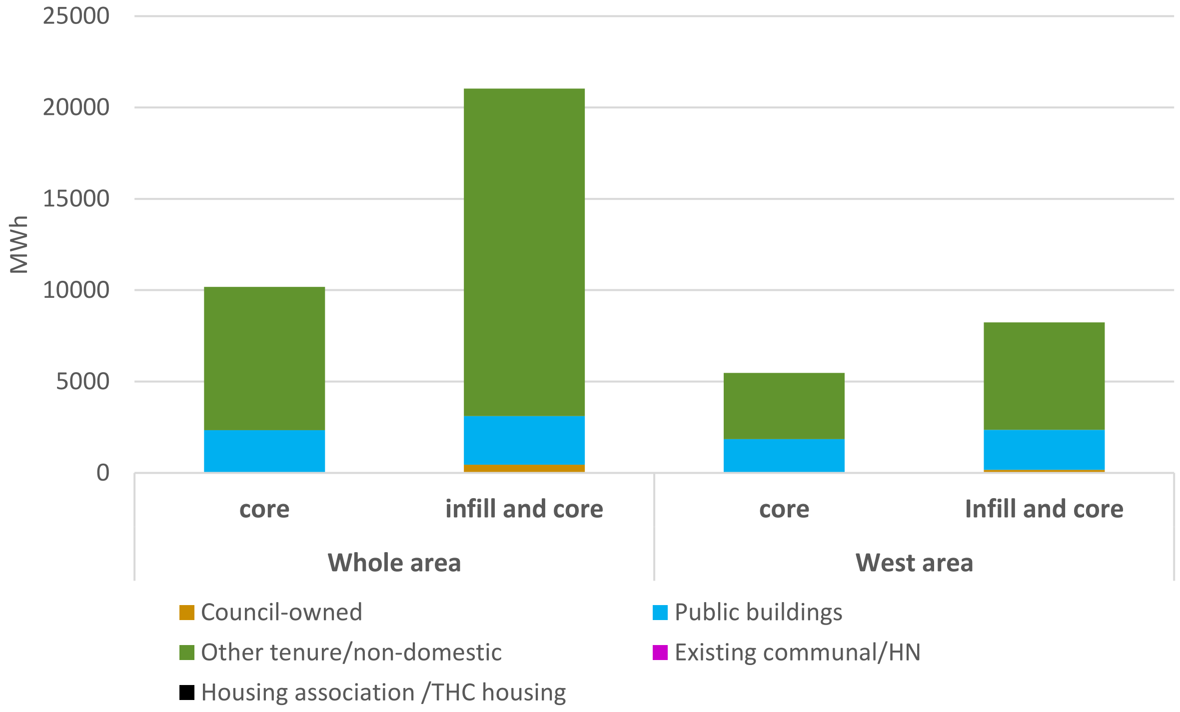

Figure 4—9 Heat demand based on the connection typologies defined in section 3.5 for full and west boundary.

The two largest industrial demands are excluded from the graph. These are the previously mentioned Bairds Maltings site and the Tarmac plant which is adjacent to the Maltings (in the north). Both of these demands are not fully captured in the SHM. The Maltings was captured based on the previous feasibility study work; however, the Tarmac plant was only captured in the project close out meeting. As such the Tarmac plant demand is not captured in any technical analysis but noted as a key demand to examine in the future.

There is relatively limited direct public/council sector control of heat demands, however, THC do own a large portion of the land in the area which is seen as a key enabler of a heat network in the area. A summary of the key anchor loads (those with over 500 MWh/yr) are captured in Table 4—5.

Table 4—5 Key anchor loads in Longman cluster

Building name	Cluster	Building connection category	Building typology	Annual heat demand (MWh)	Data source
Scotbake	West/ Whole	Other tenure/non-domestic	Industrial buildings	1175	SHM
MacGregor Industrial Supplies Ltd	West/ Whole	Other tenure/non-domestic	Industrial buildings	1097	SHM

Inverness Sheriff Court and Justice of the Peace Court	West/ Whole	Public buildings	Offices	1120	SHM
Insight Systems Ltd (and other offices in 50 Seafield Rd)	Whole	Other tenure/non-domestic	Industrial buildings	1021	SHM
Royal Mail – delivery office	Whole	Other tenure/non-domestic	Offices	904	SHM
Police Scotland Inverness Burnett Street	West/ Whole	Public buildings	Offices	737	SHM
Transport Inverness	West/ Whole	Other tenure/non-domestic	Retail	683	SHM
Scottish Water offices	West/ Whole	Other tenure/non-domestic	Offices	667	SHM
Thrifty Car Rental (and other retails in 33Harbour Road)	Whole	Other tenure/non-domestic	Retail	596	SHM
Stagecoach Inverness	Whole	Other tenure/non-domestic	Offices	571	SHM
Highland Industrial Supplies	Whole	Other tenure/non-domestic	Retail	563	SHM
Thornbridge Timber Inverness	Whole	Other tenure/non-domestic	Retail	557	SHM

It is worth noting that the Longman House building, with an annual demand of 215 MWh/yr, has been added as a core connection to the whole Longman network. The building is owned by the Scottish Government and is considered core because it is close to the 250 MWh/yr core threshold in public buildings and has a BAR report, which provides greater certainty and indicates engagement.

Another important load not captured in the table above is the SSEN office in Longman – as it falls below the 500 MWh/yr threshold. Alongside the Scottish Water offices this would be two of the main connections for the heat network being planned by SSE and SWH in Longman (due to the presence of a strategic partnership between the companies). The other two demands would be the Tarmac plant and the Bairds Maltings site – which is discussed in section 4.2.3.1.

4.2.3.1 Bairds Maltings site

Bairds Maltings represent a significant potential heat load in Longman cluster, with an estimated heat demand of 60000 MWh/yr, accounting for approximately 60% of the total estimated demand in the cluster. According to the previous Buro Happold study (2019), the existing Bairds Malting plant (before it was expanded) had an estimated demand of 29000 MWh/yr with a peak demand of 8.2 MWh/yr. Following Bairds planned expansion (now complete) the demand was projected to result in an additional 31000 MWh/yr of heat demand with the estimated peak of peak of 8.7 MW – bring it up to the 60000 MWh/yr.

While the existing plant operates at high temperature requirement (~160ºC), making it unfeasible to integrate directly to the heat network, the expansion is expected to have lower temperature requirement (60-80ºC). This presents an opportunity to utilise heat from the heat network.

Therefore, for the purposes of this study 50% of the heat demand is considered as potential demand to be met the heat network. This could act as a pre heat for the older portion of the site or as direct supply for the newer (lower temperature area). Stakeholder engagement would be required to establish the scale of demand which could be served by the network and the willingness to connect – it is understood this would be one of the first actions of the SSE/SWH collaboration looking to develop a network in Longman.

4.2.4 Heat sources and energy centre

The key heat source in the areas SW pumping station, which is already being explored by SSE/SWH. This was the best heat source identified in Inverness for any of the potential heat networks. The land availability next to the heat source makes this an ideal site for the energy centre. The high level of THC land ownership in the area means pipe routing from an energy centre in this location would also be relatively straightforward.

The previous feasibility examined utilising sewage heat recovery as a potential heat supply. The analysis is assed based a sewage flow rate of 190 l/s (based on the SWH dataset records) and a temperature differential of 5^{o}C. Assuming a COP of 3.2 for the heat pump and utilising 100% of flow, the estimated deliverable heat would be up to 5.7 MW_{th}, with a potential maximum annual heat supply of 50000 MWh. The SWH and SSE partnership is expected to provide more accurate estimations of this heat resource. However, this initial indication suggests the amount of heat would be sufficient to supply Longman in any of the scenarios examined.

With the exception of the Maltings and Tarmac loads the heat demands in the area are relatively small and the heat density is thus lower than other areas. This low heat density means cheap heat is very important to a heat network in the area.

In addition to the SWH site there is potential waste heat form hydrogen electrolysis at site of historic landfill. This project was submitted under the UK’s Hydrogen Allocation Round 2 (HAR 2) for funding support, with a final award decision expected in June/July 2025. The proposed development at Longman Landfill includes a 50 MW hydrogen production facility that uses renewable energy for electrolysis, producing green hydrogen with an expected output of approximately 20,000 tonnes annually. This hydrogen opportunity is thus relatively early stage and not confirmed. Complex routing with A9 but could be viable if a hydrogen pipeline is deployed at the same time. Very early stage so not considered as fully as SWH. If this was to connect into a large energy centre which also captures the SWH heat it will be important to future proof the site in terms of space. However, Longman could only act as a heat transmission corridor for any waste heat from hydrogen into the more heat dense City Centre area, in which case this heat source would not need to be considered in the energy centre location.

There were also some heat demands that were considered as potential waste heat sources but discounted for a variety of reasons. One is the Maltings which is instead considered primarily as heat demand, the other is Scotbake. BuroHappold’s experience of the potential of waste heat from bakeries for heat networks led to it not being explored further. The key reasons for this are: less complex and larger heat sources in the area, the need to fit around what are often short periods of time the site is not being used for production for the relevant equipment to be fitted, and the flammable condensate that often accumulates in the oven flues (which is where heat offtakes would generally be fitted).

4.2.5 Heat network characteristics

A summary of the key network characteristics is provided in Table 4—6.

Table 4—6 Longman cluster summary

	West Area		Full Area	
	Core network	Core and infill network	Core network	Core and infill network

Total demand (MWh/yr)	5480	8240	10180	21029
Network length (m)	2780	3480	5180	9715
LHD (MWh/yr/m)	2	2.4	2	2.2
LHD (MWh/yr/m) with 30000 MWh/yr Bairds Malting demand	11.6	10.2	7.4	5.2

The associated costs with a network at Longman are provided in Table 4—7.

Table 4—7 Indicative capital cost and carbon savings

		West Area		Full Area	
		Core network	**Core and infill network**	**Core network**	**Core and infill network**
Without Bairds Malting	**Capex £m**	9.4	12.5	17.5	33.7
	Carbon saving TCO2e over 40 years	34039	50333	62789	129029
With Bairds Malting	**Capex £m**	19.2	22.2	27.7	41.9
	Carbon saving TCO2e over 40 years	230719	247538	258888	325753

These tables highlight that without considering Bairds Maltings the LHD and carbon savings are much lower in Longman, showing the importance of this large connection for driving the viability of a network in the area.

4.2.6 Key risks and mitigations

The key risks associated with the Longman area and potential mitigations are summarised in Table 4—8.

Table 4—8 Key risks and mitigations for heat networks at Longman.

Risk / constraints	Mitigation
Electricity network capacity	The nearest SSEN electrical substation is currently unconstrained according to the high level SSEN heat map, however, there is known to be general upgrade work being undertaken in the area. Early engagement with SSEN is required as part of a full formal application in determining network capacity in the area. As SSE are set to be a key partner for delivery of a heat network in the area this is not seen to be a major risk.
Low Linear heat density	Low-cost heat can make lower LHD more viable. The two large industrial demands (the Maltings and Tarmac plant) substantially improve the linear heat density – reducing this risk. Finally, the potential interconnection to the City Centre opportunity would improve the heat density and many of the connections in Longman would be considered as additional connections. These mitigations would generally align to a focus on the West of Longman.

	This is due to the much high LHD in the City Centre and lack of heat supply options – this is explored in section 4.3.
Heat demand and heating system data accuracy	There is a risk that the heat demand estimates may be inaccurate as some of them are benchmarked. Moreover, the key connections are assumed to be all gas boiler and technically suitable to join the heat network. A feasibility study with stakeholder engagement is required to validate and confirm the assumptions, confirm suitability and addresses potential complexities. This is particularly key for Longman given the nature of the load.
Dependency on two private sector large consumers large consumer	Bairds Maltings and the Tarmac plant would account for a large portion of total network demand, meaning any operational changes, shutdowns, or process modifications at the plant could impact the financial viability of the heat network. A long-term heat supply agreement would be essential to mitigate this risk and ensure demand stability. Engagement with Bairds Maltings and the Tarmac plant to establish willingness to connect and how much demand would be suitable to be served by a heat network. If these demands are not interested in connection, it will heavily limit the viability of a network in Longman.
Sewage potential heat	The practical implementation of sewage heat recovery depends on the actual flow rates and temperature variations throughout the year. A detailed feasibility study would be required to validate expected energy output and ensure consistent performance. As SWH are already looking to utilise the asset this risk is considered to already be going through the mitigation process.
High portion of hard dig	High level of THC ownership opens multiple route options – helping to reduce impact and cost of hard dig.
Missing heat supply opportunities	In addition to the SWH site the Longman area could benefit from the planned electrolysis unit on the old landfill site north of the A9. Continued monitoring and engagement are key to benefiting from this potential asset (in the main part waste heat from the electrolysis unit). For Longman this heat could best be used outside of the area in the neighbouring City Centre. Understanding the scale and availability of these potentially large heat sources could be key for ensuring economic viability of heat network opportunities.

4.3 City Centre

4.3.1 Area overview

Inverness city centre is a one of the highest density areas in the city, with a large concentration of buildings with high heat demand. The area includes a mix of retails, offices and hotels, alongside several council -owned buildings, such as Inverness Castle, Inverness Library and Inverness Town House. Among those, the Eastgate shopping centre represent the largest heat load.

In addition, a major redevelopment is underway on Rose Street, involving demolition of an existing car park and retail units to make way for a new hotel, retails and student accommodation. As discussed previously, the new development is noted but as this is not a feasibility study demands are not benchmarked.

Buro Happold was commissioned in 2023 to assess the feasibility of a low-carbon heat network for the Castle area (for details see 3.1). Figure 4—10 provides the feasibility study boundary, proposed connections and heat network route.

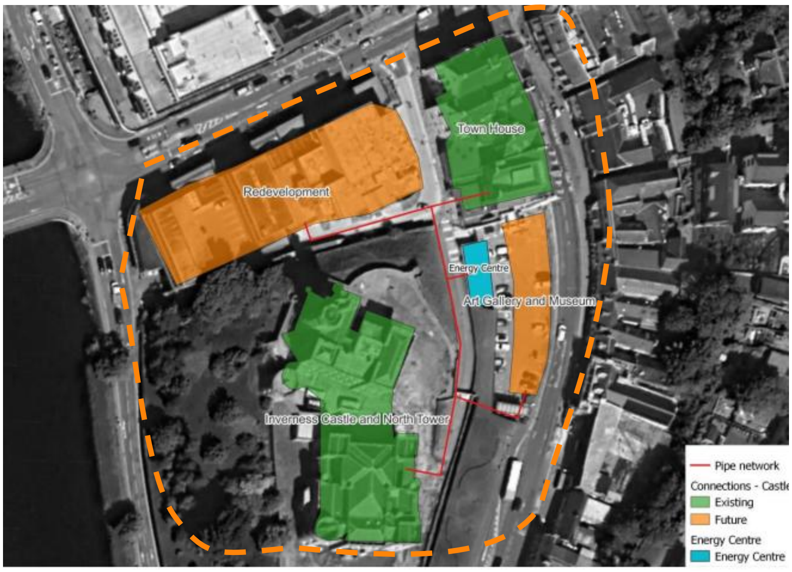

Figure 4—10 Inverness Castle feasibility study boundary, connections and heat network route[20].

As mentioned previously the heat network opportunity in the area is being pursued. A new energy centre, funded by the UK Government Levelling Up Fund, is currently under construction on Castle Street. The energy centre is deploying ASHP along with back up gas boiler and thermal storage to provide heat to the redeveloped Inverness Castle and the Inverness Town House[21].

4.3.2 City Centre Cluster

The City Centre area, with high building density and significant heat demand, is identified as a key area for heat network development, based on the LHD analysis described in section 3.3.

The initial proposed boundary initially encompasses the City Centre, expanding from the A82 in the north to the Inverness Castle area in the south. However, as previously detailed, a low-carbon energy centre is currently under construction on Castle Street. It is designed to supply heat to the redeveloped Inverness Castle and the Inverness Town House. It has been confirmed that the energy centre does not have the capacity to accommodate additional equipment and heating plant. As the Castle area is already integrating low-carbon heat sources, it is not considered priority for connection and was excluded from the proposed City Centre cluster. However, the Castle area could be considered for future integration, with the potential to link to the existing energy centre.

The proposed cluster also extends southeast to the Crown Avenue, which presents some challenge due to its higher elevation, which means additional pumping will be required. However, the area includes an academy, a retirement living complex and several council-owned low-rise flats, making it a viable for heat network connection consideration.

Figure 4—11 presents the LHD clusters and the proposed revised City Centre cluster boundary, with the left showing the initial proposed boundary and the right showing the updated boundary which now excludes the Inverness Castle area.

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[20] Inverness Castle Feasibility Study 2023 Buro Happold

[21] https://www.highland.gov.uk/news/article/15438/work_set_to_get_underway_on_castle_street_energy_centre

Figure 4—11 LHD 4 MWh/yr/m and 8 MWh/yr/m bubbles and City Centre proposed heat network boundary; initial proposed boundary (left) and the updated boundary (right) (*Base map OS Crown Copyright*)

The City Centre cluster contains ~300 buildings, with an estimated 16 buildings exceeding 500 MWh/yr demand. The total demand is over 40 GWh/yr but this includes all buildings regardless of their typology or suitability for heat network connection, 4.3.3 provides more details of the demands assumed to be priorities for heat network connection.

As explained in section 3.7, buildings are considered for heat network connection based on factors such as scale of heat demand, typology and tenure as core or infill connections. Two assessments were performed:

1) A heat network consisting of only core connections – focusing on the high demand buildings to establish financial viability of the network
2) A heat network consisting of the core and infill connections – where additional buildings are integrated to improve network utilisation and efficiency

Key features of the City Centre cluster are shown in Figure 4—12, where the left presents a heat network with only core connections, right presenting a heat network with both infill and core connections.

As previously discussed, a major redevelopment is planned on Rose Street, involving the demolition of an existing car park and retail units with a new hotel, retails and student accommodation. While the benchmarked demand of the existing retail units on Rose Street has been included in the cluster analysis to provide a partial assumption for the new development, the exact demand figure remain unknown due to lack of the precise detail on building typologies and floor areas.

Figure 4—12 City Centre cluster heat network left only core connections and right both core and infill connections (*Base map OS Crown Copyright*)

Further detail on the heat network key heat demands, heat sources and distribution network along with high level capex are provided in the subsequent sections. Moreover, the key risks and potential mitigations identified for successful development of the heat network are addressed in section 4.3.6.

4.3.3 Heat demand and key loads

The City Centre cluster comprises different typologies, with the retails and hospitality being the most prominent in terms of both the number of buildings considered for connection and their contribution to the overall heat demand. The total heat demand within the cluster is estimated to be 40 GWh/yr (this includes small heat demands, often domestic, that were excluded based on the screening criteria outlined in the methodology). The core connections network is connecting circa 22 GWh/yr of the demand, while the network with both infill and core connections connects 35 GWh/yr of heat demand.

Figure 4—13 shows the total annual heat demand and its distribution across different building categories. In both network options, council-owned and public buildings accounts for relatively small share of total demand, representing less than 6% in the core connections network and under 9% in the core and infill connections network.

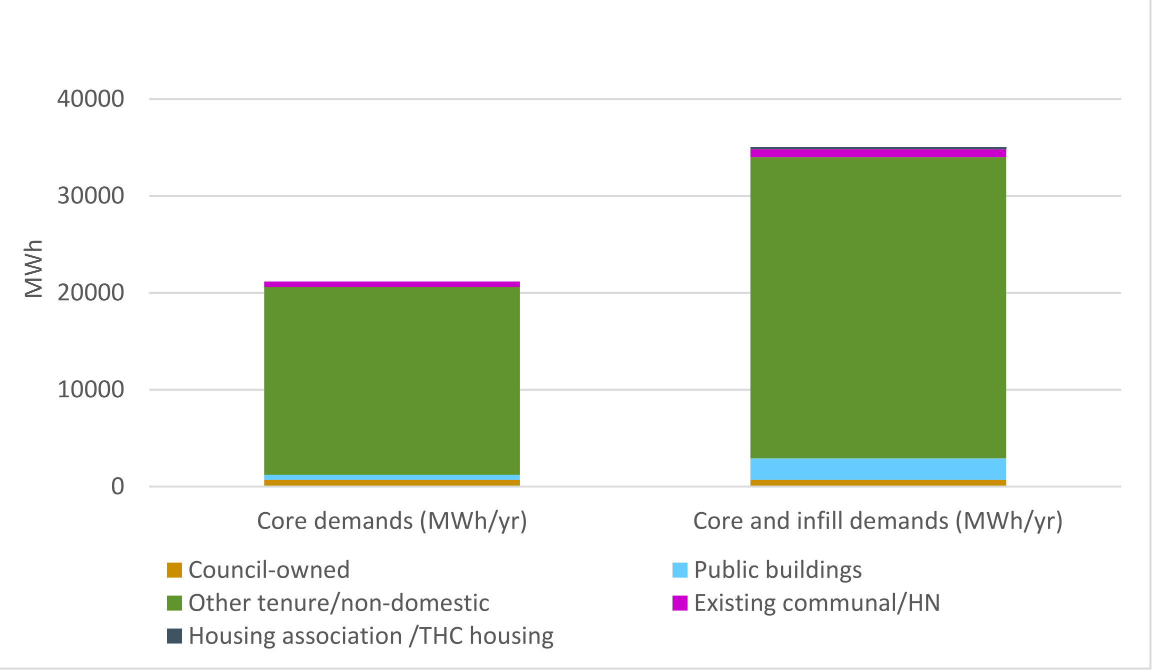


Figure 4—13 Heat demand based on the connection typologies defined in section 3.5

Further details of the key heat demand are provided in Table 4—9. The top anchor loads account for an estimated 20 GWh/yr, with Eastgate shopping centre being the largest demand in the cluster with over 6 GWh/yr demand.

Table 4—9 Key anchor loads in City Centre cluster

Building name	Building connection category	Building typology	Annual heat demand (MWh)	Data source
Eastgate shopping centre (consists of a number of buildings)	Other tenure/non-domestic	Retail	6400	SHM

Mercure Hotel	Other tenure/non-domestic	Hotels	3219	SHM
By the Bridge accommodation / Holiday let	Other tenure/non-domestic	Hotels	2610	SHM
The Royal Highland Hotel	Other tenure/non-domestic	Hotels	2207	SHM
Pentahotel	Other tenure/non-domestic	Hotels	1390	SHM
Morrison Supermarket	Other tenure/non-domestic	Retail	1161	SHM
TK Maxx Department store	Other tenure/non-domestic	Retail	965	SHM
Travel Lodge Hotel	Other tenure/non-domestic	Hotels	850	SHM
Marks and Spencer	Other tenure/non-domestic	Retail	730	SHM
Mixed-use building in Baron Taylor's St with communal heating	Existing communal/HN	Domestic	580	SHM
Wasps Inverness Creative Academy	Public buildings	Education	516	SHM

4.3.4 Heat sources and energy centre

No significant waste heat source is identified in the City Centre area that could supply heat to the City Centre Cluster. There is also potential to utilise WSHP due to proximity to the River Ness. The feasibility of this remains uncertain, as there is insufficient data on key factors such as river temperature variations through the year, flowrate and depth fluctuations. A more detailed study is required to assess the viability of this option and to evaluate the practical limitations of installing equipment and water abstraction. Additionally, the area near the Ness is not likely to be a priority for heat network build out, making the strategy for a heat network in this area challenging if it is the selected heat source.

The primary heat source is proposed to be a large-scale ASHP. Due to the dense City Centre environment, available space for an energy centre is limited. The Rose Street planned redevelopment site has been identified as a suitable location for the energy centre, as it allows for streamlined planning and infrastructure work alignment and it serves as a trigger for enabling heat network development.

ASHP have a lower COP than WSHP, meaning electricity costs will generally be higher. However, WSHP often come with higher capital and maintenance costs, making their suitability more dependent on the scale of the network and funding available.

Gas boiler is included for back-up and peaking plants due to their low cost, compact size, and rapid ramp up. However, to meet the long-term goal of full decarbonisation by 2045, gas boiler must be replaced by low-carbon alternatives, such as electric boilers. Electric boilers will have an elevated running cost compared to gas due to the relative difference in price and also require substantial headroom on the electricity network.

4.3.5 Heat network characteristics

Figure 4—12 presents the proposed network route for both options: the core connections (left) and the combined infill and core network (right). The proposed network has been developed using the Steiner tree methodology (as detailed in section 3.6), which determine the shortest possible routes while following existing road networks to minimise the construction complexity.

The core network spine includes a main trunk of pipework running along Rose St, Maragaret St, and Academy St with branches to key demand sites such as the Inverness Library, Spectrum Centre several hotels. The network splits into two branches at Academy St, with one branch heading east to the Eastgate Shopping Centre and on heading to west to supply heat to a number of hotels. Another branch from the Crown Rd, extending down Crown Avenue, serves the inverness Creative Academy. Pipe network construction in the City Centre cluster presents additional challenge due to high urban density and limited access which leads to increased pipework cost compared to other clusters with more suburban areas.

A summary of the key network parameters including the total heat demand, network length and LHD for both networks is provided in Table 4—10.The City Centre cluster shows a LHD of 7.9 MWh/yr/m with core connections, suggesting strong potential for network expansion. The core and infill network, which extends network to additional buildings, has a lower LHD of 5.5 MWh/yr/m, indicating viability even with further expansion.

Table 4—10 City Centre cluster summary of key network characteristics.

	Core	Core and infill
Total demand (MWh/yr)	21540	35000
Network length (m)	2.7	6.4
LHD (MWh/yr/m)	7.9	5.5

As detailed in section 3.9, a simplified techno-economic model was utilised. The model incorporates the pipe length data (including soft dig/suburban/dense urban environment), major obstacles, the annual heat demand by building typologies. It creates a heating profile and annual load duration curve to size the low-carbon plant and back-up plant. The ASHP size is estimated to be around 4.9 MW for the core network and 8.2 MW for the core and infill network. In both heat network options, over 79% of heat demand is expected to be met by heat pump, and the remaining demand is supplied by the gas boiler peaking plant. Table 4—11 provides an indicative capital cost and estimated carbon savings compared to a gas boiler counterfactual for both networks.

Table 4—11 Indicative cost and carbon savings for the City Centre indicative heat network

	Core	Core and infill
Capex £m	22.2	44.3
Carbon saving TCO2e over 40 years	131690	214130

The planned development on Rose Street, along with Inverness railway station area planned development and potential SSEN cable upgrade work, could be the key trigger for enabling heat network development in the City Centre. This opens up the possibility for energy centre locations in the area, which is spatially constrained. It also introduces new demands, which could be key connections for a heat network. Finally, the cable upgrade can help reduce the cost of pipework trenching and minimise disruption – avoiding the same road being closed on multiple occasions in relatively quick succession.

4.3.6 Key risks and mitigations

Table 4—12 below outlines key risks, constraints and potential mitigations for the City Centre heat network opportunity.

Table 4—12 Key risks and mitigations for the City Centre

Risk / constraints	Mitigation
Electricity network capacity	The nearest SSEN electrical substation (Inverness Substation, south of the cluster, across the river) is currently unconstrained. However, the Dalneigh substation is overloaded. Early engagement with SSEN is required as part of a full formal application in determining network capacity in the area. Based on engagement with THC SSEN have planned upgrades in the area, including cabling.
High level of hard dig	Planned SSEN trenching for cables and other developments should be coordinated for heat network deployment. Based on THC engagement this is already being considered and is thought of as a catalyst for realising the heat network opportunities in the City Centre.
Buildings compatibility for heat network connection	For the new development, engagement with planned developments is required to ensure secondary systems are connection ready to DHN. For existing buildings, enabling works on the buildings that currently operate at high temperatures to ensure heating system compatibility. Enabling works may include design and contractor works to replace existing heat emitters (radiators and fan coil units) to operate at lower temperatures.
Lack of space for an energy centre and limited waste/ low carbon heat potential	Rose Street redevelopment key trigger point to allow energy centre location. Potential import of heat from the Longman area could reduce the emphasis on infrastructure in the area, which is important given the higher cost of land and lower availability of space. Linking the two areas would help improve demand diversity and could potentially increase the size of thermal store available to the City Centre (enabled by the greater space in Longman). Additionally, this interconnection will allow greater access to low cost heat than within the city centre area.
Heat demand and heating system data accuracy	There is a risk that the heat demand estimates may be inaccurate as some of them are benchmarked. Moreover, the key connections are assumed to be all gas boiler and technically suitable to join the heat network. A feasibility study with stakeholder engagement is required to validate and confirm the assumptions and address potential complexities.
Listed building connections	There are several listed buildings in the City Centre. Physical alteration works to the buildings to accommodate pipework and heat off take substations would need to be considered on a building-by-building basis along with the existing heating systems, which are understood to be included within the listed protection.

Relatively few strategic key loads	Eastgate is one of the key pulls for a heat network into the centre. Again, early targeted engagement is key. Including understanding suitability for connection.
Many private sector heat demands	Requires focused engagement to ensure suitable interest for deployment. Whilst Eastgate represents one strategic connection there needs to be concerted early engagement to key loads such as the hotels in the area.
Low level of THC land ownership	Optimise routings and strategically route to minimise the number of landowners who require engagement.
Not fully utilising existing assets	The new energy centre near the museum does not have capacity to serve the network area. Interconnection of the two energy centres is considered in the final strategy.

4.4 Raigmore

This section is not as detailed as others with the accompanying feasibility study providing detailed analysis of the area. An overview of the heat demand across the area is provided in Figure 4—14.

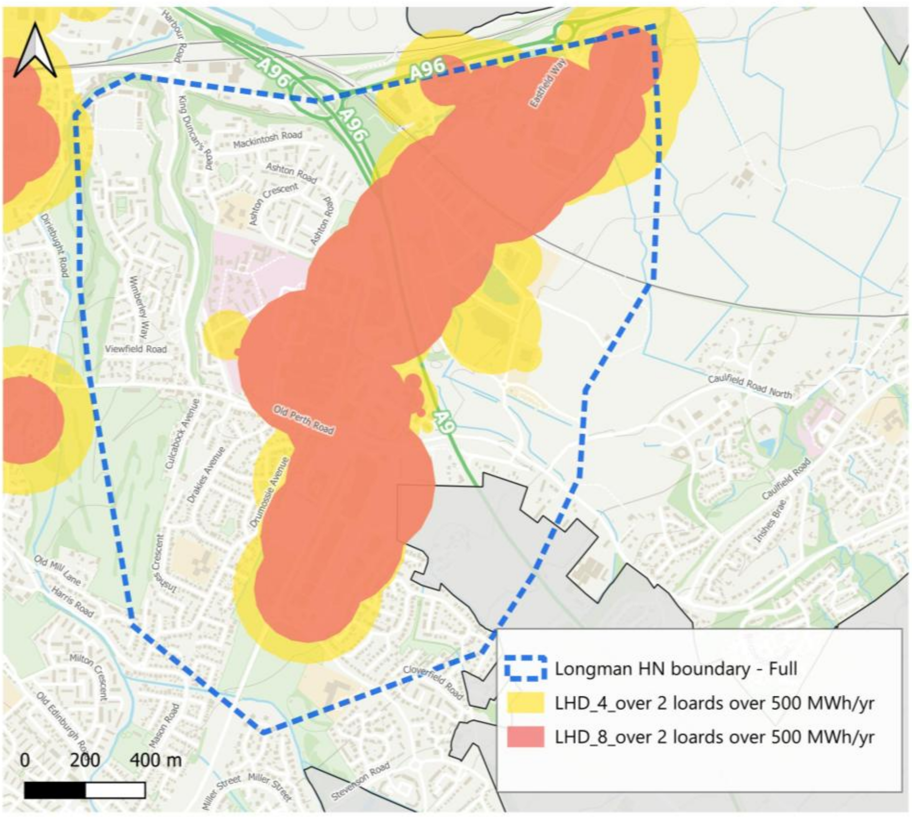


Figure 4—14 LHD 4 MWh/yr/m and 8 MWh/yr/m bubbles and Raigmore proposed heat network boundary (*Base map OS Crown Copyright*).

The Raigmore area is split by the A9, meaning the linking of the whole area could be challenging. Additionally, initial assessment of heat resources suggested there were relatively few options for heat supply in the area[22], meaning there was no specific driver for connecting all demands into one network given the increased costs likely to be incurred by the road crossing. As such the area was split into an East study and a West study. Maps of the two areas are provided in Figure 4—15 and Figure 4—16 respectively.

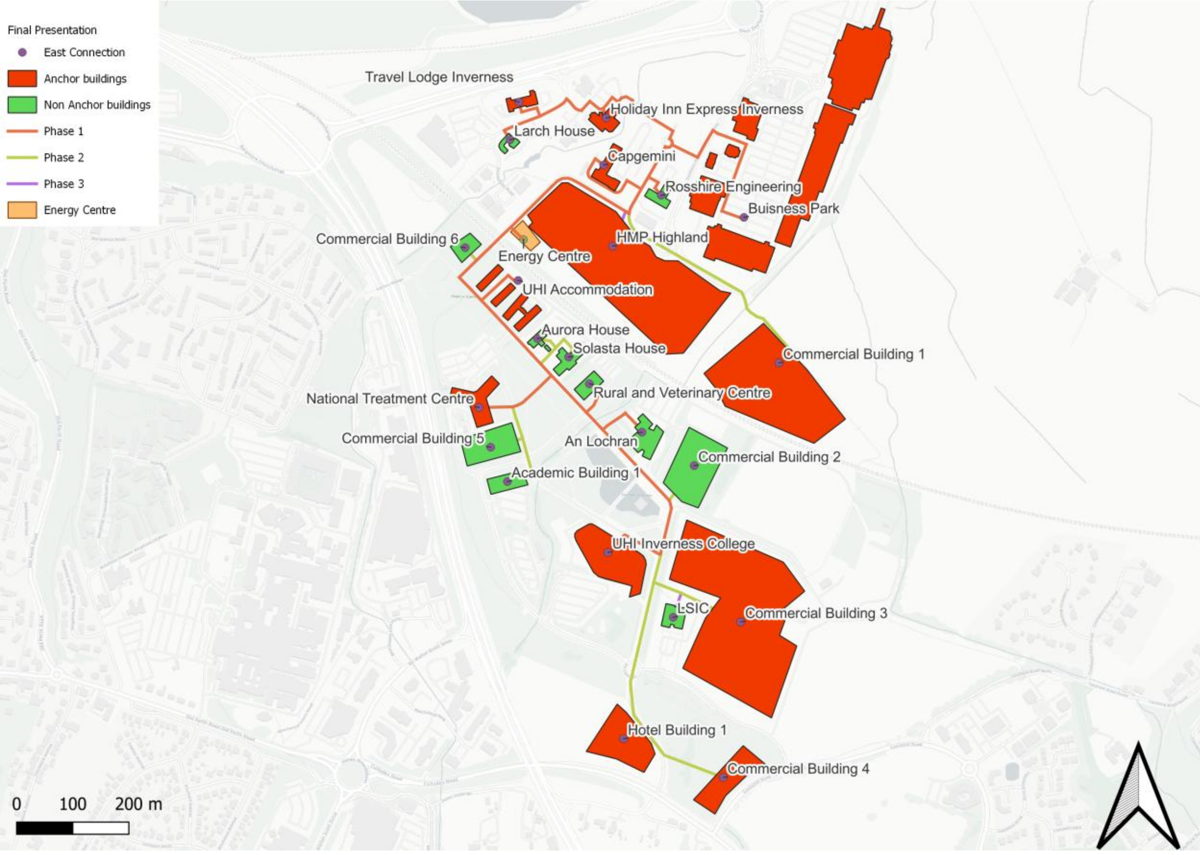


Figure 4—15 Raigmore East network overview

[22] Although updates to the SWH website during the study indicated that there is a potential heat supply from a large sewer, however, the study indicated similar economics to an ASHP.

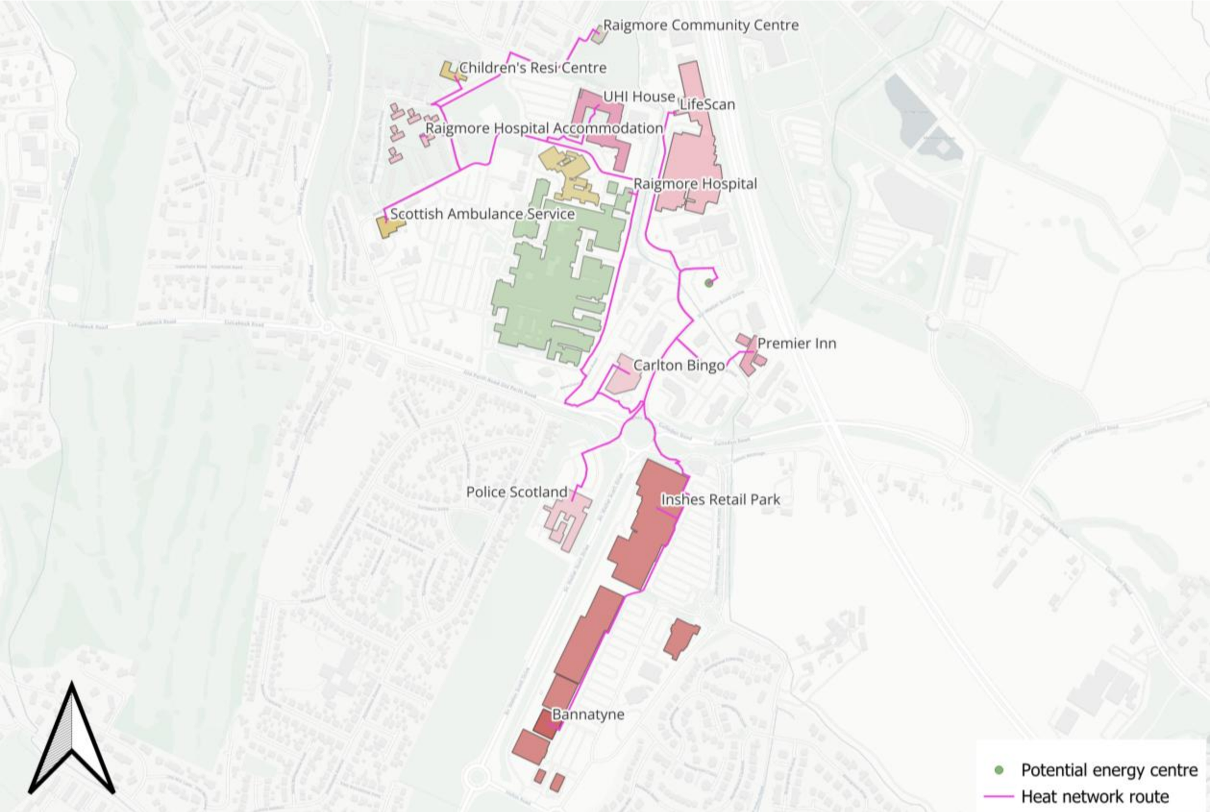


Figure 4—16 Raigmore West Network overview

The East side was decided as the final focus of the feasibility study due to more active stakeholder engagement during the feasibility study. The results indicated a network was viable with funding support, an IRR of 12% with 50% CAPEX funding was the output of the techno-economic model. The network and deployment approach is highly reliant on future developments in the are linked with the Freeport.

The West side is in a large part dependent on the NHS Raigmore Hospital – due to being the largest demand in the area and strategically located near the centre of any network routing. However, repeated attempts for engagement during the feasibility study were unsuccessful. After the study competition there is now seen to be increased interest from the NHS. As such the West side also appears to be attractive for heat network development.

The characteristics of these networks are summarised in this report in section 6.4, with more detail in the feasibility study. Section 6.4 also captures a theoretical full Raigmore network. The interest of the hospital may make a full Raigmore network more attractive and as such it is captured as a third option for the Raigmore area in the following sections. Additionally, if the full area is considered it provides an option for a heat network developer to phase deployment across the two sides of the A9 based on the timing of the new demands. This can be attractive from an investment perspective, with a large final network but a spread of capital investment.

5 Multi Criteria Analysis

After the different potential heat network zones are identified and characterized there is a need to compare and understand their viability for deliverability within the context of the KPIs outline by Highland Council. This is done using a multi-criteria analysis (MCA) approach. This characterizes the potential heat network zones based on various criteria. The MCA allows different levels of priority or weighting to be placed on certain criteria, helping to assess how much of a priority opportunity each potential heat network zone represents.

5.1 Assessment criteria

In total 20 different assessment criteria for the MCA were decided upon. These are based on the specified KPIs and the available data at a potential zonal level. These assessment criteria are described by theme (decarbonisation, deliverability, economic, and social) in sections 5.1.1 to 5.1.4. Within each of these sections the different criteria and their importance are described. This includes how important each criteria is to a private sector delivered heat network or a public sector (delivered network with a focus on Highland Council involvement).

5.1.1 Decarbonisation

The decarbonisation theme considers potential heat savings based on assumptions on current heating systems and also considers the low carbon heat supply opportunities in the area. A summary of the assessment criteria used is provided in Table 5—1.

Table 5—1 Summary of assessment criteria to explore the decarbonisation theme in the MCA.

Assessment criteria	Description	Importance to private sector delivery	Importance to public sector delivery
Carbon saving	Calculates the carbon dioxide saving using the DESNZ Heat Network Zoning tool or in the case of Raigmore the recent feasibility study. This is strongly linked to the heat demand in the zone.	Some heat network providers have internal targets relating to decarbonisation. Legislation is also driver of decarbonisation. Whilst private sector will decrease carbon it is not going to be the reason a particular heat network opportunity is selected over another.	With carbon reduction targets, particularly in their own estate, it is more likely to be a driver for public sector delivery than private sector.
Low carbon heat source (number and viability)	Considers the number of potential heat sources and how viable these are. A high score would be based on several low carbon heat sources, which are easily accessible.	Can be a key enabler for deployment. Rather than the low carbon nature the cost of the heat source will be a key consideration. For example, energy from waste even though it has a higher carbon footprint is likely to be favoured over a heat pump solution (because of lower cost). If a low carbon heat source is available at a lower cost than air source heat pumps this is likely to be a major driver for selection.	Similar considerations to the private sector.
Low carbon heat source potential supply	This focuses on the quantity of heat available and the economics of this compared to an air source heat pump. For example, a river source heat pump would not be able to score full marks in an MCA	Indicator of the feasibility of deployment. A high quantity of available low carbon heat is a positive. Possible purchase of the asset or other contractual	Similar importance to the private sector for network viability but generally lower

	as the economics of this potential supply does not offer a large improvement compared to air source heat pumps. In denser urban areas where space for large air source heat pumps is more constrained a greater weighting would be given to the quantity of available heat, however, in Inverness only the City Centre opportunity is spatially constrained.	arrangements for a key heat source are likely to be an area of interest.	likelihood for purchase of heat source.

5.1.2 Deliverability

The deliverability theme covers many assessment criteria. There can be a cross over between some of these items and the economic criteria, however, duplication is avoided to avoid inflating the importance of one criterion without making this an active decision. A summary of the assessment criteria used is provided in Table 5—2

Table 5—2 Summary of assessment criteria to explore the deliverability theme in the MCA.

Assessment criteria	Description	Importance to private sector delivery	Importance to public sector delivery
Council land	Based on the percentage of Highland Council owned land in each area. This is an important factor as it can aid and help de-risk pipework deployment.	Positive as one major and easy to engage land owner, easing pipe routing deployment.	Key opportunity for the Council to be a major stakeholder and influence the network - particularly if coupled with a high number of Council demands.
Demand from Highland Council buildings	This captures the demand from Highland Council buildings and also considers the percentage of overall demand from these buildings. The total heat demand from all loads is used to consider revenue but the demand from Highland Council buildings impacts deliverability as such buildings have less risk associated with likelihood to connect. Thus, a high demand from Highland Council buildings indicates a high likelihood of connection and ease of connection negotiation.	Easy stakeholder to engage, helping to derisk deployment as more likely guaranteed connection.	High level of Council influence means timing, strategy and ownership options for the Council are strongest. Also allows for easier tie in with local Council building decarbonisation targets and strategy. This is seen as a major positive for a network in which the Council has a stake.
Demand from public sector buildings	This is assessed in the same manner as Council owned buildings and for similar reasons.	Very similar to Highland Council buildings. Easy stakeholder to engage, helping to derisk deployment as more likely guaranteed connection.	Similar to the private sector development - still an important positive weighting but not as significant for Council involvement as their own buildings.
Dig type	The dig type impacts the level of disruption as well as the cost of the pipework deployment (this latter point is captured in the CAPEX). A high level of soft dig (e.g. playing field or footpath) is far less disruptive than hard dig (e.g. city centre roads). The DESNZ Heat	Key cost and delivery complexity, needs to be managed carefully to avoid negative public perception. Less intrusive dig is always preferable.	Possibly even more significant for the public than private sector, due to road disruption commonly being associated with the Council. Consideration of other planned road closures and

	Network Zoning tool considers soft, sub-urban and urban dig - the assessment for this work aligns to this with a high level of hard dig being scored negatively and a high level of soft dig positively.		maintenance to reduce impact.
Number of connected buildings	Details the number of buildings connected in each scenario. The accompanying strategic report provides information as to the type of buildings connected in each scenario. This impacts both the economic elements as this impacts revenue but also the deliverability as a large number of properties derisks the network. Consequently, the number of connections is captured in the deliverability whilst the demand is in the economic section.	Having a large number of potential connections (so long as they are of a reasonable size - this is a screening criteria) can help spread the risk, as if one load does not connect it does not impact the network. It can also allow some phasing of deployment which is a positive from a private sector perspective, as it can help spread capital investment.	Similar to the private sector, however larger networks with more connections will be harder to manage.
Number of existing heat networks/communal systems	This uses a combination of Home Analytics and the Scotland Heat Map and some local data gathering to identify existing communal and heat network systems. These existing networks are likely to connect into larger schemes and may also have available plant room to aid deployment, improving deliverability. Additionally, depending on their scale and central government legislation there may be a requirement to connect to wider networks.	Similar consideration to other large loads, dependent on scale and ownership but their presence is a positive.	Similar to the private sector, although there is even greater impact of ownership and social factors such as fuel poverty. These would need to be explored on a case-by-case basis, but it is not a major opportunity in Inverness due to a low number of existing heat networks and communal systems.
Number of Highland Council buildings	Is based on the total number of Highland Council connections. As with demand from Highland Council buildings this helps de-risk connections, improving deliverability.	Similar to demand from Council buildings. Having a large number of demands can also help spread certainty of different areas of the network being deployed, this needs to be explored spatially.	As with demand form Council buildings this can be a key driver for a high level of Council involvement. Similarly to the public sector it can help determine the extent of a network in an area.
Number of public sector buildings	This is assessed in the same manner as Council owned buildings and for similar reasons.	Similar to the impact of numbers of public sector buildings.	Very similar impact to the private sector but having a greater level of influence will often increase significance.
Planned growth in the area	Draws on planning data, considering the number, type and size of developments. A high number of new developments can provide an opportunity for simplified connections (rather than relying on retrofit). New developments can also offer opportunities for hosting a plant room - particularly if there is a high level of Council involvement.	This allows the ability to phase development, which is very attractive from a cashflow perspective. Additionally, new developments and demands are generally easier to connect and can be a trigger for deployment.	The cash flow is still important but generally less so than the private sector, the other factors are of a very similar level of significance.

5.1.3 Economic

The economic theme gives various indicators to the likely economic performance of a heat network in the potential zone. These values are indicative only and should not be used for investment decisions. A summary of the assessment criteria used is provided in Table 5—3.

Table 5—3 Summary of assessment criteria to explore the economic theme in the MCA.

Assessment criteria	Description	Importance to private sector delivery	Importance to public sector delivery
CAPEX/MWh thermal	This considers the total cost (derived from either the DESNZ Heat Network Zone assessment tool or feasibility studies) divided by the total demand in the area. This is used rather than a pure CAPEX to provide an indicator of how the system performs in terms of capital expenditure per unit of heat delivered. These costs are high level and indicative rather than a true financial model.	Being the main economic metric, this is key as it is an indicator of how quickly investment is likely to be paid back.	As with private this is a key factor, however, slightly lower rates of return can be acceptable due to loan and funding options in the public sector. So, whilst it is still significant generally a slightly lower importance than the private sector.
Demand from anchor loads	Considers the total thermal demand from anchor loads. These large consumers are key drivers of heat network economic viability. There is a risk if a large amount of demand is from one anchor load, if this does not connect it impacts the whole network viability.	A key metric, high demand from anchor loads means less onerous stakeholder engagement to deliver a viable network.	Important to consider but somewhat less so than the private sector. If large anchor loads are Council owned this makes it more significant, but these factors are also considered elsewhere.
Demand from connected buildings	The total heat demand (annual rather than peak) for the buildings connected in the scenario. This determines the likely heat sales and thus likely revenue.	A key metric shows the potential scale of the scheme. Private sector investment is more likely to be achieved for larger schemes due the potential scale of the final opportunity.	Whilst this can be important for public sector involvement it will be balanced by other factors, such as Council assets.
Linear heat density (MWh/m/yr)	This is based on the heat demand per meter of pipe from the indicative pipe routings generated during feasibility or the Steiner analysis (see the accompanying strategic report for details). The linear heat density is one of the key economic indicators for a heat network, with a high value indicating improved economic viability. Low heat densities can be offset by factors such as very cheap heat sources and easy dig.	Key early-stage indicator of network economic viability is a key concern to the private sector.	Economic viability indicated by this is highly important to public sector schemes (including ability to access funding) but can be somewhat offset by other factors such as a high level of their own estate being included, reducing costs or wider societal benefits such as addressing fuel poverty offsetting the relative importance.
Number of anchor loads	Provides a total count of anchor loads. These large single points of connection are a key economic driver of viability and pipework routing.	Very important a relatively high portion of large energy consumers helps viability of the network and eases engagement and delivery. A	Similar to the private sector, however, the public sector being more concerned with a high number of Council

		large number of anchor loads alongside a large anchor load demand helps increase network viability as if the network is too reliant on one large anchor load (such as the Maltings in Longman) the overall network viability is at significant risk of the large heat demand does not connect.	properties does reduce the relative importance, with number of core connections as well as items in the deliverability section significant related factors.
Number of core connections	Similarly to anchor loads core connections are an indicator of large loads that are likely to connect. For the core scenario this will be the same as the total number of loads in deliverability. Its inclusion in the economic section is similar to that of anchor loads.	Similar to anchor loads.	Similar to the private sector but slightly more important as it also accounts for ownership, weighting towards Council connections - which can help improve operating costs for the Council's Estate.

5.1.4 Social

The social theme considers fewer criteria than the others, in part as the level of analysis at this stage makes consideration of the more precise social impacts harder. However, social characteristics of the potential zone overall can be measured, with the two parameters explored detailed in Table 5—4.

Table 5—4 Summary of assessment criteria to explore the social theme in the MCA.

Assessment criteria	Description	Importance to private sector delivery	Importance to public sector delivery
Fuel poverty	Provides the average fuel poverty score in the heat network area based on Home Analytics. This does not consider heat network connection but rather the characterisation of the area as a whole. Areas with negligible or no housing (such as Longman) have a score of 0 for this indicator.	Whilst private sector heat network developers will consider fuel poverty abatement in an area it is unlikely to be a driver for them.	Can be a key target for encouraging deployment in an area.
Total social housing number	Provides a count of social housing in the area based on Home Analytics. Again, this does not consider connection to the heat network but rather the presence of this housing type in the area. Areas with negligible or no housing (such as Longman) have a score of 0 for this indicator.	Similarly to fuel poverty not often a driver. However, a high level of social housing would often be preferred to a high level of normal housing due to fewer stakeholders to engage.	As with the private sector can be seen as enabler, due to easy stakeholder engagement. Particularly when combine with high fuel poverty this is likely to be a driver.

5.2 Applying the assessment criteria

Based on values derived from the analysis carried out in the strategic work, an accompanying feasibility study for Raigmore, and a review of previous studies, each of the potential heat network zones is assigned a number between 0-1 in the MCA tool. With 1 being the potential zone performs as well as is feasibly possible against the desired criteria (for example, if the area was entirely owned by the Highland Council it would score a 1 against the *Council land* criteria) and 0 shows it does not contribute in any way to that criterion (for example, if there is no housing it will score 0 measured against fuel poverty). This approach was selected rather than a pure ranking for two key reasons, having relatively few potential zones limits the suitability of ranking, ranking does not differentiate in a useful way between two similar values (for example, a linear heat density of 6.2 MWh/m/yr at this level of analysis is not substantially different to one of 6 MWh/m/yr but a ranking would draw out a large difference).

The approach taken means that for many criteria none of the potential heat network areas would score the maximum of 1. An example of a reason for this is no highly economic heat sources were identified; these would typically include energy from waste plants or large data centres. However, it is the relative performance of each potential zone against the others that is most important for informing the strategy.

The accompany *Inverness strategic heat network support MCA tool* provides a breakdown of these scores. A video has also been recorded alongside the tool provide guidance on how it can be used. This is meant as an internal tool for THC.

The video includes a description of how the weightings of different criteria can be adjusted, this is also explored briefly in section 5.2.1. The MCA score between 0 and 1, alongside the different ratings are used to give each potential zone a percentage rating. It is important to note that the MCA tool is not used to screen out potential zones, this should be done through review of section 4, it is used to compare and prioritise the potential zones.

The values siting behind the MCA are relative to each other but not ranked. As a result even if a potential zone is the best performing in a certain characteristic it does not necessarily a value of 1. An example of this is related to social housing, none of the potential areas have particularly high level of social housing so no zones are scored the maximum value of 1. This avoids placing undue weight onto a characteristic, which may be of interest to THC but in reality none of the potential zones perform particularly well by this measure. Similarly, if all potential zones perform in a similar manner it is important that any minor differences are not over emphasised.

5.2.1 Applying weightings

The MCA tool is highly flexible allowing weightings to be adapted by the user. This includes a manual approach where the user can manually define the relative weighting of each of the twenty different criteria listed in section 5.1.

The simpler adaption method is to give a weighting to the different themes, these automatically splits the weightings even across each of the criteria in the theme. This theme based adjustment is done by altering the percentage split for each theme shown in Figure 5—1.

Theme	Percentage split
Decarbonisation	25
Deliverability	25
Economic	25
Social	25
Total	100

Figure 5—1 Screenshot of theme based MCA weighting adjustment table.

This is summarised, alongside the relative weighting it gives the various criteria in a graph below the table, the corresponding weighting to the above example are provided in Figure 5—2.

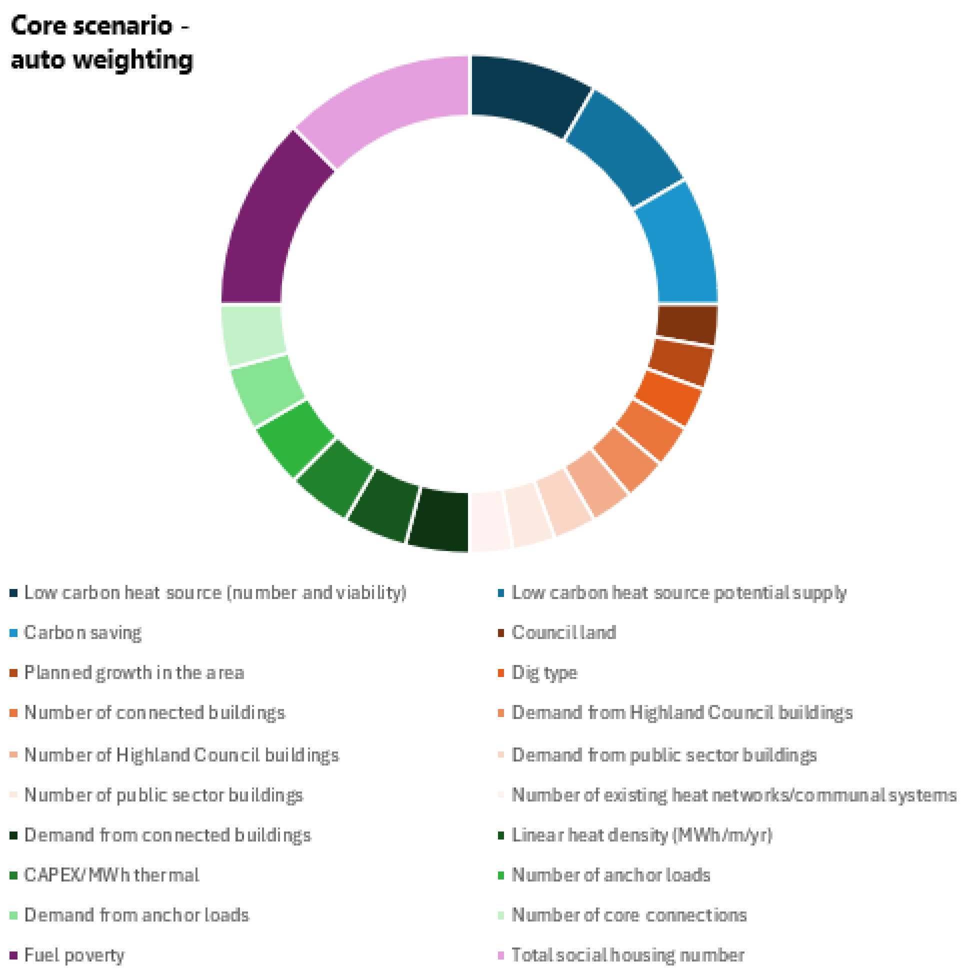


Figure 5—2 MCA theme weighting summary from an auto weighting approach.

It is likely that the greatest emphasis will be placed on deliverability and economic factors. If the percentage share is upped for these it is important to decrease the percentage shares for social and decarbonisation factors, the user should ensure these always add up to 100.

The manual adaption can be used to explore just one criterion or explore a combination of them these, an example is provided exploring just economic and deliverability factors in Figure 5—3.

Figure 5—3 MCA theme weighting summary from a manual weighting approach.

The application of these weightings will then give each potential heat network zone a summary score, with the theoretical maximum being 100%. However, as mentioned previously very few criteria hit the maximum score of 1 in the MCA and thus a score of 100% is not expected to be reached. Although it is purely an indication anything over 60% can be considered a good score, the interpretation of results is explored further in 5.2.

5.2.2 Interpreting results

An example of the scores achieved for some of the potential heat network zones is provided in Figure 5—4. This summary is for the same weightings as outlined in section 5.2.1.

Connection scenario and weighting criteria	West Bank	City Centre	Longman Full	Longman Full + Bairds	Longman West	Longman West + Bairds	Raigmore (combined)	Raigmore (West)	Raigmore (East)
Core auto weighting	59	44	26	39	22	37	63	54	34
Core manual weighting	60	46	23	51	19	52	54	45	42

Figure 5—4 Screenshot of MCA summary score.

The summary show that for the selected weightings the Raigmore combined network performs best in the auto weighting and West Bank for the manual weighting. For the manual weighting (which only considers economic and deliverability criteria) both the potential Longman zones which include Bairds Maltings perform better than City Centre. This is due to the presence of maltings increasing the quantity of heat demand and thus the overall economic performance.

The significance of Bairds Maltings does somewhat skew the MCA, being by for the largest overall load considered in the strategic analysis. It is useful to contrast the Longman zones with and without the Maltings – the difference in scores highlights how important it is at this high level of analysis for driving a zone.

In both selections the City Centre does not perform particularly well, despite having high heat density. This is due to multiple factors including the lack of public sector demands and also various factors relating to increased dig complexity. The potential alignment with SSEN planned work in the area may help improve the deliverability and its relative performance.

A summary of the relative scorings for the core and the core + infill scenarios are provided in Table 5—5 and Table 5—6 respectively – on the next two pages. As highlighted previously it is important to note that the different Raigmore networks examined have the same values for each scenario. The tables are colour coded (aligning to the colour palette outlined in Figure 5—1), with a greater depth of colour representing a higher score and more positive weighting.

Various sensitivities were assessed using the MCA tool to help inform the strategic summary in section 6.

Table 5—5 Summary of weighting criteria values for the core scenario - scored 0 to 1 based on measured data

Core Scenario Zone Assessment	West Bank	City Centre	Longman Full	Longman Full + Bairds	Longman West	Longman West + Bairds	Raigmore (combined)	Raigmore (West)	Raigmore (East)
Low carbon heat source (number and viability)	0.4	0.25	0.5	0.5	0.5	0.5	0.75	0.75	0.5
Low carbon heat source potential supply	0.5	0.25	0.75	0.75	0.75	0.75	0.5	0.5	0.5
Carbon saving	0.6	0.55	0.3	0.77	0.15	0.72	0.8	0.6	0.4
Council land	0.75	0.1	0.55	0.55	0.7	0.7	0.15	0.2	0.05
Planned growth/development in the area	0.05	0.4	0.2	0.2	0.2	0.2	0.7	0.6	0.85
Dig type	0.5	0.25	0.3	0.3	0.3	0.3	0.3	0.3	0.4
Number of connected buildings	0.8	0.7	0.5	0.5	0.2	0.2	0.9	0.55	0.7
Demand from connected buildings	0.55	0.5	0.2	0.75	0.15	0.7	0.85	0.65	0.5
Demand from Highland Council buildings	0.75	0.15	0	0	0	0	0.2	0.2	0
Number of Highland Council buildings	0.6	0.15	0	0	0	0	0.3	0.3	0
Demand from public sector buildings	0.4	0.1	0.25	0.25	0.25	0.25	0.9	0.7	0.7
Number of public sector buildings	0.5	0.1	0.25	0.25	0.25	0.25	0.9	0.45	0.8
Number of existing heat networks/communal systems	0.3	0.25	0	0	0	0	0.2	0.2	0
Linear heat density (MWh/m/yr)	0.5	0.75	0.1	0.72	0.1	1	0.55	0.56	0.5
CAPEX/MWh thermal	0.65	0.4	0.2	0.8	0.2	0.8	0.4	0.42	0.4
Number of anchor loads	0.75	0.8	0.65	0.7	0.3	0.35	0.85	0.3	0.65
Demand from anchor loads	0.65	0.6	0.25	0.82	0.3	0.8	0.9	0.75	0.55
Number of core connections	0.8	0.7	0.5	0.5	0.2	0.2	0.9	0.55	0.7
Fuel poverty	0.7	0.8	0	0	0	0	0.5	0.5	0
Total social housing number	0.7	0.3	0	0	0	0	0.75	0.75	0

Table 5—6 Summary of weighting criteria values for the core + infill scenario - scored 0 to 1 based on measured data

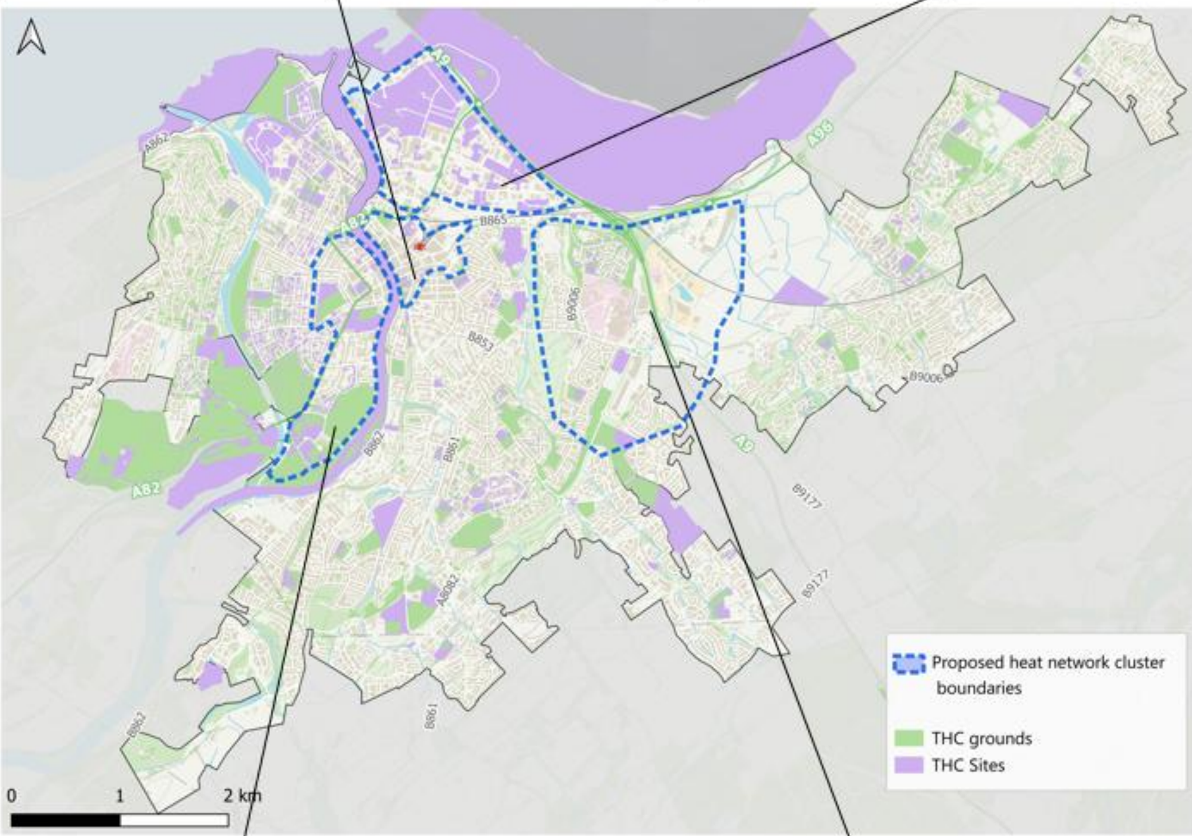
Core + Infill Scenario Zone Assessment	West Bank	City Centre	Longman Full	Longman Full + Bairds	Longman West	Longman West + Bairds	Raigmore (combined)	Raigmore (West)	Raigmore (East)
Low carbon heat source (number and viability)	0.4	0.25	0.5	0.5	0.5	0.5	0.75	0.75	0.5
Low carbon heat source potential supply	0.5	0.25	0.75	0.75	0.75	0.75	0.5	0.5	0.5
Carbon saving	0.7	0.68	0.5	0.82	0.2	0.74	0.8	0.6	0.4
Council land	0.75	0.1	0.55	0.55	0.7	0.7	0.15	0.2	0.05
Planned growth/development in the area	0.05	0.4	0.2	0.2	0.2	0.2	0.7	0.6	0.85
Dig type	0.5	0.25	0.3	0.3	0.3	0.3	0.3	0.3	0.4
Number of connected buildings	0.85	0.9	0.5	0.5	0.2	0.2	0.9	0.55	0.7
Demand from connected buildings	0.71	0.74	0.4	0.86	0.2	0.78	0.85	0.65	0.5
Demand from Highland Council buildings	0.77	0.15	0.1	0.1	0.05	0.05	0.2	0.2	0
Number of Highland Council buildings	0.75	0.2	0.2	0.2	0.1	0.1	0.3	0.3	0
Demand from public sector buildings	0.45	0.2	0.3	0.3	0.2	0.2	0.9	0.7	0.7
Number of public sector buildings	0.62	0.62	0.45	0.45	0.3	0.3	0.9	0.45	0.8
Number of existing heat networks/communal systems	0.3	0.25	0	0	0	0	0.2	0.2	0
Linear heat density (MWh/m/yr)	0.4	0.55	0.11	0.55	0.12	1	0.55	0.56	0.5
CAPEX/MWh thermal	0.4	0.35	0.22	0.65	0.23	1	0.4	0.42	0.4
Number of anchor loads	0.75	0.8	0.65	0.7	0.3	0.35	0.85	0.3	0.65
Demand from anchor loads	0.65	0.6	0.25	0.82	0.3	0.8	0.9	0.75	0.55
Number of core connections	0.8	0.7	0.5	0.5	0.2	0.2	0.9	0.55	0.7
Fuel poverty	0.7	0.8	0	0	0	0	0.5	0.5	0
Total social housing number	0.7	0.3	0	0	0	0	0.75	0.75	0

6 Strategic overview and summary

There four areas examined for heat networks all have distinct characteristics, these are summarised at a high level in Figure 6—1 (please note the background THC areas indicate land rather than building ownership).

City Centre – high number of private sector stakeholders/demands, limited public sector land ownership, limited heat sources, trigger points include Rose Street/Network Rail related development and potential SSEN roadworks.

Longman – best heat source, active SSE and SWH partnership, high level of THC ownership, two large industrial demands key drivers, low level of public sector demand.



West Bank – high level of THC demand, high level of THC land ownership, east side high public land ownership (HIE rather than THC), relatively simple dig, good ability to phase.

Raigmore – high level of public sector demand, recent increased NHS interest, east side high public land ownership (HIE rather than THC), Freeport development key trigger point (generally high level of planned/ongoing development), possible SWH heat source.

Figure 6—1 High level summary of some key strategic items the four heat network areas examined.

A more detailed summary of each area is presented in sections 6.1 to 6.4, this includes consideration of factors including heat source, amount and type of demand, land ownership, trigger points for development, and economic indicators. One of the key indicators discussed is the £k/MWh (showing what the total CAPEX is against energy generation per annum). Providing a good indication (but not a full economic analysis) of how a heat network performs. As a general rule of thumb, a network would not be expected to achieve less than 0.7 £k/MWh (although less would indicate a highly viable network but such a low value is rarely observed) and anything more than 1 £k/MWh is likely to require optimisation. This is based on previous BuroHappold studies and reporting of heat network feasibility studies in England through Heat Network Zoning and the Heat Network Development Unit. Whilst feasibility studies provide more detailed economic measures, such as internal rate of return, this is a useful early stage economic indicator. It should be viewed alongside 21 different values are generated for each heat network scenario, that are reported – and form the basis of - the summaries provided below.

6.1 West Bank summary

A summary of key assessment criteria for West Bank is provided in Table 6—1. This considered alongside the greater detail provided in section 4.1 to give an understanding of the character of the West Bank. Although all the indicators are likely to be of interest LHD, CAPEX £/kW/MWh thermal and those relating to anchor loads are the most important form an economic perspective, whilst the Council land (share) and number of Highland Council buildings and number of public sector buildings are key from a deliverability perspective.

Table 6—1 West Bank summary of assessment criteria.

Assessment criteria	Core	Core + Infill
Linear heat density	4.62	3.5
Low carbon heat source number	ASHP, GSHP, WSHP	ASHP, GSHP, WSHP
Low carbon heat source potential supply	Medium	Medium
Council land (share)	46.80%	46.80%
Planned growth in the area	Low	Low
Carbon saving TCO2e over 40 years	158175	224748
CAPEX £m	20.3	37.1
CAPEX £k/MWh thermal	0.85	1.12
Fuel poverty (mean)	29%	29%
Count of properties with fuel poverty probability over 50%	162	162
Dig type (hard)	58%	64%
Number of anchor loads (>=500MWh/yr)	13	13
Demand from anchor loads (MWh/yr)	20339	20339
Number of core connections	23	23
Demand from modelled connections	24015	33213
Number of connected buildings	23	94
Demand from Highland Council buildings	13569	14291
Number of Highland Council buildings	8	14

Demand from public sector buildings	4565	5069
Number of public sector buildings	8	12
Total social housing number	419	419
Number of existing heat networks/communal systems	4	4

Despite having a relatively low LHD low dig costs help to keep costs down, with the core connections achieving a CAPEX £k/MWh of 0.85 (based on previous BuroHappold studies and DESNZ publications a CAPEX £k/MWh of 0.7-1 would generally be expected at this level of analysis for a potential heat network). The infill connections reduce the linear heat density indicating the size of the network needs to be constrained, at least initially, to maximise viability. The infill connections in the northern part of the West Bank increase the overall pipe length, with the loads being relatively small and the dig more challenging than other parts of the area (seen by the increase in % of hard dig).

The high Council influence both in terms of land and assets makes THC well placed to drive delivery of a heat network in the West Bank area. The high level of social housing and risk of fuel poverty means it is well aligned to a high level of Council influence. There is a risk in more commercially driven that these smaller domestic connections may not be a focus. Council influence should help ensure they are fully considered.

These housing connections and those around Eden Court and the Highland Council HQ would be the second part of the network if a phased approach is selected. The leisure centre area is a suggested first phase with early action to align to the planned work at the leisure centre.

The suggested approach for West Bank is to focus on the area between the southern area A82 and B861 and the river, with the only demand that is a focus for connection outside of this being the Inverness High School.

The heat source appraisal does not capture waste heat from the potential data centre in the area as the status of this project is very early stage. This is considered in later in section 6.6.

In conclusion the West Bank area presents a good heat network opportunity, with a high level of THC land ownership and large THC demands. The soft dig in the area offsets a relatively low LHD (but still above 4), this could be improved by a more optimised network design. The CAPEX £/MWh/yr measure of 0.85 for the core connections scenario is indicative of economic viability at this level of analysis.

6.2 Longman summary

The key assessment criteria are summarised in Table 6—2 in Table 6—3, covering the core and core + infill scenarios respectively.

Table 6—2 Longman summary of assessment criteria for core scenarios.

Assessment criteria	Longman Full	Longman Full + Bairds	Longman West	Longman West + Bairds
Linear heat density	2	7.4	1.97	11.61
Low carbon heat source number	ASHP Wastewater	ASHP Wastewater	ASHP Wastewater	ASHP Wastewater
Low carbon heat source potential supply	Medium/High	Medium/High	Medium/High	Medium/High
Council land (share)	38.30%	38.30%	44.30%	44.30%

Planned growth in the area	Low	Low	Low/Moderate	Low/Moderate
Carbon saving TCO2e over 40 years	62789	258888	34039	230710
CAPEX £m	17.5	27.7	9.38	19.23
CAPEX £k/MWh thermal	1.72	0.69	1.71	0.54
Dig type (hard)	67%	67%	67%	67%
Number of anchor loads (>=500MWh/yr)	12	13	6	7
Demand from anchor loads (MWh/yr)	9693	39693	5480	35480
Number of core connections	14	15	6	7
Demand from modelled connections	10180	40180	5480	35480
Number of connected buildings	14	15	6	7
Demand from Highland Council buildings	0	0	0	0
Number of Highland Council buildings	0	0	0	0
Demand from public sector buildings	2345	2345	1858	1858
Number of public sector buildings	4	4	2	2

Table 6—3 Longman summary of assessment criteria for core + infill scenarios.

Assessment criteria	Longman Full	Longman Full + Bairds Malting	Longman West	Longman West + Bairds
Linear heat density	2.15	5.2	2.37	10.22
Low carbon heat source number	ASHP Wastewater	ASHP Wastewater	ASHP Wastewater	ASHP Wastewater
Low carbon heat source potential supply	Medium/High	Medium/High	Medium/High	Medium/High
Council land (share)	38.30%	38.30%	44.30%	44.30%
Planned growth in the area	Low	Low	Low/Moderate	Low/Moderate
Carbon saving TCO2e over 40 years	129029	325753	50333	247538
CAPEX £m	33.75	41.97	12.48	22.2
CAPEX £k/MWh thermal	1.60	0.82	1.51	0.33

Dig type (hard)	67%	67%	67%	67%
Number of anchor loads (>=500MWh/yr)	12	13	6	7
Demand from anchor loads (MWh/yr)	9693	39693	5480	35480
Number of core connections	14	15	6	7
Demand from modelled connections	9965	51029	5480	38244
Number of connected buildings	47	48	16	17
Demand from Highland Council buildings	442	442	169	169
Number of Highland Council buildings	3	3	1	1
Demand from public sector buildings	2670	2670	2183	2183
Number of public sector buildings	6	6	4	4

Without Bairds Malting (the Tarmac plant was not captured in the analysis but from the strategic perspective can be grouped with the Maltings site in terms of messaging) the potential heat network performs poorly on key indicators such as LHD and CAPEX £k/MWh/yr thermal. The low-cost heat source in the area will help mitigate this to an extent, and there could be dig cost savings, but based on this analysis the economics would still be questionable – as the key LHD indicator will still be under 2.5 in all instances.

The addition of Bairds Maltings and the Tarmac plant are thus seen as key to making a network in the area financially attractive – reflected by the high LHD and low CAPEX £k/MWh/yr when the Maltings is included.

As discussed previously the West area is seen as the most promising area for deployment. The LHD increases with the infill connections, showing that these can be picked up without limited additional branches to the network. However, it also shows the importance of stakeholder engagement (much of which is private) to increase network viability.

THC has very limited heat demand in the area but does have a large share of land ownership, particularly around the strategic sewer pumping station (which is a source of low cost and low carbon heat). This means that THC could be a key enabler of a heat network in the area. This approach is enhanced by the SWH/SSE collaboration in the area, which is seen as the key driver for a heat network. THC influence will be useful for any wider strategic elements including the potential role of Longman for providing heat to the city Centre or as a path for wider heat transmission through the area.

In conclusion the strategic partnership between SWH and SSE is seen as a key driver for a heat network in Longman. The area has the best low carbon heat source identified in any of the heat network areas in Inverness, which improves the attractiveness of the area. THC being a key land owner in Longman is seen as a key enabler for heat network deployment. Without two large private sector industrial loads connecting the LHD and CAPEX £k/MWh/yr indicators perform poorly for the area, highlighting the importance of private sector stakeholder engagement at an early stage.

6.3 City Centre summary

The City Centre heat network opportunity is summarised in Table 6—4.

Table 6—4 City Centre summary of assessment criteria.

Assessment criteria	Core	Core + Infill
Linear heat density	7.77	5.57
Low carbon heat source number	ASHP, GSHP	ASHP, GSHP
Low carbon heat source potential supply	Low	Low
Council land (share)	9.70%	9.70%
Planned growth in the area	Moderate/High	Moderate/High
Carbon saving TCO2e over 40 years	129600	213782
CAPEX £m	22.94	45.66
CAPEX £k/MWh thermal	1.08	1.40
Fuel poverty (mean)	36%	36%
Count of properties with fuel poverty probability over 50%	44	44
Dig type (hard)	67%	67%
Number of anchor loads (>=500MWh/yr)	16	16
Demand from anchor loads (MWh/yr)	20457	20457
Number of core connections	17	17
Demand from modelled connections	21154	32640
Number of connected buildings	17	107
Demand from Highland Council buildings	697	697
Number of Highland Council buildings	2	3
Demand from public sector buildings	517	2193
Number of public sector buildings	1	12
Total social housing number	153	153
Number of existing heat networks/communal systems	3	3

The City Centre is typical of many heat network opportunities in urban areas of Scotland, with a high heat density (reflected in a LHD of 7.77 for the core connections). However, the dig complexity drives up the CAPEX £k/MWh value to over 1 in both the Core and Core + Infill scenarios. SSE have planned cable upgrades in the area which could act to decrease trenching costs for the heat network – dropping the CAPEX £k/MWh value. SSE’s high level of interest should help achieve this alignment. There are also substantial public perception benefits for aligning the work, minimizing disruption and demonstrating a cogent strategy helping to build confidence.

Whilst there is not a high level of housing in the City Centre the properties that are there are seen as having a high likelihood of being in fuel poverty. As such it is important that these are not neglected from a heat network strategy in the area. The somewhat limited social housing would provide a good starting point for connection but there would also need to be engagement of the private housing sector. Fortunately, these domestic connections are unlikely to have a large impact on main pipe routing or sizing.

The relative lack of THC or broader public sector heat demands means engagement of anchor loads is likely to be more challenging. Early engagement of these private sector anchor loads will thus be key, to encourage sign up to the scheme. Thus, this is considered an important focus for understanding how viable a heat network is in the short term, as it is these large private sector loads that will be key to driving pipe routing in the area.

The relative low level of heat resource and space for ASHP means interconnection to Longman for heat could be important for driving viability. However, the Rose Street redevelopment and National Rail showing interest in hosting an energy centre means that for this level of study it is considered viable to heat the City Centre network without relying on broader interconnection (although this may not be the most attractive option). The Rose Street area is one of the few parts of the City Centre where THC own a substantial amount of land, which along with the strategic location make it well suited for an energy centre. Similarly to Longman this makes THC a key enabler for a heat network but the relative lack of influence in terms of demands means it is considered less of a focus for THC led development than the West Bank.

In conclusion the City Centre presents a good opportunity for a heat network with a high demand density. However, the dig complexity (with a high level of hard dig) indicates that the cost of network construction will be high – planned work by SSEN could help mitigate these costs by reducing the civils costs associated with digging up the roads. The heat network has little public sector influence in terms of land or demand ownership, increasing the complexity of stakeholder engagement. The planned development in the Rose Street area and planned work by National Rail creates an opportunity for constructing an energy centre in what is a spatially constrained area of Inverness. There is also potential to link with the Longman area, and its large waste heat sources, but this requires more detailed analysis; including the economics of such a connection and the amount of waste heat that will be used within the Longman area. If the majority of the heat is used in Longman (which is likely the case if the Maltings and Tarmac plant are connected) the quantity of low cost heat that can be supplied to the City Centre will reduce, reducing the benefit of interconnection.

6.4 Raigmore summary

A summary of the heat network options for Raigmore is provided in Table 6—5. It is important to reiterate Raigmore was appraised slightly different to the other three areas of Inverness. As such only one set of scenarios are presented for the three different heat network options.

The cost of crossing the A9 is not included in the Raigmore full network, this would depend on structural assessment of the Golden Bridge. Depending on the results of this the interconnection of the two sides of the A9 would be expected to cost in the range of £1-5 million based on the DESNZ indicative values provided in Table 3—3 (likely in the middle of this range).

Table 6—5 Raigmore summary of assessment criteria.

Assessment criteria	Raigmore full	Raigmore West	Raigmore East
Linear heat density	5.02	5.4	4.6
Low carbon heat source number	ASHP, GSHP, sewer	ASHP, GSHP	ASHP, GSHP, Sewer
Low carbon heat source potential supply	Medium	Medium	Medium

Council land (share)	12%	18%	1%
Planned growth in the area	Moderate/High	Moderate/High	High
Carbon saving TCO2e over 40 years	270611	191367	79244
CAPEX £m	54.34	26.04	28.3
CAPEX £k/MWh thermal	1.12	0.93	1.24
Fuel poverty (mean)	n/a	n/a	n/a
Count of properties with fuel poverty probability over 50%	n/a	n/a	n/a
Dig type (hard) – this is assessed differently to the other three areas	91%	100%	81%
Number of anchor loads (>=500MWh/yr)	20	8	12
Demand from anchor loads (MWh/yr)	45361	26381	18980
Number of core connections	38	15	23
Demand from modelled connections	48667	27917	20750
Number of connected buildings	38	15	23
Demand from THC	835.5	835.5	0
Number of THC buildings	4	4	0
Demand from public sector buildings	25362	12782	12580
Number of public sector buildings	24	6	18
Total social housing number	n/a	n/a	n/a
Number of existing heat networks/communal systems	n/a	n/a	n/a

This table is based on the results of the Raigmore feasibility study. This focused on the large loads which drive heat network viability. The lack of large blocks of flats means social housing numbers and fuel poverty were not captured as there were no domestic considered in the feasibility. Additionally, there was a heat network marked on the SHM in the Wimberley area – the MOD were engaged to provide more information, but no additional data was forthcoming. Based on a review of the area it was considered that the scale of the heat network was overestimated in the SHM (>1 MW of heat plant) and not considered as a strategic connection – this was also due to the lack of engagement from the MOD. It should be noted as they contain multiple buildings both the main Raigmore Hospital complex and the associated accommodation blocks could be considered heat networks. However, they are not included as heat networks and as the loads are captured elsewhere in the table they are not included in Table 6—5.

The considering of strategic demands means the factors associated with domestic properties are not captured in the Raigmore feasibility study (i.e. social housing number and fuel poverty). The main areas which would contribute to these numbers in Raigmore are in the northwest – in the Raigmore Estate and Wimberley areas. These contain both social housing and indicators of fuel poverty. Indicative values for these are included in the linked MCA tool.

The feasibility study assumed a high portion of hard dig, it is likely that with the nature of the Raigmore area this dig could be easier than modelled. This will help drive down costs and viability but even with this elevated cost assumption the feasibility study and associated options appraisals indicates with grant funding all of the network options in Raigmore could be economically viable. The increased engagement of the hospital is a key factor driving the improved viability on the network.

Although the summary table indicates a low level of THC land ownership it is important to reiterate the significance of HIE as a landowner, particularly on the East. Factors like this are why it is important to examine standardised outputs, like those in Table 6—5, as an initial indicator but to also consider more localised information and insights.

In conclusion the Raigmore area presents viable heat network opportunities. The engagement of the NHS will be key for driving a network to the West of the A9 where the LHD and CAPEX £/MWh/yr measures appear to be promising (5.4 and 0.93 respectively). On the East of the A9, the planned Freeport development will be key to driving a heat network, the LHD and CAPEX £/MWh/yr (4.6 and 1.24 respectively) indicate a slightly less favourable network. However, this is offset by a likely reduction in cost due to high dig costs being assumed in the area and the economic effectiveness of connecting a new site (the Freeport development). For both sides of the A9 there are large number of public sector anchor loads, meaning engagement is likely to be straight forward if the option is taken to progress the heat network opportunities. On the East of the A9 the high level of ownership by HIE will further ease the engagement process.

6.5 Interactions between heat network zones

When considering large scale strategic interaction between heat network opportunities it is important to understand the key drivers for interaction. These can be broken down to push or pull factors:

- **Push factors** relate to a drive to export heat from an area or a low-cost heat source acting to push interconnection in the area itself. This will generally be a large-scale heat source which either exceeds the heat demand nearby or is an area which is not well suited to heat network deployment.
- **Pull factors** are those which drive import of heat to an area. This will often be related to a highly attractive heat dense area. At the strategic level another pull factor could be the lack of heat supply potential within the area to meet the heat network opportunity. Other pull factors could be societal indicators such as fuel poverty – prioritising these areas for the lowest cost source of heat.

These are summarised for the different areas in Table 6—6. In Inverness there is generally a stronger set of pull than push factors within zones, which would generally lead to a lack of interconnection.

Table 6—6 High level summary of push and pull factors for different potential heat network areas in Inverness.

Area	Push factors	Pull factors
West Bank	Very few, potentially some benefit from the River Ness but would require detail assessment to demonstrate superior economics to ASHP or GSHP. High level of THC land ownership would aid broader push of heat if suitable.	High level of THC demands key driver for heat networks in the area.
Longman	SW pumping station is the most promising heat asset identified in Inverness. Potential route for electrolysis waste heat from adjacent hydrogen production site in planning. High level of THC land ownership allowing effective push of heat from the area.	Two large industrial demands but otherwise relatively few pulls for heat to the area.

	Justice Centre well located for a strategic connection for any push to wider heat interconnection. Large amount of available land near heat source provides space for a large EC and the potential for associated thermal storage.	
City Centre	Very limited push factors, no major heat sources and spatially constrained.	High heat demand density.
Raigmore	Some waste heat potential from the sewer was shown to perform in a similar manner to ASHP, ongoing SWH activity in Inverness may help drive down costs for this technology.	Large number of public sector anchor loads.

The Longman area is the only one with significant positive push factors out of the area. The geographic proximity to the City Centre, which would have the greatest difficulty generating heat locally, means that interconnection could be considered.

Challenges for this include the danger of a relatively low-density connection route through the Longman site to the City Centre. It will be important to maximise connections on this route (such as the Justice Centre) to help improve viability of the connection. The redevelopment in the Rose Street area of Inverness is also well located for any route connecting Longman and the City Centre, which would be important to consider in any detailed layout options for the network. There is increased complexity in strategic alignment over large, interconnected areas, which is considered further in 6.6.

Both the West Bank and Raigmore areas are, based on the findings of this work, initially better placed to consider in isolation. They have suitable land and heat sources to supply their own potential networks and there are good local pull factors in terms of heat demands and land ownership. For Raigmore although the feasibility study considered the East and West sides of the A9 separately it is still important to consider the area as a whole:

- The increased interest of the hospital since the feasibility study was completed helps derisk the West network.
- The large sewer main on the East side may become more attractive, with increased SWH work in the area potentially driving down costs – this heat supply could be the push factor required to connect the East and West sides of the A9.
- The larger total heat demand is likely to be more attractive to investors.

The final point relating to scale is a key driver for interconnection of opportunities and any zoning activities. In terms of scale (although this depends on the large industrial loads in Longman), the Raigmore area and the combined Longman and City Centre areas are of a similar scale. The West Bank area is smaller, but this is offset by the large number of suitable assets for connection and the ease of dig in the area for pipework.

6.6 Sequencing and heat network trigger points

All of the areas examined in Inverness show potential for heat network deployment. As discussed in sections 6.1 to 6.5 all the potential heat networks have specific benefits and challenges and how these are balanced and consider impacts their attractiveness. This section captures key trigger points for each area, many of which have been discussed previously, in Table 6—7 to Table 6—10 and then goes on to discuss how these influence sequencing of potential heat network zones and activity.

Table 6—7 Key trigger points for the West Bank heat network area.

Key trigger points
• Planned work at the leisure centre. • Understanding of heat supply technology in anchor loads and core connections. The replacement of heating systems will be a trigger point for connection for many loads, with a heat network connection not being available it could mean connection is not viable until end of life for the new heating technology. • The potential data centre could be an important waste heat source. Ensuring compatibility with any energy centre design should be considered. This could drive the price of heat down and could be a trigger for network expansion (it is considered likely that a first phase of West Bank could progress ahead of the data centre deployment).

Table 6—8 Key trigger points for the Longman potential heat network area.

Key trigger points
• The ongoing collaboration of SSE and SWH has already acted as key trigger point for this area. This has progressed interest faster than may be expected based on the other heat demand (rather than source) led opportunities in inverness. • Shared trenching captures a number of key trigger points in Longman. This includes a potential hydrogen pipeline and waste heat transmission from the electrolysis site on the old landfill site. Another being shared trenching with a private wire from the PV site in Longman (based around the pumping station). Finally, planned SSEN upgrades in the wider area may drive Longman interconnection (this is discussed further for the City Centre). • The interest of the Tarmac and Bairds Maltings sites will be a key trigger for deployment, without these the heat network potential in the area appears marginal.

Table 6—9 Key trigger points for the City Centre potential heat network area.

Key trigger points
• The Rose Street redevelopment is a key enabler for allowing for the centralised infrastructure of an energy centre in the spatial constrained City Centre. • SSEN have planned cabling upgrades in the City Centre. They have already expressed initial interest of using this as an opportunity for heat network installation, reducing the cost of pipework. • Understanding of key anchor load requirements and interest for heat network connection. Eastgate is the single largest demand identified in the City Centre and would create a strong network spine, with the route passing other key loads like the Royal Highland Hotel.

Table 6—10 Key trigger points for the Raigmore potential heat network area.

Key trigger points
• The Freeport developments are key to driving the heat network to the East of the A9. • Recent increased interest from the hospital and understanding of required timescales and onsite plans will be key to determining timings on the West. This should also consider the potential redevelopment of the Raigmore, which could be the required trigger for connection. • Planned electricity network upgrades in the area (focused in the West) could provide opportunity for shared trenching, acting as a trigger point for pipework deployment. • There is also understood to planned ongoing in the south of the area which could be a trigger point for connection to the Police Scotland site. It may be hard to align this with the likely rate of network deployment on the West. Thus, it is important to review the ambitions on the West side of Raigmore consider whether laying a pipe to futureproof for connection to the Police Scotland building.

These trigger points help inform key considerations for heat network sequencing in Inverness, these are summarised below:

- **West Bank** – suggested to be the first network to pursue, focusing on the area to the south of Bught Park. Planned activity in the area adds an element of time criticality. Key will be engaging the Ice Centre to understand the appetite for cooling, as this will influence energy centre design. The energy centre design will also have to consider future proofing for potential expansion across Bught Park. In terms of sequencing this expansion across Bught Park is considered to be most suitable at a later stage, focusing on early delivery in the south of the area to reduce complexity and ensure the time critical opportunities are not missed.
- **Longman** – understanding the full ambition of heat networks in the wider Longman and City Centre areas is key to sequencing. The potential interconnection and transmission of heat is key to ensuring pipes are suitably sized. Many items to determine the sequencing will be based on stakeholder engagement to understand the desire of demands to connect. Shared trenching opportunities during electricity network upgrades, may drive activity earlier than would normally be expected in a heat network with the characteristics and complexities of Longman and the City Centre. In terms of overall sequencing some early activity in Longman is considered likely, due to the drive of SWH and SSE, but wider strategy and realisation of the opportunity is likely to take longer. This could potentially align well with the potential additional waste heat supply from the electrolysis site going through planning.
- **City Centre** – the city centre has some of the greatest complexities and in terms of sequencing is thus likely to be slower to progress than the other opportunities in Inverness. The main driver for any early-stage activity in the area will be cable upgrades by SSEN, potential reducing pipework trenching costs. As discussed for the Longman area the laying of pipework ahead of guaranteed connections and strategy does create substantial risks in terms of upfront investment. The trigger point of the Rose Street redevelopment is going to be key for sequencing development in the City Centre area, understanding the heat demands that are likely to connect and their scale before the redevelopment is key to effective sequencing and heat network planning for the City centre.
- **Raigmore** – is an area with relatively simple stakeholders to engage (this was demonstrated during the feasibility study. The sequencing of the East is laid out in detail in the accompanying feasibility study. The Freeport connections are key to the network and the sequencing. In the West loads are more well established and a network could potentially progress more rapidly, the engagement of the hospital at the end of the study and their ambitions will be a key actor and driver of timings in the West.

6.7 Next steps

There are large number of potential actions for progressing the heat network opportunities in Inverness, THC are exploring other opportunities outside Inverness but Inverness was the focus of this work. Some suggested actions, a few of which are already ongoing, include:

- **Consideration of delivery models** – an introduction to the options for these were provided in a workshop by Buro Happold at the end of the strategic study. Separately, Addleshaw Goddard are providing support to decide on delivery models for the different opportunities in Inverness. This will help determine the different actions for THC in the different heat network opportunities and how to progress through zone designation and delivery and bringing the opportunity to market.
- **Decision on indicative heat network zone boundaries** – this is linked to delivery models. It is suggested that both West Bank and Raigmore should be individual zones. For West Bank its relative isolation and the high level of THC demand in the area would suggest a different delivery model to the other opportunity areas. For Raigmore even though the feasibility focused on the East there could still be potential to connect both sides of the A9, particularly as the hospital is now more engaged. Additionally, the full Raigmore area is more likely to be of interest to private investment as it is of a larger scale and having the option of different

distinct areas and phases of development is likely to be of interest to developers. For the City Centre and the Longman area the decision needs to be as to whether the areas should be considered as one or two potential heat network zones. The available heat from the pumping station and the availability of waste heat from the potential hydrogen site are key influences. If it becomes apparent Longman has large volumes of cheap heat it become suitable to group the two areas, to help reduce deployment complexity. This increase in heat demand scale is also likely to increase the desirability for investors.

- **Building Assessment Reports** – the identification of key heat demands in the opportunity areas should be a driver for BARs. For West Bank in particular this is seen as a focus for THC activity, understanding the heating systems and likely replacement timetables for equipment is key to building a cogent strategy for the area.
- **More detailed analysis of West Bank** – this should initially be focused in the southern area of the network. This area has the most pressing trigger point with the work at the leisure centre being an opportunity for initial deployment. There are multiple actions, three being: a utility survey, greater understanding of a potential energy centre location, future proofing for expansion and connection of any additional heat sources (e.g. the potential data centre in the area), and appraisal of heat supply technologies (this could include more detailed consideration of the Ness as heat source including insights from the Glen Mhor project, GSHP, and engagement with SWH to ensure there is not sewer potential).
- **Stakeholder engagement** – each potential zone has key stakeholders to engage, some like SSEN are key for all (to ensure network capacity is available for low carbon heat) whilst others are more localised, some key ones being:
    - In Raigmore it is important to engage with the hospital in the West and in the East the Freeport stakeholders are important to engage as well as HIE and the new prison. More details of these and other stakeholders are provided in the feasibility study.
    - In the City Centre there are multiple private sector loads key to the network viability. For the energy centre location National Rail are willing to set aside land as part of the Rose Street development, based on conversations with THC. Continued engagement with SSEN is required to ensure opportunities align with planned cable upgrades.
    - For Longman the Maltings and Tarmac plant are key for driving a network in Longman. The potential waste heat from hydrogen is also key to monitor through stakeholder engagement (and align any pipework). SSE and SWH are already pursuing a heat network in the area and are as such the key stakeholders driving the heat network. Continued understanding of their ambition and strategy is key to the overall strategy for both Longman and the City Centre.
    - West Bank is the most dependent on internal stakeholders at the Council and related bodies like High Life Highland.

These key next steps as well as items identified elsewhere in the report, most notably in sections 6.5 and 6.6, form initial actions to help take these heat network opportunities forward in Inverness. The opportunity to align with other activity in Inverness is seen as a key driver for Highland as a local authority to progress with large scale strategic heat networks. This building of a supply chain and expertise in the area will help realise the wider heat network vision outlined in section 2, attracting interest and helping the exploration of opportunities across the wider local authority.

Appendix A – overview of heat sources considered

Table A—1 provides a summary of different low-carbon technologies applicable to heat networks providing a description of each technology and its context for use. Each technology is assessed against nine different parameters, helping to determine the appropriate technology, considering the scale of the network, cost implication, operational risks and local context. These parameters are:

- Network scale suitability – examines which scales of heat network the technology is suited to. These are small (generally communal and some discrete or campus networks), medium (generally discrete or campus schemes) or large (city scale systems or large district schemes). These are represented by a S, M or L respectively.
- CAPEX – this relates to the capital cost of installing the system.
- OPEX – the operating cost. This includes consideration of fuel expenditure and maintenance.
- Technology risk – this considers the risks associated with the technology, assessing if there are likely to be any complications or uncertainty with deployment.
- Carbon saving – the emissions associated with the different technologies. Whilst all technologies considered are low carbon compared to fossil fuels they are assessed compared to the Scottish electricity grid, which due to the high presence of renewables can often considered to be zero carbon.
- Local environmental impact – this considers local impacts of the technology, the most common being NOx emissions associated with combustion technologies.
- Security of fuel supply – this refers to how reliable the low carbon heat source is, this can either be a fuel (such as woodchip) or the sensitivity to factors like weather.
- Precedent – how frequently the technology has been deployed in a heat network context. The focus is on a UK context.
- Geographic sensitivity – how reliant the technology is on local context for deployment. This can either be related to a resource or constraints such as air quality impact.

The listed criteria provide detail on some of the aspects to consider in making an appropriate technology choice. These parameters are assed using a Red-Amber- Green (RAG) analysis:

- **Red** - High level of consideration required – large sensitivity
- **Amber** - Moderate level of consideration
- **Green** - Little need to consider – similar in nearly all contexts

In this instance the red does not necessarily mean the technology is not viable, but the factor is key to consider in detail.

Table A—1 Low carbon heat sources matrix

Low-carbon Heat Technologies and description	Network scale suitability	Capex	Opex	Technology Risk	Carbon saving	Local env. impact	Security pf fuel supply	Precedent	Geographic sensitivity
Air source heat pump: An air source heat pump uses heat from the outdoor air giving it flexibility in design which has led to its large-scale deployment across the world.	S M L	Amber	Amber	Green	Green	Green	Green	Green	Green
GSHP – closed loop: Closed loop ground source heat pump (GSHP) utilise the thermal energy stored in the surface of the earth. The ground is heated by exposure to sunlight and/or proximity the earth's core and maintains a relatively consistent temperature over the year as soil compositions are not as exposed to seasonal change. A closed loop system heats a working fluid, usually glycol, around an extraction loop. The ground transfers the heat through uninsulated pipework to	S M L	Red	Amber	Green	Green	Amber	Green	Green	Green

the circuit raising the fluid temperature. Once the working fluid passes over the evaporator and cools, it returns within the same loop to be heated again.									
GSHP – open loop: Open loop ground source systems utilise the thermal energy stored in aquifers beneath the surface of the earth. The aquifer is heated through proximity to the earth's core. This provides a relatively consistent temperature over the year as aquifers are not exposed to seasonal changes in atmospheric temperature. An open loop system extracts the water from an aquifer, once cooled by the evaporator, the water is reinjected back into the aquifer at a different location.	L								
Bivalent source heat pump: A bivalent system utilises multiple sources of heat for a separate heat pump unit. This provides flexibility in design depending on availability of source but also can allow the system to run efficiently throughout the full year. For example, a heat pump unit with a separate evaporator and closed loop ground source array can run the evaporator unit during warmer days and use the ground array during colder periods. The separation of the heat pump unit and sources allows for more flexible installation and efficient heat management, especially in larger or more complex heating setups.	M L								
WSHP – closed loop: Closed loop water source heat pumps (WSHP) utilise thermal energy stored in a body of water such as a loch, river, or the sea. The water is heated through exposure to sunlight and the ground beneath the body of water. A closed loop system heats a fluid, usually glycol, around an extraction loop submerged within the water body. The water then transfers the heat through uninsulated pipework to the circuit raising the fluid temperature. Once the heat transfer fluid passes over the evaporator and cools, it returns within the same loop to be heated again**.**	M L								
WSHP– open loop: Open loop water source heat pump utilise the thermal energy stored in a body of water such as a loch, river of the sea. The water is heated through exposure to sunlight and the ground beneath the body of water. An open loop WSHP system extracts heated water from a water body and once cooled by the evaporator, the water is reinjected back into the source at a different location.	M L								
Waste heat recovery: A heat recovery heat pump is used to enhance the heat that would otherwise be wasted from industrial and commercial processes (e.g., exhaust air from data centres cooling, exhaust air from tubes ventilation shaft). Through the heat recovery process, this heat can be captured and utilised for heating supply. Many waste heat sources are low-grade, and heat pump can be employed to upgrade this heat to suitable temperature. In some instances, the heat pump may not be required.	M L								
Wastewater heat recovery: Low-grade heat recovery systems utilise the thermal energy stored in effluent water from industry, common sources include effluent from wastewater treatment plants, cooling water from data centres, breweries, dairies and abattoirs. Cooling water is particularly effective as the elevated source temperatures allow for heat pumps to operate at greater efficiencies and the energy demand for cooling is mitigated.	M L								
Sewer heat recovery heat pump: Sewer heat recovery utilises the thermal energy present in wastewater flowing through sewer networks, typically originating from domestic or commercial sources but can also include drainage water. In these systems, wastewater is extracted from a mains sewer line before reaching the wastewater treatment works. The constituency of wastewater requires additional infrastructure including screening and potentially maceration before a heat exchange process.	M L								
Substation waste heat recovery: Captures heat from the transformer cooling systems on substations. This is most suited to large substations and those with specific cooling systems, oil cooled generally being the most suitable. There is a general switch towards cooling systems that are less suitable for heat recovery, but long asset lifetimes mean they are often viable to consider. There is often a level	M L								

of seasonality and daily variation in heat availability, but this often matches relatively well to heat demand.		Amber	Amber	Amber	Green	Green	Amber	Amber	Red
Minewater source heat pump: Mine water systems utilise pumped water from disused mine shaft systems. The mine water is at an increased and constant temperature after being geothermically heated. These high temperatures allow for a low running costs of the heat pump. In some instances, mine water is already being extracted by the coal authority to limit contamination to drinking water aquifers. This risk assessment is for solutions where drilling is required. Drilling to the exact depth of the mine system is complex and entails a very high risk and cost, if performed incorrectly, there is a potential to contaminate flows of natural water.	L	Red	Amber	Red	Green	Amber	Green	Amber	Red
Biomass boiler: Biomass boilers are using organic materials such as wood pellets, chips, agricultural wastes as a fuel to generate heat. They can be used outside areas where there are air quality concerns such as air quality management areas, and in locations where there is space and access for a woodchip or wood pellet store.	S M L	Amber	Amber	Green	Amber	Red	Red	Green	Green
Biomass CHP: Use of biomass (similar to the biomass boiler) to generate heat and power.	M L	Red	Amber	Amber	Amber	Red	Red	Green	Green
Hydrogen boiler: The hydrogen boiler utilises hydrogen as its fuel, which can be either 100% hydrogen requiring a full conversion of the existing natural gas grid to accommodate hydrogen or a blend of natural gas and 20% hydrogen. When burned, hydrogen produces heat and water vapor. Hydrogen produced from renewable electricity (green hydrogen) would be considered to be renewable.	S M L	Green	Red	Red	Amber	Amber	Amber	Red	Amber
Direct electric boiler: Uses electricity to heat water. This has a very high operation cost compared to other technologies due to the far higher efficiency of heat pumps and the lower fuel price of natural gas. Consequently, it is not seen as a standalone decarbonisation for heat networks.	S M L	Green	Red	Green	Green	Green	Green	Amber	Green
Thermal store: This often takes the form of large water tanks, although there are more complex and high-density storage materials being explored. Thermal stores are key a key part of most heat networks, ensuring improved operation and heat generation technology optimisation. Increasing the size of thermal store can be a key mechanism to avoid electricity network reinforcement and benefit from low electricity prices.	S M L	Amber	Green	Green	Green	Green	Green	Green	Amber

While air source heat pumps (ASHP) perform well in RAG analysis, they generally have lower coefficient of performance (COP), meaning greater electrical input is required. Other heat pump technologies may offer higher COP and lower operating costs. However, they often come with higher capital and maintenance costs, making their suitability more dependent on the scale of the network.

Suitable waste heat sources and low carbon technologies are determined for each cluster following a screening of each area for identifying suitable technology.

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