Agenda Item	7
Report No	CCC/12/23

THE HIGHLAND COUNCIL

Committee: **Climate Change**

Date: **17 May 2023**

Report Title: **Inverness West Bank and Inverness Castle Heat Network Feasibility Studies**

Report By: **Depute Chief Executive**

1 Purpose/Executive Summary

1.1 As part of the Council's statutory obligations to develop a Local Heat and Energy Efficiency Strategy (LHEES). We must identify areas of potential for heat networks. This report informs work to date on two sites identified as having potential within Inverness. This piece of work started in 2021 and has provided officers with a better understanding of how to progress this type of opportunity.

2 Recommendations

2.1 Members are asked to:-

i. **Note** the contents of the report.

3 Implications

3.1 The work has helped shape our understanding of Heat networks within the highlands. The Council must identify potential areas for Heat Networks as part of its work in developing a Local Heat and Energy Efficiency Strategy (LHEES).

3.2 **Legal** - As part of the Scottish Government's commitment to energy efficiency and carbon reduction, the Local Heat and Energy Efficiency Strategies (Order) 2022 places a statutory duty on the Highland Council and all local authorities across Scotland to prepare the LHEES Strategy and Delivery Plan on or before 31 December 2023, subsequently on a 5-year cycle. LHEES Strategy will set out the long-term plan for decarbonising heat in buildings and improving their energy efficiency across an entire local authority area and help highlight zones within a local authority where heat networks present a potential decarbonisation option and support planning for the development of heat networks.

LHEES work is already ongoing at the Highland Council. The Council is drafting heat cluster maps for the heat network zoning work in progress. The areas around Inverness Castle and West Bank have been identified as relatively high-heat demand areas.

3.3 **Community (Equality, Poverty, Rural and Island)** - The development of two heat networks in Inverness provides an opportunity to connect several buildings to an affordable and low-carbon source of space heating and hot water for the local community and employees to enjoy warm space at various buildings such as the Eden Court, the Highland Hospice, the Council Headquarters, and other buildings included in the feasibility studies.

3.4 **Climate Change / Carbon Clever**

i. In the Heat In Buildings Strategy: Achieving Net Zero Emissions in Scotland's Buildings, connecting to a heat network is part of the strategy to achieve net zero emissions in Scotland's buildings and mitigate climate change.

ii. The proposed Heat networks offer an opportunity to transition from Fossil Fuels to Low carbon Heat across several properties within the Council Estate while supporting the same chance to external stakeholders across the centre of Inverness, contributing to both the Council and the Regional Net Zero ambition.

3.5 **Risk**

i. The delivery of heat networks in the Highlands will rely on upskilling of the supply chain that supports the design, construction, operation, and maintenance of heat networks. Currently, there are a range of skill gaps creating challenges in heat networks development, covering areas of project management, heat network design, installation, optimisation, technical operation, and maintenance.

ii. Capital and operating costs can be seen as one of the biggest challenges in the development of heat networks in Inverness. Further assessment of capital costs will be required by a Quantity Surveyor.

iii. The Heat Networks (Scotland) Act 2021 has set statutory targets that 2.6 Terawatt hours (TWh) of output by 2027 and 6TWh by 2030 – 3% and 8% respectively of current heat supply should be supplied by heat networks. If we were to fail the development of heat networks in the Inverness, the Highland Council will not be contributing towards these targets.

3.6 **Gaelic** - There are no Gaelic implications arising from this report.

4 Background

4.1 In 2021, two pre-feasibility assessments of proposed district 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. Geospatial software[1] was used to spatially analyse the heat network opportunity and a techno-economic model[2] was conducted to assess the financial opportunity present.

[1] Geospatial software is designed to store, retrieve, manage, display, and analyse all types of geographic and spatial data.

[2] A techno-economic model is an integrated process and cost model. It combines elements of process design, process modelling, equipment sizing, capital cost estimation, and operating cost estimation.

Preliminary geospatial data[3] showed that the linear heat density of the buildings under review had a promising heat network opportunity.

4.2 In November 2022, LHEES Officer and Climate Change & Energy Team Manager have applied to the Heat Network Support Unit (HNSU) for funding to conduct two feasibility studies to assess the opportunities in the development of district network in Inverness. The Council has been awarded £50,000 per project.

4.3 Zero Waste Scotland (ZWS) and the Scottish Government (SG) have commissioned Buro Happold Engineering to undertake various low-carbon district heat network (DHN) feasibility studies within the Scottish Cities Alliance (SCA). It is a thirteen-week feasibility study during which briefing and review of existing information, policy alignment, site visits and surveys, energy data consolidation and analysis, assessment of feasible heat supply and storage options, initial commercial structure considerations, carbon assessment, and environmental impacts were completed.

Two district heating feasibility studies have been completed. Inverness Castle District Heat Network Feasibility Report and its Appendices can be found in **Appendix 1** and Inverness West Bank District Heat Network Feasibility Study report and its Appendices can be found in **Appendix 2**.

5 Key next Steps

5.1 Set up a meeting with Zero Waste Scotland, Scottish Future Trusts, Burro Happold, and Scottish Government to discuss delivery models.

5.2 Progress both feasibility studies to the business case stage with an Outline Business Case (OBC).

Designation:	Depute Chief Executive
Date:	28 April 2023
Author:	Ruta Burbaite, LHEES Co-ordinator Neil Osborne, Climate Change & Energy Team Manager
Background Papers:	Pre-feasibility reports Heat Networks (Scotland) Act 2021 Heat networks delivery plan Heat In Buildings Strategy: Achieving Net Zero Emissions in Scotland's Buildings Heat Networks (Scotland) Act 2021 (legislation.gov.uk)

[3] Geospatial data is used to describe data that represents features or objects on the Earth's surface.

Heat Network Support Unit

Inverness Castle

Heat Network Feasibility Study

Prepared by: Buro Happold

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Date: 28 March 2023

ZERO WASTE SCOTLAND

Scottish Government
Riaghaltas na h-Alba
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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
ASHP	Air source heat pump
GSHP	Ground source heat pump
EC	Energy centre
EB	Electric boiler
HN	Heat Network
IRR	Internal rate of return
LHD	Linear Heat density
OBC	Outline business case
NPV	Net present value
O&M	Operation and maintenance
PHEX	Plate heat exchanger
RSHP	River source heat pump
TES	Thermal energy storage
WWHR	Wastewater heat recovery
Zero Waste Scotland	ZWS

1 Executive summary

This heat network feasibility study report was prepared by the Buro Happold Cities Energy Team on behalf of Zero Waste Scotland (ZWS) for the Highland Council. This study follows a pre-feasibility study carried out in 2021 which considered air source heat pump and water source heat pump technologies in a heat network.

Understanding the project

The Highland Council is moving towards net zero carbon greenhouse gas (GHG) emissions, targeting net zero by 2045. Provision of heat can account for a significant portion of annual carbon dioxide emissions across the built environment. Buildings connected to a heat network are considered as having a "low or zero heating system"[1].

In the castle study area, Inverness Castle and North Tower, are undergoing major refurbishment works as part of the transition to major tourism centres in the city. As part of this refurbishment, the buildings are to be upgraded for improved energy performance. Planning permission has already been requested to include a low-carbon energy centre and heat network at the site.

Report purpose

The purpose of this heat network feasibility study is to inform the Highland Council of the opportunity for a heat network in the Inverness Castle study area. The study provides:

- Review of the currently proposed low-carbon approach in the study area, which includes an energy centre, heat network and Air Source Heat Pumps (ASHPs)
- Propose an opportunity to decarbonise further, switching from gas-fired boilers as the backup heating technology to electric boilers, for an all-electric energy centre
- High-level cost estimate of the proposed heat network
- Outline of the key risks associated with the project and how they can be mitigated
- Recommendations and next steps.

Report audience

The audience for this report is the Highland Council.

Challenges

The Highland Council's challenge is to balance the need to:

- Decarbonise heating for buildings in Inverness, targeting net zero GHG by 2045
- Consider cost implications of low-carbon heat technology and heat network(s)

Key findings

There is an opportunity for a low-carbon heat network (HN) in the castle study area in Inverness, using ASHP technology (Figure 1.1).

[1] www. Gov.Scot. Heat in Buildings Strategy, 2021. Page 16. URL: Heat In Buildings Strategy: Achieving Net Zero Emissions in Scotland's Buildings (www.gov.scot) Accessed 28/03/2023

Figure 1.1 Proposed energy centre location and heat network route

A heat network at the castle site is likely to require capital funding. High-level, pre-tax, techno-economic model of the proposed solution indicated a Net Present Value (NPV) of £0.01M and Internal Rate of Return (IRR) of 3.6% at the end of the 40-year period considered in this study, with additional capital cost funding of 50% (£1.41M). These values are indicative only and not financial advice.

Carbon savings of 90% were estimated for the proposed heat network when compared to the business-as-usual scenario of each of the buildings continuing to use their current gas-fired boiler or gas-fired boiler/CHP unit (or proposed in the case of the future developments ASHP) heating technologies.

A heat network in the castle study area could consist of:

- Energy centre adjacent to the castle (making use of an existing Highland Council owned structure)
- Equipment at the energy centre could comprise:
  - ASHP, 451 kW
  - Top-up electric boilers, 480 kW
  - Thermal stores, 12 m^3
- Heat network, 188 m (trench length), connecting the following buildings:
  - Inverness Castle
  - North tower
  - Inverness Town House
  - New proposed development on the main street (assumed office space as part of energy modelling)

- New proposed museum and art gallery adjacent to the castle

Key next steps

It is recommended to progress this study to the business case stage with an Outline Business Case (OBC). Preparing a business case involves:

- A five-case Outline Business Case (OBC) presenting the strategic, management, commercial, economic, and financial cases
- As part of the OBC, there is a component of design development, to approximately a RIBA stage 2, Concept Design level.
- Heads of Terms for heat network connections (agreements to connect to the heat network)
- Assessment of capital costs by a Quantity Surveyor

Policy underpinning recommendations

Local Heat and Energy Efficiency Strategy (LHEES) work is ongoing at the Highland Council. As part of the heat network zoning work in progress, the Council is drafting heat cluster maps. The area around Inverness Castle has been identified as an area of relatively high heat demand.

2 Introduction

This Inverness Castle heat network feasibility study was commissioned by Zero Waste Scotland and carried out by Buro Happold for the Highland Council. This follows on from a pre-feasibility study carried out in 2021, which considered air source heat pump and water source heat pump technologies in a heat network.

Between the pre-feasibility study and this feasibility study, plans to build a new energy centre to provide heat to the Inverness Castle area have been developed and submitted for planning permission in September 2022. The proposed heat strategy has been carried forward to tender design (March 2023).

The new energy centre is planned to make use of an array of eleven ASHPs (total 451 kW) with three back-up/peaking gas boilers (480 kW) and a bank of thermal stores (12 m^3). It is understood that ASHPs were selected as the preferred low-carbon heating technology following a technology options appraisal. Options considered unsuitable for the site included: heat recovery from a nearby wastewater system, water source heating from the River Ness, and ground source heating.

As plans for a new heat network in the area have already been progressed, this feasibility study provides an independent technical review and qualitative assessment of the heat network by reviewing the opportunities for:

1. **Thermal storage optimisation:** The heat sales price on heat networks with electrically driven heat pumps can be high in comparison to gas as a heating fuel. This can be mitigated by optimising the volume of thermal storage.
2. **All electric heating:** Original proposals for the new heat network make use of gas boilers for back-up/top-up heating. The Highland Council highlighted that an all-electric solution is preferrable as part of their plans to decarbonise.
3. **Understanding funding gap:** The Highland Council have expressed interest in operating the heat network at Inverness Castle. By targeting an IRR hurdle rate typical of Local Authority led heat networks (approx. 3.5%), an impression of any funding gap that may be present can be understood.

2.1 Stakeholders

Stakeholders to the feasibility study are the Highland Council, Inverness Museum and Art Gallery, Inverness City Committee and High Life Highland. The future tenant(s) if the new proposed development will also be a key stakeholder.

2.2 Report structure

This report is organised into the following sections:

- **Section 1**. Executive summary. Overview of the report, key findings, conclusions, next steps
- **Section 2**. Introduction. Information about this feasibility study and description of the stakeholders, study area and methodology
- **Section 3. Policy review** – key points relating to the route to net zero carbon, and implications for the Inverness Castle area. Context on Local Heat and Energy Efficiency Strategy (LHEES).
- **Section 4. Site visit** – observations from site visit and survey to Inverness Castle, North Tower, and Town House
- **Section 5. Energy demand analysis**– estimation of the heating demand from buildings
- **Section 6. Heat supply technology** – technology suitability considerations, for low-carbon heating solutions for the site
- **Section 7. Energy Modelling –** modelling of heat demand profiles for entire heat network
- **Section 8. Spatial Coordination** – Indicative pipe route for heat network, energy centre layout, and high-level schematic of the proposed network.
- **Section 9. Techno-economic modelling**– technical and economic modelling results
- **Section 10. Carbon emission assessment**– carbon emissions analysis of the heat network

- **Section 11. Heat network development** – steps in heat network development, considering development, commercialisation, and delivery
- **Section 12. Risk mitigation** – identification of potential project risks and mitigation measures
- **Section 13. Conclusions and next steps** – conclusion and suggested route forward

2.3 Methodology

The approach for the feasibility study is presented in Figure 2.1.

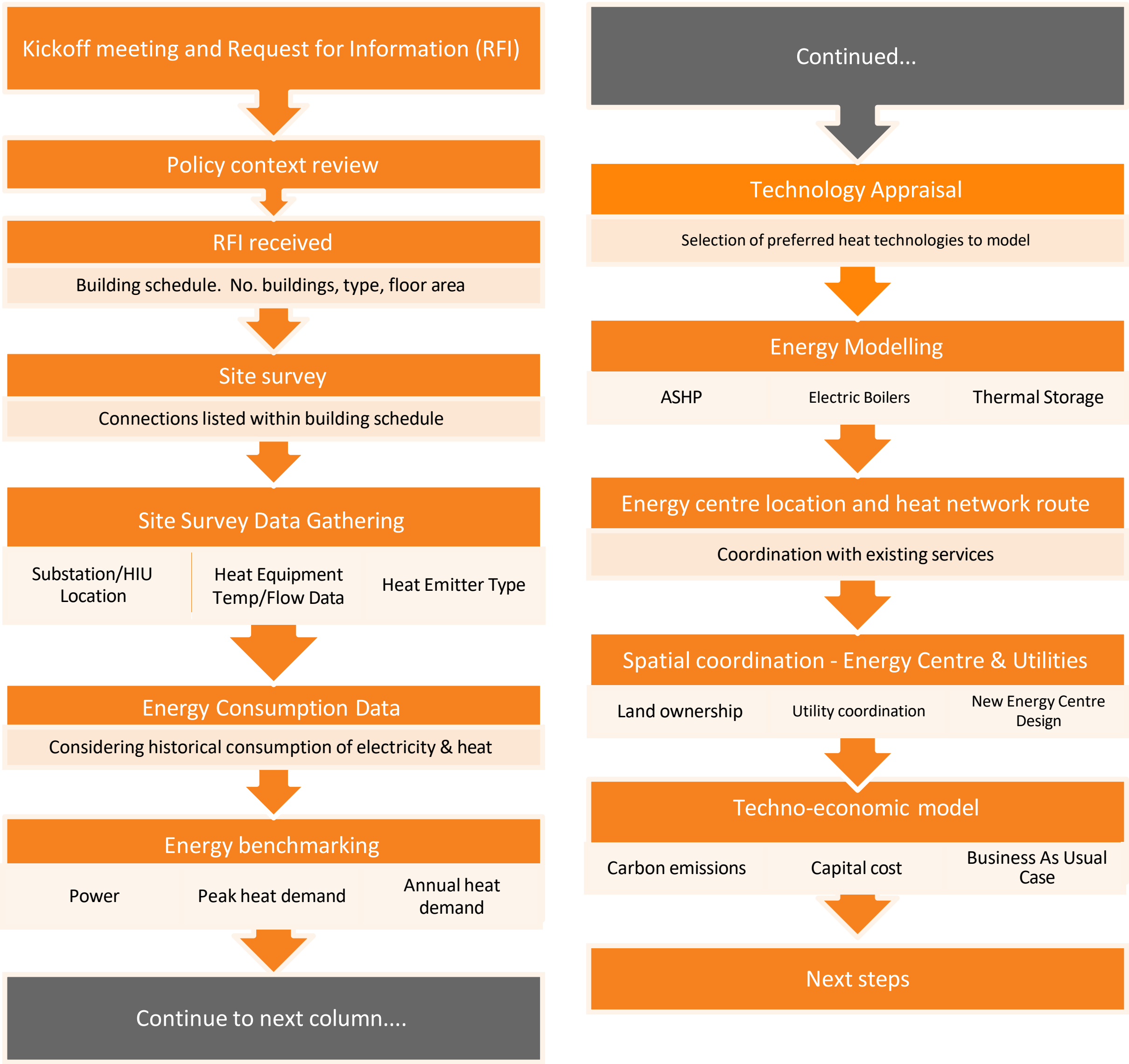

Figure 2.1 - Methodology

2.4 Study area

The red line boundary for this feasibility study is shown in Figure 2.2. The buildings considered include Inverness Castle (often referred to as the South Tower), North Tower, Inverness Town House, a proposed "Redevelopment" to the north of Inverness Castle, and a proposed building planned to house Inverness Art Gallery and Museum.

Figure 2.2: Inverness Castle feasibility study red line boundary

2.4.1 Phasing

The three-phase programme for the Inverness Castle redevelopment project is outlined below:

Phase 1: Castle and Town House Redevelopment.

- Building fabric upgrades are to finish November 2024 (heating will be required from this time).
- Internal decoration works will follow completion of the external works. These are due to be completed prior to the spring/summer 2025 opening.

Phase 2: Construction of a new premises for Inverness Museum and Art Gallery.

- A timeline has yet to be confirmed.

Phase 3: Construction of a new development complex to include retail, office and residential space (further information can be found in Section 4.5).

- A timeline for the new complex to the north of the castle is determined by construction of a new space for Inverness Museum and Art Gallery.

2.5 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[2]

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.

3 Policy review

This section of the report presents key policies that are anticipated to affect the castle study area and the Highland Council.

3.1 Net zero GHG targets

Targets years to achieve net zero Green House Gas (GHG) emissions have been agreed from national to local levels in the UK. Scotland is to reach net zero by 2045, and the target of the Highland Council's is currently in development.

	Net zero GHG emission target year
United Kingdom	2050
Scotland	2045
Highland Council	Under development

Table 3-1 Net zero GHG emission targets at national and local levels

2 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]

3.2 Heat in Buildings Strategy

In the Heat in Buildings Strategy, connecting to a heat network is part of the strategy to achieve net zero emissions in Scotland's buildings[3]

"Low and Zero Emissions Heating Systems. In this Strategy, by "low and zero emissions heating systems" we mean systems that have zero direct greenhouse gas emissions, such as individual electric heat pumps and connection to heat networks, or electric systems such as storage heaters, and systems that have very low emissions such as those that use hydrogen.

3.3 Highland Council

3.3.1 Carbon CLEVER

Carbon CLEVER is a Highland Council-led initiative that has since been revised. A summary of the initiative is provided below.

Buildings across the region will have been energy renovated, and new buildings are to be energy efficient. Most buildings in rural areas will be heated by renewable sources. Electricity will be generated from a range of renewable sources, and excess energy can be transmitted to surrounding regions through smart grids or stored efficiently.

The Council recognises two important elements for being carbon neutral:

ii Reducing carbon emissions
iii Offsetting those emissions which it is not feasible or practical to reduce

In the region, projects will be implemented to work towards the following CLEVER goals:

- **C**arbon emission reduction
- **L**ead by example
- **E**ngagement with others
- **V**alue for money
- **E**conomic benefits
- **R**aising awareness and promote behaviour change

The Council has identified 5 key strategic themes for achieving a Carbon CLEVER Highlands:

- Economy
- Energy
- Land use and resources
- Transport
- Engagement strategy

3.3.2 Hydro Ness

The Highland Council has declared a Climate and Ecological emergency and has set its Net Zero aspirations. As part of this delivery, the Council has implemented the River Ness Hydro Scheme; this will help to reduce the organisation's carbon footprint, and further generation and use of renewable energy. A 93-kW hydroelectric power twin turbine will generate an estimated 550,000 kWh per annum, supplying the nearby Inverness Leisure Centre with approximately 50% of its electricity use.[4]

[3] Gov.Scot. Heat in Buildings Strategy, Oct 2021. URL: Heat In Buildings Strategy: Achieving Net Zero Emissions in Scotland's Buildings (www.gov.scot) Accessed 28/03/2023
[4] https://www.highland.gov.uk/info/1210/environment/971/hydro_ness (Accessed January 2023)

The River Ness Hydro doubles as a tourist attraction and will attract many visitors, providing an interactive experience for all ages and promoting the use of renewable energy and STEM learning in Highlands.

3.4 LHEES: Inverness

Local Heat and Energy Efficiency Strategies (LHEES) analysis at the Highland Council for the area of Inverness is ongoing. Draft heat demand mapping work has identified areas of high heat demand around Inverness Castle.

4 Site visit and survey

On Wednesday 25th January and Thursday 26th January, a site visit was carried out to the castle, north tower, and town house. In attendance was Lewis Burnett from Buro Happold, Ruta Burbaite of the Highland Council and Sam Collins from Zero Waste Scotland. A table of site contacts present on behalf of each building is given in **Error! Reference source not found.**Table 4-1.

Table 4-1: Site contacts

Building	Site Contact	Contact Role & Organisation
Inverness Castle Inverness North Tower Future Redevelopment Site	Jason Kelman	Project Manager, The Highland Council
Inverness Town House	Joe McCracken	Facilities & Maintenance, The Highland Council

Non-obtrusive site surveys were carried out at each building with the aim of establishing type, capacity and condition of heat generation technology. During the site visit, observations were recorded on the operating temperatures for Low Temperature Hot Water (LTHW) systems, building energy strategy, Management System (BMS) strategy, and building usage patterns.

4.1 Heating technology site suitability

Whilst at site, it was established that previous assessments had been carried out to assess the suitability of nearby wastewater resources as a possible alternative heat source. The nearby resources, a pair of sewer pipes that run beneath Castle Street and Castle Road, were considered unsuitable as a heat source due to insufficient volumetric flowrate and insufficient access space to make a connection, respectively. Full reports including temperature and flowrate measurement can be found in the Appendix B.

4.2 Inverness Castle and North Tower

Inverness Castle (often referred to as the South Tower) and the North Tower are undergoing a major refurbishment as part of their conversion from a Sheriff Court to a major tourist attraction in the city. To facilitate this, both the Castle and North Tower were recently purchased by the Highland Council. As of March 2023, the project is part complete with the extent of this refurbishment illustrated in Figure 4.1.

As part of the ongoing refurbishment, energy performance improvements measures such as internal wall insulation, changeover to LED lighting and installation of double-glazed windows are being implemented to bring the energy performance of the Victorian structures to as close to that of a modern building as possible.

Figure 4.1: Inverness Castle during refurbishment works

A new energy strategy suitable for a more energy efficient Inverness Castle and North Tower includes the construction of a new energy centre that will supply heat to both buildings. A nearby public bathroom is to be re-purposed as the new energy centre. Further information can be found in Section 4.3.

The new heating systems within both buildings will be designed for a 40°C flow temperature with wet radiators and Air Handling Units (AHUs) in the Castle and North Tower. The heat network flow and return temperatures have been specified as 60°C and 40°C, respectively.

Initially only Inverness Castle and North Tower will be connected to the proposed heat network. However, there is an intention to connect the nearby Inverness Town House. However, as discussed in more detail in Section 4.4, significant enabling work will be required to connect the Town House to a low temperature heat network due to the building's current system being designed for higher flow temperatures. The existing Town House gas boilers will be retained as back-up/top-up.

Future development plans for the area also include construction of a new mixed use (office, retail and /or commercial) complex directly north of the castle. One of the current tenants of the existing complex, Inverness Museum and Art Gallery, are to be relocated to a new purpose-built premises that has been earmarked to be built on a plot of land currently occupied by the Castle Street Town House Car Park. However, construction of the new office block/retail complex can only take place once the new premises for Inverness Museum and Art Gallery has been completed. A source of funding for the new Inverness Museum and Art Gallery is still unknown and therefore a robust timeline for its construction has not yet been established.

4.3 Proposed energy centre

The new proposed energy centre, outlined within the planning application, will be built to provide heat for the redeveloped Inverness Castle, North Tower as well as the longer-term connections of Inverness Town House, Inverness Art Gallery & Museum, and the redevelopment due to be built north of the castle.

Technical information including heat capacity of new plant and floor plans in this study are based on information included in the planning permission.

The energy centre will make use of an existing public bathroom building structure (Figure 4.2). An image included as part of the planning application[5] for the proposed energy centre is shown in Figure 4.3.

Figure 4.2: Existing public bathrooms

Figure 4.3: Castle future energy centre

Main heating plant to be installed in the new energy centre includes an array of eleven ASHPs (451 kW), three back-up gas boilers (480 kW) and a bank of three thermal stores (12 m³). A new electrical substation will be built on the ground floor in the energy centre to accommodate the increased local electrical demand associated with an array of ASHPs as well as six electric car charging points in the parking area.

5 https://wam.highland.gov.uk/wam/applicationDetails.do?activeTab=details&keyVal=RHIRHDIHH7K00 (Accessed February 2023)

The equipment schedule for the new energy centre is given in Table 4-2. A floor plan general arrangement of the new energy centre allocating spatial requirements for equipment is given in Figure 4.4. Equipment number and location should be considered as indicative only.

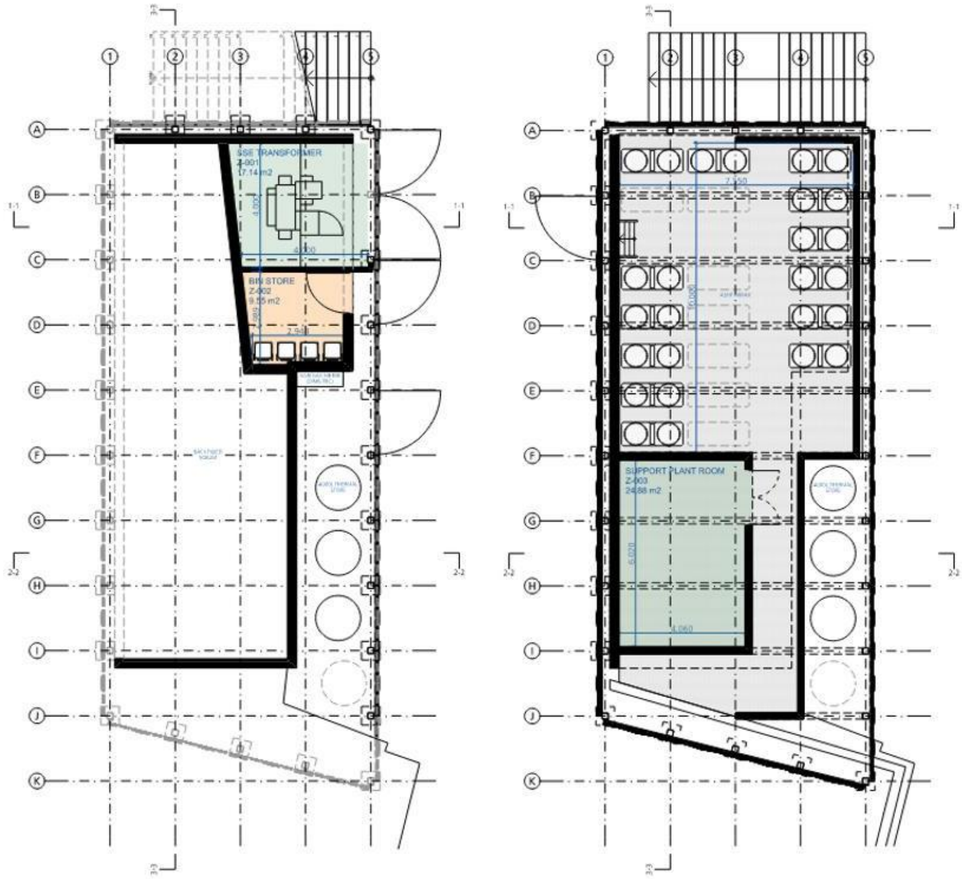

Figure 4.4: Future energy centre Floor Plan

Table 4-2: Castle new energy centre equipment schedule

Equipment Item	Duty/Capacity per unit (-)	Quantity (-)	Make	Model
ASHP	$41kW_{th}$	11 (Space allocated for 16)	Mitsubishi	CAHV-P500YA-HPB
Gas Boiler	$160\ kW_{th}$	3	Remeha	Quinta Ace 30 160
Thermal Storage	$4m^3$	3 (Space allocated for 4)	-	-
Distribution Pumps	-	-	-	-

Initial plans would see the energy centre fitted with an array of eleven ASHP and three Thermal Stores. However, floor plans also clearly show that space has been allocated to increase the number of ASHPs to a total of sixteen in total and increasing the number of thermal stores to four.

4.4 Inverness Town House

Inverness Town House was opened in 1882 and is owned and maintained by the Inverness City Committee. The building plant room was re-fitted and refurbished in 2013 with the main equipment items within the plantroom is summarised in Table 4-3 providing heating and DHW to the building.

Table 4-3: Town House equipment schedule

Equipment Item	Duty/Capacity per unit (-)	Quantity (-)	Make	Model
Gas Boiler	80-100 kW	5	Veismann	Vitodens 200-W
Gas CHP	**Electrical:** 22 kW **Thermal:** 51 kW	1	KW Energie	Smartblock 22
Buffer Vessel	1,000 litres	1	Cordivari	Term Puffer VC VT LT.1000

Figure 4.5 shows the boiler array of five Veismann gas boiler whilst Figure 4.6 highlights the KW Energie CHP unit. At the time of the site visit the CHP unit was not in operation and the site contact confirmed that it had not been operating for some time. Similarly, it was confirmed that only three of the five boilers had ever been known to run at the same time, suggesting the system had been over specified to meet the heat demand of the building.

Figure 4.5: Inverness Town House Boiler Array

Figure 4.6: Inverness Town House CHP unit

Access into the plant room, as shown in Figure 4.7, is through a pair of double doors that open directly onto Castle Wynd. External access provides simplified access and egress into the plantroom for plant replacement, installation, and maintenance activities.

Figure 4.7: External facing doors to the boiler room

The heating system in the building makes use of a combination of wet radiators and Air Handling units. However, it was noted that portable electric heaters are often used in particularly cold parts of the building to improve thermal comfort.

Gas boilers were set at a 75°C flow temperature with a spot check return temperature of 53°C observed on the day.

With many staff continuing to work from home, occupancy in the building was reported to be around one quarter of pre-COVID levels. This includes the Highland Council staff that have taken up occupancy of part of the building. As a result, opportunities to rent floors to external companies is being considered to bring the building closer to its capacity.

4.5 Future Redevelopment Site, Art Gallery & Museum

As outlined in Section 4.3, a new retail, office, and residential development to the north of the castle cannot take place until a new building has been completed to allow Inverness Museum and Art Gallery to vacate their current premises. However, a timeline for this has not yet been established as funding has not yet become available for the project.

5 Energy demand analysis

An energy demand assessment was carried out to determine the required heating loads for the buildings on the proposed heat network. A combination of metered energy consumption (gas and electricity) along with industry standard benchmarks were used. The buildings considered in the assessment, and their respective floor areas, are detailed in Appendix C. The source and nature of any metered data provided is detailed in Appendix D. For the buildings where industry benchmarks were used to consolidate the heating demand, the nature and source of the benchmark used is outlined in Appendix E.

5.1 Energy demand summary

The annual heat demands from the energy demand assessment for the Inverness Castle heat network are illustrated in Figure 5.1 below. From this, it is evident that the largest annual heating demand on the network is the Town House.

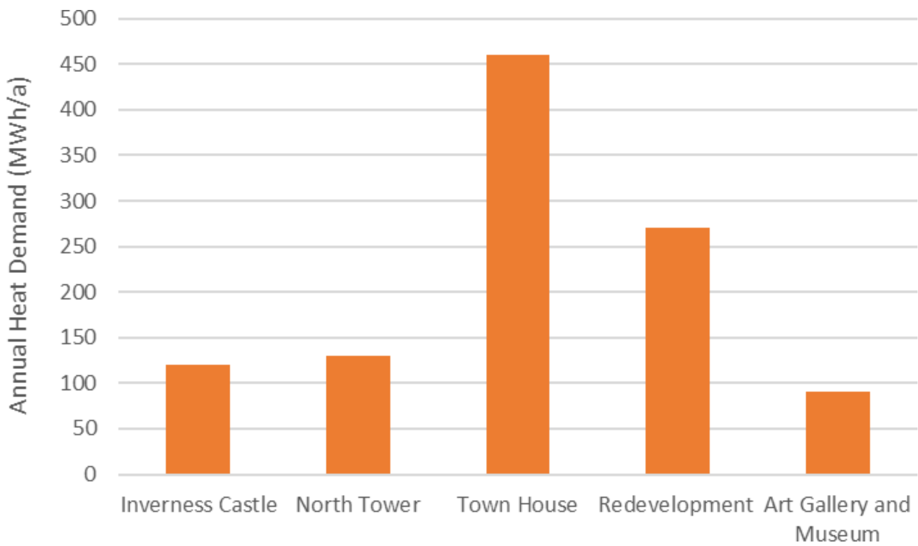

Figure 5.1 – Annual heat demands

A summary of energy demand data, combining both metered data and industry standard is provided in Table 5-1.

Table 5-1: Energy demand for each connection

Building	Connection Phase	Building Typology	Annual Heat Demand (MWh/a)	Peak Demand (kW)
Inverness Castle	1	Cultural activities	120	150
North Tower	1	General office	130	110
Town House	2	General office	460	190
Redevelopment	3	General office	270	370
Art Gallery and Museum	3	Cultural activities	90	90
Total			**1,070**	**910**

6 Heat supply technology - suitability assessment

A qualitative heating technology suitability assessment was carried out for the castle study area as part of the initial work carried out in the study. The assessment identified technologies which could potentially be suitable for the site, for further consideration:

- Air Source Heat Pumps. Site suitable for ASHP
- Water Source Heat pumps. The site is close to the River Ness
- Top-up electric boilers. To switch entirely away from gas-fired boilers, electric boilers could be used for top-up heat.
- Thermal Storage. Can be used to meet peak demands

Over the course of progress meetings with the stakeholders at the Highland Council, it became understood that a planning application had already been submitted for an energy centre with ASHP at the Castle. At the site visit and through information sharing on the project, it became known that some work had already been carried out to consider the suitability of low-carbon technologies, and ASHP was selected as the preferred option due to the other technologies being unsuitable for the site.

Heat technologies are scored against a set of seven key drivers. Each driver is weighted according to its perceived importance on the overall project. A score between one to five, with five being the highest scoring, is assigned for each key and an overall score for each technology being assessed gives an indication of that technology's suitability.

Planning permission (and subsequently tender design information) for a new energy centre has already been submitted, which incorporated an array of ASHPs, back-up gas boilers and an initial thermal store volume of 12m^3. Therefore, only one energy scenario was chosen to be modelled based off the proposed design and energy strategy. However, the Highland Council highlighted their strong preference for an all-electric solution. As such, electric boilers were selected as the back-up/top-up technology in place of gas boilers.

Table 6-1: Technology Suitability Assessment

Row	Technology	Resource availability	Carbon reduction potential	Commercial complexity + Technology maturity	Capital Cost	Operating Cost	Spatial requiremenhts	Local environmental benefits (e.g. air quality)	Weighted Score (Out of 5)	Recommendation	Additional notes
	Driver Priority:	1	2	3	4	5	6	7			
	Driver Weighting:	15%	40%	15%	10%	10%	5%	5%			
1	Air Source Heat Pump	5	4	4	4	3	3	4	**4.0**	**Y**	Existing energy strategy for the Castle & North Tower refurbishment will incorporate ASHPs.
2	Water Source Heat Pump	4	5	4	3	3	4	4	**4.2**	**Y**	Good access to nearby river Ness. Previously discounted due to space limitations at banks of River Ness to incorporate river source heat.
3	Top up Electric boilers	4	3	5	4	2	4	5	**3.6**	**Y**	As a main heat generator operational costs are higher than heat pumps. Can be used effectively to meet peak demands.
4	Thermal Storage	5	3	5	5	5	4	5	**4.2**	**Y**	Has already been incorporated into existing energy strategy
5	Waste Heat Recovery - Sewer Heat	4	5	4	3	2	3	4	**4.1**	**Y**	Castle Road sewer has sufficient volumetric flowrate and suitable temperatures. Previous investigations eliminated sewer heat due to spatial limitations along Castle Road.
6	Ambient Loop Heat Network	4	4	3	4	4	5	5	**4.0**	**N**	Existing energy strategy is not compatible with an ambient loop system.
7	Ground Source Heat pumps	1	5	4	2	4	3	4	**3.7**	**N**	Very little space available for boreholes and ground source heat in the castle area. Space in the Town House car park will be taken up by the Art Gallery and Museum building.
8	Alluvial Aquifer Source - Water Source Heat Pump	3	5	4	3	4	4	4	**4.2**	**N**	Geotechnical survey (outside scope of Feasibility Study) required to establish presence of alluvial aquifer beneath the castle.
9	Biomass	4	2	5	4	3	4	3	**3.2**	**N**	City centre location and air quality requirements are prohibitive
10	Gas CHP	5	2	5	5	3	5	3	**3.5**	**N**	Carbon emitting technology. The Highland Council are moving away from carbon emitting heat.
11	Biogas CHP	3	4	4	3	2	4	3	**3.5**	**N**	City centre location and air quality requirements are prohibitive
12	Gas Boiler	5	1	5	5	3	5	3	**3.1**	**N**	Carbon emitting technology. The Highland Council are moving away from carbon emitting heat. Can be used effectively to meet peak demands. To be avoided if possible.

7 Energy modelling

For a heat network to operate efficiently (maximise carbon saving whilst minimising costs), the primary low carbon heating technology and peaking equipment within the energy centre must be accurately sized. Additional components such as thermal stores should also be sized appropriately to optimise the plant room design and utilisation of the low-carbon technology.

The Heat Supply Technology Suitability Assessment carried out in Section 6 identified ASHPs as the main heat generation technology suitable for the new energy centre

Instead of identifying the preferred energy supply solution for the Inverness Castle heat network, the energy modelling carried out sought to adjust the existing design by:

- Incorporating electric boilers,
- Optimising the volume of the thermal stores,
- Determining a suitable phasing of plant installation to maximise the heat demand met by the AHSPs

This heat network is comprised of both existing buildings and future new developments. For the new developments, or in the absence of half-hourly (HH) data from the client for the existing buildings, synthetic profiles for a given building typology were used. These profiles represent a typical week as an hourly profile and are taken from previous Buro Happold project experience. Based on the heating demand assessment completed, the profiles were adjusted to reflect the heating loads of the connections. The profiles cover both space heating (SH) and domestic hot water (DHW) use. Where the client provided HH data, annual profiles were put directly into the model. A model was set-up in EnergyPRO software to represent the heating loads for each connection. The annual loads were taken from the developed load schedule. The model also accounts for ambient air temperature fluctuations using historical local weather data; this considers the increase in heat demand with lower external temperatures. This methodology is detailed in Figure 7.1.

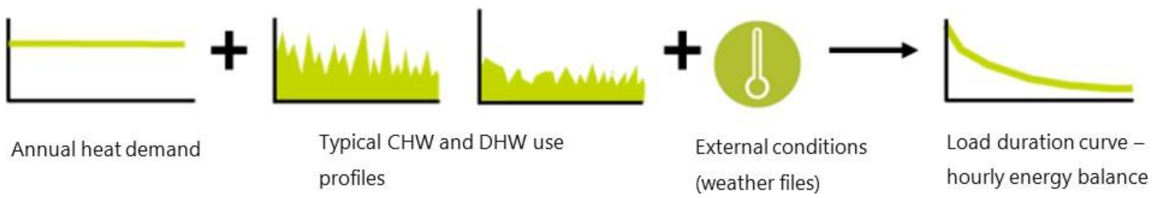

Figure 7.1: Heat Demand Profiling Methodology

In completing the energy modelling, a key criterion was to ensure that at least 85% of the annual heat demand (heat fraction) was met by the low carbon heating technology. The remaining annual demand would be satisfied by the peaking technology. This is to ensure that most of the heat for the network is supplied by the lowest carbon heating solution; therefore, limiting the carbon emissions from the network.

7.1 Scenario 1. ASHPs, Electric Boilers + 12m³ Thermal Storage

Scenario 1 seeks to follow the energy strategy outlined within the tender design information for the new energy centre.

As such, Scenario 1 models:

- An array of 11 x ASHPs operating with a Seasonal Coefficient of Performance (SCOP) of 2.80. The SCOP is a COP that accounts for seasonal variations in ambient air temperature and provides a more accurate representation of how an ASHP performs over an annual period.
- 3 x back-up/top-up 160kW Electric Boilers
- 12m³ of Thermal Storage

Phased energy modelling was carried out to determine the order in which plant should be installed into the energy centre to maxmise the heat fraction met by the ASHPs, whilst minimising the amount of plant made redundant during the early phases of the project before the full heat demand can be found.

7.1.1 Phase 1: Inverness Castle + North Tower

Table 7-1 summarises the equipment to be installed in the new energy centre to optimally meet the demand of Phase 1 of the heat network.

Table 7-1: Phase 1 equipment

Technology	Number Installed	Capacity	Efficiency (%)	Heat Fraction (%)
Air Source Heat Pumps	2	82 kW	280%	93
Electric Boilers	2	320 kW	99%	7
Thermal Storage	2	8m³	-	

The annual heat demand for Phase 1 is given in Figure 7.2 and highlights the proportion of the demand met throughout the year by the ASHPs and the electric boilers.

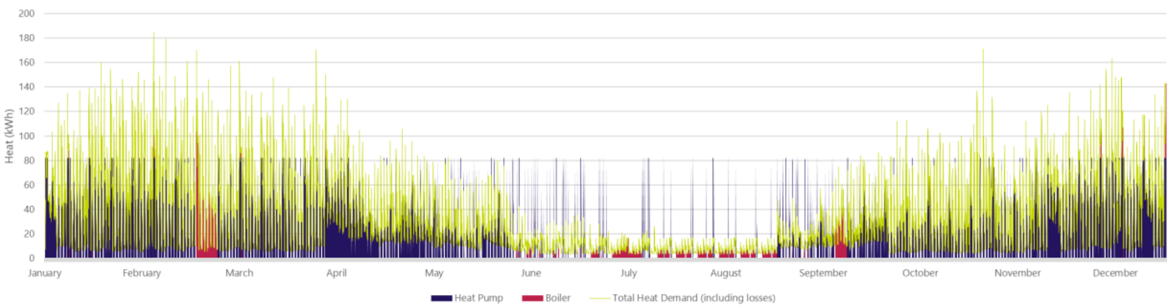

Figure 7.2: Phase 1 annual energy demand

Figure 7.3 is the daily demand over a winter's day. In the early hours of the morning when the heat demand is too low for the heat pump to operate, the thermal store acts as the source of heat. When heat demand increases, the heat pumps operate to meet the heat demand whilst also charging the thermal store. As demand continues to rise and the thermal stores become depleted, additional top-up is provided by the electric boilers.

When demand drops at the end of the day, the heat pumps continue to operate but instead charge the thermal stores.

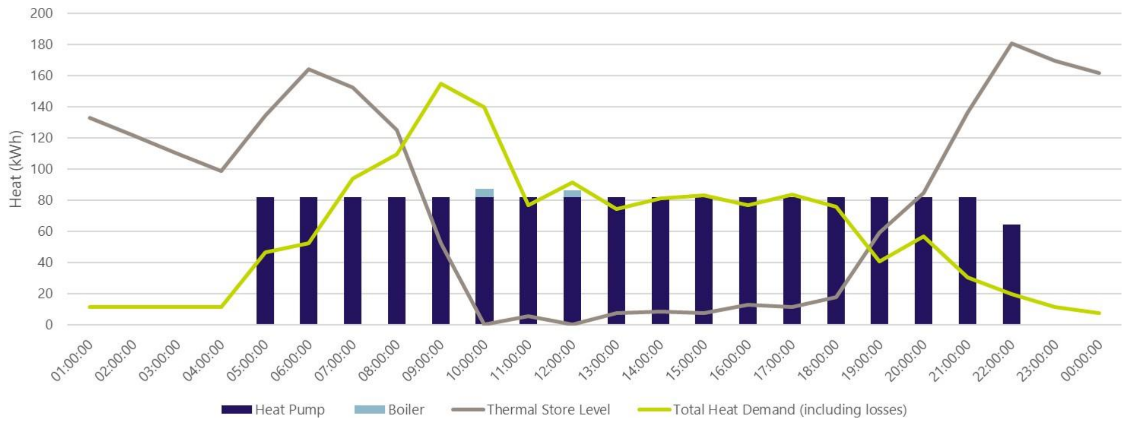

Figure 7.3: Daily demand profile (winter)

Figure 7.4 is the daily demand over a summer's day. In the morning, heat demand is too low to enable the heat pumps to operate. The top-up electric boilers operate to meet the heat demand. As demand increases later in the morning, the heat pumps operate to meet the demand whilst also charging the thermal store. The thermal stores discharge until later that evening until the demand picks up again and the heat pumps are switched on to meet demand and charge the stores again.

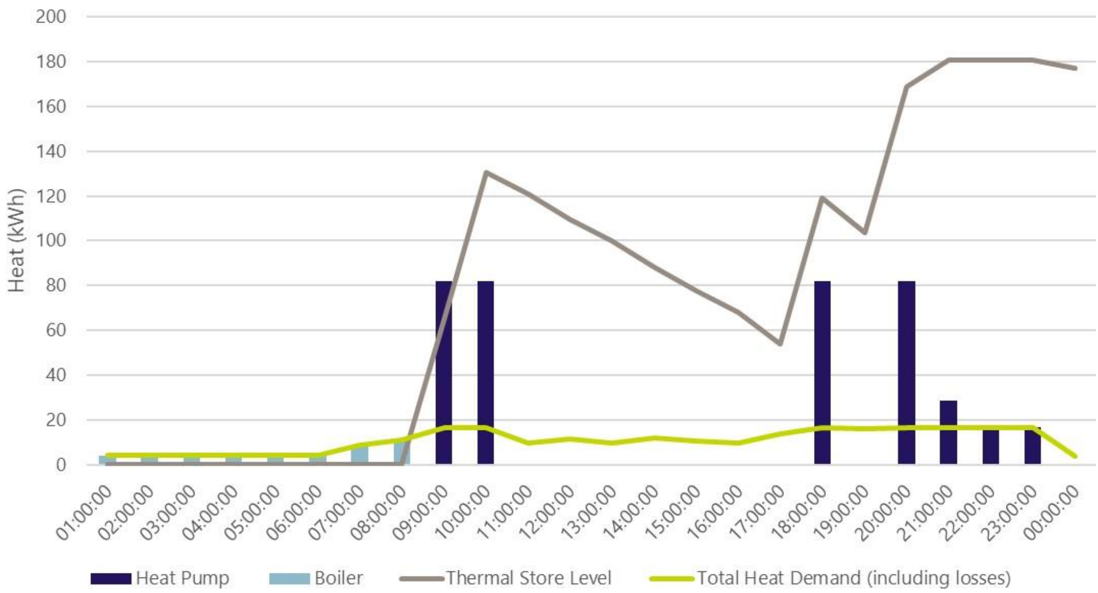

Figure 7.4: Daily demand profile (summer)

7.1.2 Phase 2: Inverness Castle + North Tower + Inverness Town House

As part of Phase 2, Inverness Town House is connected to the heat network, subsequently increasing demand. To meet this demand whilst maintaining a high heat fraction met by the Air Source Heat Pumps, the equipment outlined within Table 7-2 was found to maintain a high annual heat fraction met by the heat pumps.

Table 7-2: Phase 2 equipment

Technology	Number Installed	Capacity	Efficiency (%)	Heat Fraction (%)
Air Source Heat Pumps	5	205 kW	280%	96.3
Electric Boilers	3	480 kW	99%	3.7
Thermal Storage	2	$8m^3$	-	

The annual heat demand profile for Phase 2 (Figure 7.5) plots how the heat demand of the network varies throughout the year.

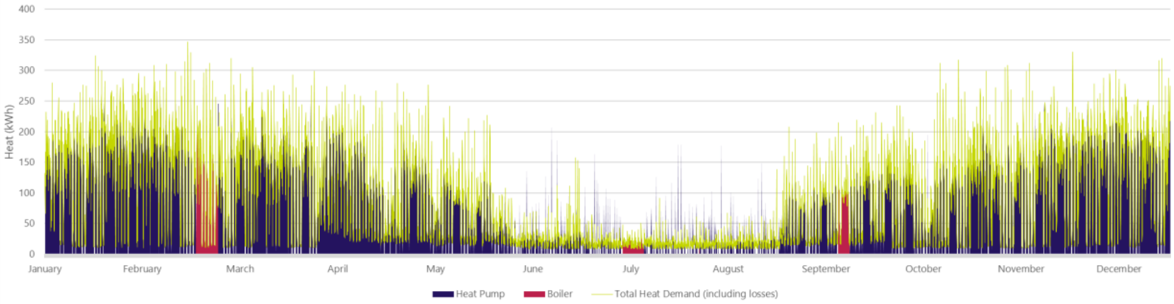

Figure 7.5: Annual demand profile

The Phase 2 daily heat demand curve for a typical winter's day is given in Figure 7.6. As expected, the demand is higher than that of Phase 1, with the ASHPs operating for a greater extent of the day. During times of relatively low demand and a practically full thermal store, such as early in the morning, the heat pumps are working to meet the heat demand whilst also charging the thermal stores.

When demand drops near the end of the day and the heat pumps cannot ramp down to meet it, the thermal stores begin to discharge to meet the particularly low demand.

Figure 7.6: Daily demand profile (winter)

The typical daily demand curve for a Phase 2 summer's day is presented in Figure 7.7. The ASHPs only operate when the demand is high enough. When operating, the ASHPs meet the heat demand and simultaneously charge the thermal stores. If demand becomes too low for the ASHPs to operate the thermal stores discharge to meet demand.

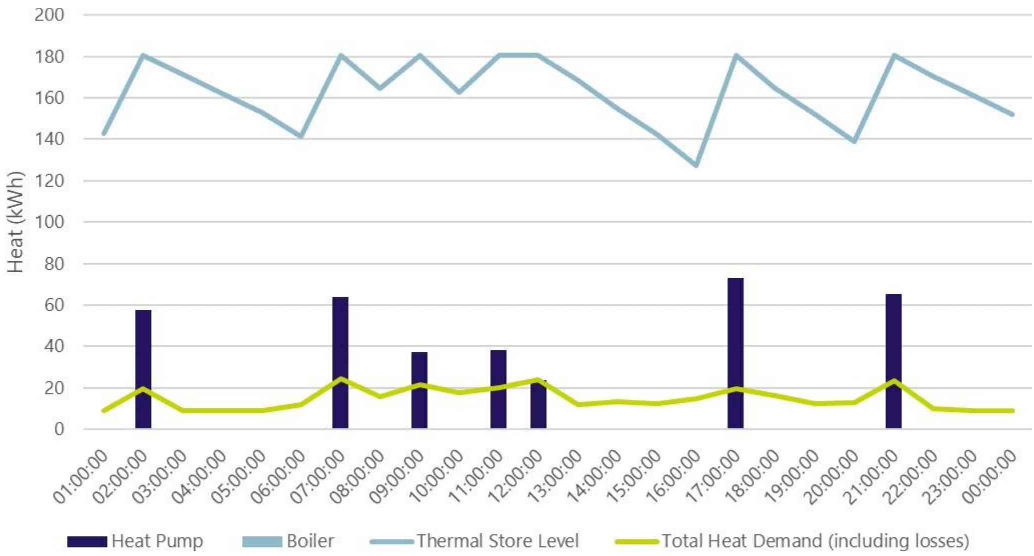

Figure 7.7: Daily demand profile (summer)

7.1.3 Phase 3: Inverness Caste + North Tower + Inverness Town House + Redevelopment + Inverness Museum & Art Gallery

Phase 3 represents the full build out of the heat network with all buildings being connected. At full build out, all plant outlined within the planning design is installed. Table 7-3 provides a high-level equipment schedule of the main items in the fully built out energy centre.

Table 7-3: Scenario 3 equipment

Technology	Number Installed	Capacity	Efficiency (%)	Heat Fraction (%)
Air Source Heat Pumps	11	451 kW	280%	96
Electric Boilers	3	480 kW	99%	4
Thermal Storage	3	12m^3	-	-

The annual profile given in Figure 7.8 represents how the total heat demand for the network is met over a year. Most of the demand is met by the ASHPs (96%) with electric top-up boilers providing the additional heat required during periods of peak demand. The thermal storage allows the ASHPs to operate for a higher proportion of the year.

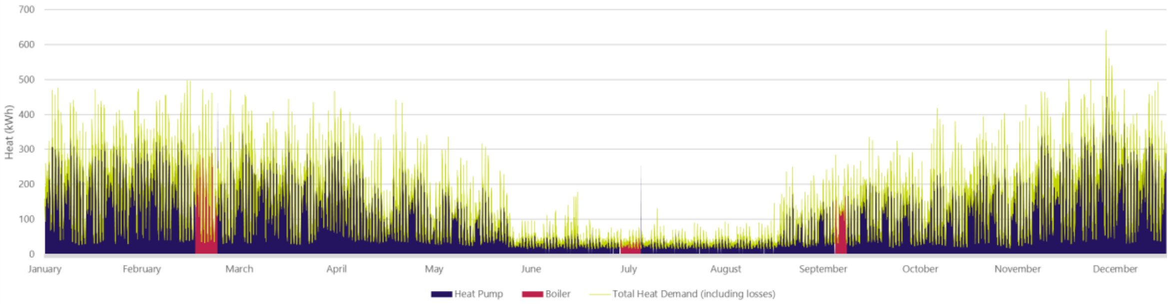

Figure 7.8: Annual demand profile for Scenario 1

Daily demand profiles that highlight a typical day in winter and summer are given in Figure 7.9 and Figure 7.10, respectively. The winter's day profile shown in Figure 7.9 highlights the very high utilisation rate of the ASHPs with little to none of the heat demand of the network being met by either the Thermal Store or the electric top-up boilers.

Figure 7.9: Daily demand profile (winter)

As expected, heat demands on a typical summer's day (Figure 7.10) are significantly lower than those in winter. When heat demand is lower than the 50% turndown capacity of the ASHPs, heat is provided by the charged thermal storage.

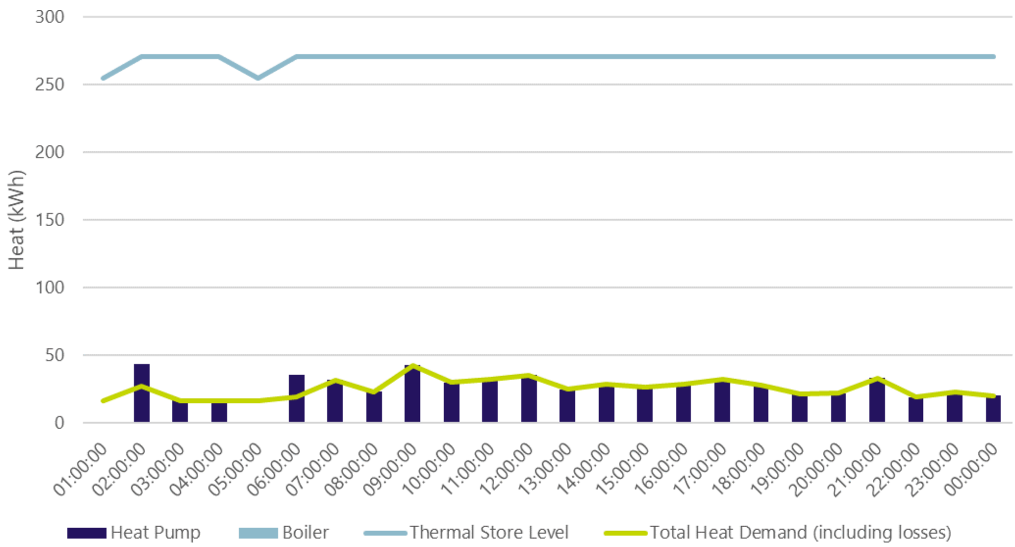

Figure 7.10: Daily demand profile (summer)

7.2 Scenario 2. ASHPs, Electric Boilers + 16m^3 Thermal Storage

Increasing the volume of thermal storage in a heat network can be a good opportunity to maximise the utilisation of the low carbon and cheap to operate heat generation equipment such as heat pumps. The equipment specification in the new energy centre allocates an initial 12m3 of thermal storage but outlines additional storage capacity for up to 16m3.

Energy modelling indicated that the annual heat fraction met by the ASHPs remained unchanged with the addition of another 4m3 of thermal storage.

The highest heat fraction observed was for Phase 2 of Scenario 1. This can be attributed to the higher annual heat demand of Phase 3, compared to Phase 2, which slightly reduces the heat fraction observed. As such, there is no financial or carbon benefit to increasing the thermal store volume, compared with the proposed 12 m^3 capacity. It should be noted that due to the non-operational periods considered for the heat pumps in the energy modelling, the achievable heat fraction for the heat pumps would never reach 100%.

8 Spatial coordination

8.1 Inverness Castle heat network

A map of the Castle heat network area is presented below in Figure 8.1. The imminent connections of Inverness Castle, North Tower and Inverness Town House are highlighted in green whilst the longer-term connections of the Art Gallery and Museum and redevelopment are shown in orange.

The energy centre location shown is an existing Highland Council owned public bathroom building, which was detailed as the chosen location in the planning permission application. An indicative route for the Buried Network pipework is shown in red.

Figure 8.1: Indicative Buried Network route

8.2 New energy centre

As per the tender design documentation, floor plans for the ground floor and first floor of the new energy centre are presented below in Figure 8.2.

The only equipment deviation in this feasibility study compared to the tender documentation is the phased approach for installation and the use of electric boilers (instead of gas boilers) as top-up/back up technology. It is assumed that suitable spatial assessment has been carried out for the planned ASHPs and thermal stores. Therefore, Figure 8.2 only highlights the additional spatial coordination required to include the proposed electric boilers.

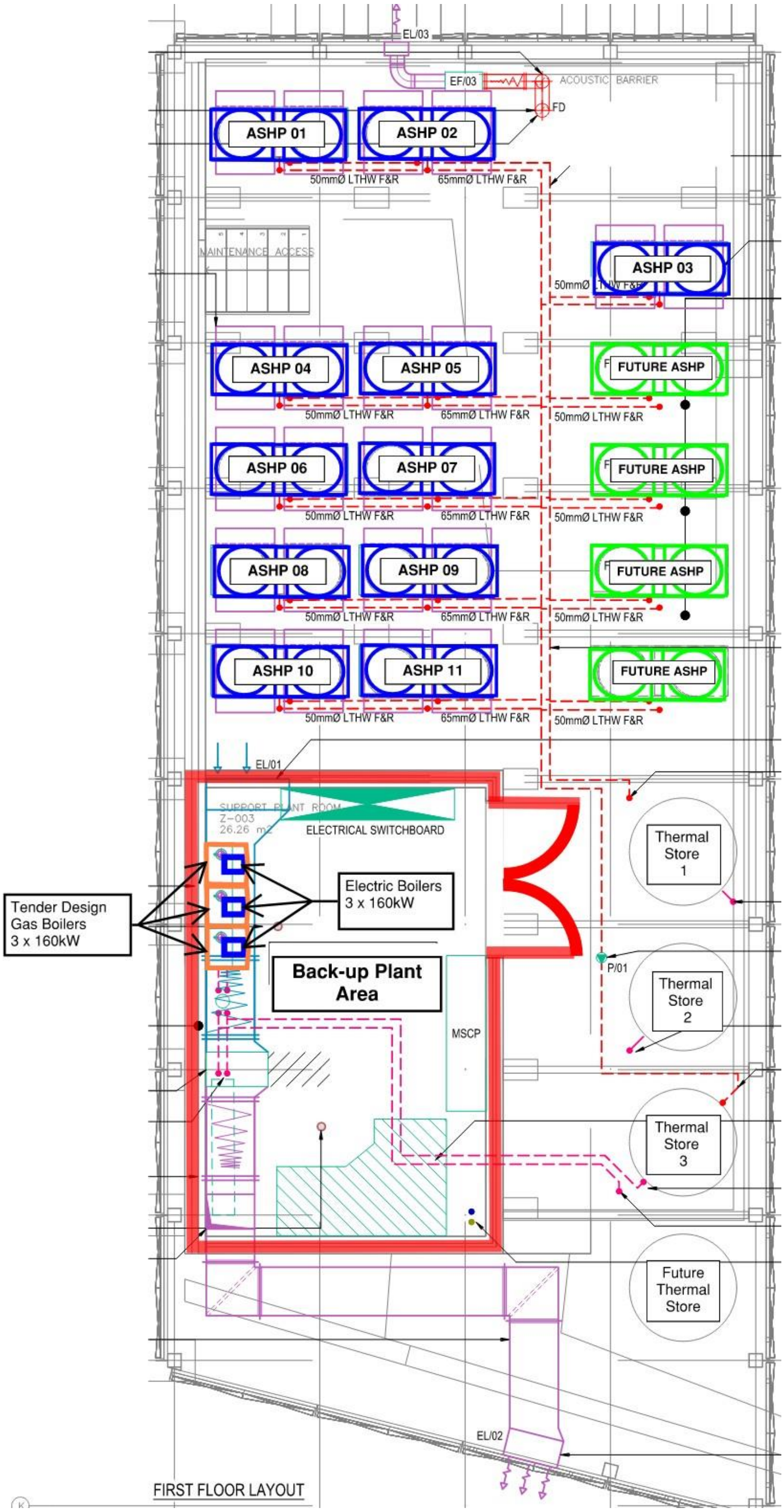

Figure 8.2: New energy centre - First Floor Plan

8.3 Heat network pipe sizing

An indicative Buried Network route is shown below in Figure 8.3. The heat network is broken down into numbered sections, with each section being sized to be able to meet the demand of the buildings downstream of that section of pipe. The associated pipework dimension of each section of pipe is presented in Table 8-1. The total trench length of the heat network is 188m.

Figure 8.3: Buried network for the Castle area

Table 8-1: Pipe schedule for the Castle District Heat network

Pipe reference	Pipe DN / mm	Trench length / m	Pipe length / m
1	100	7	14
2	80	22	44
3	65	36	72
4	50	28	56
5	65	34	68
6	65	18	36

Pipe reference	Pipe DN / mm	Trench length / m	Pipe length / m
7	80	43	86

8.4 Heat network schematic

A schematic diagram of the proposed heat network at Inverness Castle is given in Figure 8.4.

Heat is provided to all the connections via the new energy centre to be constructed in the retrofitted existing public bathrooms. The technologies used within the new energy centre aligns with the information given within the planning application except for the use of electric boilers (in place of gas- fired units).

Heat Interface Units (HIUs) or substations at each connection will separate the building side heating from the heat network. Each individual connections heat consumption will be metered for billing and metering purposes.

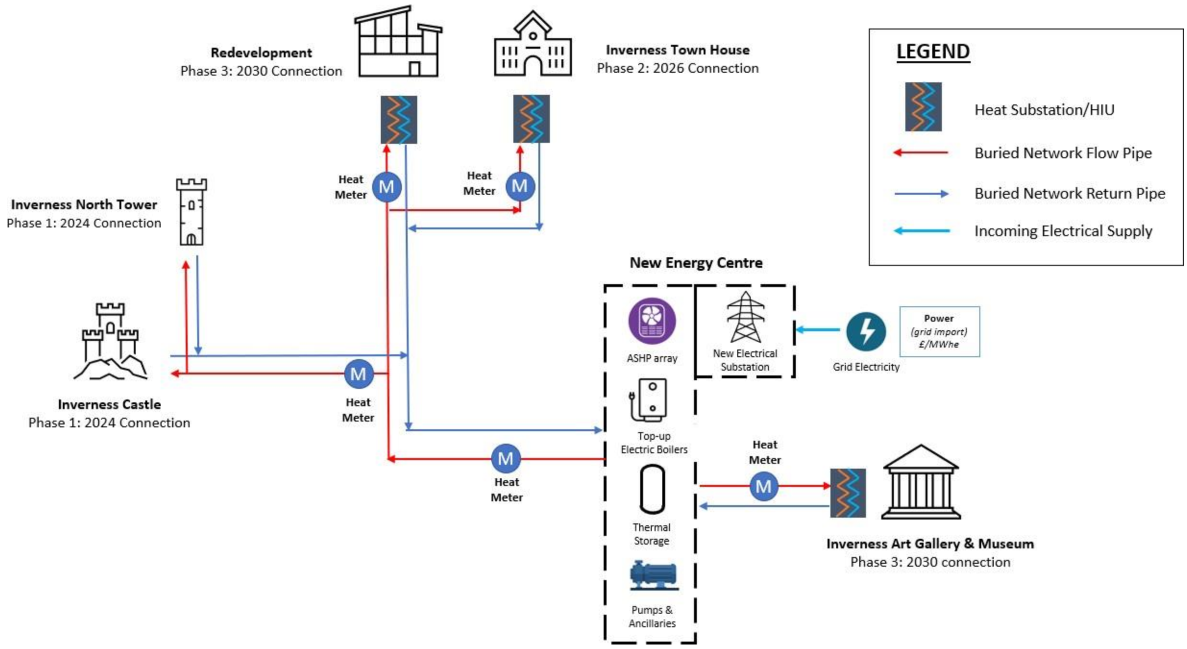

Figure 8.4: Inverness heat network Schematic

9 Techno-economic modelling

This section outlines the techno-economic modelling (TEM) carried out for the chosen heat network scenario, providing information on the capital and operational expenditure (CAPEX, OPEX) and the financial performance of the heat network.

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.

9.1 Methodology

A techno-economic model has been developed to assess the possible return on investment that can be achieved from each scenario over the 40-year project life. To do so, an annual cash flow was produced, combining technical details of the scheme (CAPEX, OPEX) with appropriate cost/price inputs.

The viability of each scenario is represented in the model by Net Present Value (NPV), Internal Rate of Return on investment (IRR) and discounted payback. A positive NPV achieved at 40 years represents a financially attractive scheme.

The charges to the consumer have been broken down in the model. Each connection will have two costs for heat: a variable rate and a fixed rate. Additionally, a connection charge will be added for each development to connect to the heat network; this charge represents the otherwise avoided cost to the consumer by connecting to the district heat network. As such, the three main revenue streams can be viewed as:

1 Variable heat sales (p/kWh)
2 Fixed rate costs (£/unit of £/kW)
3 Connection charge (£)

9.2 Scenario development

The heat network design to be progressed to the TEM was based on the technology assessment and initial linear heat density calculation completed for this scheme. For this TEM, one scenario was considered based upon the chosen technology of ASHPs. The scenario selected for techno-economic modelling was:

- **Scenario 1:** Centralised ASHP low carbon heating technology with peaking electric boilers providing heat to the core network. Thermal storage of 12m^3.

To gain a better understanding of how this scenario compares to alternative heating options, the following additional scenarios have been developed but have not been analysed in the techno-economic model:

- **Business as Usual (BAU) Case:** this scenario assumes that each building will continue to use its existing heating technology for the 40-year duration considered in the project.
- **Counterfactual scenario:** assumes the direct replacement of existing heating technology with ASHPs, with the ASHP providing 100% of the annual heat demand of each connection for the 40-year duration considered in the project.

9.3 Heat sales price

To develop the heat sales price, the fixed and variable rate were calculated following methodology from the DECC in ‘Assessment of costs, performance, and characteristics of UK heat networks’6. The breakdown of these costs is shown in Figure 9.1.

[6] https://www.gov.uk/government/publications/assessment-of-the-costs-performance-and-characteristics-of-uk-heat-networks (Accessed 22/11/22)

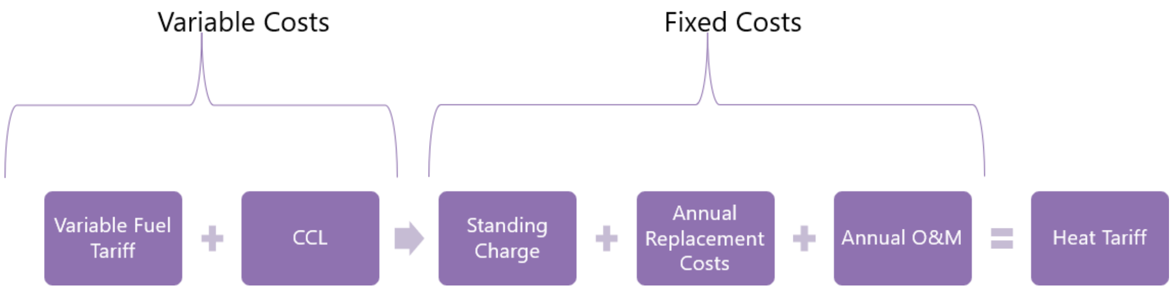

Figure 9.1: Breakdown of heat sales price

As illustrated above, the variable cost of heat considers the variable fuel tariff. The fuel import rate used in this modelling is based on BEIS Green Book Tables 4-8 Retail Fuel Prices7. The relevant import prices for natural gas and electricity are displayed in Table 9-1. The costs used in the modelling reflect the 2023 Commercial figures; for the natural gas prices, Scenario B, which represents the average of daily fuel prices, was used.

Table 9-1: Fuel import rates

Fuel import	Commercial / Public sector price p/kWh	Source
Electricity	28.98	BEIS Green Book retail 2023 fuel prices
Natural Gas	8.92	

Following confirmation from the Highland Council that all buildings will be charged the same rates, the average calculated counterfactual cost of heat for each building was calculated taken. The heat sales price and fixed charge are displayed in Table 9-2. These charges are based on a building-level ASHP counterfactual.

Table 9-2: Heat sales price

	Heat sales price (p/kWh)	Fixed rate (£/kW)
Commercial connection	12.14	71.68

7 https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fassets.publishing.service.gov.uk%2Fgovernment%2Fuploads%2Fsystem%2Fuploads%2Fattachment_data%2Ffile%2F1129255%2Fdata-tables-1-19.xlsx&wdOrigin=BROWSELINK [Accessed March 2023]

9.4 Connection charge

A connection charge is calculated for the individual ASHP counterfactual scenario. This cost is calculated based upon the costs that the customer would avoid if they decided to connect to the heat network. The charge represents the CAPEX associated with the counterfactual heating technology for each building.

An allowance for plant space saved, due to the centralised energy centre solution for the network, has not been included in the current connection charge estimates.

The connection charge for each building is displayed in Table 9-3.

Table 9-3: Connection Charge

Connection name	Connection charge (£'000s)	Year Paid (-)
Inverness Castle	113.8	2024
Inverness North Tower	87.5	2024
Future Redevelopment Site	298.8	2030
Inverness Museum and Art Gallery	66.6	2026
Inverness Town House	185.0	2030
Total	**751.7**	

9.5 Capital costs

A phased and itemised CapEx breakdown for the project, split in equipment/works categories, is given in Table 9-4.

Item	Phase 1 (2024)	Phase 2 (2026)	Phase 3 (2030)	Total	Information source	Notes (inclusions & Assumptions)
Heat Pumps	60	90	181	332	Manufacturer/contractor quotation.	Total of 11 x 41 kW_{th} Mitsubishi CAHV-P500YA-HPB units.
Electric Boilers	32	16	-	47	Manufacturer/contractor quotation.	Total of 3 x 160 kW_{th} electric boilers
Alterations to energy centre Building	576	-	-	576	BH previous project experience	Based upon £/m2 for new energy centre with 20% reduction to account for retrofit.
Thermal Storage	12	-	6	18	Manufacturer/contractor quotation.	Total of 3 x 4,000 l capacity stores as specified in planning documents.
Heat Network Ancillaries	421	24	-	445	BH previous project experience	Heat network ancillary equipment - circulation pumps, water treatment, expansion and controls etc
DHN Pumps	2	2	2	7	Manufacturer/contractor quotation	Assuming capacity from Energy Modelled peak of approx. 900kW.
Expansion vessel	7	-	-	7	Manufacturer/contractor quotation	
Pressurisation	2	-	-	2	Alfa laval quotation	
Water treatment	3	-	-	3	BH Project Experience	
Dirt separator and deaerator	23	-	-	23	BH Project experience	
Controls	300	-	-	300	Manufacturer/contractor quotation	
Other energy centre M&E	88	22	-	110	Prelims, design fees, contingency. Assumed 20% of total CapEx cost	
Buried Network Pipe costs	135	31	133	298	BH previous project experience	High Level cost based upon £/m of buried network pipework corresponding with sized pipework dimensions

Item	Phase 1 (2024)	Phase 2 (2026)	Phase 3 (2030)	Total	Information source	Notes (inclusions & Assumptions)
Building Connection Ancillaries	24	22	44	90	Manufacturer/contractor quotation.	Heat meters and Heat Substations for every connection.
Heat meters	2	2	4	9	Manufacturer/contractor quotation.	One per connection. Assumes approx. DN50 sized unit.
Substation PHX	22	20	39	81	Manufacturer/contractor quotation.	Each substation sized for peak capacity for its corresponding connection. From 900kW of peak building demands.
Upgraded Electrical Infrastructure	210	-	-	210	Manufacturer/contractor quotation.	Includes earthing, substation upgrades, LV Switchboards and LC Cabling.
New electrical substation	15	-	-	15	Manufacturer/contractor quotation.	To accommodate ASHPs. Confirmed by PM on site.
Earthing	26	-	-	26	Manufacturer/contractor quotation.	
LV Switch Board	49	-	-	49	Manufacturer/contractor quotation.	
LV Cabling	120	-	-	120	Manufacturer/contractor quotation.	
Total CapEx	**2,059**	**256**	**512**	**2,826**		Includes additional costs - contingency, prelims, design fees etc.

Table 9-4: Breakdown of CAPEX costs for each scenario

9.6 Operating costs

The ongoing operational costs within the model are categorised as follows:

- Operation and maintenance costs
- Fuel costs
- Replacement costs

9.6.1 Operation and maintenance costs

Table 9-5 shows the key operation and maintenance cost assumptions in the TEM. Operational expenditure (OPEX) for equipment was modelled as a percentage of CAPEX or as a cost per unit/connection.

Table 9-5: Operation and maintenance assumptions

	Unit	Cost
Heat pump (fixed and variable operating cost)	% of capex	2
	p/kWh	0.25
Electric boilers	% of capex	5
Plate heat exchangers	% of capex	2
Heat meters	£/unit	650
Metering and billing (bulk)	£/connection/year	500
District heat network	p/kWh	0.06

9.6.2 Fuel costs

The fuel import costs used within the model are shown in Table 9-6, these are the costs currently being paid by the Highland Council for fuel as well as their forecasted values.

Table 9-6: Fuel import costs

Fuel	23-24 predicted	Units
Electricity	25.41	p/kWh
Gas	7.54	p/kWh

After 2024, the cost of fuel has been indexed in line with BEIS Green Book Supplementary Guidance, (Table 4-8: Retail prices) projections for future fuel costs. Future costs of electricity and gas have been indexed to Central and Scenario B price projects, respectively.

9.6.3 Replacement costs

Table 9-7 shows the life expectancy of the major equipment required for the DHN. As the scheme lifetime being considered is 40 years, it is recognised that the equipment will need replacing during this time. Within the modelled 80% of the CAPEX for the equipment is modelled as a REPEX at the end of the equipment lifetime. Replacement costs have been assumed to be paid off as part of a sinking fund within the model.

Table 9-7: Equipment life expectancy

Equipment	Replacement period (years)
Heat pump	15
Electric boiler	20
Plate heat exchangers	15
Heat interface units	15
Heat meters	25
DHN pipework	Longer than scheme lifetime (40 years)

Table 9-8: REPEX over 40-year timeline

Item	Scenario 1: ASHP + Electric Boilers + 12 m3 thermal store (£'000s)	Benchmark RepEx	Notes
Heat pumps	800.1	Replace after 15 years	Buro Happold past project experience
Heat exchangers	198.7	Replace after 15 years	Buro Happold past project experience
Electric Boilers	92.9	Replace after 20 years	Buro Happold past project experience
Heat Meters	12.8	Replace after 15 years	Buro Happold past project experience

9.7 Modelling assumptions

The following key assumptions were made in the development of the TEM:

Key Assumptions

- **Project Timeline**
  - 40-year time period for the estimate of Net Present Value (NPV) and Internal Rate of Return (IRR).
- **Heat network Ownership**
  - The heat network owner/operator would act as a bulk heat supplier, owning and operating the energy centre equipment and buried network up to the connection at Heat Interface Units (HIUs) and Heat Substations.
- **Capital Costs**
  - Capital costs have been phased in alignment with the indicative timeline for build out of the heat network.
- **Replacement Expenses (RepEx)**
  - Replacement cost sinking fund – spreads cost of equipment replacement over project lifetime instead of one lump sum every time equipment is to be replaced.
  - Assumed equipment life expectancies and total REPEX over the 40-year project timeline are given in Table 9-7 and Table 9-8, respectively.
- **Connection Charges**
  - Connection charges are a one-off payment made by each building to connect to the heat network in the year that the building is due to connect to the network.
  - Connection charges have been calculated based upon the avoided costs that the building would have otherwise paid to make use of the counterfactual technology (individual ASHPs at each building)
  - The connection charge fee and date when that fee is to be paid is given in Table 9-3.
- **Connection Heat Sales Tariffs**
  - Variable and fixed rates were calculated using methodology within the DECC 'Assessment of costs, performance, and characteristics of UK heat networks'[8].
  - All buildings are assumed to be paying the same heat sales price, regardless of building ownership.
  - The calculated heat sales prices are:
    - **Variable rate:** 12.14 p/kWh
    - **Fixed rate:** 71.68 £/kW
- **Fuel Cost Projections (energy centre)**
  - Future fuel price projections were provided by the Highland Council.
  - The predicted fuel costs for the council in the financial year 2023-2024 were used. These were:
    - **Electricity:** 25.41 p/kWh
    - **Gas:** 7.54 p/kWh
    - These values were indexed from 2024 to BEIS Green Book Supplementary Guidance, (Table 4-8: Retail prices) projections for future fuel costs
- **Building Connection Dates**
  - Phasing has been applied with Inverness Castle and North Tower assumed to connect in 2024, Inverness Town House in 2026 and the new development and Inverness Museum and Art Gallery in 2030.
- **Heat Supply Technology**
  - At full build out, the new energy centre is assumed to contain:
    - **ASHPs:** eleven 41kW units producing a total heat output of 451kW.
    - **Electric Boilers:** three 160kW units producing a total heat output of 480kW
    - **Thermal Storage:** 12m^3
  - A summary of the heat technologies used, along with their phasing and the proportion of the annual heat demand met by each technology for each phase can be found in Section 7.

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[8] https://www.gov.uk/government/publications/assessment-of-the-costs-performance-and-characteristics-of-uk-heat-networks (Accessed 22/11/22)

- **Discount Rate**
  - HM Treasury Green Book Guidance Discount Rate of 3.5% assumed.

9.7.1 Counterfactual scenario

The counterfactual scenario was used as a basis for establishing the heat sales price and connection charge cost for the heat network scenario. The counterfactual scenario represents the mechanism by which heat would be delivered to consumers if the proposed heat network was not instated.

- **Individual ASHP counterfactual:** each connection on the network will have a communal ASHP, per building, as the main heating technology. This ASHP will meet 100% of the annual heating demand for each building.

9.7.2 Scenario 1: ASHPs + Electric Boilers

Scenario 1 has been developed in line with the tender design documentation for the new energy centre. Contrary to this design, Scenario 1 considers electric boilers as the peaking technology, following conversation with the Highland Council that concluded the council's preference for an electric energy centre. Original planning included the use of back-up gas boilers.

9.8 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. At the next stage, we recommend confirming costing with a Quantity Surveyor.

9.9 Economic results

9.9.1 Without funding

A summary of the key results for each scenario for the base case economic model, against the low carbon counterfactual, is displayed in Table 9-9. Any results presented in brackets represent a negative value.

Table 9-9: Economic results against a low carbon counterfactual (40-year period)

Economic Metric	Scenario 1: ASHP + Electric Boilers + 12 m^3 thermal store
Total CAPEX (£M)	2.83
Total fuel costs (£M)	2.04
Total O&M (£M)	0.74
Total REPEX (£M)	0.88
NPV at 40 years (£M)	(1.41)

Economic Metric	Scenario 1: ASHP + Electric Boilers + 12 m^3 thermal store
IRR at 40 years (%)	-
Social IRR (%)	-
Discounted payback period (years)	Longer than scheme lifetime
Heat sales revenue (£M)	2.39
Fixed charge revenue (£M)	2.55
Connection charge revenue (£M)	0.75
Total revenue (£M)	5.68

The cash flow curve for Scenario 1: ASHPs + electric boilers +12m^3 thermal storage is presented below in Figure 9.2.

Significant CAPEX expenditures are present in years 2024, 2026 and 2030, coinciding with the phased construction of the heat network. Most of the construction work (build out of the energy centre and most of the buried network) takes place in 2024 and as such, the majority of the CAPEX expenditure of the heat network occurs at this time. Additional CAPEX to connect the Town House and Redevelopment/Inverness Museum & Art Gallery are represented in the 2026 and 2030 CAPEX expenditures, respectively.

Peaks in revenue are also seen during these three time periods as new connections pay their one-off connection fees. As time progresses Net Present Value maintains a positive inflection, suggesting a positive revenue/expenditure balance on the heat network. However, Net Present Value stays negative over the entirety of the 40-year lifetime of the project.

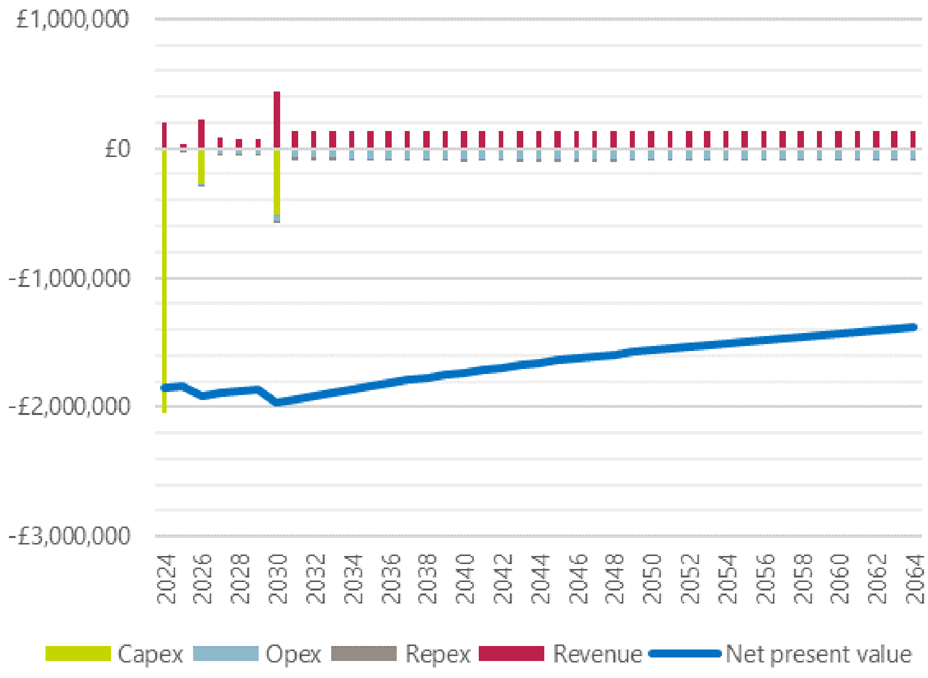

Figure 9.2: Scenario 1 Cash Flow Curve

9.9.2 With funding – 50% CAPEX funding (targeting 3.5% IRR)

To gain an appreciation of the amount of funding that could potentially be required to make the Inverness Castle heat network an attractive project for a local authority, an IRR of 3.5% was targeted, by varying the amount of funding available to the project.

Based on the potential funding opportunities, the IRR achieved when 50% CAPEX funding was considered (£1.41 M) was assessed in the model. Table 9-10 captures the economic results of the Inverness Castle Heat Network when targeting a council-favourable IRR (assumed 3.5% from BEIS Green Book).

Table 9-10: 50% CAPEX funding outcomes

Parameter	Value
Funding (£M)	1.41
NPV at 40 years (£M)	0.01
IRR at 40 years (%)	3.6

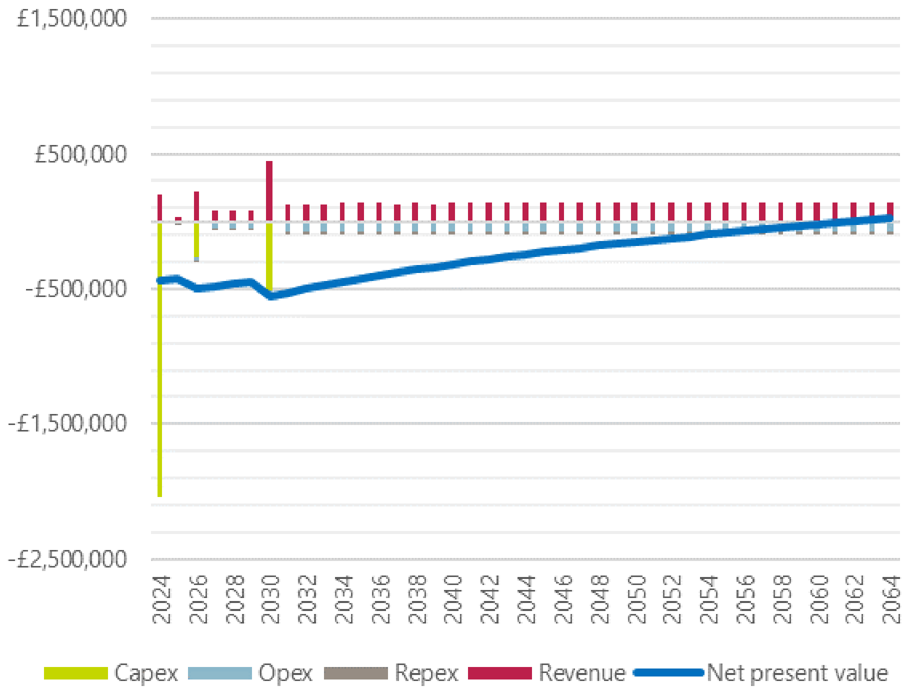

Figure 9.3: Scenario 1 Cash Flow Curve – with funding targeting 3.5% IRR

9.10 Sensitivity analysis

Within the TEM, the effect of key parameters on the overall economics of the scheme was assessed. The key parameters considered were:

- Annual heat load
- Heat sales price
- Heat pump efficiency
- Capital cost
- Fuel cost

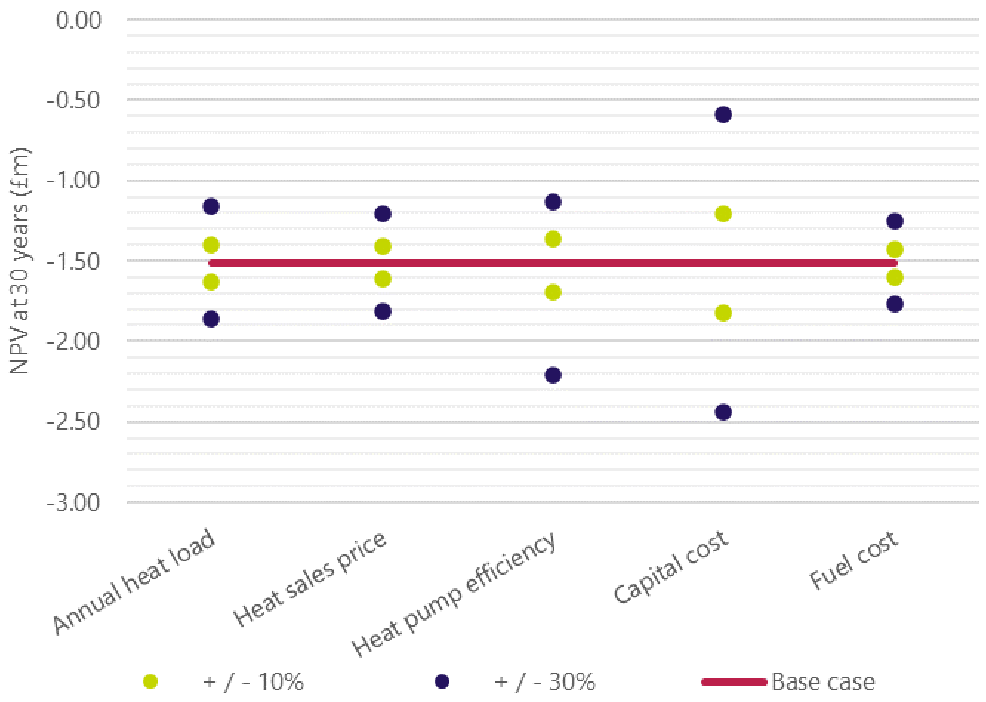

Figure 9.4: Sensitivity analysis

For Scenario 1, as shown in Figure 9.4, the parameter to which the scheme is most sensitive is the capital cost. A 30% reduction in the capital expenditure for this scheme significantly improves the NPV at 30 years, increasing the value to -£0.59M compared with the base case of -£1.41M. This is conducive with the results of the funding analysis; the funding requirement for a 3.5% IRR represents approximately 50% of the total capital expenditure for the network and achieves a NPV of £0.01M.

It should be noted that the fuel cost and heat sales price are also key sensitivities. The heat sales price is directly related to the cost of fuel import.

9.11 TEM summary

Techno-economic modelling has been completed for an ASHP led, all electric heat network solution for the area around Inverness Castle. The modelling has been completed based upon an initial energy centre design that included ASHPs and 12m^3 of thermal storage. However, electric boiler back-up technology was considered in contrast to the initially proposed gas boiler solution.

For the unfunded base case scenario, the project did not return a positive NPV. Instead, a NPV of -£1.41M was calculated at year 40.

Additional analysis was carried out to gain an appreciation of the approximate amount of funding that would be required to make the project potentially viable for a Local Authority. To do this, a target IRR of 3.5% was set and additional funding of 50% CAPEX was applied. Funding of 50% CAPEX corresponds to a value of £1.41M. With this additional funding, the project achieved a NPV of £0.01M and an IRR of 3.6%, suggesting a potentially favourable project for a Local Authority.

For the proposed scenario, a sensitivity analysis was completed to assess the impact of key parameters on the NPV achieved at year 30. The sensitivity analysis demonstrated that the heat network is most sensitive to capital costs.

10 Carbon emissions assessment

10.1 Carbon emissions factors

The carbon emission factor of a fuel is defined as the amount of carbon emitted per unit of fuel energy consumed (kg CO_2e/kWh consumed). Calculating the carbon intensity of consumed heat via this metric is a method to assess the carbon performance of each scheme option. BEIS provide annual carbon emission factors for fuels used in the UK. BEIS also produce annual future projections for the carbon emission factor of power grid electricity. The UK's grid is much more susceptible to changes in its composition due to the wide-ranging mix of generating technologies, e.g., nuclear power stations, gas power plants, wind farms, coal power stations etc.

The penetration of renewable power in the UK has been increasing and is projected to continue to increase over the coming decades. BEIS also expect nuclear power to provide a more significant portion of the UK's power demand in the future. This will decarbonise the national grid and, as this occurs, technologies such as heat pumps will become less carbon intensive whilst technologies such as gas CHP will become more carbon intensive with its generated electricity having a higher carbon factor than the grid.

10.2 Calculated carbon emissions

The carbon assessment presents a carbon emission reduction for the preferred option, ASHPs and electric boilers, against a 'counterfactual' case. The counterfactual case is the 'baseline' carbon emissions of the buildings proposed for connection to the Castle heat network; this is the emissions associated with building heating energy if the heating network was not built. This provides a means for assessing how well the scheme performs on an environmental basis. The counterfactual case carbon emissions have been calculated for separate heating scenarios for the consumers based on building-level ASHPs working with a weighted thermal efficiency of 244% across the different building connections. A weighted efficiency has been instated as the COP for the heat pump would vary given that the operating temperature of the different buildings is not the same.

Similarly, a Business-as-Usual scenario was considered which assumes that no replacement of heating technology takes place, and each building continues to make use of its current technology.

The following presents a comparison between the counterfactual carbon emissions and the ASHP-led heat network scenario carbon emissions over a 40-year period. Table 10-1 provides information on the lifetime carbon emissions for each scenario over the 40-year period, as well as the carbon emissions savings for each option. This is graphically presented in Figure 10.1.

Table 10-1: Carbon emissions from each option over 40-year project lifespan

Option	Lifetime carbon emissions (tCO_2e)	Carbon emissions savings (tCO_2e)
Business as usual – Gas Boilers/CHP units	7,191	-6,534
Counterfactual Scenario – ASHPs only	657	0
Scenario 1: ASHPs and electric boilers	711	-54

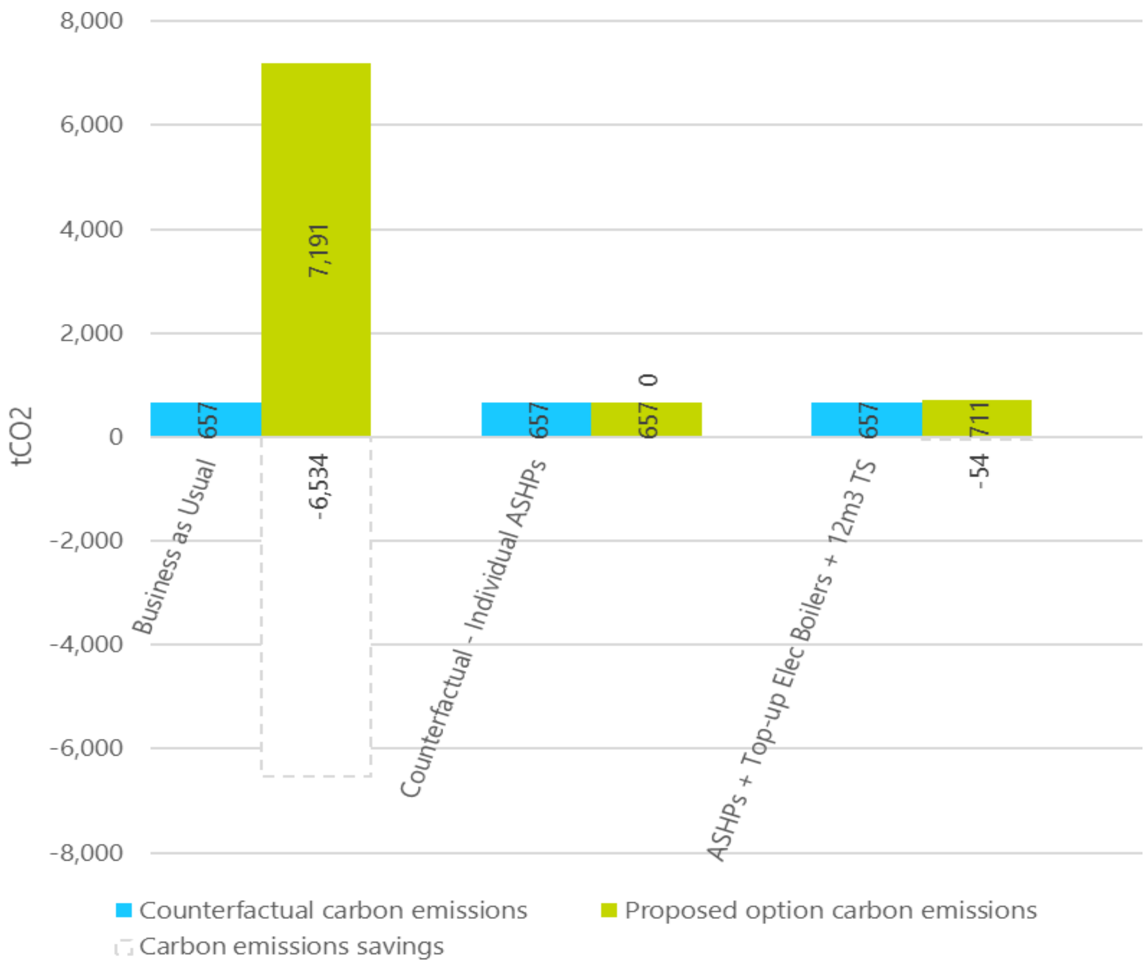

Figure 10.1: Carbon emissions savings

A plot of the annual carbon emissions for each of the three situations is presented in Figure 10.2. The gradual decrease in carbon emissions for both the counterfactual and Scenario 1 is correlated to BEIS predicting the national grid will gradually decarbonise.

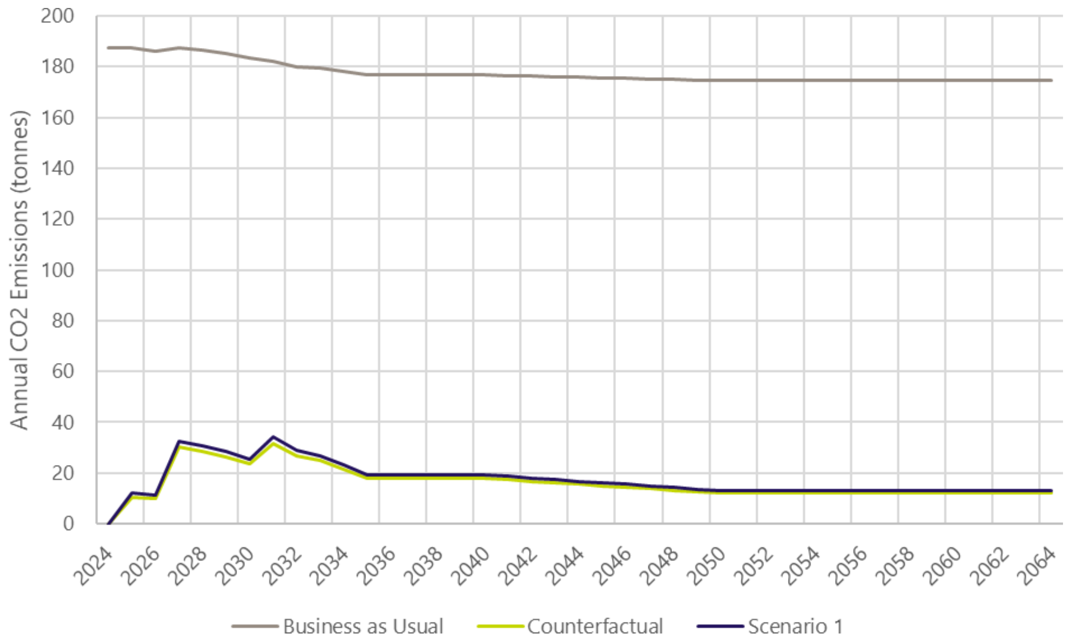

Figure 10.2: Annual carbon emissions over 40-year project lifetime

The District Heat Network (DHN) does not offer any carbon emissions savings compared with the counterfactual option. This is because the counterfactual does not consider network losses; the district heat network solution accounts for 10% losses in line with CP1. As such, the DHN option has a higher overall heat demand than the decentralised counterfactual alternative. Hence, there is a greater overall fuel consumption for the heat network and therefore higher associated carbon emissions.

Additionally, within the techno-economic model, an electrical consumption associated with the pumping requirements for the heat network is calculated. This is calculated as a percentage of the heat demand per scenario. A 2% parasitic pumping requirement is applied for the ASHP DHN.

11 Heat network development

The development process for a public sector sponsored district heating scheme typically has a number of stages:

- **Development** – this includes feasibility (the current stage) and Outline Business Case (OBC) once the feasibility has been established. This will ultimately lead to the completion of a business case for the scheme. This stage would typically take up to 12 months.
- **Tendering and procurement** – following a decision to proceed on the business case. Finance for the project would be procured and contracts negotiated. This stage would typically take 12 months.
- **Delivery** – this would include the final detailed design of the scheme, construction and commissioning. This would typically take 18 to 24 months.

Based on the assumed timeline, it's assumed that the heat network will be operational by Q1 of 2026. It would be recommended that the Outline Business Case for the scheme is developed as soon as possible.

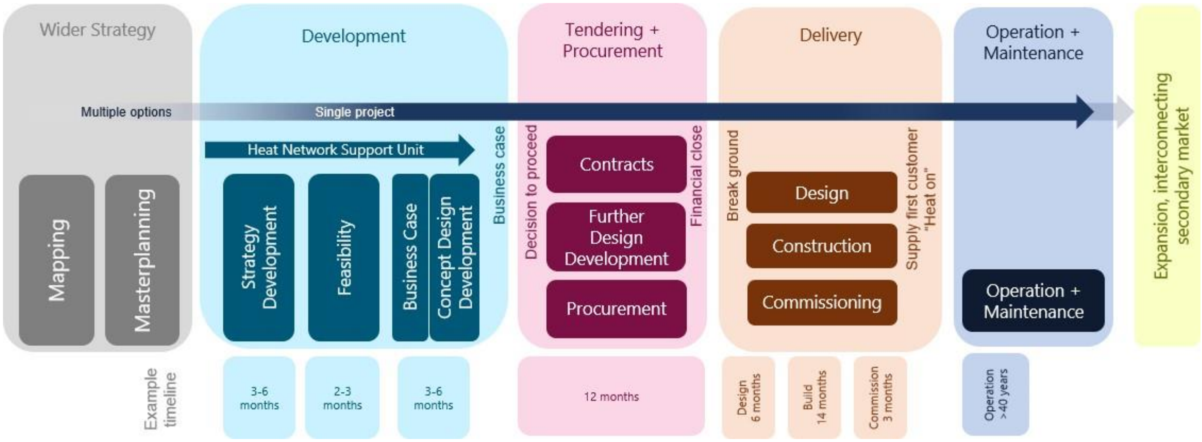

Figure 11.1: Heat Network Project Delivery Timeline

11.1 Commercial options and delivery routes

This section provides a review of commercial options for delivering the Inverness Castle DHN, it aims to inform the Highland Council of possible routes to procurement for the preferred DHN option.

11.1.1 Commercial structures

The commercial case for the district heat network should demonstrate that the scheme will have a viable procurement and contractual strategy that provides a sustainable basis for the long-term operation of the system.

11.1.1.1 Objectives

A commercial strategy needs to ensure that the project delivers an optimal return while aligning with the Highland Councils drivers for a low-carbon development and ensuring fair energy/heat pricing for consumers. As such it needs to consider the commercial arrangements between principal parties including the council, any potential funders/investors, contractors, suppliers and customers.

Key roles to be allocated for the development of a district heat network are given in Table 11-1. The allocation of these roles is dependent on the allocation of risks, ability to fund and requirements for participation and control.

Table 11-1 Key roles associated with a heat network

Role	Explanation
Property developer	Often has a limited engagement with a decentralised energy project and is mainly concerned with delivery of a real estate project including compliance with planning conditions and net floor area for revenue generation.
Building owners	Building owners tend to focus on reliable heat supply and a heat sales price from a heat network that compares well with an alternative low-carbon approach
Asset owner	The party that owns the physical assets, such as the generation technology and associated infrastructure.
Operator	Responsible for the technical operation of the energy scheme.

Role	Explanation
Retailer	The party responsible for the retailing of energy, i.e., purchasing it from the generator, arranging transportation to the consumer and sale to the consumer.

11.1.1.2 Options available

The Highland Council will decide the formal role they will take in the design, installation, commissioning and long-term operation of the system. If no private sector involvement is possible (e.g., due to lack of commercial performance for private sector involvement) or desired, then the council can choose to self-deliver and operate the network. Councils have access to low-cost finance through the Public Works Loan Board as well as other potential sources of public funding such as the eat Network Fund (HNF) and the Green Growth Accelerator and could benefit from the revenue generation of a heat network scheme.

The commercial structure options are outlined in Table 11-2. This table, provided in the Heat Networks Code of Practice (CIBSE), shows that the system can be broken down as required.

Table 11-2 Ownership and operation options (Heat Networks Code of Practice CP1)

Option	Energy centre		Heat network		Heat supply
	Own	Operate	Own	Operate	
A	PSCo	PSCo	PSCo	PSCo	PSCo
B1	LA	LA	LA	LA	LA
B2	LA	PSCo	LA	PSCo	LA
C	SPV	SPV	SPV	SPV	SPV
D1	PSCo	PSCo	LA	LA	PSCo
D2	PSCo	PSCo	LA	LA	LA
D3	PSCo	PSCo	SPV	SPV	PSCo
E1	LA	LA	PSCo	PSCo	PSCo
E2	LA	LA	PSCo	PSCo	LA
F	COCo	COCo	COCo	COCo	COCo

LA – Local Authority

PSCo – private sector company

SPV – public-private special purpose vehicle

COCo – community owned company

The possible structures are summarised in Table 11-3.

Table 11-3 Potential commercial structures

Commercial structure	Description
Private ESCo	Common approach whereby a private ESCo company installs, owns, and operates the district heating network and acts as the energy service provider. Where the scheme is likely to be attractive to a private ESCo, this can remove any burden of operation and maintenance from the Council.
Council owned (direct involvement)	Council undertakes delivery and operation of the project in its entirety. This will include sourcing all necessary funds, undertaking procurement and owning and operating the scheme, including acting as heat supplier to end customers. Any capacity the Council does not have in-house would be contracted to third parties, e.g., through operating and maintenance contracts with equipment suppliers and billing and metering with a dedicated company. The Council gains more strategic control, but also takes on more risk.
Council owned (DBOM)	If there is no appetite for the Council to operate the network directly, this can be done via a Design, Build, Operate and Maintain (DBOM) contract in which a private entity is responsible for design and construction as well as long-term operation and maintenance. The public sector secures the project's financing and retains the operating revenue risk and any surplus operating revenue.
Council Joint Venture	Council enters into a formal agreement with a third party for supply of funding and / or operational and technical expertise. A Joint Venture can bring significant benefit by bringing expertise in the sector by managing delivery and operation however there needs to be a clear benefit to all JV partners.

The fundamental issue facing the Highland Council should they invest directly in the DHN will be around the relationship the council decides to have with the private sector. The suitability and applicability of the preferred commercial structure can be determined by the desired level of control, risk and return on investment. The relationship between control as well as risk and reward are summarised in Figure 11.2 for the various commercial structures.

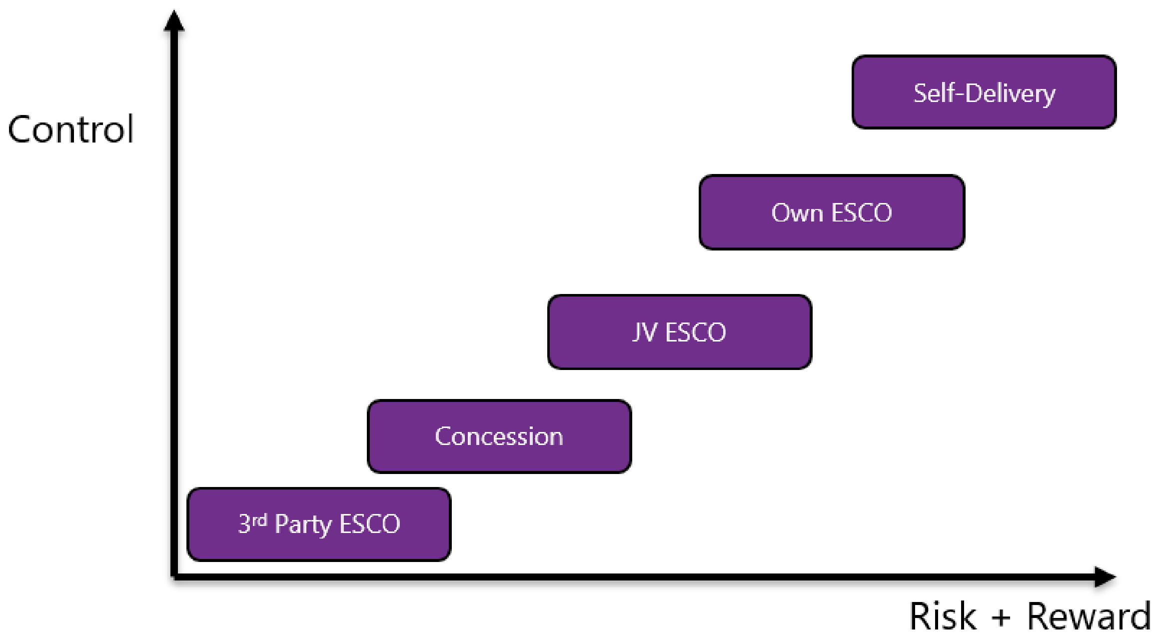

Figure 11.2 Risk/reward vs. level of control

The evaluation of the options usually revolves around several considerations, these are outlined in Table 11-4.

Table 11-4 Considerations for Council involvement

Consideration	Explanation
Control vs. risk	The tensions between the desire for control over project outcomes and the willingness to take on project risk.
Commercial attractiveness	The rate of return the project will actually support and whether this will be acceptable to the private sector.
Cost of raising capital	The recognition that the cost of raising capital for the private sector is generally greater than for the public sector which, on a capital-intensive project, has a major impact on viability and ultimately on cost of heat supply.
Availability of capital	The availability of capital to both public and private sector is limited but is also closely linked to the degree of risk involved and the organisations' understanding of the risks involved.

The amount of control that the council or the various stakeholders have over the scheme may be important in achieving their overall objectives. Similarly, drivers to participate may not be sufficiently strong to ensure agreements for connection are reached. For private sector developers, it is likely that some form of compulsion will be required to ensure connection, through planning conditions which require this and safeguard infrastructure and heating system types to enable future connection.

In relation to the preferred project vehicle, particularly whether to set-up a separate operating company (Special Purpose Vehicle), it is recommended that legal advice is obtained during the initial stages of design development prior to proceeding. Issues such as State Aid, legal authority for the council to undertake various activities, continued stakeholder engagement, flexibility and implications for an exit strategy will need to be considered. If a JV is preferred, it is likely that the establishment of an SPV would be the preferred route.

11.2 Financing options

There are a number of funding mechanisms which the council can explore to obtain both loan and grant funding to develop the Inverness Castle heat network.

These are described in more detail below:

11.2.1 District Heating Loan Fund

The District Heating Loan Fund provides low unsecured loans up to £1 million, with repayment terms of either 10, or 15 years. Loan terms for larger projects will be considered on a case-by-case basis. Typical interest loan rates of circa 3.5% are available. The scheme is managed by the Energy Saving Trust and is open to councils, registered social landlords, SMEs, and ESCOs with less than 250 employees.

11.2.2 Scotland's Heat Network Fund

The objectives of Scotland's Heat Network Fund are to:

- Stimulate and accelerate the delivery of zero emission heat network opportunities across Scotland through capital co-funding
- Help prepare the market for future regulations including the Heat Network (Scotland) Act 2021 and support meeting our deployment targets
- Support the reduction of our heat demand and ensure poor energy efficiency is no longer a driver for fuel poverty
- Create smart resilient heat networks that provide us with a reliable and affordable source of heat
- Support a secure supply chain with high value, local, sustainable jobs across Scotland and help people to transition to new, secure jobs as part of a just transition
- Support the delivery of heating systems that enable and efficiently use Scotland's renewable energy sources
- Support the delivery of heat networks that enable flexible and stable operation of our energy networks[9]

11.2.3 Green Growth Accelerator

Unlocking £200m of public sector investment (with further investment from the private sector also anticipated), the Green Growth Accelerator (GGA) programme is an outcome-based funding model that requires a Local Authority to commit to agreed economic, environmental and social value goals[10].

The GGA aims to help deliver Scotland's just transition to a net-zero emissions economy. In this funding model, the Scottish Government makes regular payments over a set period, reflecting the value associated with the goals achieved. The set period is typically 25 years. The focus of outcomes for the GGA will include carbon emissions reductions, unlocking net zero and just transition opportunities and targeting growth in green jobs.

[9] https://www.gov.scot/publications/heat-network-fund-application-guidance/#:~:text=The%20objectives%20of%20Scotland's%20Heat,support%20meeting%20our%20deployment%20targets
[10] https://www.gov.scot/news/accelerating-green-growth/ (Accessed November 2022)

12 Risk mitigation

A complete risk register for the development of the proposed heat network at Inverness Castle is provided in the accompanying appendix J. However, a summary of the key project risks and proposed mitigations is provided below.

1. **Capital Cost**
   - The proposed heat network is particularly sensitive to CapEx costs. Further engagement with a Quantity Surveyor should take place to accurately forecast equipment and material costs to adequately capture inflation. Due to the delayed connections of Phase 2 and 3.
2. **Air source heat pumps efficiency**
   - Manufacturer SCOP has been used as basis for ASHP performance. Further engagement with manufacturers required to mitigate the risk of poorer than expected performance on the NPV of the heat network.
3. **Electricity network capacity**
   - The new energy centre will house a new SSE substation to accommodate the installation of the ASHPs. Further checks are required to confirm sufficient head room to incorporate new electric boilers.
4. **Capital Cost - Building operating temperatures**
   - Operating the heat network at lower temperatures, 60°C flow/40°C return implies carrying out enabling works for Inverness Town Hall for 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.
5. **Securing future connections – Inverness Art Gallery & Museum and Redevelopment**
   - The new development and Inverness Art Gallery & Museum are scheduled to connect to the heat network in 2030.
   - Early engagement with both connections should take place to guarantee their connection to the heat network.

13 Conclusion

In conclusion

This heat network feasibility study report was prepared by the Buro Happold Cities Energy Team on behalf of Zero Waste Scotland (ZWS) for the Highland Council. This study follows a pre-feasibility study carried out in 2021 which considered air source heat pump and water source heat pump technologies in a heat network.

Key findings

There is an opportunity for a low-carbon Heat Network (HN) in the castle study area in Inverness, using ASHPs (Figure 1.1).

High-level, pre-tax, techno-economic modelling of the proposed solution indicated a Net Present Value (NPV) of £0.01M and IRR of 3.6% at the end of the 40-year period being considered in this study with additional CAPEX funding of 50%(£1.41M). These values are indicative only and not financial advice.

Carbon savings of 90% were found for the proposed heat network when compared to the business-as-usual scenario of each of the buildings continuing to use their current (or proposed in the case of the future developments) heating technologies.

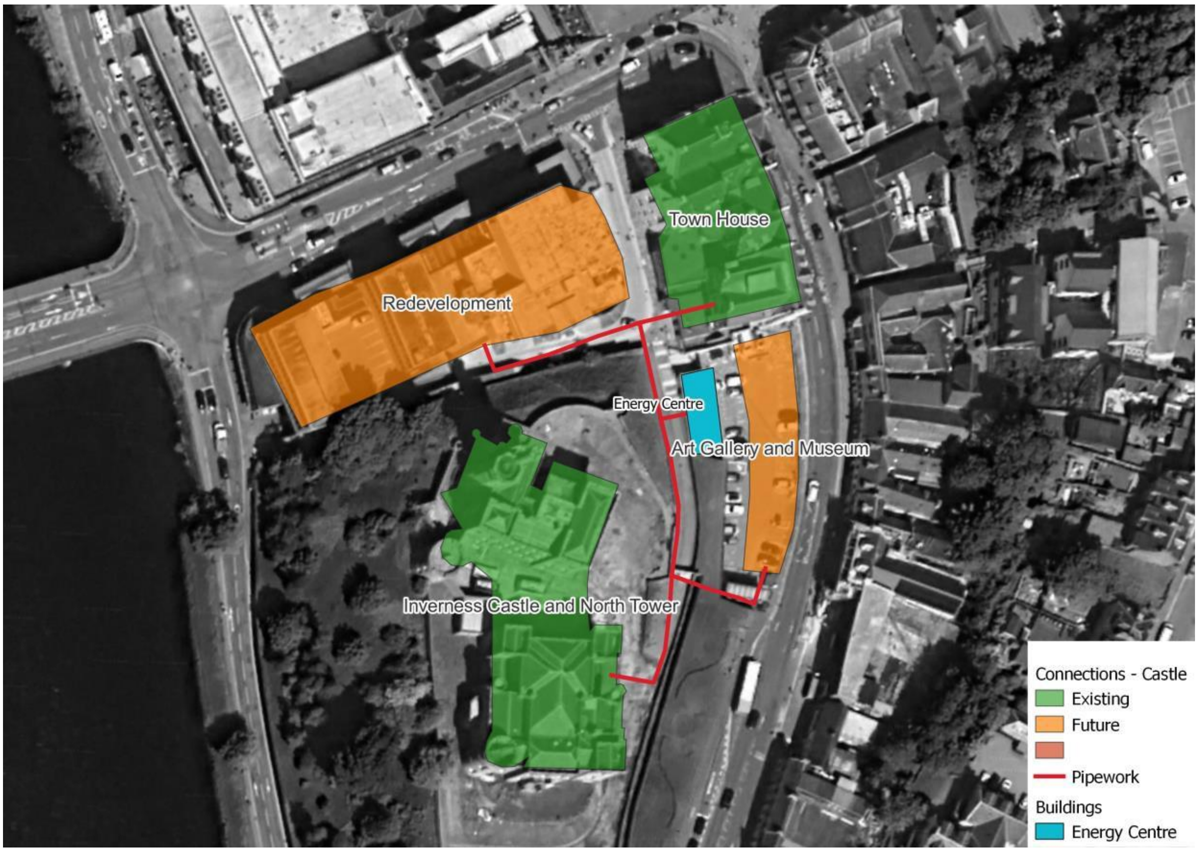

Figure 13.1 Proposed energy centre location and heat network route

A heat network in the area could consist of:

- Energy centre adjacent to the castle (making use of an existing Highland Council owned structure)
- Equipment at the energy centre could comprise:
  - ASHP: 451 kW
  - Top-up electric boilers, 480 kW
  - Thermal stores, 12 m3

- Heat network, 188 m (trench length), connecting the following buildings:
  - Inverness Castle
  - North Tower
  - New development on the main street (assumed office space as part of energy modelling)
  - Inverness Town House
  - New museum and art gallery adjacent to the castle

Key next steps

It is recommended to progress this study to the business case stage with an Outline Business Case (OBC). Preparing a business case involves:

- A five-case Outline Business Case (OBC) presenting the strategic, management, commercial, economic, and financial cases
- As part of the OBC, there is a component of design development, to approximately a RIBA stage 2, Concept Design level.
- Heads of Terms for heat network connections (agreements to connect to the heat network)
- Assessment of capital costs by a Quantity Surveyor

As part of the work supporting the OBC, it is recommended to consider building connection phasing. Consider starting with the energy centre, first connecting to the leisure centre with a high heat demand, and then building out from there.

Elements to be addressed in the next stages of work:

Management

- Consider management of the construction, installation, operation, and management of the heat network
- Consider customer management and metering and billing services

Technical

- **Engagement with the Distribution Network Operator (DNO**) - to understand possible grid constraints, electrical connection budget application for a new supply, and an indication of costs. To minimise risk of extensive grid infrastructure upgrades, alternative resilience strategies should be considered to work around potential grid constraints and peak lopping from thermal stores could also be considered to minimise electric boiler capacity.
- **Building condition surveys** – secondary system temperature strategy and connection costs.
- **Updated energy demands and plant sizing** - accounting for updated plans to buildings or new construction(s) etc. -also considering future expansion with buildings

Economic

- **Explore grant funding options** - that could be available for the heat network, including Scotland's Heat Network Fund and the Green Growth Accelerator.
- **Assessment of the economic and carbon benefit of completing enabling works and expansion of Network** - in the buildings to achieve a lower operating temperature, e.g., increasing radiator size
- Confirming costing with a Quantity Surveyor

Commercial

- **Explore commercial model** - for the scheme and consideration of the most suitable connection charge strategy.
- **Engagement with developers** to gain engagement for proposed new buildings

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Appendix 2

Heat Network Support Unit

Inverness West Bank DHN

Feasibility Study

DRAFT

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Date: 30 March 2023

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

Glossary

Term	Definition
ASHP	Air source heat pump
EB	Electric boiler
EC	Energy centre
HN	Heat network
IRR	Internal rate of return
LHD	Linear heat density
NPV	Net present value
OBC	Outline business case
O&M	Operation and maintenance
PHEX	Plate heat exchanger
RSHP	River source heat pump
TES	Thermal energy storage
WWHR	Wastewater heat recovery
ZWS	Zero Waste Scotland

1 Executive summary

This heat network feasibility study report was prepared by the Buro Happold Cities Energy Team on behalf of Zero Waste Scotland (ZWS) for the Highland Council. This study follows on from a pre-feasibility study carried out in 2021 that considered opportunities for an air source heat pump led heat network(s) on the west bank of the river Ness in Inverness.

Understanding the project

The Highland Council is moving towards net zero carbon greenhouse gas (GHG) emissions, targeting net zero by 2045. The provision of heat can be a significant source of annual carbon dioxide emissions across the built environment. Buildings connected to a heat network are considered as having a “low or zero heating system”[1].

The west bank area of the river Ness includes several buildings with high heating demands, such as the Highland Council Head Quarters (HQ), Inverness Leisure Centre and Inverness Botanic Gardens.

Report purpose

The purpose of this heat network feasibility study is to inform the Highland Council of the opportunity for a heat network in Inverness on the west bank of the River Ness. The study provides:

- Energy modelling of the buildings proposed to connect to the heat network
- High-level cost estimate of the proposed solution
- Spatial coordination of the proposed solution
- An assessment of the carbon emissions that could be saved compared to a Business-as-Usual scenario
- A high-level schematic diagram of the proposed heating solution
- Outline of the key risks associated with the project and how they can be mitigated
- Recommendations and next steps.

Report audience

The audience for this report is the Highland Council.

Challenges

The Highland Council’s challenge is to balance the need to:

- Decarbonise heating for buildings in Inverness, targeting net zero GHG by 2045
- Consider cost implications of low-carbon heat technology and heat network(s)

Key findings

[1] www. Gov.Scot. Heat in Buildings Strategy, 2021. Page 16. URL: Heat In Buildings Strategy: Achieving Net Zero Emissions in Scotland's Buildings (www.gov.scot) Accessed 28/03/2023

There is an opportunity for a low-carbon heat network (HN) in the west bank study area in Inverness, using an open loop, alluvial aquifer fed Ground Source Heat Pump system (

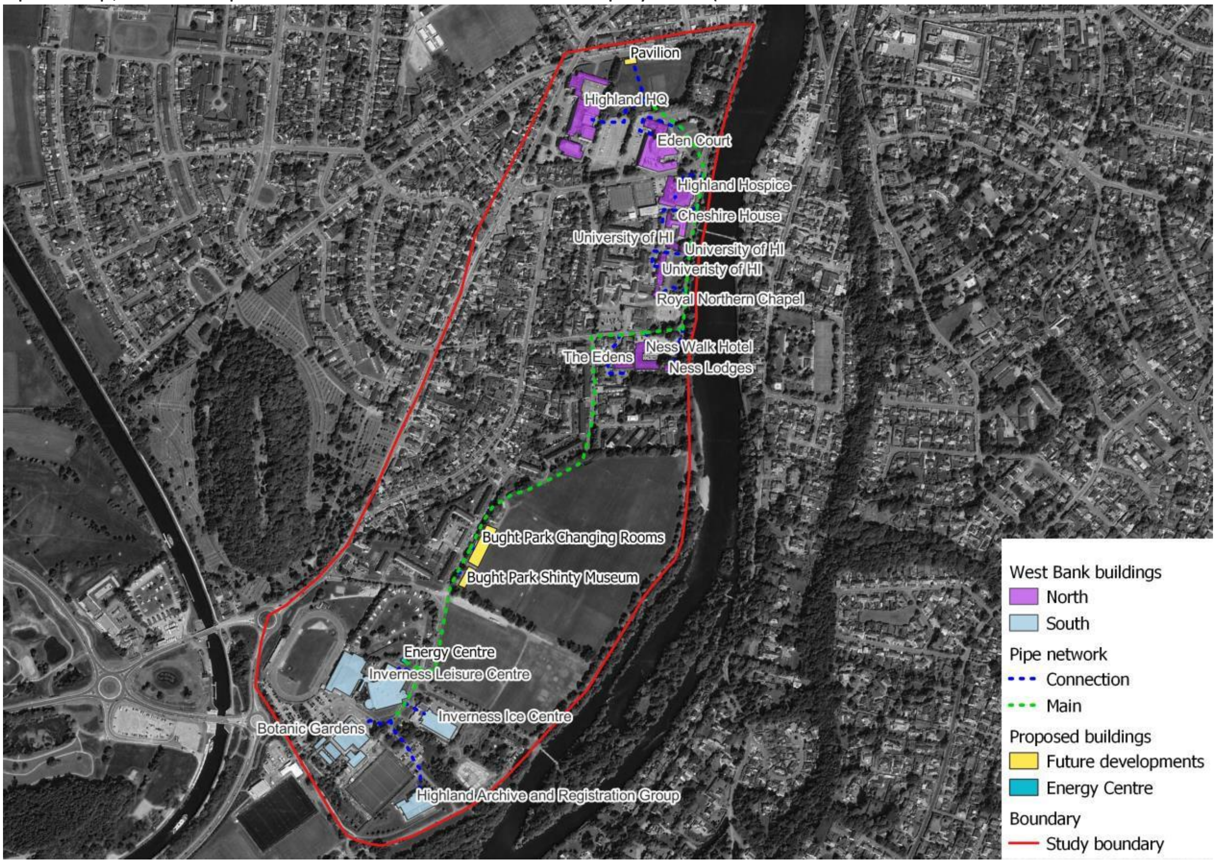

Figure 1-1).

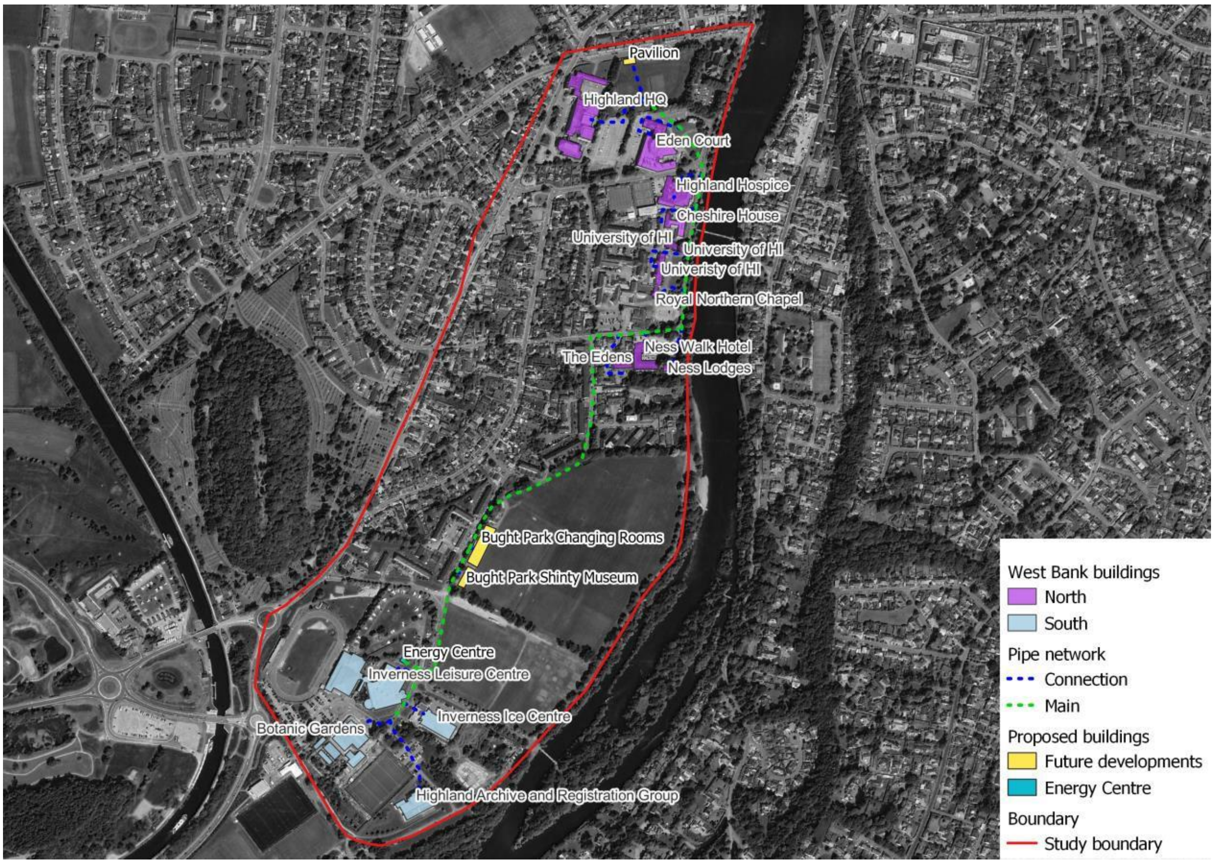

Figure 1-1 Proposed energy centre location and heat network route

As part of this study, the opportunities for heat networks connecting different areas in the west bank were considered. The Linear Heat Density (LHD) was estimated for each, giving an early indication of suitability for a heat network. The higher the LHD, the more likely a heat network is to be economically viable:

a) Entire study area, all buildings considered for connection to a heat network (HN), LHD: 4.80 MWh/a/m

b) North area, with buildings near the Council HQ connecting to HN, LHD: 2.79 MWh/a/m

c) South area, with buildings near the leisure centre connecting to the HN, LHD: 12.60 MWh/a/m

The Council's preference was to consider the entire west bank study area for heat network connection, due to the driver to decarbonise heating for buildings.

Entire west bank study area

A heat network in the west bank area is likely to require capital funding. A high-level, pre-tax, techno-economic model of the proposed solution indicated a Net Present Value (NPV) of £0.03M and Internal Rate of Return (IRR) of 3.6% at the end of the 40-year period considered in this study, with additional capital cost funding of 50% (£7.43M). These values are indicative only and not financial advice.

Carbon savings of 91% were estimated for the proposed heat network when compared to the business-as-usual (BAU) scenario of each of the buildings continuing to use their current gas-fired boiler, gas-fired boiler/CHP unit, or ground source heat pumps (GSHPs) in the case of the future developments' heating technologies.

A heat network in the area could consist of:

- Energy centre, on Highland Council land adjacent to Inverness Leisure Centre
- Heat network flow & return temperatures, 75°C and 55°C, respectively.
- Equipment at the energy centre, comprising:

    - Open loop ground source heat pumps fed via an alluvial aquifer, 2,100 kW
    - Top-up electric boilers, 5,800 kW
    - Thermal stores, 60 m^3
- Heat network, 2,721 m, connecting the following building typologies:
    - Leisure Centre
    - Office Space
    - Care Homes
    - Storage facilities
    - Hotels
    - Public Buildings
    - Performing arts centre

Key next steps

It is recommended to progress this study to the business case stage with an Outline Business Case (OBC). Preparing a business case involves:

- Inverness High School should be engaged to assess the feasibility of the school connecting to a heat network in the area. Inclusion of an additional high heat demand user could improve the prospects of a potential heat network in the area. Given this building's proximity to the Highland Council HQ, it is a logical extension for the network.
- A five-case Outline Business Case (OBC) presenting the strategic, management, commercial, economic, and financial cases.
- As part of the OBC, there is a component of design development, to approximately a RIBA stage 2, Concept Design level.
- Heads of Terms for heat network connections (agreements to connect to the heat network)

At the next stage, it is recommended to consider phasing the building connections (e.g., year assumed for building connections), to start with the energy centre and the leisure centre and building out from there.

The council may also be interested to revisit the opportunity for a heat network in the south area of the west bank where the LHD is estimated to be the highest, compared to the entire study area or the northern part of the study area. When considering phasing, the south area could be considered as the first phase.

2 Introduction

This feasibility study was commissioned by Zero Waste Scotland and carried out by Buro Happold for the Highland Council. This follows on from a pre-feasibility study which considered air source heat pumps for a heat network in the entire west bank area, or the north area, or the south area.

This feasibility study develops the assessment of a potential heat network in the Inverness west bank area using supplied heat demand data, consideration of suitable heat generation technologies and spatial coordination of the proposed heat network. Spatial coordination considers local utilities, site specific infrastructure and the spatial restrictions of the area for both the heat network and a potential new energy centre.

The options considered as part of this feasibility study include:

- **Technology 1:** Closed Loop Ground Source Heat Pumps - closed loop vertical boreholes
- **Technology 2:** Open Loop Ground Source Heat Pumps – open loop boreholes, alluvial aquifer

After comparing the advantages and disadvantages of an alluvial aquifer led Ground Source Heat Pump system with the alternative solution of ground source heating via boreholes, this analysis identified the alluvial Source heating solution as the recommended heat-supply technology.

2.1 Stakeholders

Stakeholders to this feasibility study are the Highland Council, High Life Highland, Eden Court Highlands, Inverness Ice Centre Ltd, Leonard Cheshire Disability, University of Highlands and Islands and Twelve Ness Walk Ltd.

2.2 Report structure

This report is organised into the following sections:

- **Section 1. Executive summary** - Overview of the report, key findings, conclusions, next steps
- **Section 2. Introduction** - Information about this feasibility study and description of the stakeholders, study area and methodology
- **Section 3. Policy review** – key points relating to the route to net zero carbon, and implications for the Inverness west bank, at the regional, and local levels.
- **Section 4. Site visit and survey** – observations from site visit to Inverness west bank
- **Section 5. Energy demand analysis** – estimation of the heating demand from buildings
- **Section 6. Heat supply technology** – technology suitability considerations, for low-carbon heating solutions for the site
- **Section 7. Energy modelling –** modelling of consumption profiles for entire heat network
- **Section 8. Spatial coordination** – indicative pipe route for heat network and proposed energy centre location
- **Section 9. Techno-economic modelling** – technical and economic modelling results
- **Section 10. Carbon**– carbon emissions analysis of the heat network
- **Section 11. Risk mitigation** – identification of potential project risks and mitigation measures
- **Section 12. Heat network development** stages – steps in heat network development, considering development, commercialisation, and delivery
- **Section 13. Conclusion** – summary and suggested route forward

2.3 Methodology

The approach for the feasibility study is presented in Figure 2-1.

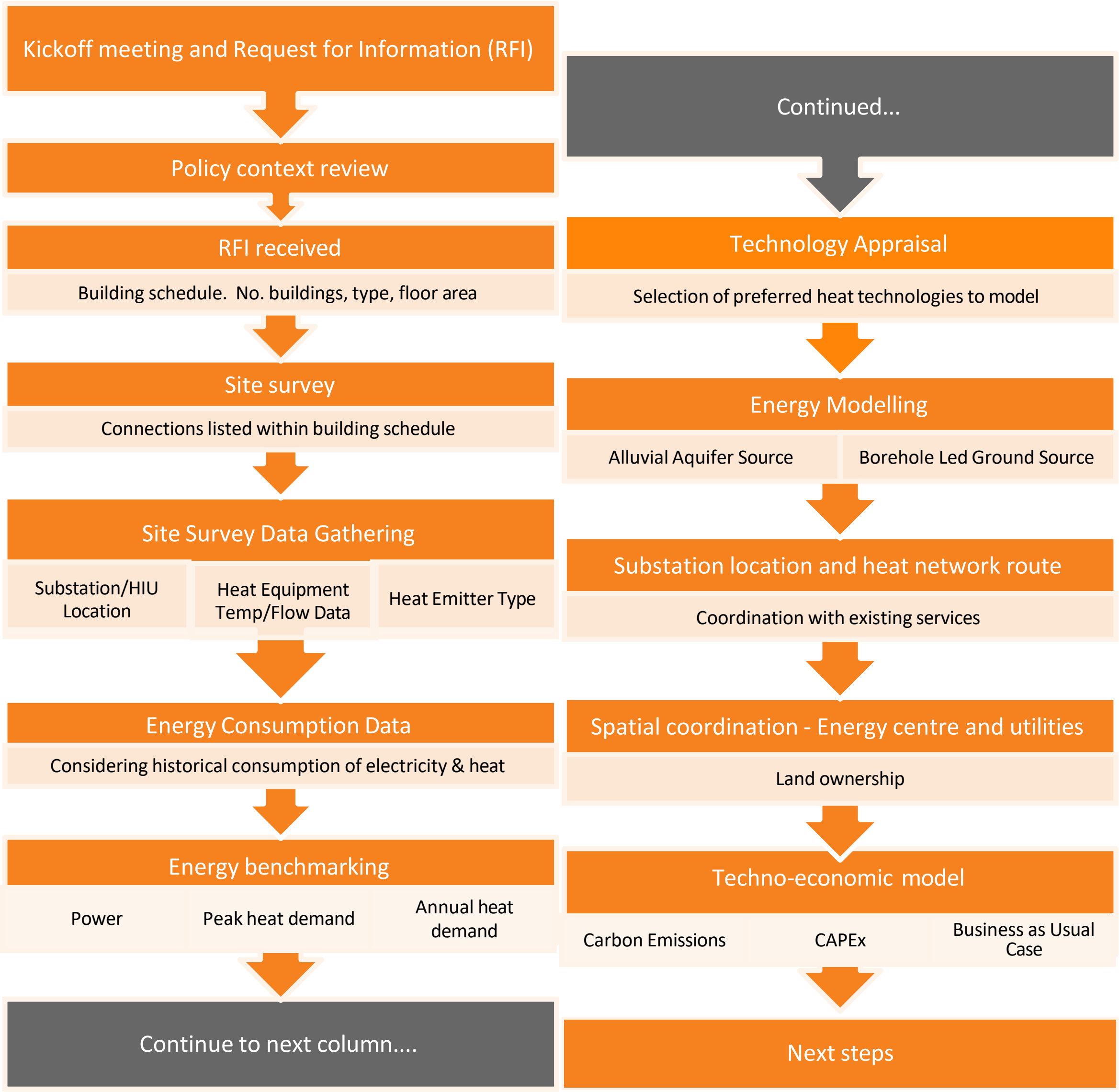

Figure 2-1 – Methodology

2.4 Study area

The red line boundary for this feasibility study is shown in Figure 2-2.

Figure 2-2: Inverness west bank feasibility study red line boundary

The buildings included in the study along with their address and ownership information are listed in Table 2-1.

Building Name	Type	Address	Owner	Operator
Inverness Leisure Centre	Leisure Centre	Bught Ln, Inverness IV3 5SS	Highland Council	Highlife Highland
Highland Council HQ	Office Space	Glenurquhart Rd, Inverness IV3 5PB	Highland Council	The Highland Council
Botanic Gardens	Visitor attraction and cafe	Bught Ln, Inverness IV3 5SS	Highland Council	Highlife Highland
Highland Archive and Registration Centre	Storage and events space	Highland Archive and Registration Centre, Bught Rd, Inverness IV3 5SS	Highland Council	Highlife Highland
Inverness Ice Centre	Ice skating centre	Bught Dr, Inverness IV3 5ST	Inverness Ice Centre Limited	Inverness Ice Centre Limited
Highland Hospice	Medical, office space and cafe	Ness House, 1 Bishops Rd, Inverness IV3 5SB	Highland Hospice	Highland Hospice

Building Name	Type	Address	Owner	Operator
Eden Court	Performing arts venue	Bishops Rd, Inverness IV3 5SA	Eden Court Highlands	Eden Court Highlands
Cheshire House	Home for young adults with disabilities	Cheshire House Ness Walk, Inverness IV3 5NE	Leonard Cheshire Disability	Leonard Cheshire Disability
University of Highlands and Islands	Higher education facility	12b Ness Walk, Inverness IV3 5SQ	University of Highlands and Islands	University of Highlands and Islands
Royal Northern Infirmary Chapel	Chapel/religious centre	Royal Northern Infirmary Chapel, Ness Walk, Inverness IV3 5SF	The Roman Catholic Church	The Ordinariate in Inverness
Ness Walk Hotel	Hotel	12 Ness Walk, Inverness IV3 5SQ	Twelve Ness Walk Limited	Twelve Ness Walk Limited
The Edens Hotel	Hotel	22 Wellingtonia Ct, Inverness IV3 5SX	Eden Hotel Collection Limited	Eden Hotel Collection Limited
Ness Lodges	Holiday apartment rentals	12A Ness Walk, Inverness IV3 5SQ	Private ownership	-
Northern Meeting Park Development	Café/restaurant	TBC, still in planning permission	Highland Council	Unknown, assumed Highlife Highland
Bught Park Shinty	Museum and events space	TBC, still in planning permission	Highland Council	Unknown, assumed Highlife Highland
Bught Park Changing Rooms	Shinty/sports field changing facilities	TBC, still in planning permission	Highland Council	Unknown, assumed Highlife Highland

Table 2-1 Potential building connections to proposed heat network

2.5 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[2].

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.

3 Policy review

3.1 Net zero GHG targets

Targets years to achieve net zero greenhouse gas (GHG) emissions have been agreed from national to local levels in the UK. Scotland is to reach net zero by 2045, and the Highland Council also by 2045. A breakdown of both UK Government and Scottish Government national policy can be found in Appendix A.

	Net zero GHG emission target year
United Kingdom	2050
Scotland	2045
Highland Council	2045

Table 3-1 Net zero GHG emission targets at national and local levels

3.2 Heat in Buildings Strategy

In the Heat in Buildings Strategy, connecting to a heat network is part of the strategy to achieve net zero emissions in Scotland's buildings[3]

"Low and Zero Emissions Heating Systems." In this Strategy, by 'low and zero emissions heating systems' we mean systems that have zero direct greenhouse gas emissions, such as individual electric heat pumps and

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2 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]

3 Gov.Scot. Heat in Buildings Strategy, Oct 2021. URL: Heat In Buildings Strategy: Achieving Net Zero Emissions in Scotland's Buildings (www.gov.scot) Accessed 28/03/2023

connection to heat networks, or electric systems such as storage heaters, and systems that have very low emissions such as those that use hydrogen.

3.3 Heat Networks Delivery Plan

The Scottish Government's Heat Networks Delivery Plan[4] sets out how the Heat Network Scotland Act 2021 and policy support increasing heat networks in Scotland.

Building Assessment Reports (BARs) will be required for public-sector non-domestic buildings and certain other non-domestic buildings to assess suitability for heat network connection.

As an initial step to increase use of waste heat, the Scottish Government will consider introducing a requirement for heat suppliers to provide information about recoverable heat when requested.

Future target setting, required by the Heat Network Act 2021, are planned to be set (Table 3-2).

Targets	Heat from heat networks and buildings
2022-23	Consult on phased targets for all publicly owned buildings to meet zero emission heating requirements by 2038.
2023	Scottish Government to consult on target for 2035 regarding heat output from heat networks
2024	Heat network regulatory regime in place by 2024
2024	New Build Heat Standard requiring new buildings consented from 2024 to install only zero direct emission heat sources. Subject to devolved competence, bring forward regulatory proposals to require the installation of zero or very near zero emissions heating systems in existing buildings.
2024	Majority of heat from heat networks, and additional plants for extensions, to be provided from low and zero emissions heat sources. In the near term, as small percentage of annual heat provided through some new heat networks may need to be sourced from natural gas for the purposes of packing and backup.
2027	Heat to be supplied by heat networks: 2.6 Terawatt hours (TWh) of output (3% of current heat supply)
2030	6 TWh heat output from heat networks (8% of current heat supply)
2035	Target heat output from heat networks to be agreed

[4] Gov.Scot. Heat networks delivery plan, March 2022. URL: Heat networks delivery plan - gov.scot (www.gov.scot) accessed 09/03/2023

Targets	Heat from heat networks and buildings
2038	All publicly owned buildings to meet zero emission heating requirements by 2038, to be agreed

Table 3-2 Future heat network targets

3.4 Highland Council

3.4.1 Carbon CLEVER

Carbon CLEVER is a Highland Council-led initiative; the initial initiative set a target of a carbon neutral Inverness, in a low carbon Highlands, by 2025[5]. This has since been revised and the target is to achieve this by 2045. By 2045, the Highlands will be a region where its residents and visitors can move around easily by low carbon and sustainable forms of transport. Buildings across the region will have been energy renovated, and new buildings are to be energy efficient. The majority of buildings in rural areas will be heated by renewable sources. Electricity will be generated from a range of renewable sources, and excess energy can be transmitted to surrounding regions through smart grids or stored efficiently.

The Council recognises two important elements for being carbon neutral:

1. Reducing carbon emissions
2. Offsetting those emissions which it is not feasible or practical to reduce

In the region, projects will be implemented to work towards the following CLEVER goals:

- Carbon emission reduction
- Lead by example
- Engagement with others
- Value for money
- Economic benefits
- Raising awareness and promote behaviour change

The Council has identified 5 key strategic themes for achieving a Carbon CLEVER Highlands:

- Economy
- Energy
- Land use and resources
- Transport
- Engagement strategy

3.4.2 Hydro Ness

The Highland Council has declared a Climate and Ecological emergency and has set its Net Zero aspirations. As part of this delivery, the Council has implemented the River Ness Hydro Scheme; this will help to reduce the organisation's carbon footprint, and further generation and use of renewable energy. A 93-kW hydroelectric power twin turbine will generate an estimated 550,000 kWh per annum, supplying the nearby Inverness Leisure Centre with approximately 50% of its electricity use.[6]

The River Ness Hydro doubles as a tourist attraction and will attract many visitors, providing an interactive experience for all ages and promoting the use of renewable energy and STEM learning in Highlands.

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[5] https://www.highland.gov.uk/info/1210/environment/321/climate_change/2 (Accessed January 2023)
[6] https://www.highland.gov.uk/info/1210/environment/971/hydro_ness (Accessed January 2023)

4 Site visit and survey

On Wednesday 25th January and Thursday 26th January, a site visit was carried out to the buildings within the connection schedule in Table 2-1. As part of this site visit, non-obtrusive site surveys were carried out at each of these buildings with the aim of establishing the type, size, and condition of the heat generation technology. Along with recording the operating temperatures for LTHW systems within the building, the site visit also sought to establish key elements of the building's energy strategy, including but not limited to: Building Management System (BMS) strategy, obtaining layout drawings and establish usage patterns.

In attendance was Lewis Burnett and Wendy Saigle from Buro Happold, Ruta Burbaite of the Highland Council, and Sam Collins from Zero Waste Scotland. A table of site contacts present on behalf of each building is given in Table 4-1.

Table 4-1: Site contacts

Building	Contact	Organisation
Inverness Leisure Centre	Kevin Brown	High Life Highland
Highland Council HQ	Duncan Scott	The Highland Council
Inverness Botanic Gardens	Ewan MacKintosh	High Life Highland
Highland Archive and Registration Centre	Richard Aitken	High Life Highland
Inverness Ice Centre	N/A	N/A
Highland Hospice	Marcus Hemmings	High Life Highland
Eden Court	Emma Watson	Eden Court
University of Highlands and Islands	Leanne MacKinnon	University of Highlands and Islands
Bught Stadium	Mike Macleod	High Life Highland
Northern Meeting Park	Nick Gamble	High Life Highland

4.1 Inverness Leisure Centre

Owned by the Highland Council, but operated by Highlife Highland, Inverness Leisure Centre complex is composed of a "dry side" building, built in 1993 that houses a gym, climbing wall and conference/meeting facilities. The "wet side" was built in 1997 and houses three swimming pools, steam rooms and saunas. The outdoor pool was confirmed as being permanently closed as of Monday 23rd January 2023.

Site survey also identified a potential energy centre location adjacent to the leisure centre. The site representative from the Leisure centre confirmed there was no current plan to make use of the proposed land that they were currently aware of.

4.1.1 Dry side

The heating and DHW services in the dry side of the facility is provided by the equipment given in Table 4-2. All equipment was replaced around 2014/2015.

A spot check found flow and return temperatures of 78°C and 75.4°C temperatures across the boilers, respectively. Heat recovery within the AHUs is prohibited due to the perceived risk of increased COVID transmission. All AHUs are designed for an 82°C flow and 71°C return temperature.

Table 4-2: Leisure Centre Dry Side equipment schedule

Equipment	Manufacturer	Model	Quantity (-)	Capacity
Gas Boiler	Hamworthy	WM250/750c	3	250kW each
Indirect Gas Heater	Unit: VES Burner: Powrmatic	Small Unit: Unknown Large Unit: HEMNVX 175-21 Burner	1 each. 2 total	Small unit: 50kW Large unit: 175kW
Calorifiers	McCallum Calorifiers	2,000 l vented calorifier	1	2,000 l

Figure 4-1: Leisure Centre dry-side gas boilers

Figure 4-2: Dry side gas fired heaters - small unit in foreground and large unit in background

4.1.2 Wet side

The heating and hot water system in the wet side of Inverness Leisure Centre makes use of both gas-fired boilers and a gas-fired CHP unit, installed in 2014 and 2006, respectively. A summary table of equipment in the energy centre is given in Table 4-3. As of November 2021, the CHP unit (Figure 4-3) has come to the end of its useful life, having consistently run since its installation in 2006.

The site representative from the Leisure Centre confirmed that the BMS control on the wet side of the complex is poor with much of it relying on manual input. Certainly, the building was very warm during the site visit, with some areas significantly warmer than others. A review of the TREND control system showed that there was an element of external temperature control of the system, however its effectiveness appeared to be poor.

A spot check of boiler flow and return temperature found values of 80°C of 73.5°C, respectively. The wet side makes use of a mixture of AHUs and underfloor heating.

Table 4-3: Wet side equipment schedule

Equipment	Manufacturer	Model	Quantity (-)	Capacity
Gas Boiler	Hamworthy	Wessex ModuMAX 250	4	250kW
Gas CHP	Centrica	ENER G	1	

Equipment	Manufacturer	Model	Quantity (-)	Capacity
Calorifiers	McCallum Calorifiers	N/A	2	1,100 l with 2.off 18kW immersion heaters each

Figure 4-3: Wet side CHP unit - retired

A requirement of the swimming pools in the wet side of the leisure centre is that air temperature surrounding the pools should be maintained at ±1°C of the water temperature. However, the site contact confirmed that they struggle to maintain these temperatures, given in Table 4-4.

Table 4-4: Leisure Centre swimming pool water temperatures

Pool	Water Temperature (°C)
Competition	28.5
Leisure	30.5
Kids	32.0
Outdoor Pool	Permanently Closed as of 23.01.2023

4.1.3 Leisure centre energy centre location

An area outside of the leisure centre, shown below in Figure 4-4 and Figure 4-5, has been identified as being a potential location for a new energy centre.

The land belongs to the Highland Council and the site contact at the leisure centre confirmed that there were no known plans for the area or earmarked expansion of the leisure centre.

Figure 4-4 Potential energy centre Location to the north of leisure centre

Figure 4-5 Potential energy centre Location to the north of leisure centre, view from green area

4.2 Highland Council HQ

A combination of three separate buildings, the Highland Council HQ is composed of a main building originally built in 1962, surrounding blocks built in the 1970s and an older section dating to the 1800s.

Entrance into the basement level boiler house is via a set of double doors in the centre of the complex. A table summarising the key equipment items in the boiler house is given below in Table 4-5.

Table 4-5: Highland Council HQ boiler house equipment schedule

Equipment	Manufacturer	Model	Quantity (-)	Capacity
Gas Boiler	Viessmann	Vitorond 200	2	1,080kW
Gas CHP	KW Energie	Energimizer Smarblock 33 NG	1	Thermal: 74kWth Electrical: 33kWe
Calorifiers	McCallum Calorifiers	PHCS 700	2	Vessel: 700 l Electrical Immersion Heaters: assumed 11kW
Buffer Vessel	Cordivari	TERM. BUFFER VC 3000 V/12	1	3,000 l

Figure 4-6: Basement level entrance to the Highland HQ energy centre

The site contact confirmed that the CHP has been isolated from the system since August 2022 due to its inability to run consistently. Prior to it being disconnected it was known to rarely run.

Figure 4-7: Highland HQ CHP Unit

Flow temperatures from the boilers were set to 85°C, whilst the return temperatures from the main building and council chambers were noted as approximately 75°C. Constantly high return temperatures will prevent the CHP from running as the unit will not be able to cool itself to enable operation. Priva Compri HX control system throughout the building. Element of ambient temperature control.

Figure 4-8: Highland HQ Gas Boiler

The complex makes use of a combination of wet heating radiator systems, AHUs, and electric heating in particularly cold areas. The water radiators look to date around the time when the building was first built (Figure 4-10). Figure 4-9 outlines the layout of the Highland Council HQ along with the heat emitter technology and age of each area.

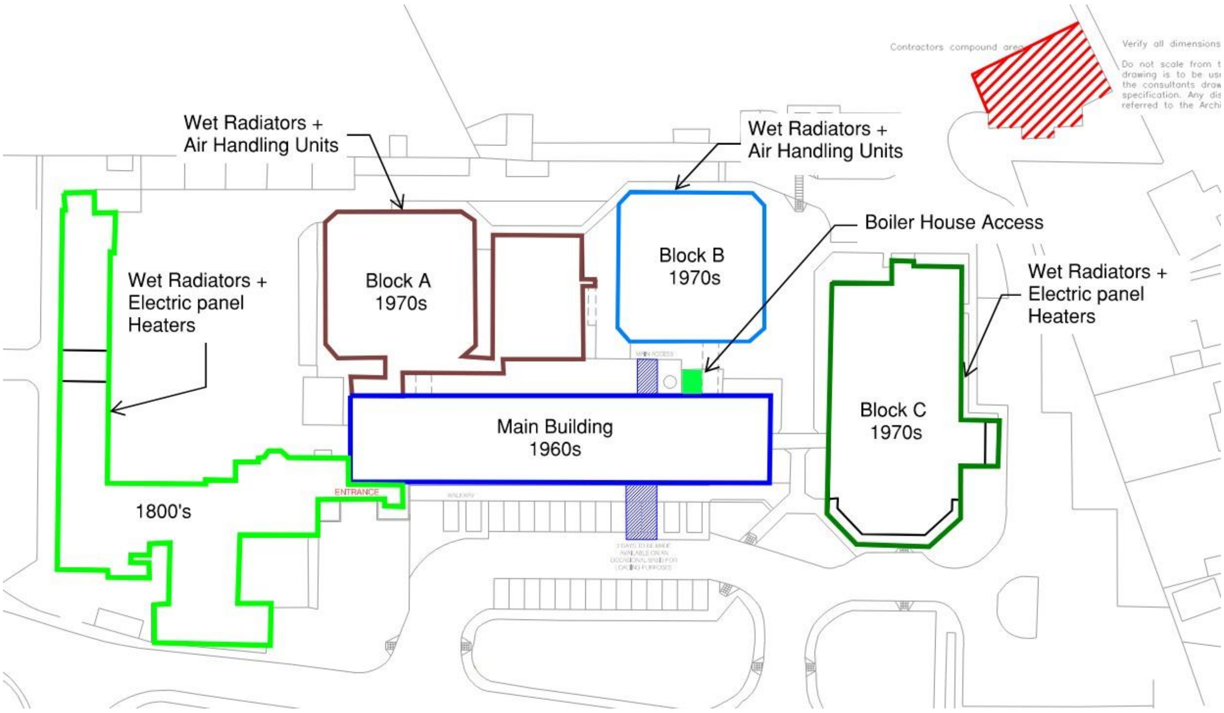

Figure 4-9: Highland Council HQ Site Layout and heat emitters


Figure 4-10: Highland HQ heater

4.3 Inverness Botanic Gardens

The Botanic Gardens are owned by the Highland Council and managed by High Life Highland.

The glass greenhouses are heated by a biomass boiler and gas boilers. At the time of the site visit, the biomass boiler was not operating – maintenance was required and was in the process of being arranged. The gas boilers were at the end of their economic life, and to be replaced shortly. Works were ongoing, replacing the heating pipework from the plant room to the glass greenhouses. The purpose of the works was to replace the heating pipework with insulated pipework.

The polytunnel is heated by a kerosene boiler, with the fuel storage tank adjacent to the polytunnel.

Office areas are heated with electric radiators, as well as the two existing portacabins. There are an additional six portacabins onsite that will soon be put into use – also with electric radiators.

The central polytunnel greenhouse has electric heating, supplied by an electric convection heating unit.

The flow temperature was approximately 80°C.

Heating equipment and capacities are listed in Table 4-6.

Table 4-6: Botanic gardens heating system typologies

Heating Equipment	Capacity	Area Served
Biomass boiler	155kW	Glass Greenhouses
Thermal store (for biomass boiler)	5000 l	Glass Greenhouses
Gas-fired boilers	1 x 335 kW	
2 x (unknown kW)	Glass Greenhouses	
Kerosene boiler	97.8 kW	Polytunnel
Kerosene fuel store	200 l	Polytunnel
Electric convection heater	2.8kW	Central polytunnel
Electric radiators		Office, café, 2x portacabins
Electric radiant heaters		Garage area
Wood burning stove		Cafe

Figure 4-11 External plantroom housing gas boilers, West side of site

Figure 4-12 Existing gas-fired boilers, soon to be replaced with new gas-fired boilers

Figure 4-13 Polytunnel, kerosene boiler

Figure 4-14 Kerosene fuel storage, at northern wall of site

Figure 4-15 Biomass boiler in container unit, adjacent to west wall

Figure 4-16 Thermal store for biomass boiler, In container unit

Figure 4-17 Polytunnel, Electric heater

Figure 4-18 Café, electric heaters

Figure 4-19 Café, wood burner

Figure 4-20 Portacabins, Electric radiators

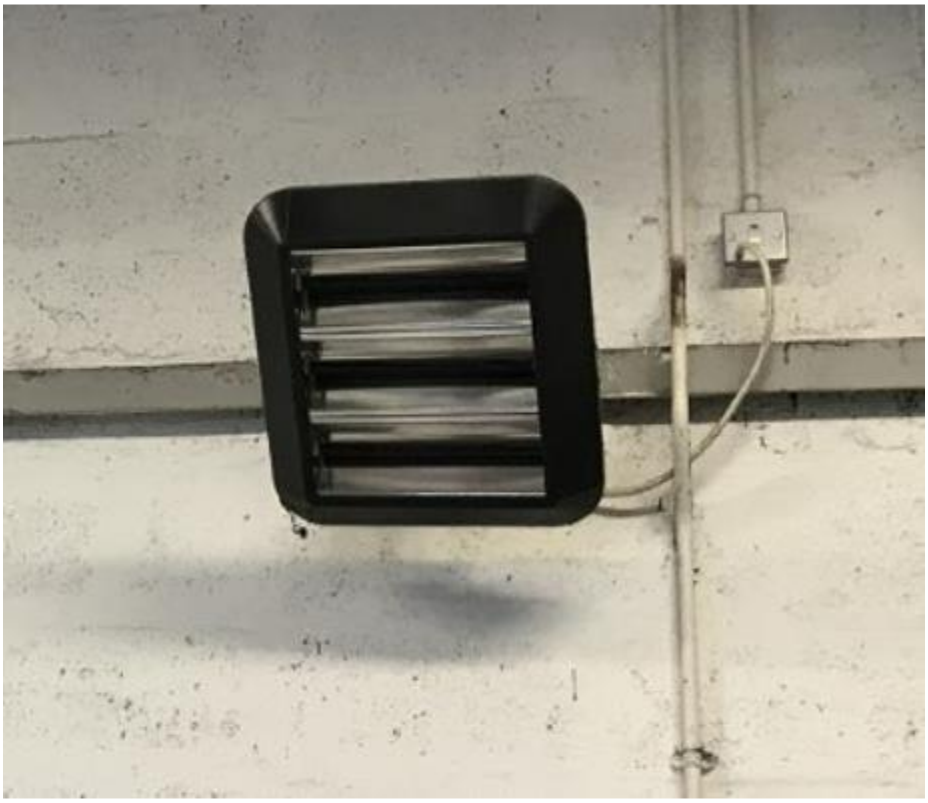

Figure 4-21 Garage/storage, Electric radiant heaters

Figure 4-22 Glass greenhouses, backup electric heaters (oil-filled)

4.4 Highland Archive and Registration Centre

The Highland Archive and Registration Centre is owned by the Highland Council and operated by High Life Highland. Completed in 2009, the building collects and conserves historical records of the Scottish Highlands and makes them accessible to the public.

Following the COVID-19 pandemic, the building is back to normal capacity with twenty to thirty staff present in the building on a full-time basis. The building is also used on weekends with access to records maintained for the public, wedding celebrations and events.

Heating is provided through a pair of 503-kW gas boilers (Figure 4-23) with DHW supplied via a 30.5-kW instantaneous gas fired water heater (Figure 4-25).

A constant cooling load is required for the building's repository. This is provided by packaged outdoor air-cooled chillers (Figure 4-26) which are due to be replaced imminently. An equipment schedule for the key equipment in the Highland Archive and Registration Centre is given in Table 4-7.

The heat system makes use of AHUs, wet radiators, and underfloor heating. Heating in the building has been designed for a moderate flow temperature of 60°C. Building BMS shows a 58°C flow temperature with a return of 51.8°C.

A solar thermal system installed on site has been disconnected and the tank removed due to poor performance. Similarly, the building has been fitted with a pair of solar panel arrays. At the time of the site visits, one of the arrays was producing approximately 5.1-kWe of power. One of the arrays is thought to be composed of 241 panels with an output of approximately 80kWe.

Table 4-7: Highland Archive and Registration Centre Equipment Schedule

Equipment item	Manufacturer	Model	Quantity (-)	Capacity
		Heating Services		
Gas Boiler	MHS Boilers	Ultramax 600	2	503kW each
Gas Fired Water Heater	Andrews Water Heaters	CWH 30/100	1	30.5kW
		Cooling Services		
Air Cooled Chiller	GEA	GLAC 0302 BD1	2	74.2 kW each

Figure 4-23: Highland Archive gas boiler

Figure 4-24: Highland Archive Solar Power panel

Figure 4-25: Highland Archive gas fired instantaneous hot water heater

Figure 4-26: Highland Archive air-cooled chillers

4.5 Inverness Ice Centre

Although included in the building schedule, access into Inverness Ice Centre could not be arranged as part of the site visit. However, exterior photographs of Inverness Ice Centre are given in Figure 4-27 and Figure 4-28.

Figure 4-27 Inverness Ice Centre, view looking north-east

Figure 4-28 Inverness Ice Centre, view south-west

4.6 Highland Hospice

The Highland Hospice has 170 staff and 900 volunteers.

The building has hospice, office, and café areas. The hospice has in-patient, ward, day patient, and counselling spaces. The original Victorian building has been added to with new facilities built in 1999 and 2016.

Heating is supplied to the building from three plantrooms, with gas-fired boilers and an Air Handling unit. There is one incoming gas supply.

Heating equipment is listed in Table 4-8.

Plantroom	Heating Equipment	Capacity	Area Served	Temperatures
Ground floor (Netley Building)	Gas-fired boiler, Vaillant	1x ?? kW 2x 46 kW	Netley Building	Flow 70°C Return 61°C
Ground floor (Netley Building)	DHW cylinder	2 x 1800 x 500 l	Netley Building	
In-patient Unit (First floor)	Gas-fired boiler, ACV Prestige	3x (unknown capacity) kW	In-patient Unit	
In-patient Unit (First floor)	DHW cylinder, ACV		In-patient Unit	
In-patient Unit (First floor)	Air Handling Unit		In-patient Unit	
Victorian Café & Kitchen (Ground floor)	Gas-fired boiler, Vaillant Ecotec	2 x 63.7kW	Victorian Café & Kitchen	Flow 62°C

Table 4-8 Highland Hospice

The building has roof-top solar photovoltaic panels.

4.7 Eden Court

Eden Court is a large theatre, cinema and performing arts venue composed of three interconnected structures. The three wings of the building date back to 1976, 2007 and the 1875 Bishop's Palace.

Facilities include two theatres, two cinemas, two performance studios, a chapel, and several office spaces for Eden Court staff members. Energy performance of each block aligns with the age of the structure with the Bishop's Palace block being very cold and the section built in 2007 performing quite well. The parts of the building dating back to 1976 are considered to be sub optimal only.

Heating and hot water in the building is provided by a bank of ten 220-kW gas boilers (Figure 4-29). However, two of these are currently out of commission and only six have been known to run at most. Similarly, the main distribution pump had a broken motor set removed. The motor has not been replaced, leaving the system particularly vulnerable to extended maintenance activities or outright failure of the remaining pump motor.

There is a bank of sixty-four solar coils on the roof. However, the system is thought to be outdated with spare parts difficult to source.

Boiler flow temperatures are varied seasonally with a winter flow temperature of 80°C and summer temperature of 70°C. Temperature difference between flow and return is poor with only 5°C being lost between the two.

As shown in Figure 4-30 and Figure 4-31 a variety of heat emitters are used throughout the building with trench heating, UFH, natural ventilation systems and wet radiator system used to provide heating and passive cooling. Underfloor heating runs at 50°C flow and achieves a 30°C return. However, many areas are reportedly uncomfortably cold in winter, particularly Bishop's Palace.

The Trend 963 BMS system is manually changed and is thought to do provide a good level of control.

Table 4-9: Eden Court main plant

Plantroom	Heating Equipment	Capacity	Area Served	Temperatures
Main Boiler House (basement level)	Gas Boilers, Hamworthy Wessex ModuMAX	10x 220kW	All	Flow: 80°C winter 70°C summer
DHW Plantroom	DHW Calorifiers, McDonald Indirect Solar Dual Coil Power*flow* 2000 commercial	3x 1,000 l 9 x 12kW immersion heaters 3x ??kW Solar Immersion heater connections	All	Aiming for 60°C

Figure 4-29: Main plantroom boiler plant

Figure 4-30: Wet radiator space heating

Figure 4-31: Trench heating near main entrance

Figure 4-32 Eden Court, Victorian block

Figure 4-33 Eden Court

4.8 University of Highlands & Islands

Although the building is currently owned and tenanted by UHI, plans are being explored to relocate staff from this building to another, and perhaps to let this building in the near future.

There are three plantrooms with gas-fired boilers on the ground, first, and second floors. There is also a separate air conditioning system which provides heating and cooling to the main meeting room with a dx split system.

Heating equipment is listed in Table 4-10.

Plantroom	Heating Equipment	Capacity	Area Served	Temperatures
Ground floor	Gas-fired boiler, EvoMax	60kW	Ground floor	Flow: 64°C Return 60°C
First floor	Gas-fired boiler	2x 60kW	First floor	
Second floor	Gas-fired boiler	60 kW	Second floor	Flow 72°C Return 65°C
Meeting room, ground floor	DX split heating and cooling system, Mitsubishi		Meeting room, ground floor	

Table 4-10 University of Highlands & Islands

4.9 Bught Stadium

The buildings at Bught park include an existing stadium and clubhouse, team portacabin (Wildcats), playing field regularly used for games of shinty, a significant area of land which is also used as playing fields, and an area between the playing fields which is currently used for parking.

The existing clubhouse at the back of the stadium with bleacher seating is planned to be demolished and replaced with a newbuild clubhouse which has changing and WC facilities. A modular construction approach may be used.

There are also plans to construct a new pavilion adjacent to the stadium seating, next to the shinty playing field. The new pavilion may include bar, function sweet, museum, and office spaces.

Both the new clubhouse and pavilion will be built in accordance with Passivhaus principles.

There are plans to upgrade the electricity connection on the site.

The programme envisioned for the newbuild is for the existing clubhouse to be demolished in September 2023, and the newbuild clubhouse to be completed by December 2024.

Net zero carbon greenhouse gas emissions is the target for the newbuild clubhouse and pavilion, which is a requirement of the Levelling Up funding. Plans for the site include heating with Ground Source Heat Pumps in a plant room under the stadium seating, and a vertical borehole array to the north of the clubhouse.

Heating equipment is listed in Table 4-11.

Heating Equipment	Capacity	Area Served
Electric heaters	-	Existing clubhouse
GSHP	20 kW	Newbuild clubhouse - future

Heating Equipment	Capacity	Area Served
GSHP	320 kW	Newbuild pavilion - future
Direct Electric Immersion Heater (electric back-up for DHW)		Newbuild pavilion - future

Table 4-11 Bught Stadium

An energy centre could potentially be located adjacent to the new pavilion or in the area which is currently used for parking between the playing fields.

Figure 4-34 Bught stadium (roof, seating) and existing clubhouse

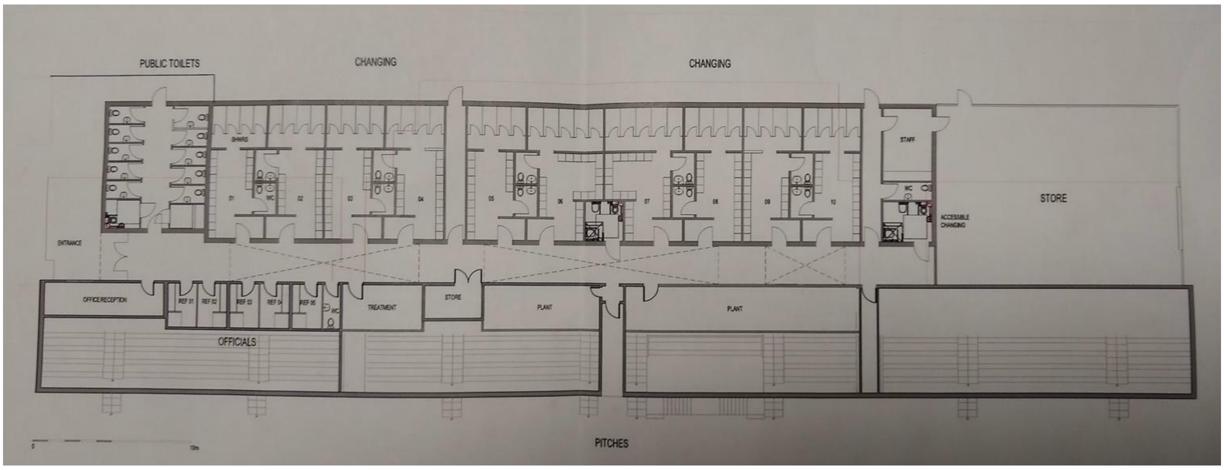

Figure 4-35 Bught stadium, layout for newbuild clubhouse, retaining existing stadium seating

Figure 4-36 Bught stadium, parking area where an energy centre could potentially be located

Figure 4-37 Bught stadium, parking area where an energy centre could potentially be located, view through park

4.10 Northern Meeting Park

The Northern Meeting Park is said to be one of the oldest playing fields in the north of Scotland. The site comprises of an old clubhouse, which is a listed building, a kiosk, playing field, and stone wall around the perimeter with metal gates.

The old clubhouse is a listed building. It has no heating and is intended to be repurposed as a storage building. The kiosk is planned to be demolished, and a new pavilion is planned to be constructed in its place.

The newbuild pavilion is planned to be heated using GSHP with a vertical borehole array and is to be built following Passivhaus principles.

There are plans to upgrade the electricity connection on the site.

An energy centre could be located to the south of the playing field in the parking area, or alternatively, to the west of the playing field, repurposing an existing stone storage unit as an energy centre.

Heating equipment is listed in Table 4-12.

Heating Equipment	Capacity	Area Served
None	N/A	Existing clubhouse
GSHP	10 kW	Newbuild pavilion - future

Table 4-12 Northern Meeting Park Heating Equipment

Figure 4-38 Northern meeting park stadium and existing clubhouse

Figure 4-39 Northern meeting park kiosk, to be demolished, and new pavilion to be constructed In Its place

Figure 4-40 Northern meeting park, playing field, and west wall, outside of which an energy centre could be located

Figure 4-41 Storage structure, where an energy centre could be potentially located in the future. On Council HQ land, adjacent to the Northern Meeting Park, on the south side

Figure 4-42 Potential energy centre location, in the parking area to the south of the Northern Meeting Park

Figure 4-43 Existing substation on the north side of the Northern Meeting Park. An upgrade Is planned for the electricity connection.

5 Energy demand analysis

The buildings considered in the heat demand assessment are detailed in the building schedule in Appendix B, along with relevant floor area information. Where available, metered energy consumption has been used to determine the energy demand of the buildings in the schedule. The metered data available for the different buildings is detailed in Appendix C. 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 quality of data received for different buildings varied. For some of the buildings, only cost and consumption data was provided; as such, a combination of the consumption data and industry benchmarks was used to determine the overall demand of the building. Where half-hourly (HH) data was provided, the annual profile for the building was generated and used directly in the energy modelling.

5.1 Energy demand summary

Annual low and high heat demands from the energy demand assessment for heat network are illustrated in

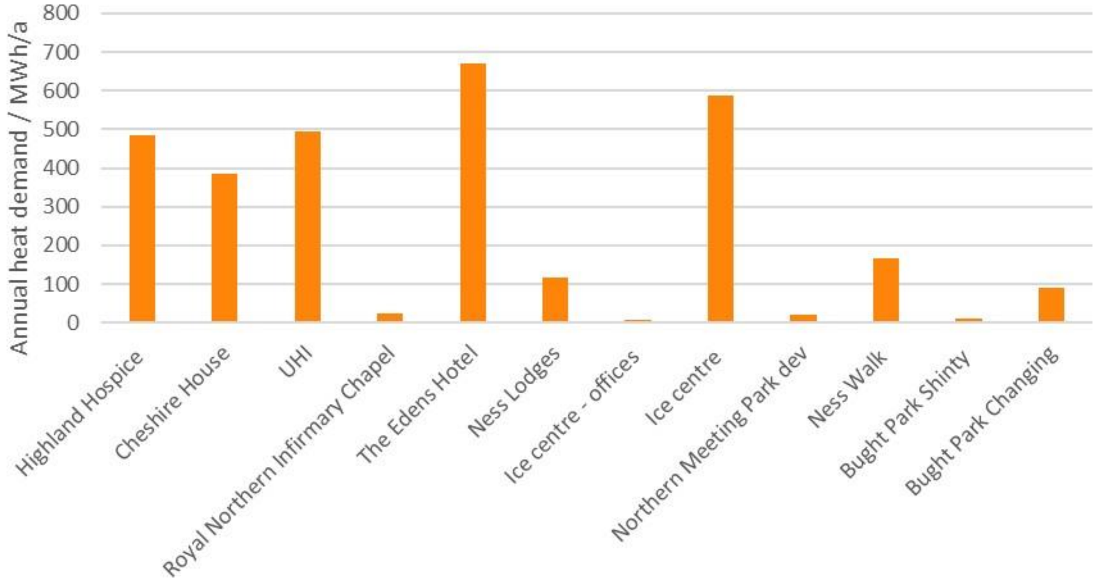

Figure 5-1 and

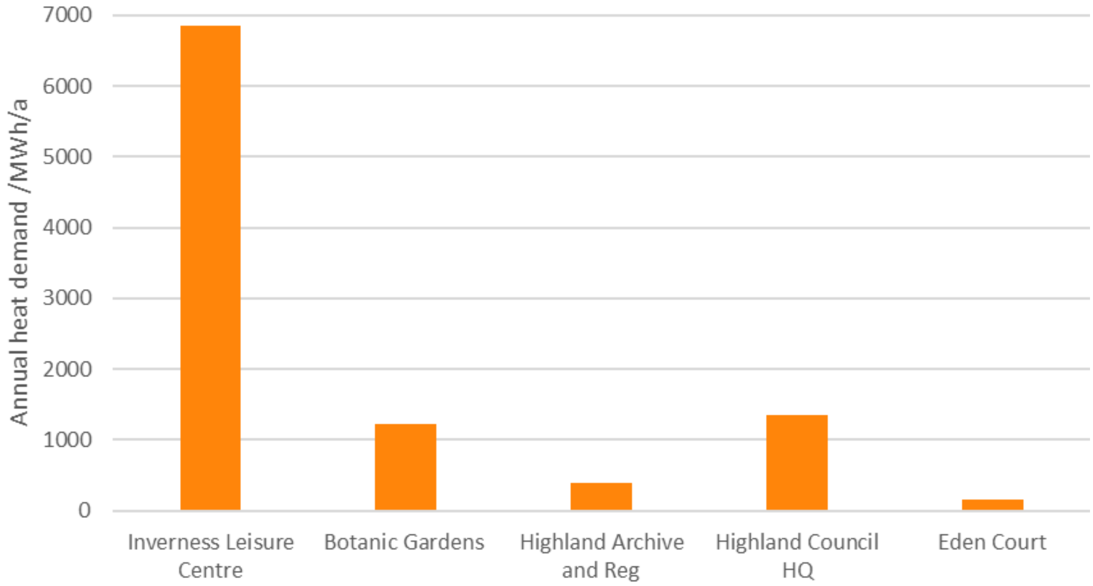

Figure 5-2, respectively. From this, it is evident that the largest annual heating demand on the network is the Inverness Leisure Centre.

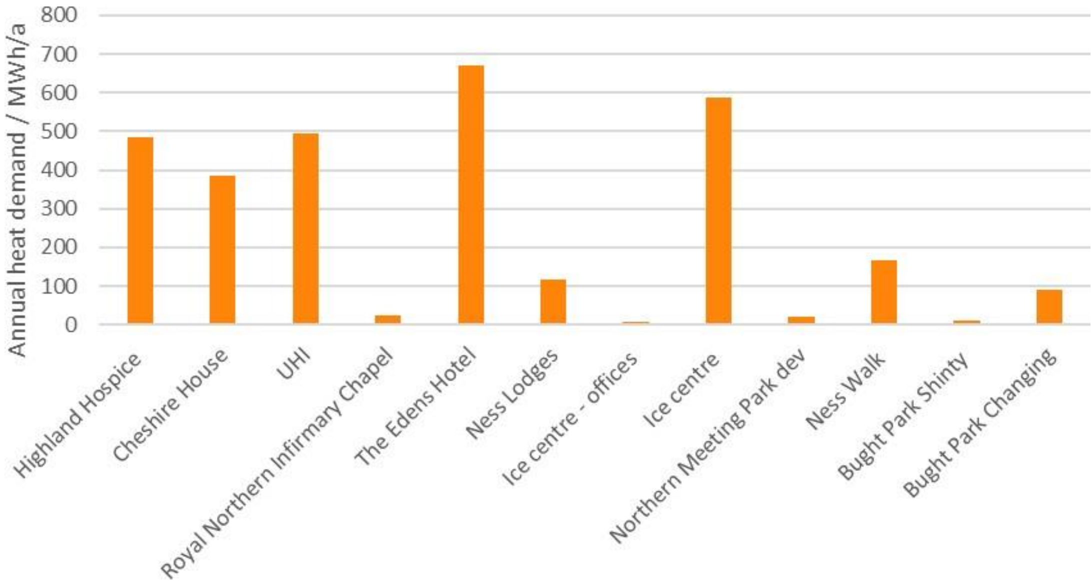

Figure 5-1: Annual demand summary (low demand)

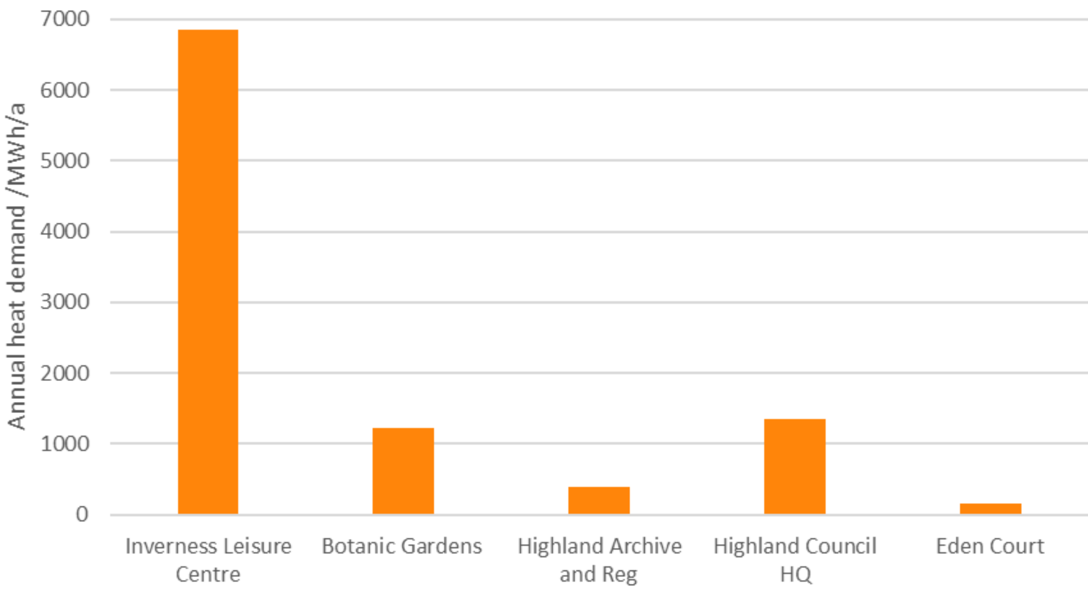

Figure 5-2: Annual heat demand summary (high demand)

A summary of energy demand for the network, derived from combining metered data and industry standard benchmark data, is provided in Table 5-1.

Table 5-1: Energy demand summary table

Building	Building Typology	Annual Heat Demand (MWh/a)	Peak Demand (kW)
Highland Hospice	Residential care home	490	100
Cheshire House	Residential care home	380	80
University of Highlands and Islands	University campus	500	200
Royal Northern Infirmary Chapel	Office	20	20
The Edens Hotel	Hotel	670	160
Ness Lodges	Hotel	120	30
Inverness Ice Centre – Offices	Office	10	10
Inverness Ice Centre	Dry sports and leisure	590	420
Pavilion – Northern Meeting Park development	Restaurant	20	10
Inverness Leisure Centre	Swimming pool centre	6,860	1,340
Ness Walk	Hotel	170	220
Botanic Gardens	Cultural activities	1,230	570
Highland Archive and Registration Centre	General office	390	290
Highland Council HQ	General office	1,360	1,220
Eden Court	Restaurant	160	820
Bught Park Shinty Museum	Museum	10	20
Bught Park Changing Rooms	Sports changing ground facilities	90	320
Total		**13,070**	**5,830**

For detail on the energy demands, and a full breakdown of the data used to establish the heating loads, please see Appendix D.

5.2 Linear heat density

Linear heat density (LHD) is an industry standard benchmark used to provide a high-level indication of a proposed heat network's feasibility. It is the sum of the annual heat loads of the buildings to be connected to the network, divided by the trench length of the pipework required to connect those buildings. A value greater than 4 MWh/a is the industry accepted threshold for a heat network that shows a potentially promising opportunity.

Geographically, the west bank area is split into north and south clusters with high heat demands, with relatively long stretches of land (mainly through Bught Park) separating the two regions. Although there are potential building connection opportunities between the north and south areas, these connections have a significantly smaller annual heat demand compared to the buildings in the North and South.

LHD was calculated to gain a better understanding of how a heat network may perform for three situations:

- Northern area heat network only
- Southern area heat network only
- Combined heat network - north and south areas

The south area shows the highest LHD at 12.6 MWh/a, indicating a promising opportunity for a heat network in that region, connecting those buildings only. This can be attributed to the high heat density of this region. Similarly, the combined network shows promise with a calculated LHD of 4.8. For the north-only network, the LHD is 2.79 MWh/a, this does not show an initial indication of a commercially attractive heat network scheme.

When calculating the LHD for the different scenarios, it should be noted that for the combined and south-only options, the energy centre location was selected as next to Inverness Leisure, whilst for the north-only option, the energy centre location is in the Highland Council HQ car park. Table 5-2 summarises the calculated LHDs, whilst Appendix P provides further detail on the buildings included in each area.

Although, based on the LHD calculations, the south shows the most promise for an economically viable heat network, stakeholder engagement with the Highland Council over fortnightly progress meetings led to the understanding that a combined network of both north and south areas would be the preference at this stage due to the Council's driver to decarbonise heat for the highest number of buildings.

Table 5-2: West bank area linear heat densities - North, South, and combined

Area	Total annual heat demand (MWh/a)	Pipework trench length (m)	Linear Heat Density, LHD (MWh/a)
Northern area	3,880	1,390	2.79
Southern area	9,180	730	12.60
Combined – north and south areas	13,070	2,720	4.80

Area	Total annual heat demand (MWh/a)	Pipework trench length (m)	Linear Heat Density, LHD (MWh/a)
Baseline benchmark LHD for comparison			4

6 Heat supply technology

A qualitative heat supply technology appraisal was carried out to determine the most suitable heat supply technology for the area. Full details of the assessment can be found in Appendix E. The assessment identified technologies for further consideration, which could potentially be suitable for the site:

- Ground Source Heat Pumps (GSHP)
    - Open Loop. Heating from borehole(s) to an alluvial aquifer source
    - Closed loop. Making use of a vertical borehole array
- Air source heat pump (ASHP). Open spaces available in the study area
- Water Source Heat Pumps (WSHP). The study area is close to the river Ness.
- Top-up electric boilers. To switch entirely away from gas-fired boilers, electric boilers could be used for top-up heat.
- Thermal storage. Can be used to meet peak demands

Over the course of progress meetings with the stakeholders at the Highland Council, it became understood that the preferred heat technologies were open loop (alluvial aquifer) and closed loop (borehole array) GSHPs. This was due to the Council's preference for GSHP and boreholes as a lower-risk option to organise and manage compared to the work that may be required to progress with WSHP, using the river Ness as the heat source.

Heat recovery from nearby sewer systems was discounted due to the largest pipe nearby having insufficient flowrate to act as a reasonably sufficient source of heat for the heat network. Further information can be found in Appendix G.

Similarly, the preferred technologies to proceed with top-up/back-up electric boilers were selected due to the Highland Council's preference for a fully electric solution. This would allow the Council to transition from using fossil fuels to low-carbon heating technologies.

Thermal storage is a critical component to a heat pump led heating system, allowing heat pumps to be maximised as the main heat technology. Therefore, the inclusion of thermal stores has been included within the energy strategies brought forward for techno-economic modelling.

Table 6-1 summarises the outcome of the analysis Heat technologies are scored against a set of seven key drivers. Each driver is weighted according to its perceived importance on the overall project. A score between one to five, with five being the highest scoring, is assigned for each key and an overall score for each technology being assessed gives an indication of that technology's suitability.

Table 6-1: Heat Supply Technology Suitability Assessment

	Driver Priority:	1	2	3	4	5	6	7			
Row	**Technology**	**Resource availability**	**Carbon reduction potential**	**Commercial complexity + Technology maturity**	**Capital Cost**	**Operating Cost**	**Spatial requiremenhts**	**Local environmental benefits (e.g. air quality)**	**Weighted Score (Out of 5)**	**Recommendation**	**Additional Notes**
	Driver Weighting:	**15%**	**40%**	**15%**	**10%**	**10%**	**5%**	**5%**			
1	Air Source Heat Pump	5	4	4	4	3	3	4	**4.0**	**Y**	Relatively poor efficiency compared to WSHP and GSHP options
2	Ground Source Heat Pump	3	5	4	2	4	3	4	**4.0**	**Y**	Suitable space available within Northern Meeting Park & Bught Park
3	Water Source Heat Pump	4	5	4	3	3	4	4	**4.2**	**Y**	Good access to river Ness nearby
4	Thermal Storage	5	3	5	5	5	4	5	**4.2**	**Y**	Required to incorporate heat pumps into an energy strategy
5	Alluvial Aquifer Source - Water Source Heat Pump	3	5	4	3	4	4	4	**4.2**	**Y**	Geotechnical survey (outside scope of Feasibility Study) required to establish presence of alluvial aquifers. However similar projects nearby show promise.
6	Waste Heat Recovery - Sewer Heat	4	5	4	3	2	3	4	**4.1**	**N**	Ardross Street sewer pipe has approx. 2l/s minimum flowrate, corresponding to only approx. 42kW not taking into account additional system losses
7	Ambient Loop Heat Network	4	4	3	4	4	5	5	**4.0**	**N**	Reduced heat losses compared to high temperature system.
8	Biomass	4	2	5	4	3	4	3	**3.2**	**N**	City centre location and air quality requirements are prohibitive
9	Top up Electric boilers	4	3	5	4	2	4	5	**3.6**	**N**	As a main heat generator opertional costs are higher than heat pumps. Can be used effectively to meet peak demands.
10	Gas Boiler	5	1	5	5	3	5	3	**3.1**	**N**	Carbon emitting technology. Can be used effectively to meet peak demands. To be avoided if possible.
11	Gas CHP	5	2	5	5	3	5	3	**3.5**	**N**	Carbon emitting technology
12	Biogas CHP	3	4	4	3	2	4	3	**3.5**	**N**	City centre location and are quality requirements are prohibitive.

7 Energy modelling

For a heat network to operate efficiently (maximise carbon saving whilst minimising costs), the primary low carbon heating technology and peaking equipment within the energy centre must be accurately sized. Additional components such as thermal stores should also be sized appropriately to optimise the plant room design and utilisation of the low-carbon technology.

The Heat Supply Technology Suitability Assessment carried out in Section 6 identified borehole led GSHPs and alluvial aquifer sourced GSHPs as the heat generation technologies that were most suitable for the new energy centre. Similarly, the Highland Council highlighted their strong preference for an all-electric solution. As such, electric boilers were selected as the back-up/top-up technology.

This heat network is comprised of both existing buildings and new developments. In the absence of half-hourly (HH) data from the client for the existing buildings, synthetic profiles for a given building typology were used. These profiles represent a typical week as an hourly profile and are taken from previous Buro Happold project experience. Based on the heating demand assessment completed, the profiles were adjusted to reflect the heating loads of the connections. The profiles cover both space heating (SH) and domestic hot water (DHW) use. Where the client provided HH data, annual profiles were put directly into the model. A model was set-up in EnergyPRO software to represent the heating loads for each connection. The annual loads were taken from the developed load schedule. The model also accounts for ambient air temperature fluctuations using historical local weather data; this considers the increase in heat demand with lower external temperatures. This methodology is detailed in Figure 7-1.

Figure 7-1: Heat demand profiling methodology

When carrying out the energy modelling, a key criterion was to ensure that at least 85% of the annual heat demand (heat fraction) was met by the main low carbon heating technology (usually heat pumps). The remaining annual demand would be satisfied by the peaking technology. This is to ensure that most of the heat for the network is supplied by the lowest carbon heating solution; therefore, limiting the carbon emissions from the network. Additionally, given that the peaking technology chosen for this network is electric boilers, the target of an 85% heat fraction also relates to the operational costs for the network. The heat pump offers a higher efficiency than the electric boiler, meaning it offers a reduced electricity demand.

7.1 Phasing

For the phasing of building connections to the heat network, the Highland Council expressed a preference to connect the Council buildings in the first phase (2024), and then to connect the remaining buildings in the second phase (2026). (Table 7-1). This was based on the Council's ability to make the decision directly to connect Council buildings to the heat network, whereas further stakeholder engagement would be required to onboard the buildings owned by others.

Table 7-1: Phasing of building connections

Phase	Connection Year	Connections
Phase 1	2024	Northern Meeting Park development

Phase	Connection Year	Connections
		Highland Archive and Registration Centre Botanic Gardens Highland Council HQ Bught Park Shinty Museum Bught Park Changing Rooms Inverness Leisure Centre
Phase 2	2026	Highland Hospice Cheshire House University of Highlands and Islands Royal Northern Infirmary Chapel The Edens Hotel Ness Lodges Ness Walk Eden Court Inverness Ice Centre

When the Council revisits the opportunity to consider a heat network at the next stage, we recommend considering a phasing approach where Phase 1 is the south area of the west bank with the energy centre and leisure centre, and Phase 2 is the north area of the west bank, including the Council HQ.

7.2 Annual demand profiles

The annual demand profile for the Phase 1 buildings (given in Table 7-1) is presented below in Figure 7-2. A peak heat demand of approximately 3.25 MW can be observed around the beginning of December.

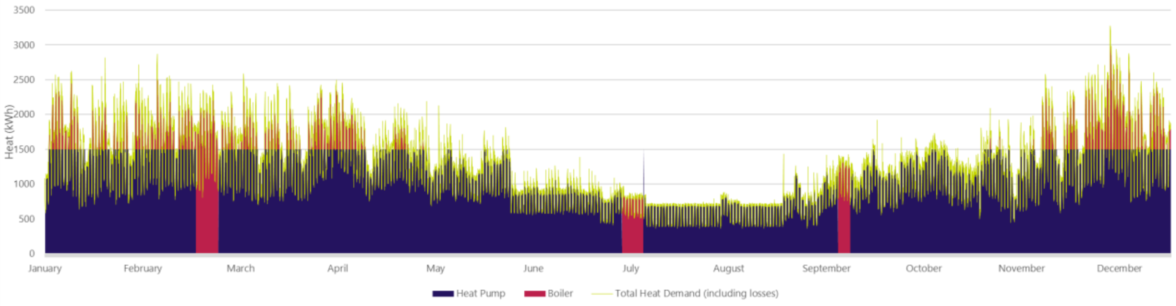

Figure 7-2: Phase 1 annual demand profile

Figure 7-3 presents the annual profile for Phase 2, with all buildings now being connected to the heat network. Like Phase 1, the peak demand of the network occurs near the beginning of December. However, now that all buildings are connected to the heat network the demand is approximately 5.0MW.

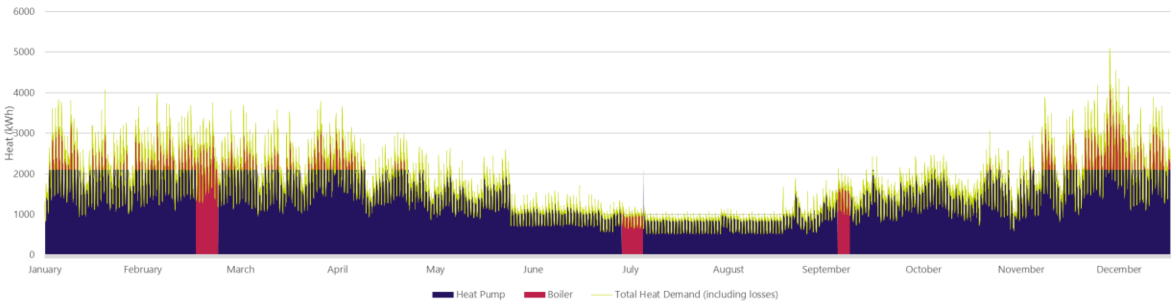

Figure 7-3: Phase 2 annual demand profile

7.3 Equipment sizing

The energy modelling outputs listed below in Table 7-2 were calculated upon completion of energy modelling and following equipment sizing strategy in the introductory paragraph to Section 7 above.

The main heat generation technology is GSHPs with a nominal capacity of 2.1 MW with additional back-up boilers sized at 5.8 MW and 60m^3 of thermal storage.

Table 7-2: Energy modelling outputs – equipment sizing

Technology	Capacity	Efficiency (%)	Heat fraction (%)
Ground Source Heat Pumps	2,100 kW	290	88.7
Electric Boilers	5.8 MW	99	11.3
Thermal Stores	60 m^3	-	-

7.4 Scenario 1. GSHPs - boreholes

7.4.1 Potential borehole locations

The potential borehole locations for the west bank area were assessed based on the open-space available; Figure 7-4 shows these areas. Following discussions with the Highland Council on their preferred energy centre location, the most suitable locations for the boreholes was areas 1-4, as per Figure 7-4.

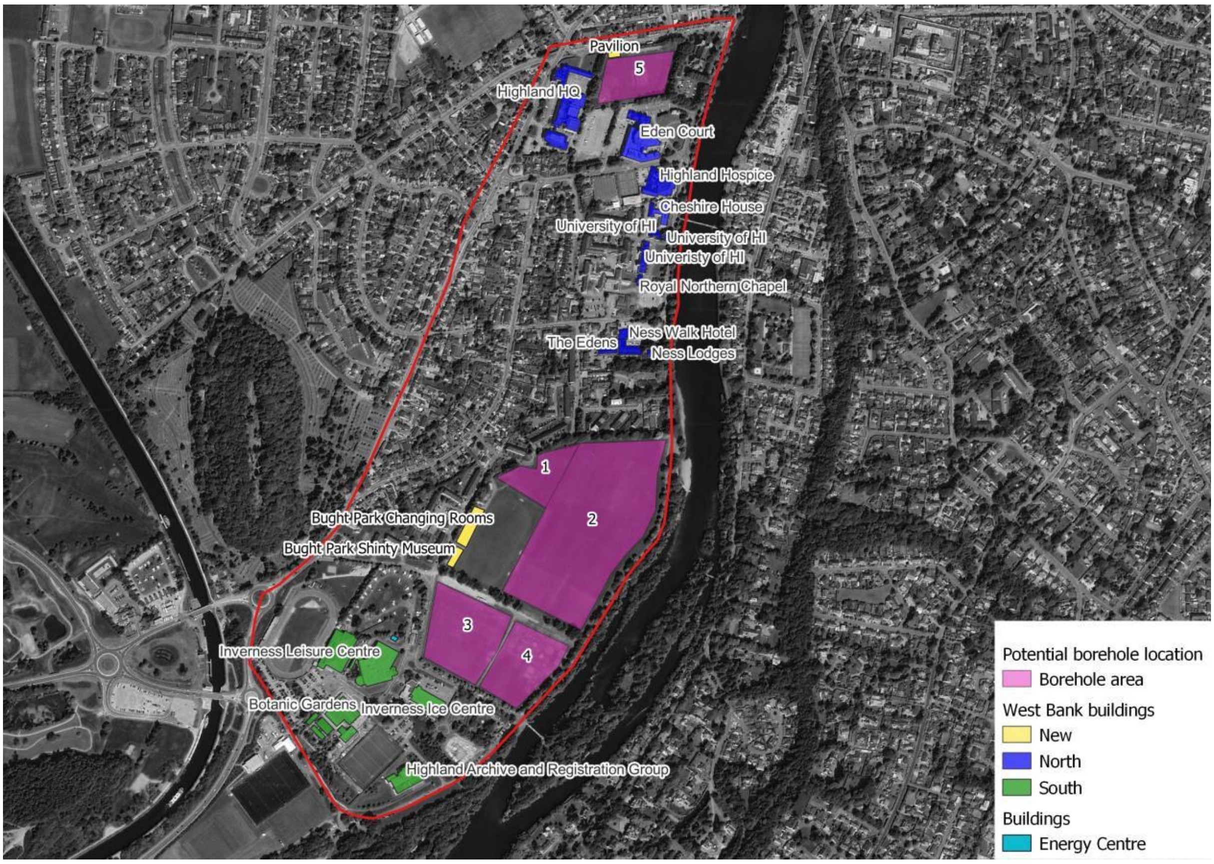

Figure 7-4: Potential borehole locations

Based on data available from local boreholes in the area, the potential heat extraction from the ground estimated. The specific heat extraction was estimated as 43.5 W/m based on the given bedrock geology for the west bank region. From this, the number of boreholes required to satisfy the energy demand for the network was estimated. Details of the borehole requirements is provided in Table 7-3, for a more detailed breakdown of the calculated heat available, please refer to Appendix L.

Table 7-3: Closed loop ground source heat pump assessment

Metric	Value
Specific heat extraction (W/m)	43.5
Borehole depth (m)	150
Heat available per borehole (kW)	6.5
Heat pump capacity, Qh (kW)	2,100
Heat required from the ground, Qc (kW)	1,370
Number of boreholes	210

For the specified number of boreholes, the area required for the borehole array, based on an approximate 9m spacing between boreholes, is ~ 15,000 m^2. The approximate areas of the proposed borehole locations are shown in Table 7-4. From this, the most suitable borehole location appears to be Area 2, in Bught Park.

Table 7-4: Area available for the borehole array

Borehole location	Area / m^2
1 – Bught park, north west	8,120
2 – Bught park, noth east	61,280
3 – Bught park, south west	19,550
4 – Bught park, south east	14,760
5 – North Inch park	10,080

7.5 Scenario 2. GSHPs – alluvial aquifer

7.5.1 Alluvial aquifer borehole requirements

The second technology considered in the energy demand assessment was an open-loop alluvial aquifer fed heat pump. To estimate the feasibility of utilising this technology in the west bank region, an assessment of the heat available from the alluvial aquifer was completed. Details of the heat available and borehole requirements are shown in Table 7-5. For a more detailed breakdown of the calculations completed to estimate heat available, please refer to Appendix M.

Table 7-5: Alluvial aquifer yields

Metric	Value
Borehole yield (l/s)	15
Heat available per borehole (kW)	314
Heat pump capacity, Q_h (kW)	2,100
Heat required from the alluvial aquifer, Q_c (kW)	1,370
Number of boreholes	5

It is evident from these calculations that the borehole yields for the open loop option far exceed that of the closed loop ground source alternative. Hence, the number of boreholes required is reduced significantly for the latter option.

7.6 Phased demand modelling

As not all buildings will connect to the heat network imminently, phased energy modelling was carried out to optimise the installation of equipment to meet the heat demands of both phases.

7.6.1 Phase 1 (2024)

The equipment modelled to meet the energy demand of Phase 1 is given in Table 7-6.

Table 7-6: Phased energy modelling

Phase	Technology	Capacity	Efficiency (%)	Heat fraction (%)
Phase 1	Ground Source Heat Pumps	1,500 kW	290	87.9
	Electric Boilers	3.8 MW	99	12.1
	Thermal Stores	60 m³	-	-

With the equipment listed in Table 7-6 installed in the new energy centre, Figure 7-5 presents the typical winter's day heat demand profile of the Phase 1 scheme and how that heat demand is met by the equipment in the energy centre.

Most of the heat demand is met by the GSHPs either through direct heat export by the heat pumps or via discharging of the thermal store. Electric boilers provide top up when the demand is at its highest and when the thermal store is fully discharged.

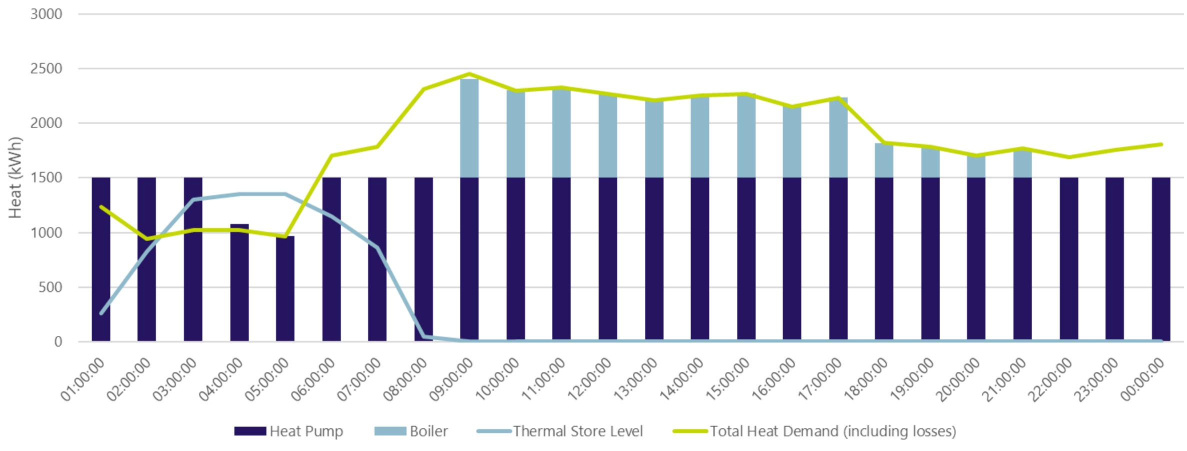

Figure 7-5: Phase 1 daily demand profile (winter)

Similarly, Figure 7-6 presents the typical heat demand of the Phase 2 heat network on a summer's day. With a turndown ratio of 40%, the GSHPs can ramp down their output to meet the reduced demand expected during the summer months. Electric boilers are not required to meet the heat demand as what relatively little demand there is can be met by the GSHPs.

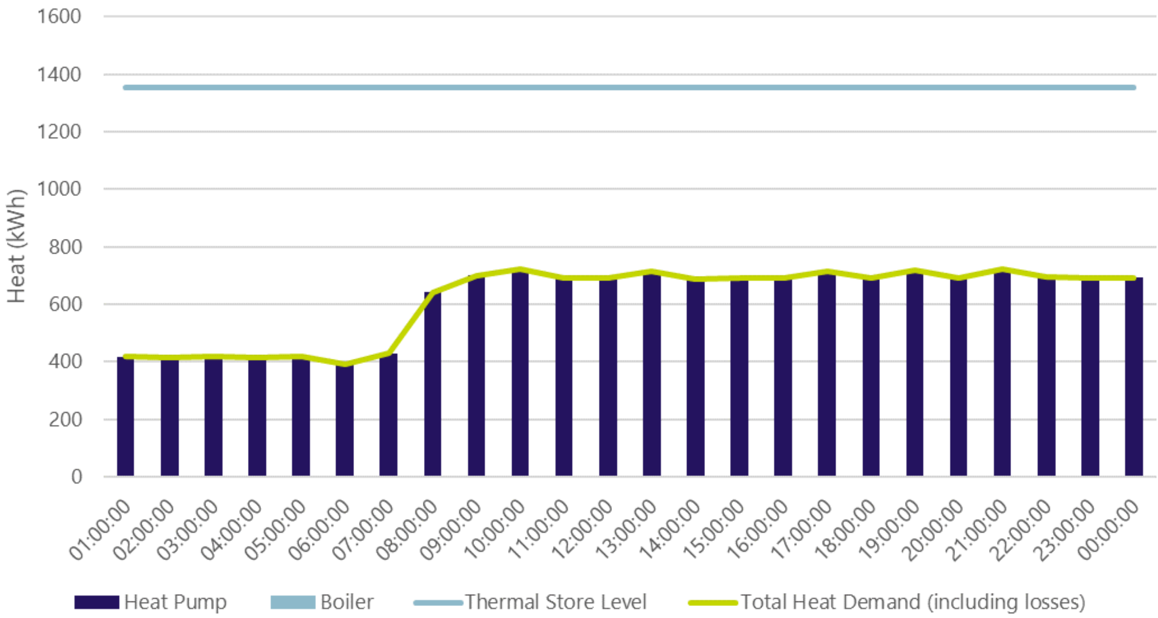

Figure 7-6: Phase 1 daily demand profile (summer)

7.6.2 Phase 2 (2026)

The equipment listed in Table 7-7 summarises the equipment in the new energy centre at full build out of the heat network.

Table 7-7: Phase 2 energy centre Equipment and heat fraction.

Phase	Technology	Capacity	Efficiency (%)	Heat fraction (%)
Phase 2	Ground Source Heat Pumps	2,100 kW	290	88.7
	Electric Boilers	5.8 MW	99	11.3
	Thermal Stores	60	-	-

The typical daily heat demand profile for a winter's day during Phase 2 is given in Figure 7-7. Like the winter's day profile for Phase 1 (Figure 7-5), the majority of the heat demand is met by the GSHPs with additional top-up provided by the electric boilers only when the GSHPs are at maximum capacity and the thermal store has been fully discharged.

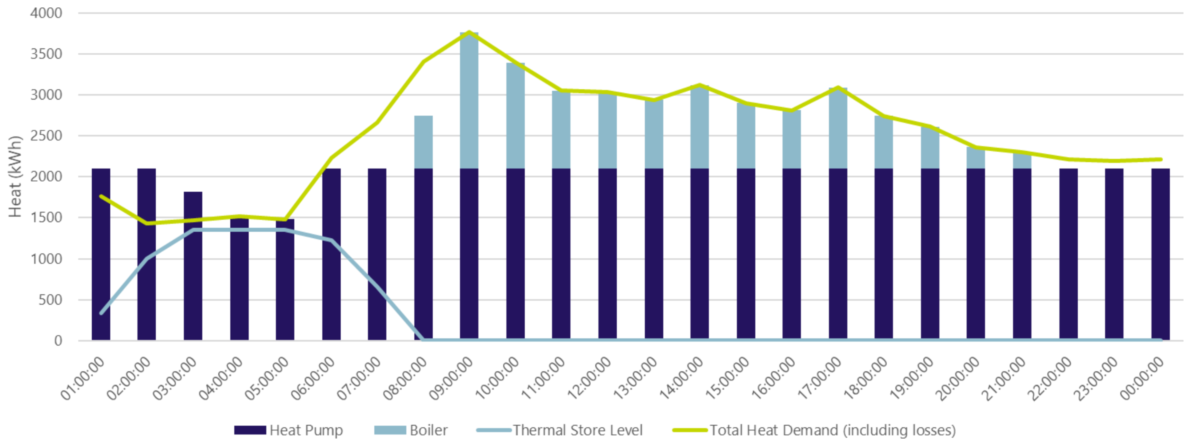

Figure 7-7: Phase 2 daily demand profile (winter)

Figure 7-8 presents the typical summers day profile for Phase 2. Top-up electric boilers are not required as the GSHPs can ramp down to approximately 40% of their maximum output and the total heat demand is greater than minimum capacity of one heat pump.

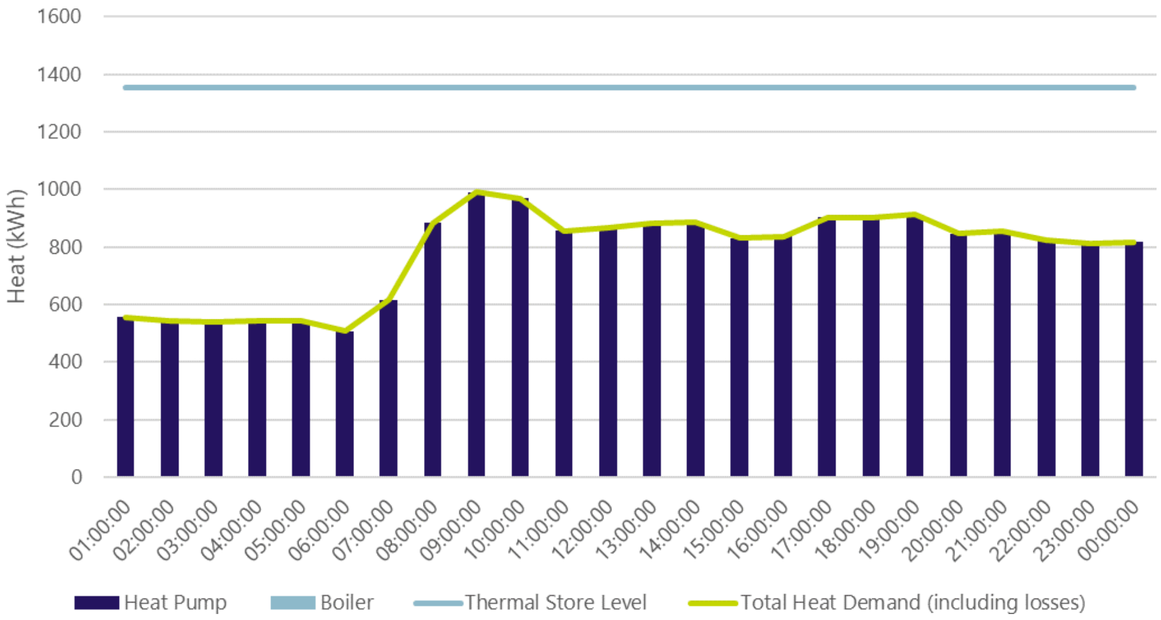

Figure 7-8: Phase 2 daily demand profile (summer)

8 Spatial coordination

A map of the entire west bank area along with the proposed heat network route is presented below in Figure 8-1.

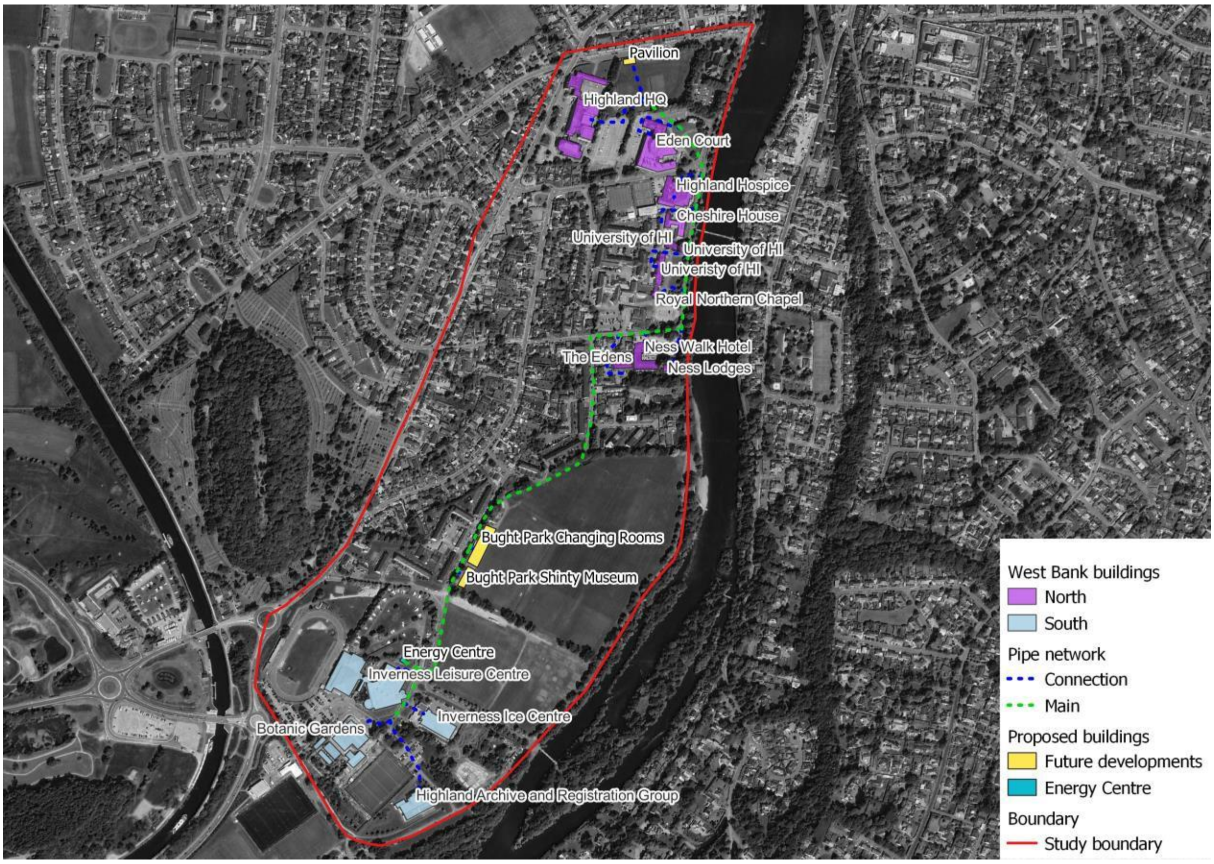

Figure 8-1: West bank Project Boundary Area

8.1 Energy centre, adjacent to Inverness Leisure

An indicative floor plan of the energy centre is presented below in Figure 8-2. The footprint of the energy centre is approximately 250 m^2; the thermal stores have been placed outside the energy centre, for space saving.

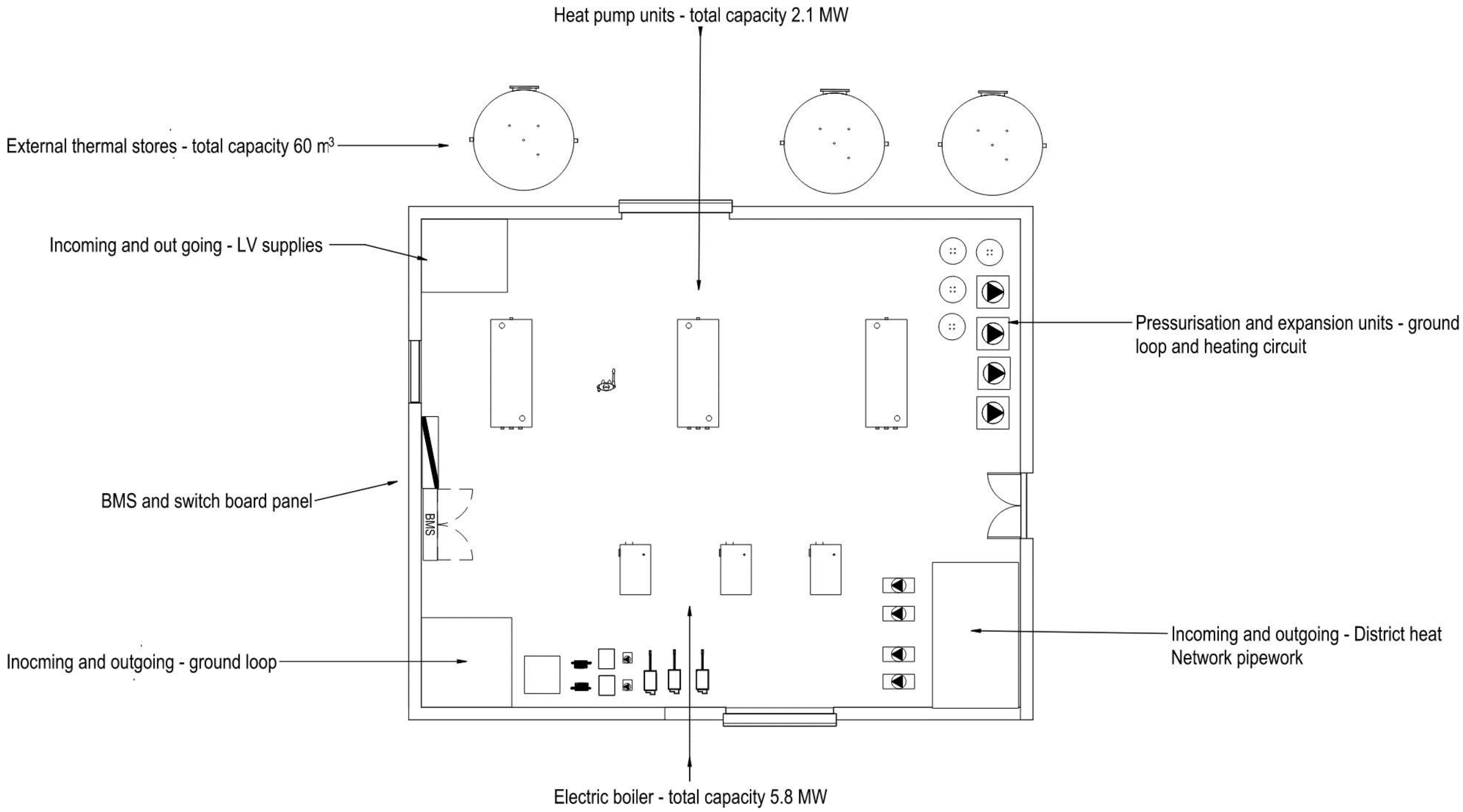

Figure 8-2: Proposed new energy centre layout

8.1.1 Electrical supply

The SSEN heat network map for Inverness suggests that the nearest SSEN substation to the west bank area at Dalneigh is currently unconstrained. This would suggest that there is an increased likelihood that the connection of the new energy centre could be achieved without significant grid reinforcement.

However, as substation capacity can be quickly taken up by other developments in the area it is recommended that SSEN be contacted as part of a full formal application in determining network capacity in the area. A screenshot of the SSEN heat network map for the area is presented in Appendix N.

8.2 Heat network route

An indicative heat network route for the Inverness west bank area is presented below in:

Figure 8-3: South area around new energy centre and Inverness Leisure Centre

Figure 8-4: Central area around Bught Park

Figure 8-5: Northern area around Highland Council HQ

The pipework route has been coordinated with existing utilities in the area following a desktop-based utilities search. Results of the desktop-based utilities search can be found in Appendix F.

Each length of pipe in the heat network has been allocated a tag number and is individually sized. A summary of the total pipe lengths for each pipe size is given in Table 8-1. A detailed breakdown of each individual pipe is given in Appendix I. In total, the heat network has an indicative trench length of 2,721m.

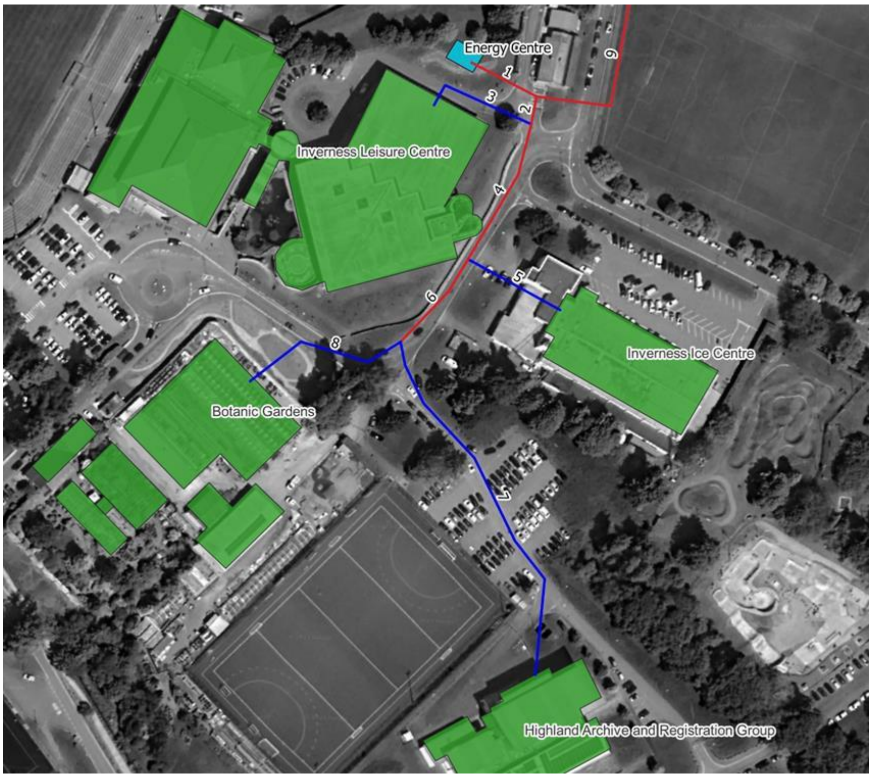

Figure 8-3: Indicative heat network - South Area

Figure 8-4: Indicative heat network - Central Area

Figure 8-5: Indicative heat network - North Area

Table 8-1: Pipe breakdown by size

Pipe Size (mm/DN)	Trench Length (m)	Pipe Length (m)
25	205	410
40	95	190
50	189	378
65	279	558
80	149	298

Pipe Size (mm/DN)	Trench Length (m)	Pipe Length (m)
100	272	544
125	1,235	2,470
150	269	538
200	28	56
Total	**2,721**	**5,442**

8.3 Heat network schematic

A schematic diagram of the proposed heat network is presented in Figure 8-7.

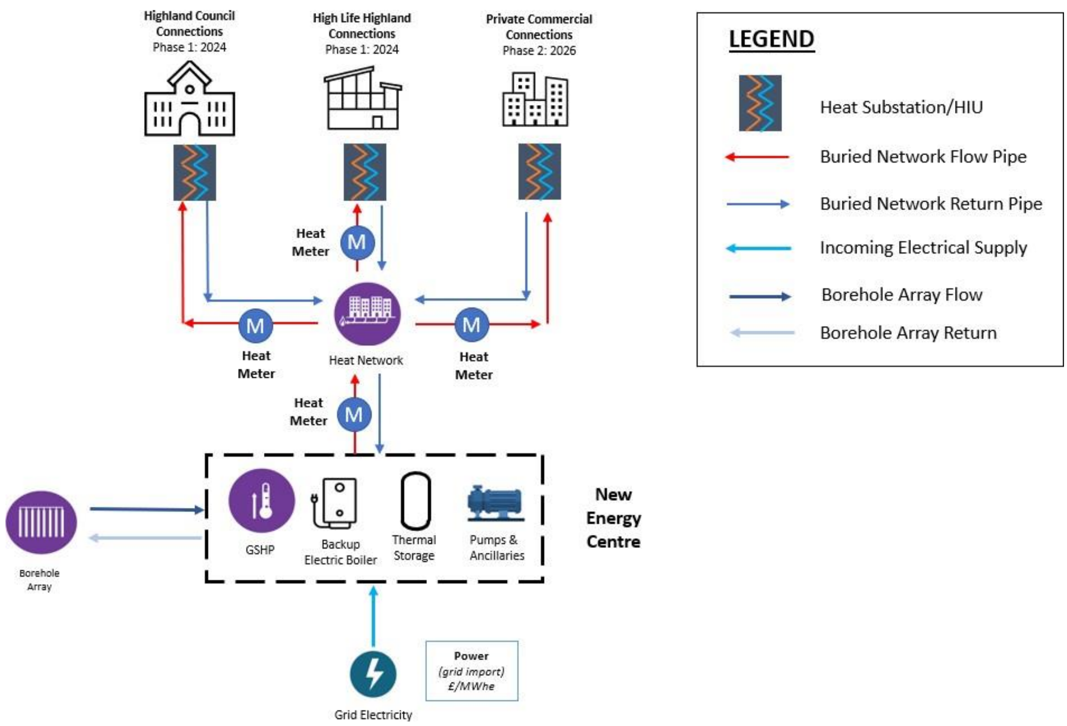

Figure 8-6: Closed loop (Borehole) GSHP heat network Schematic

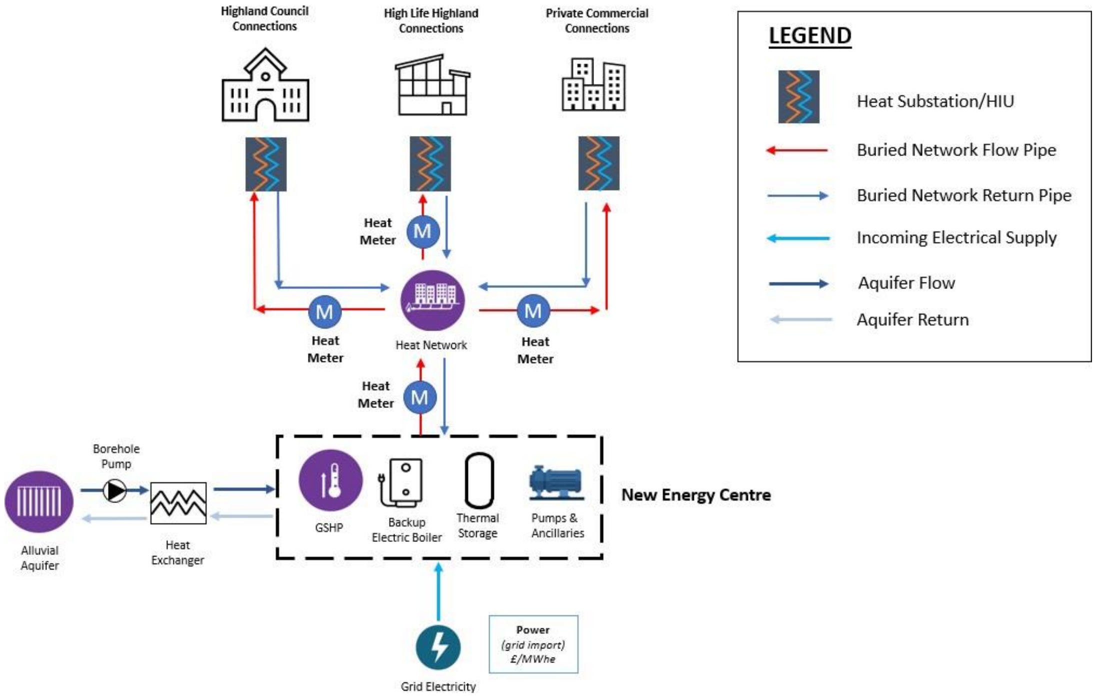

Figure 8-7: Open loop GSHP (alluvial aquifer) heat network

9 Techno-economic modelling

This section outlines the techno-economic model (TEM) carried out for each network scenario, providing information on the capital and operational expenditure (CAPEX, OPEX) and the financial performance of the heat network.

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. A copy of the TEM can be found in Appendix K.

9.1 Methodology

A techno-economic model has been developed to assess the possible return on investment that can be achieved from each scenario over the 40-year project life. To do so, an annual cash flow was produced, combining technical details of the scheme (CAPEX, OPEX) with appropriate cost/price inputs.

The viability of each scenario is represented in the model by Net Present Value (NPV), Internal Rate of Return on investment (IRR) and discounted payback. A positive NPV achieved at 40 years represents a potential financially attractive scheme.

The charges to the consumer have been broken down in the model. Each connection will have two costs for heat: a variable rate and a fixed rate. Additionally, a connection charge will be added for each building to connect to the heat network; this charge represents the otherwise avoided cost to the consumer by connecting to the district heat network. As such, the three main revenue streams can be viewed as:

1. Variable heat sales (p/kWh)
2. Fixed rate costs (£/unit of £/kW)
3. Connection charge (£)

9.2 Modelling assumptions

9.2.1 Key assumptions

The following key assumptions were made in the development of the TEM:

Project timeline

40-year time period for the estimate of Net Present Value (NPV) and Internal Rate of Return (IRR).

Heat network ownership

The heat network owner/operator would act as a bulk heat supplier, owning and operating the energy centre equipment and heat network up to the connection at Heat Interface Units (HIUs) and Heat Substations.

Capital costs

Capital costs have been phased in alignment with the indicative timeline for build out of the heat network.

An itemised CapEx costs breakdown for the project is given in Appendix Q.

Replacement expenses (RepEx)

Replacement cost sinking fund – spreads cost of equipment replacement over project lifetime instead of one lump sum every time equipment is to be replaced.

Total REPEX over the 40-year project timeline and equipment life expectancies are given in Table 9-7 and Table 9-8, respectively.

Connection charges

Connection charges are a one-off payment made by each building to connect to the heat network in the year that the building is due to connect to the network.

Connection charges have been calculated based upon the avoided costs that the building would have otherwise paid to make use of the counterfactual technology (individual ASHPs at each building).

The connection charge fees are given in Table 9-4.

Connection heat sales tariffs

Variable and fixed rates were calculated using methodology within the DECC ‘Assessment of costs, performance, and characteristics of UK heat networks’7.

All buildings are assumed to be paying the same heat sales price, regardless of building ownership.

The calculated heat sales prices are:

- Variable rate: 12.74p/kWh
- Fixed rate: 65.3 £/kW

Fuel cost projections (energy centre)

Future fuel price projections were provided by the Highland Council.

The predicted fuel costs for the council in the financial year 2023-2024 were used. These were:

- Electricity: 25.41 p/kWh
- Gas: 7.54 p/kWh

[7] https://www.gov.uk/government/publications/assessment-of-the-costs-performance-and-characteristics-of-uk-heat-networks (Accessed 22/11/22)

These values were indexed from 2024 to BEIS Green Book Supplementary Guidance, (Table 4-8: Retail prices) projections for future fuel costs

Building connection dates

Phasing has been applied with the Highland Council and High Life Highland properties assuming to connect in 2024 and the remaining connections joining the heat network in 2026.

Heat supply technology

At full build out, the new energy centre is assumed to contain:

- GSHPs: 2.1MW
- Electric Boilers: 5.8MW
- Thermal Storage: 60m^3

A summary of the heat technologies used, along with their phasing and the proportion of the annual heat demand met by each technology for each phase can be found in Section 7.6.1.

Discount rate

HM Treasury Green Book Guidance Discount Rate of 3.5% assumed.

9.2.2 Business as usual scenario – gas for existing, GSHP for proposed newbuilds

The BAU case assumes that no heat network will be built, and every building will continue to use their existing heating technology for the 40-year period that is being considered in the project.

Table 9-1 outlines the Business-as-Usual heating technologies used for the west bank heat network project. Further information can be found in Section 4.

Table 9-1: Business as usual technologies

Building	Main Heat Generation Technology
Highland Hospice	Gas boilers
Cheshire House	
University of the Highlands and Islands	
Infirmary Chapel	
The Edens Hotel	
Ness Lodges	
Ness Walk	
The Highland Archive & Registration Centre	

Building	Main Heat Generation Technology
Eden Court	
Inverness Ice Centre	
Inverness Botanic Gardens	Gas boilers, biomass and kerosene
Northern Meeting Park Development	
Bught Changing Rooms	Ground source heat pumps
Bught Shinty	
Inverness Leisure Centre	Gas boilers + gas CHP unit
Highland Council HQ	

9.2.3 Counterfactual scenario – individual ASHP

The counterfactual scenario was used as a basis for establishing the heat sales price and connection charge cost for the heat network. The counterfactual scenario represents the mechanism by which heat would be delivered to consumers if the proposed heat network was not instated. For this network, the counterfactual used is detailed below:

- Each connection on the network will have a communal ASHP as the main heating technology. This ASHP will meet 100% of the annual heating demand for each building.
- The efficiency used for the heat pump in the counterfactual scenario was different for the various building connections, depending on the condition of the building and the network temperature for these connections. Section 4 outlines the condition of each building's heating systems as well as their current operating temperatures. For the new developments, a lower operating temperature is expected and therefore a higher coefficient of performance (COP) observed.
- The weighted counterfactual SCOP for the ASHP solution is 2.51.

9.2.4 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. At the next stage, we recommend confirming costing with a Quantity Surveyor.

9.3 Heat sales price

To develop the heat sales price, the fixed and variable rate were calculated following methodology from the DECC in 'Assessment of costs, performance, and characteristics of UK heat networks'8. The breakdown of these costs is shown in Figure 9-1.

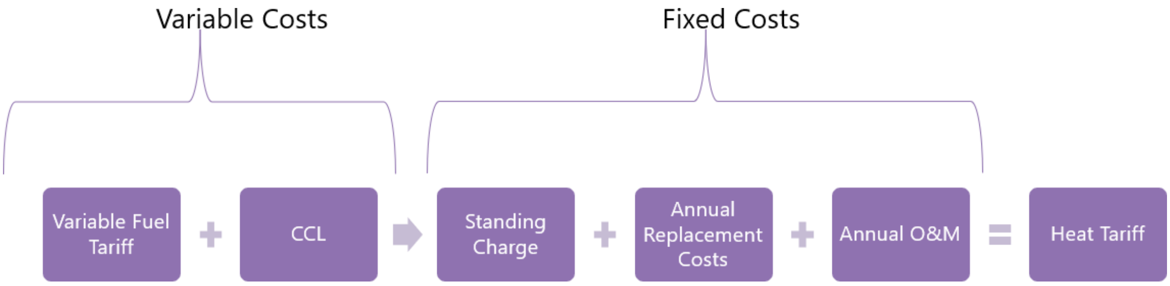

Figure 9-1: Breakdown of heat sales price

As illustrated above, the variable cost of heat considers the variable fuel tariff. The fuel import rate used in this modelling, to calculate the counterfactual cost of heat, is based on BEIS Green Book Tables 4-8 Retail Fuel Prices[9]. The relevant import prices for natural gas and electricity are displayed in Table 9-2. The costs used in the modelling reflect the 2023 Commercial figures; for the natural gas prices, Scenario B, which represents the average of daily fuel prices, was used.

Table 9-2: Fuel import rates

Fuel import	Commercial / Public sector price p/kWh	Source
Electricity	28.98	BEIS Green Book retail 2023 fuel prices
Natural gas	8.92	

Following confirmation from the Highland Council that all buildings will be charged the same rates, the average calculated counterfactual costs of heat for each building was calculated taken. The heat sales price and fixed charge are displayed in Table 9-3. These charges are based on a building-level ASHP counterfactual.

8 https://www.gov.uk/government/publications/assessment-of-the-costs-performance-and-characteristics-of-uk-heat-networks (Accessed 22/11/22)

9 https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fassets.publishing.service.gov.uk%2Fgovernment%2Fuploads%2Fsystem%2Fuploads%2Fattachment_data%2Ffile%2F1129255%2Fdata-tables-1-19.xlsx&wdOrigin=BROWSELINK [Accessed March 2023]

Table 9-3: Heat sales price

	Heat sales price (p/kWh)	Fixed rate (£/kW)
Commercial connection	12.74	65.3

9.3.1 Annual heat charges

Indicative graphs of typical annual heating bills, following the heat tariff structure outlined in Section 9.3, are presented in Figure 9-2, Figure 9-3 and Figure 9-4

Costs are split into total fixed costs (from the 65.3 £/kW fixed rate) and total variable costs (from the 12.74p/kWh heat sales price).

Buildings with a relatively higher heat demand pay more for their heating over an annual basis than those with a lower heat consumption.

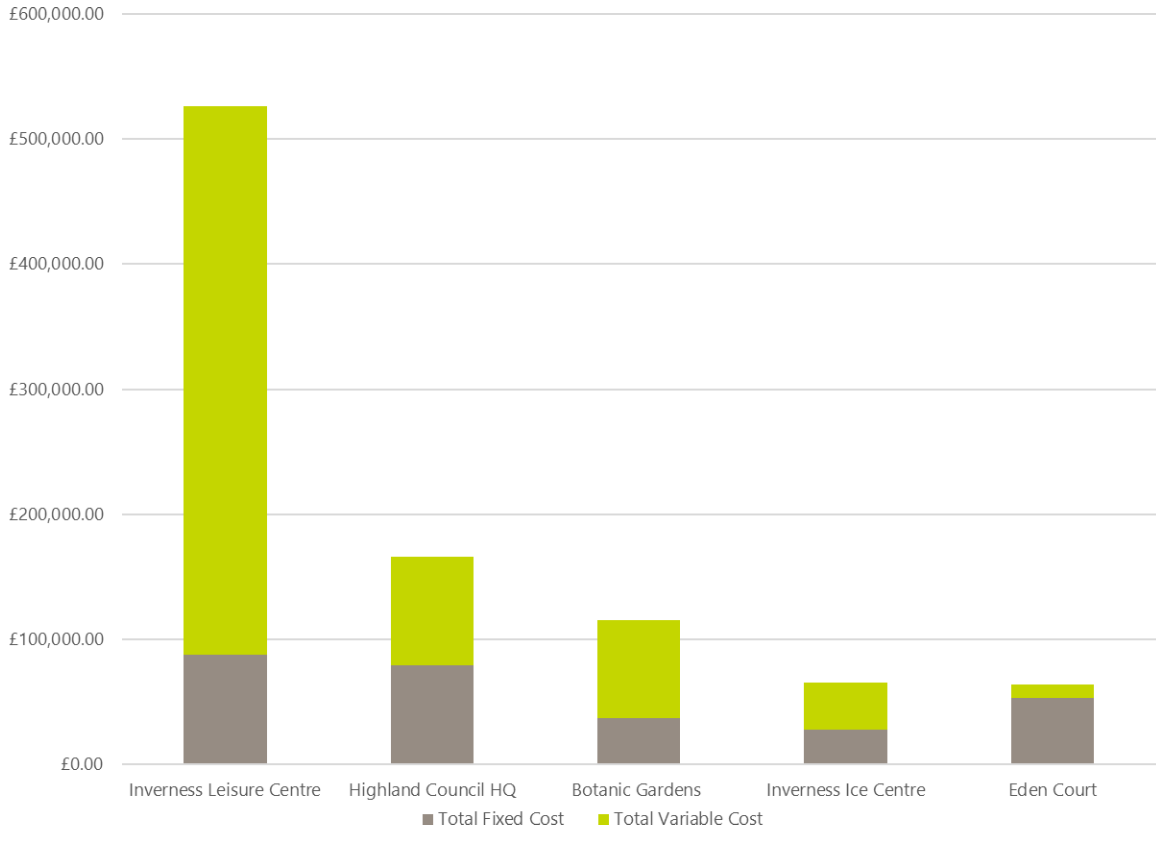

Figure 9-2: Indicative annual heating costs - higher heat consumers

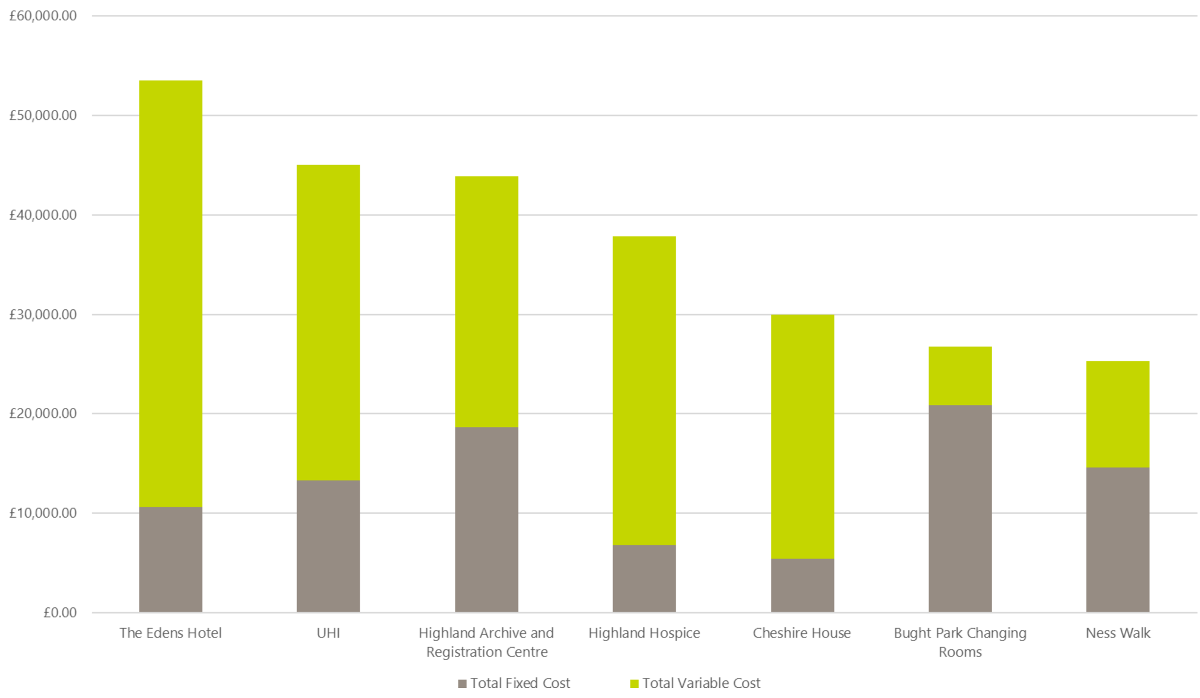

Figure 9-3: Indicative annual heating costs - medium heat consumers users

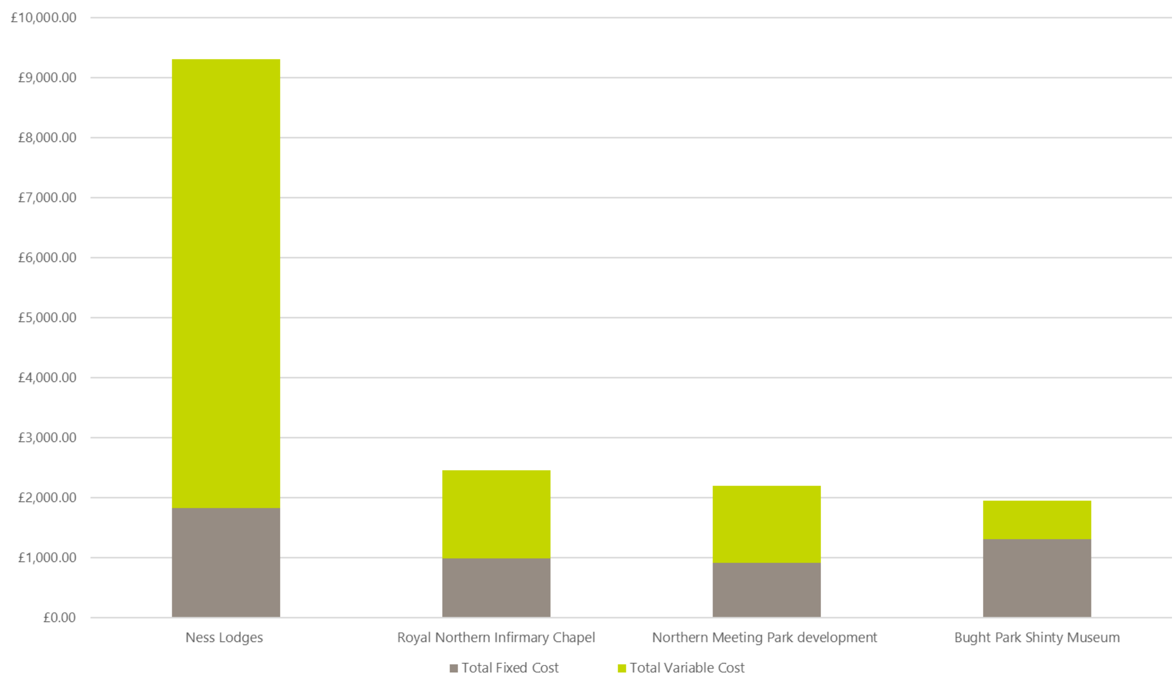

Figure 9-4: Indicative annual heating costs - lower heat consumers

9.4 Connection charge

A connection charge is calculated for the individual ASHP counterfactual scenario. This cost is charged to the customer considering the cost that would be avoided by connecting to the network. The charge represents the CAPEX associated with the counterfactual heating technology.

An allowance for plant space saved, due to the centralised energy centre solution for the network, has not been included in the current connection charge estimates.

The connection charge for each building is displayed in Table 9-4.

Table 9-4: Connection Charges

Connection name	Connection charge (£k)
Highland Hospice	80
Cheshire House	64
UHI	218
Royal Northern Infirmary Chapel	12
The Edens Hotel	174
Ness Lodges	22
Northern Meeting Park development	11
Ness Walk	240
Highland Archive and Registration Centre	250
Botanic Gardens	438
Highland Council HQ	758
Eden Court	510
Inverness Ice Centre	325
Bught Park Shinty Museum	15
Bught Park Changing Rooms	248
Inverness Leisure Centre	837
Total	**4,201**

9.5 Capital cost

The capital cost of each scenario was broken down into various items. The cost sources comprise of specific project quotes, quotes from manufacturers, industry cost benchmarks and Buro Happold's previous project experience.

Figure 9-5 and Figure 9-6 shows the CAPEX breakdown for each scenario, which varies between £18.2M for the Borehole Heating scenario and £14.9M for the alluvial aquifer solution. A full itemised breakdown of capital costs in given in Appendix Q.

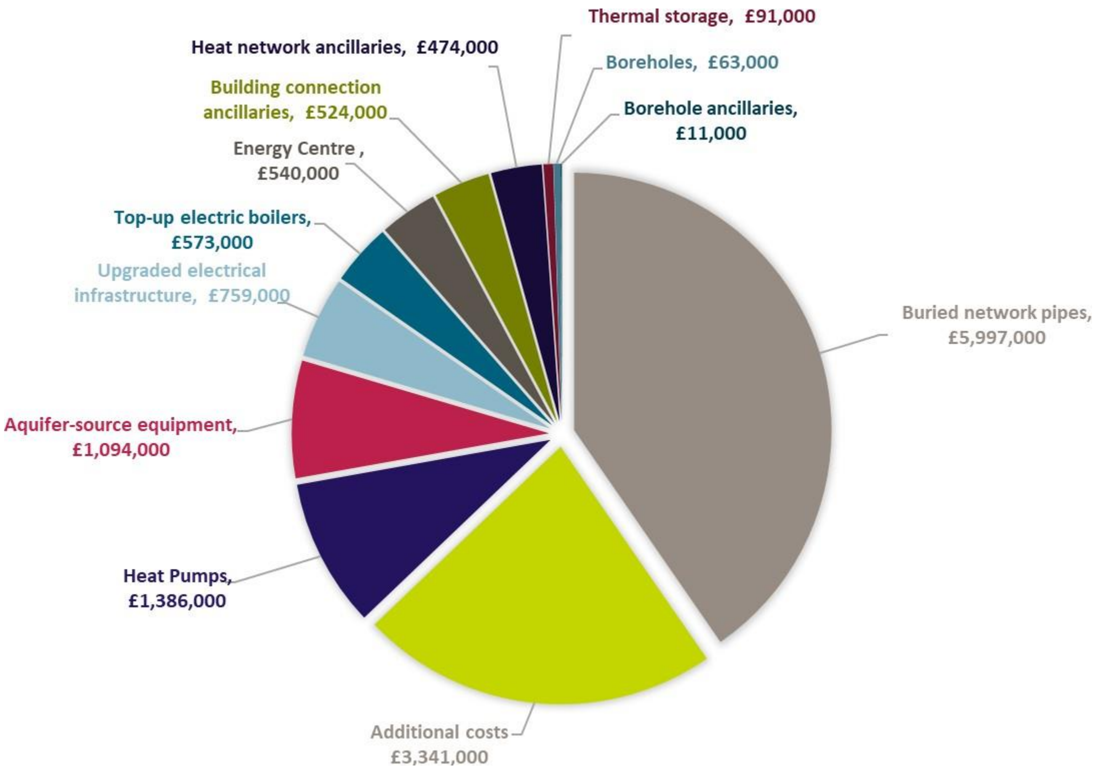

Figure 9-5: Alluvial Aquifer heat network CAPEX breakdown

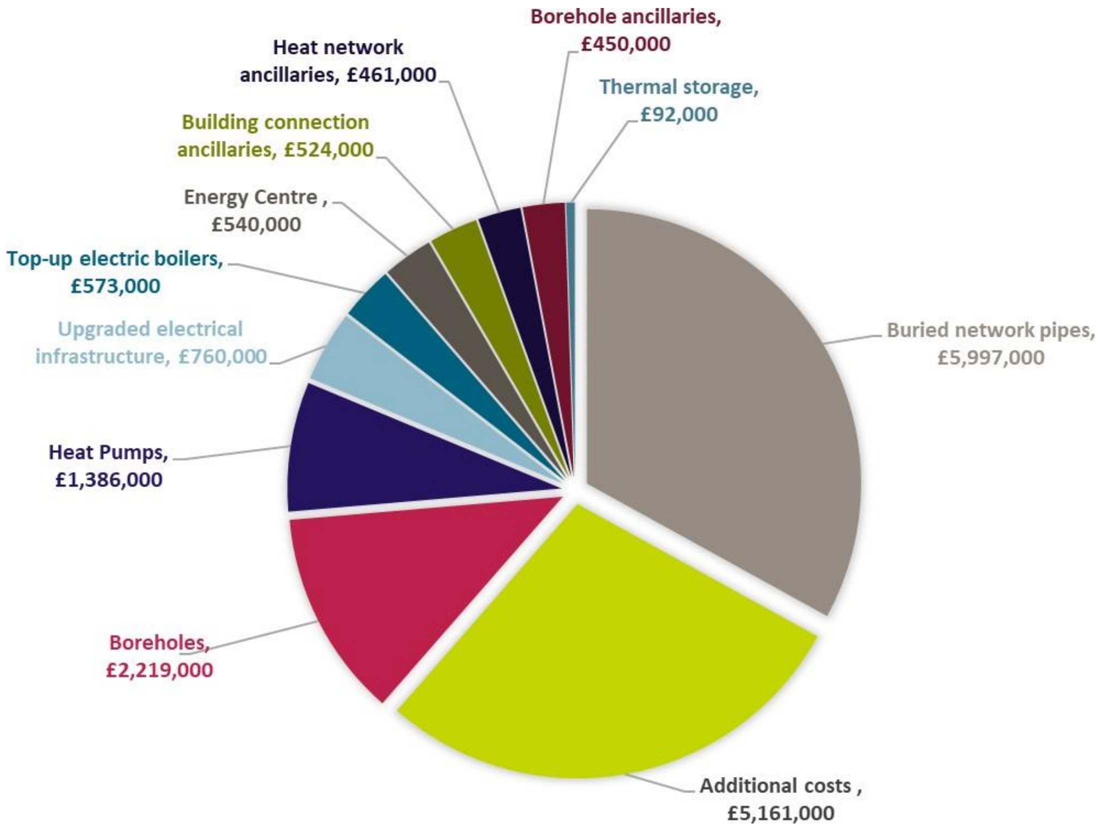

Figure 9-6: Borehole heat network CAPEX breakdown

9.6 Operating costs

The ongoing operational costs in the model are categorised as follows:

- Operation and maintenance costs
- Fuel costs
- Replacement costs

9.6.1 Operation and maintenance costs

Table 9-5 shows the key operation and maintenance cost assumptions used in the TEM. Operating expenditure (OPEX) for equipment was modelled as a percentage of CAPEX or as a cost per unit/connection.

Table 9-5: Operation and Maintenance assumptions

	Unit	Cost
Heat pump (fixed and variable operating cost)	% of capex p/kWh	2 0.25
Electric boilers	% of capex	5
Plate heat exchangers	% of capex	2
Heat meters	£/unit	650
Metering and billing (bulk)	£/connection/year	500
District heat network	p/kWh	0.06

9.6.2 Fuel costs

The fuel import costs used within the model are shown in Table 9-6, these are the costs currently being paid by the Highland Council for fuel as well as their predicted values.

Table 9-6: Fuel import costs

Fuel	23-24 predicted	Units
Electricity	25.41	p/kWh
Gas	7.54	p/kWh

After 2023, the cost of fuel has been indexed in line with BEIS the Green Book Supplementary Guidance, (Table 4-8: Retail prices) projections for future fuel costs. Future costs of electricity and gas have been indexed to Central and Scenario B price projects, respectively.

9.6.3 Replacement costs

Table 9-7 summarises the lifetime REPEX assumed for the major capex items that will need to be replaced over the modelled 40-year period for each scenario. In the model an 80% charge is incurred as a replacement cost at the end of the asset lifetime.

Table 9-7: Replacement costs for the scenarios considered

Item	Scenario 1 GSHPs - Boreholes £'000s	Option 2. GSHPs -alluvial aquifer £'000s	Notes
Heat pumps	3,642	3,642	Buro Happold past project experience
Electric Boilers	1,125	1,125	Buro Happold past project experience
Heat exchangers	1,280	1,280	Buro Happold past project experience
Heat Meters	68	68	Buro Happold past project experience

Table 9-8: Equipment life expectancy

Equipment	Replacement period (years)
Heat pump	15
Electric boiler	20
Plate heat exchangers/ Heat interface units	15
Heat meters	25
DHN pipework	Longer than scheme lifetime (40 years)

9.7 Economic results

9.7.1 Without funding

A summary of the key results for each scenario for the base case economic model, against the ASHP counterfactual, is displayed in Table 9-9. Where a value has been presented in brackets it represents a negative value.

Table 9-9: Economic results against a low carbon counterfactual (40-year period)

Economic Metric	Scenario 1: GSHP (Boreholes)	Scenario 2: GSHP (alluvial aquifer)
Total CAPEX (£M)	(18.16)	(14.85)
Total fuel costs (£M)	28.57	28.57
Total O&M (£M)	5.09	5.50
Total REPEX (£M)	4.89	4.90
NPV at 40 years (£M)	(10.56)	(7.46)
IRR at 40 years (%)	-	-
Social IRR (%)	-	-
Discounted payback period (years)	Longer than the scheme lifetime	Longer than the scheme lifetime
Heat sales revenue (£M)	30.9	30.9
Fixed charge revenue (£M)	7.86	7.86
Connection charge revenue (£M)	4.09	4.09
Total revenue (£M)	**50.05**	**50.05**

As shown in Table 9-9, neither scenario achieves a positive NPV at the end of the project lifetime.

The cash flow curves for each of the scenarios are presented in Figure 9-7 and Figure 9-8. Both schemes have positively inflected NPV curves indicating that there is an overall positive balance between revenue and outgoings (OPEX and REPEX).

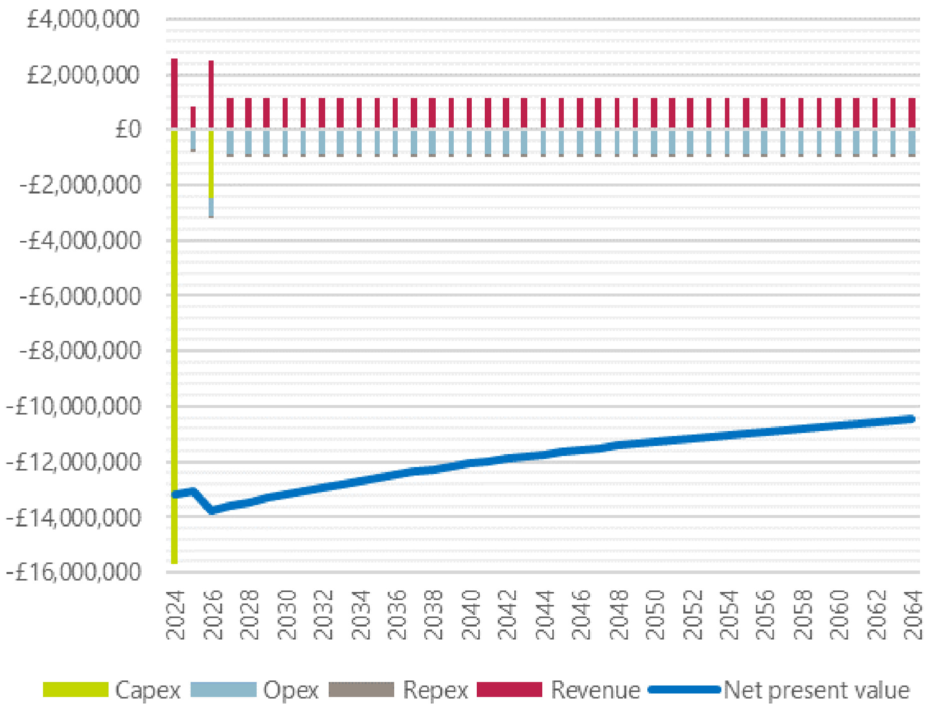

Figure 9-7: Cash flow curve - Scenario 1: Borehole GSHP (unfunded)

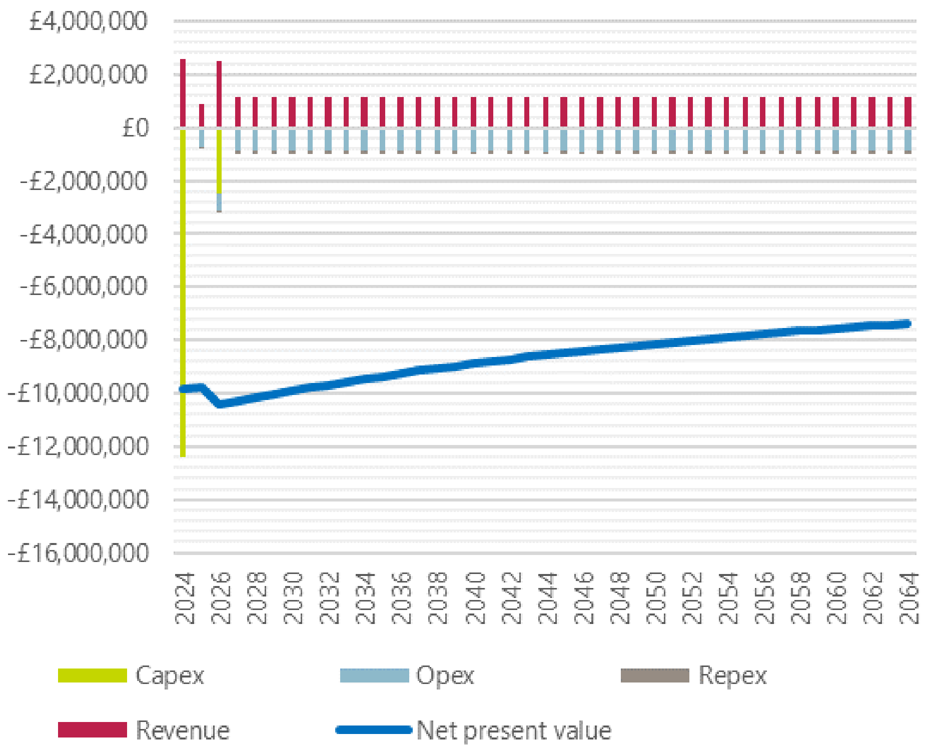

Figure 9-8: Cash flow curve - Scenario 2: alluvial aquifer GSHP (unfunded)

9.7.2 Funding assessment – 50% CAPEX

Through various funding streams, there is the potential for a heat network scheme to receive 50% of CAPEX. As neither Scenario 1 nor 2 achieved a positive NPV at the end of the 40-year project duration being considered, further techno-economic analysis was carried out to assess how an assumed 50% funding would affect the project cash flows. The results are shown in Table 9-10.

Table 9-10: 50% CAPEX funding

Parameter	Scenario 1: Borehole GSHP	Scenario 2: alluvial aquifer GSHP
Funding (£M)	9.08	7.43
% CAPEX	50	50
NPV at 40 years (£M)	(1.48)	(0.03)
IRR at 40 years (%)	-	-

In the presence of 50% CAPEX grant funding, neither scheme present a strong commercial case; however, it is evident that Scenario 2 is the more attractive option.

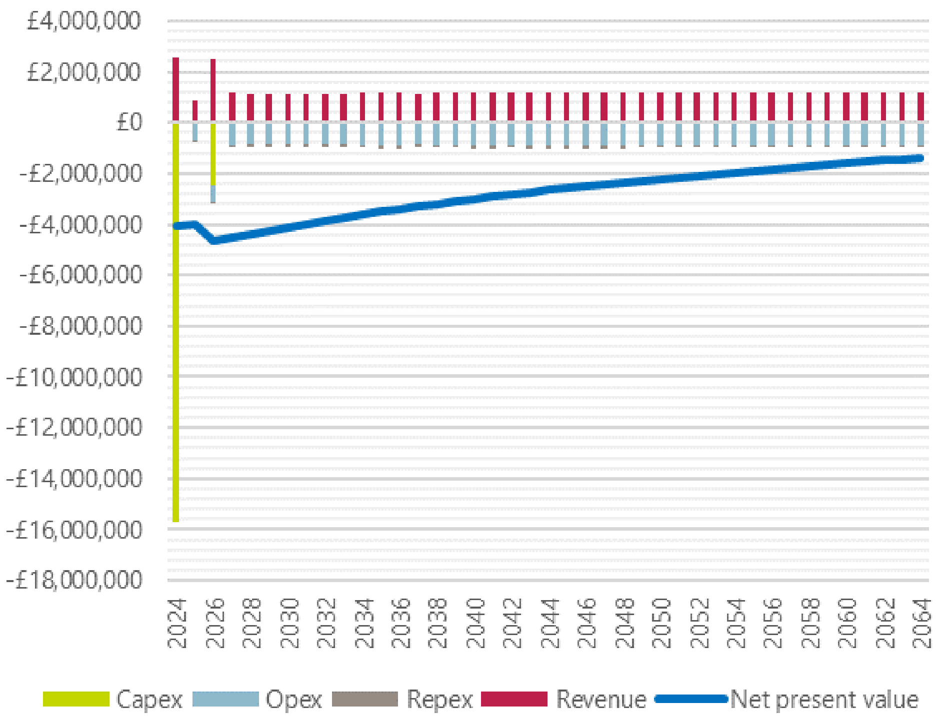

Figure 9-9: Scenario 1 cash flow curve - 50% CAPEX funding

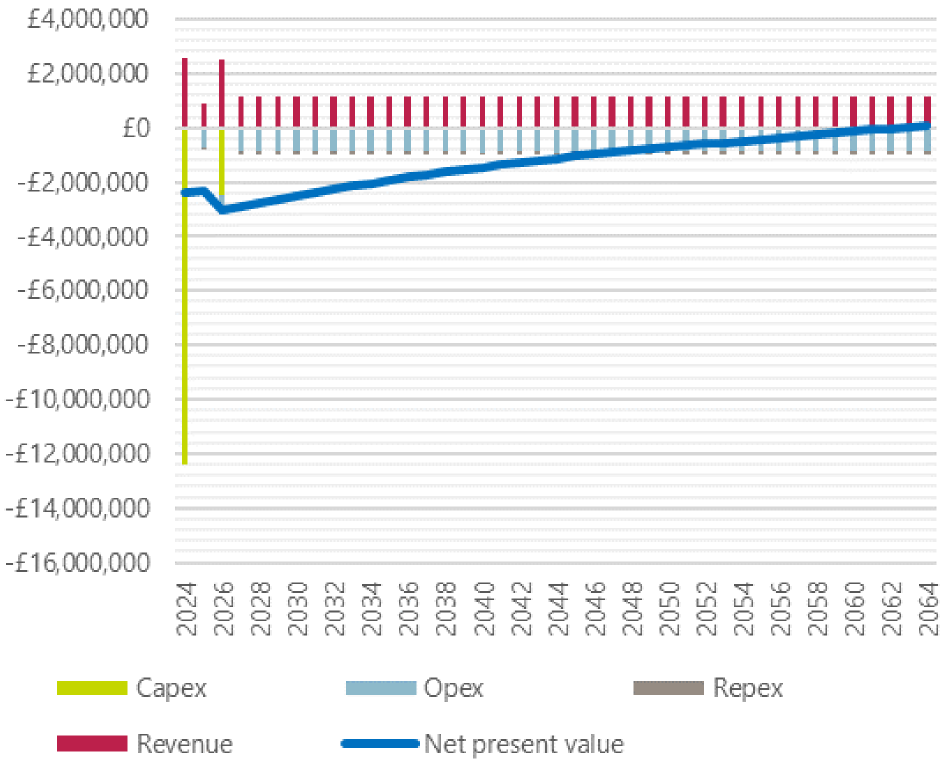

Figure 9-10: Scenario 2 cash flow curve - 50% CAPEX funding

9.7.3 With funding - targeting 3.5% IRR

Although neither scheme was shown to have a positive NPV after 40 years following an assumed funding opportunity of 50% of CAPEX, further analysis was carried out to determine the minimum variable heat tariff required for each scenario to achieve a target IRR of 3.5% IRR.

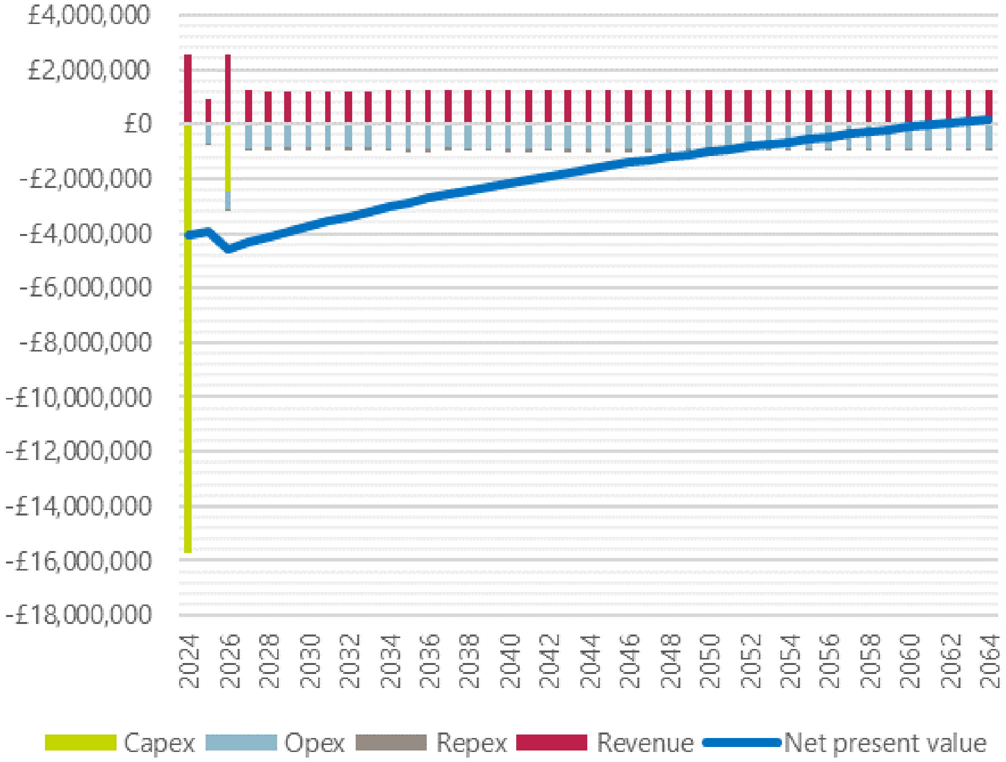

Table 9-11: Scenario 1 Targeting 3.5% IRR

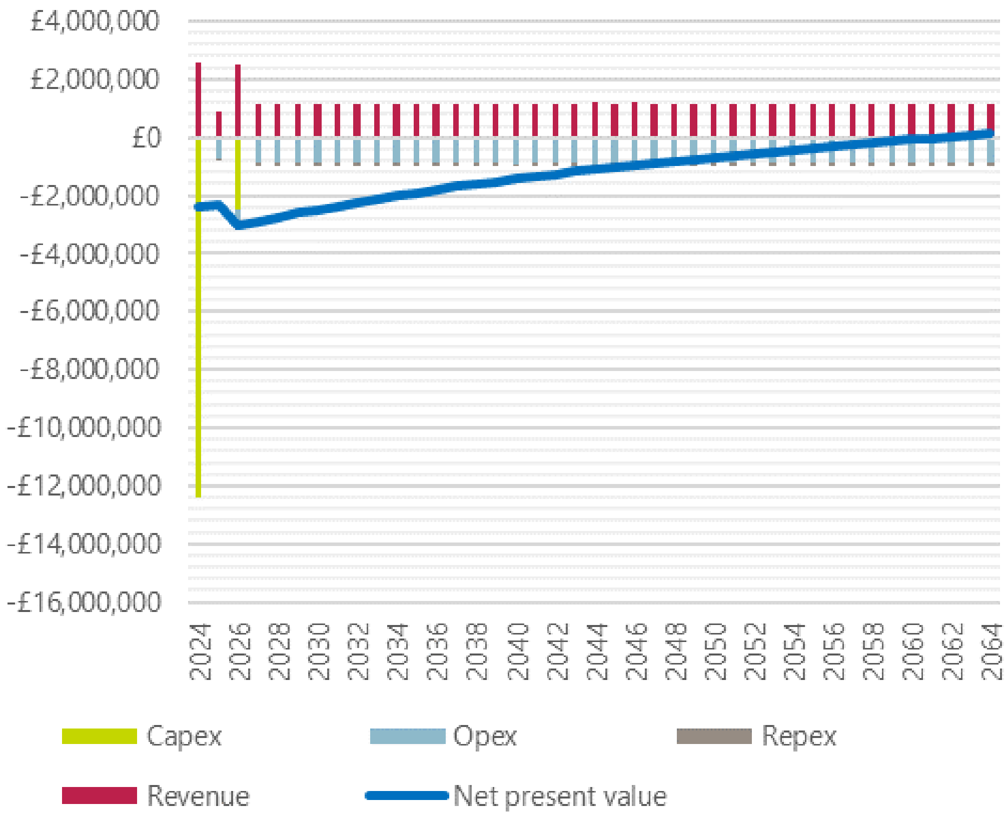

Figure 9-11: Scenario 2 Targeting 3.5% IRR

To achieve the target IRR of 3.5% for both projects 50% CAPEX funding and an increase in variable heat tariff was required for both scenarios. Table 9-12 summarises the techno-economic results for both scenarios under 50% CAPEX funding and the increase variable heat tariffs required to reach a target IRR of 3.5%.

Table 9-12: 50% CAPEX funding and increased variable heat rate

Parameter	Scenario 1: Borehole GSHP	Scenario 2: alluvial aquifer GSHP
Funding (£M)	9.08	7.43
Increased Variable Rate (p/kWh)	13.30	12.76
Fixed Rate (£/kW)	65.3	65.3
NPV at 40 years (£M)	0.05	0.03
IRR at 40 years (%)	3.6	3.6

9.8 Levelised cost of heat (LCOH)

A useful metric to compare heat generation technologies is Levelised Cost of Heat (LCOH). Total LCOH is composed of four factors:

1. **Levelised fuel costs.** Total annual cost of fuel consumption divided by annual heat consumption.
2. **Levelised operational and maintenance costs.** Total annual cost of operating and maintaining equipment divided by annual heat consumption
3. **Levelised capital and replacement costs.** Total capital cost and replacement costs of equipment divided by annual heat consumption
4. **Levelised cost of carbon.** Total cost annual cost of carbon offsetting divided by annual heat consumption

Figure 9-12 outlines the calculated LCOH for the gas boiler/CHP unit/biomass boiler business as usual (BAU) scenario, individual ASHP counterfactual, open loop GSHP alluvial aquifer scenario and closed loop GSHP borehole scenario.

BAU presents the lowest LCOH as the low capital costs associated with existing heat technologies (such as gas boilers, CHP units and biomass) are still cheaper than zero carbon technologies such as heat pumps. Similarly, natural gas is still cheaper than electricity, resulting in relatively low levelised fuel costs for the BAU scenario. However, carbon offsetting could significantly increase the cost of heat after 2045.

Comparing the counterfactual with the heat network scenarios, the counterfactual is the cheaper of the three. This is due to the significantly reduced capital costs associated with individual ASHPs when compared against the construction of a new energy centre, borehole drilling, and heat network pipework installation needed in the heat network scenarios.

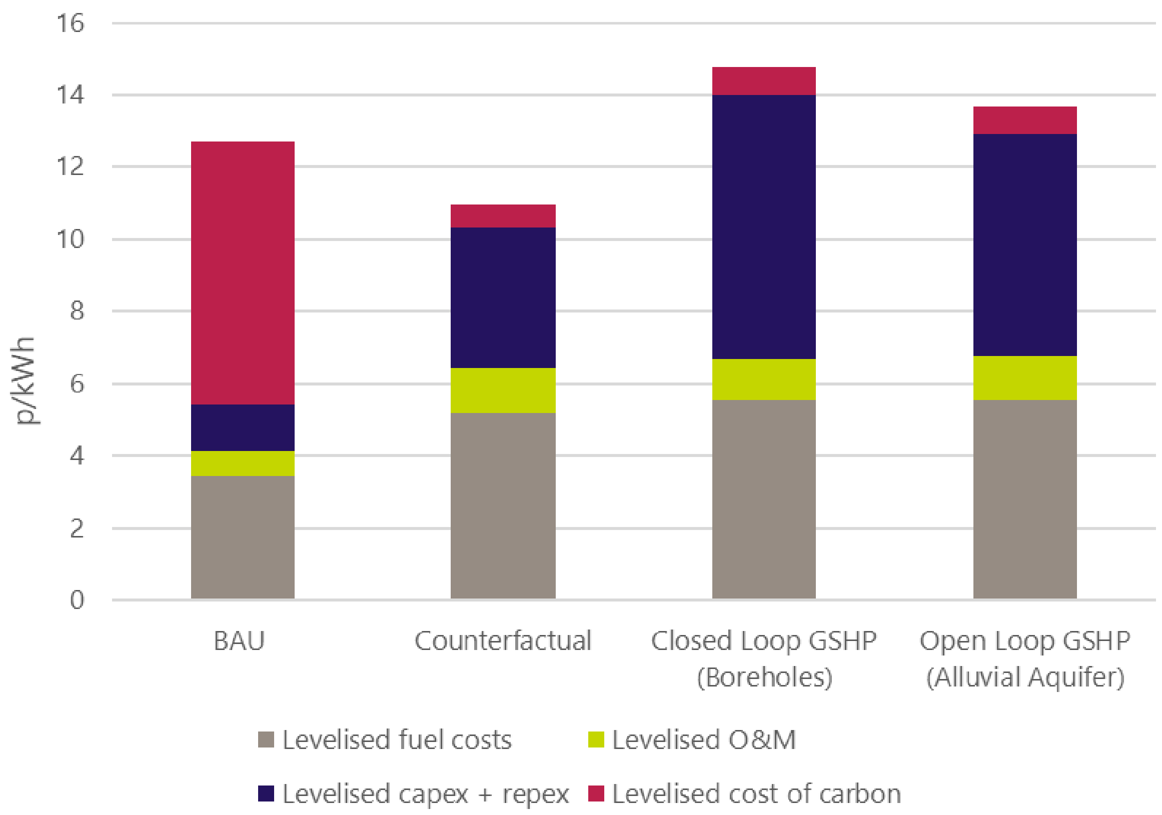

Figure 9-12: Levelised cost of heat comparison

9.9 Sensitivity analysis

Sensitivity analysis has been carried out as part of the techno-economic analysis to illustrate the key modelling inputs of the scheme and their impact on project NPV and project IRR. Various modelling inputs were varied by ±30%:

- Fuel cost (electricity import price)
- Capital cost
- Annual heat load
- Standing charge

Figure 9-13 and Figure 9-14 present the sensitivities associated with the borehole led Scenario 1 and alluvial aquifer led Scenario 2. Both the borehole led, and the alluvial aquifer led scenarios are sensitive to Capital Cost, heat pump efficiency and heat sales price.

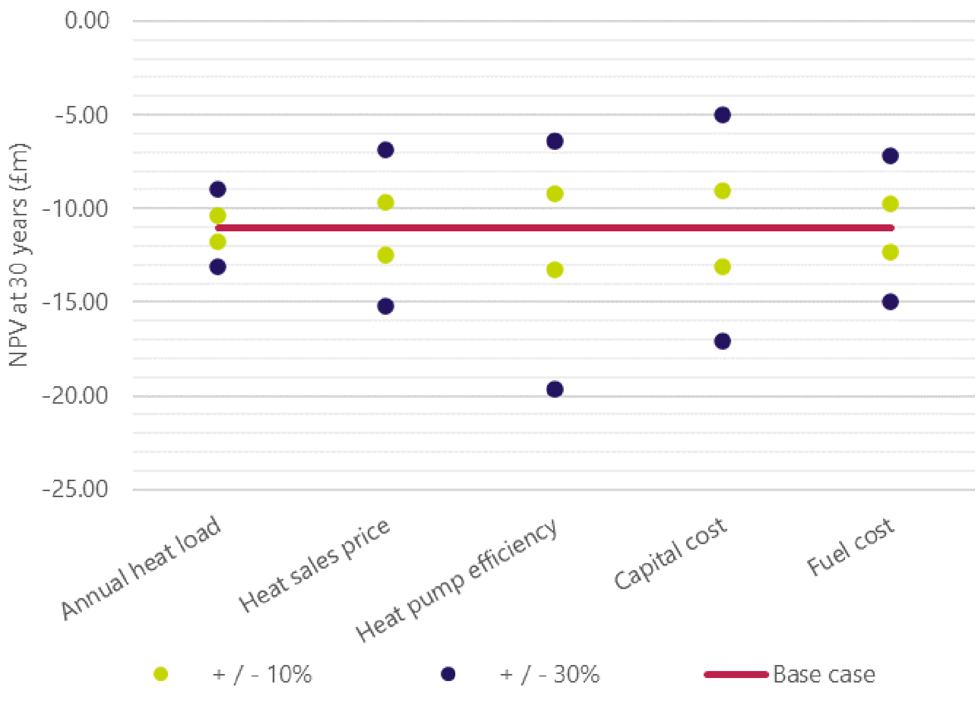

Figure 9-13: Sensitivity analysis - Scenario 1 Closed Loop GSHP (Boreholes)

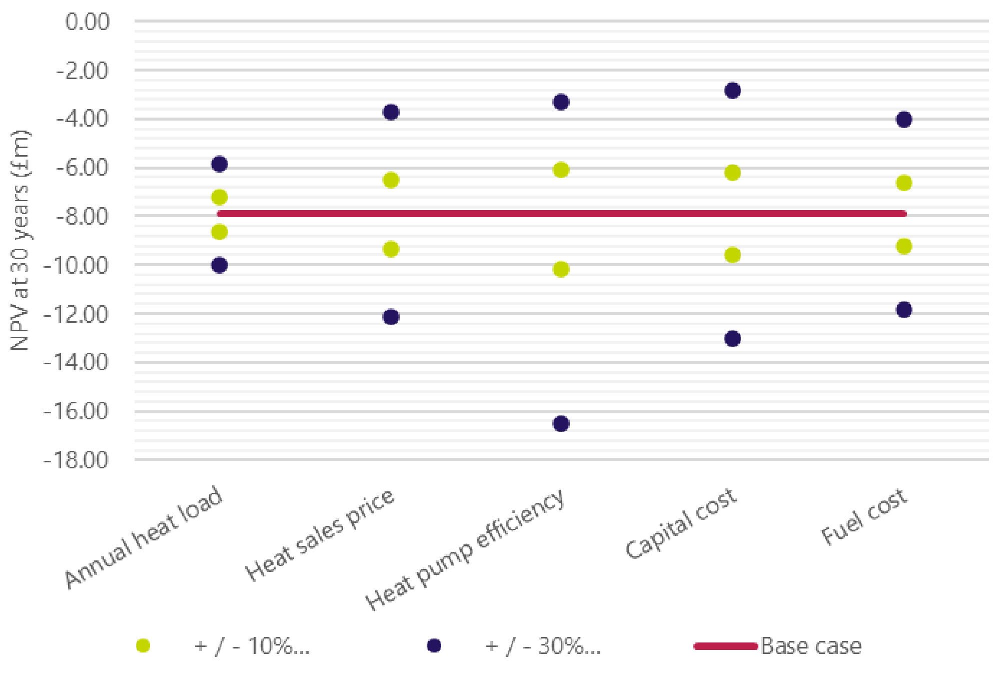

Figure 9-14: Sensitivity analysis - Scenario 2 Open Loop GSHP (alluvial aquifer)

9.10 TEM summary

Techno-economic modelling was carried out for Inverness heat network heat technologies over a 40-year time period. Scenario 1 considered a Borehole led GSHPs solution with initial CAPEX of £18.2M whilst Scenario 2 modelled an alluvial aquifer led GSHPs solution with £14.9M initial CAPEX.

Variable and fixed heat sales tariffs were calculated using methodology within the DECC 'Assessment of costs, performance, and characteristics of UK heat networks'[10]. Similarly, connection charges have been calculated based upon the avoided costs that the building would have otherwise paid to make use of the counterfactual technology (individual ASHPs at each building). Using this methodology, variable and fixed rate charges of 12.74p/kWh and 65.3 £/kW were calculated, respectively. A summary of the connection charges paid by each building is given in Table 9-4.

Techno-economic modelling for both indicates that neither scheme returns a positive NPV or IRR after 40 years However, cash flow curves for both scenarios maintain an upward inflection suggesting a positive balance between revenues and outgoings.

Additional analysis was carried out to obtain an indication of potential funding that could make the project attractive for a Local Authority. This was done by varying the amount of funding available within the techno-economic model and targeting an IRR that could be considered within a Local Authority (assumed to be 3.5% at 40 years). When 50% CAPEX funding both schemes do not achieve a positive NPV or IRR at 40 years. For Scenario 1: Borehole led GSHPs 50% CAPEX funding corresponds to £9.08M whilst 50% CAPEX funding for Scenario 2: alluvial aquifer led GSHPs was calculated to be to £7.43M.

When the opportunity to increase heat sales price was considered, both schemes can achieve both a positive NPV and IRR at 40-years. Inclusive of 50% CAPEX funding for each scenario (£9.08M for Scenario 1 and £7.43M for Scenario 2) and increasing variable heat sales prices to 13.30p/kWh for Scenario 1 and 12.76p/kWh for Scenario 2 was required to achieve the targeted 3.5% IRR respectively. The initial variable heat rate for both scenarios was 12.74p/kWh. Fixed charges remained unchanged at 65.3 £/kW throughout this analysis.

Of the two schemes, the alluvial aquifer led GSHP solution required relatively less funding and a lower increase in variable heat sales price to achieve the targeted IRR of 3.5%. For this reason, an alluvial led GSHP led solution is recommended as the best performing and most suitable for the next project stage.

10 Carbon

10.1 Counterfactual scenario

The carbon assessment presents a carbon emission reduction for the preferred options against a 'counterfactual' and 'Business As-usual' case. The counterfactual case is the 'baseline' carbon emissions of the buildings proposed for connection to the west bank heat network, i.e., the emissions associated with building heating energy if the heating network was not built. The Business As-usual case projects each connection using their existing heating technologies for the remainder of the 40-year time period considered in the project.

This provides a means for assessing how well the scheme performs on an environmental basis. The counterfactual case carbon emissions have been calculated for separate heating scenarios for the consumers based on building-level ASHPs working with 251% thermal efficiency.

10.2 Carbon emissions factors

The carbon emission factor of a fuel is defined as the amount of carbon emitted per unit of fuel energy consumed (kg CO2e/kWh consumed). Calculating the carbon intensity of consumed heat via this metric is a

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[10] https://www.gov.uk/government/publications/assessment-of-the-costs-performance-and-characteristics-of-uk-heat-networks (Accessed 22/11/22)

method to assess the carbon performance of each scheme option. BEIS provide annual carbon emission factors for fuels used in the UK. BEIS also produce annual future projections for the carbon emission factor of power grid electricity. The UK's grid is much more susceptible to changes in its composition due to the wide-ranging mix of generating technologies, e.g., nuclear power stations, gas power plants, wind farms, coal power stations etc.

The penetration of renewable power in the UK has been increasing and is projected to continue to increase over the coming decades. BEIS also expect nuclear power to provide a more significant portion of the UK's power demand in the future. This will decarbonise the national grid and, as this occurs, technologies such as heat pumps will become less carbon intensive whilst technologies such as gas CHP will become more carbon intensive with its generated electricity having a higher carbon factor than the grid.

10.3 Carbon emissions assessment

The following presents a comparison between the counterfactual carbon emissions and the ambient loop heating scenario carbon emissions over a 40-year period. Table 10-1 provides the information in tabularised form, with carbon emissions saving percentage compared against the counterfactual. Carbon emissions over time are graphically presented in Figure 10-2.

Table 10-1: Calculated carbon emissions

Option	Lifetime carbon emissions (year 40) (tCO2e)
Business As Usual	120,519
Counterfactual - ASHP	9,302
Scenario 1: Borehole led Ground Source Heat	11,331
Scenario 2: Preferred option – alluvial aquifer Ground Source Heat	11,331

A plot of carbon emissions over time for each of the scenarios considered in Table 10-1 is presented below in Figure 10-1. For the counterfactual scenario and both heat network scenarios, carbon emissions increase to 2026 as more connections are added to the heat network and as more buildings are retrofit with individual ASHPs. However, carbon emissions gradually decrease over time as the national grid (powering the heat pumps) decarbonises.

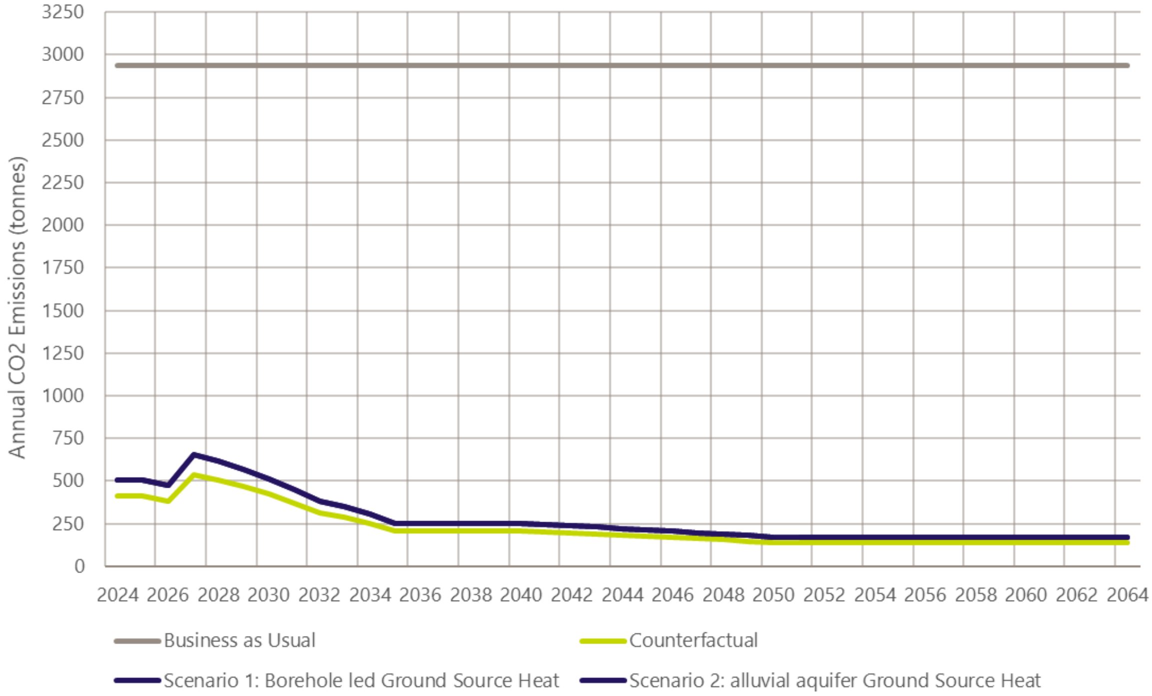

Figure 10-1: Carbon emissions over time

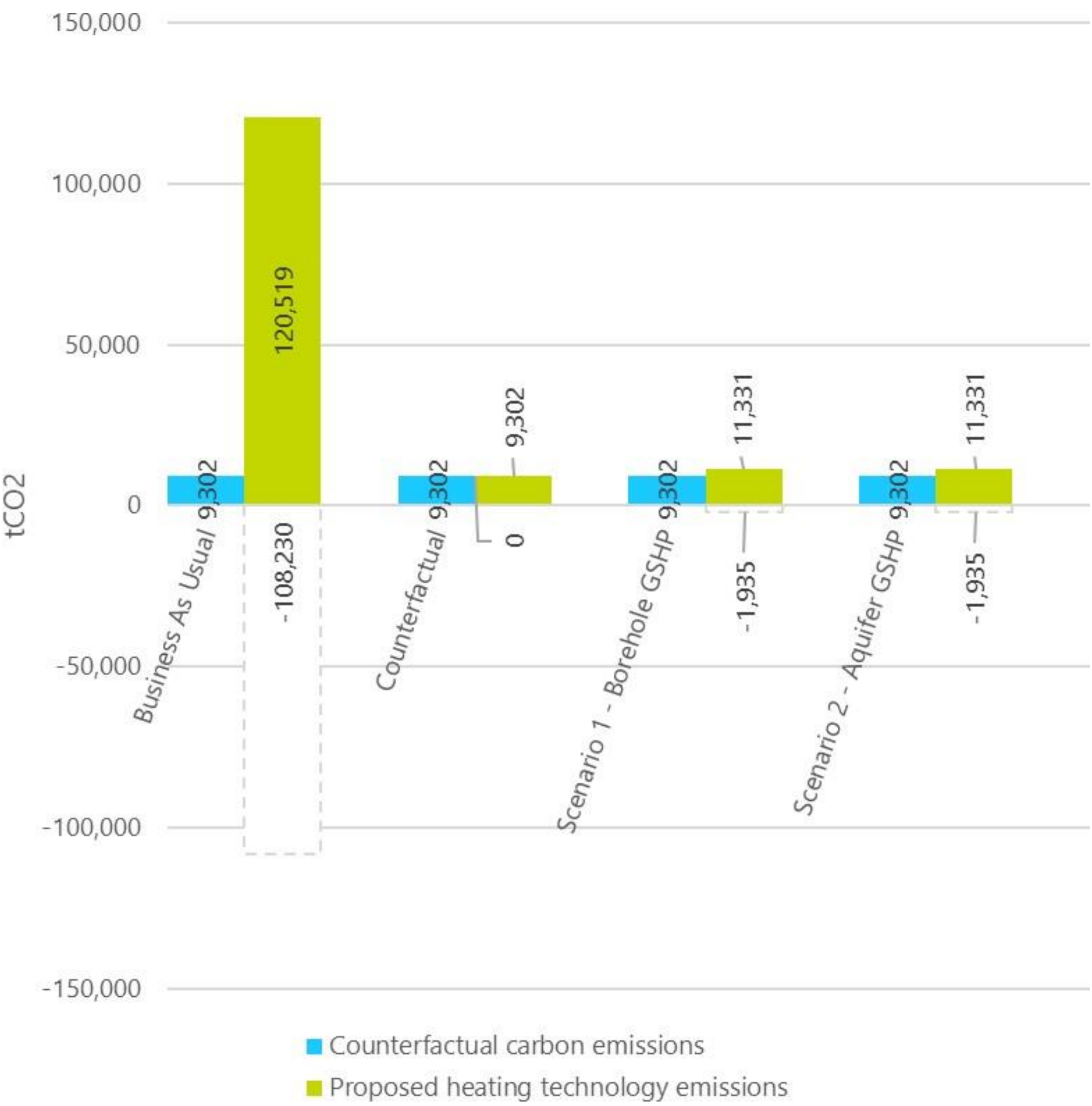

Figure 10-2: Carbon emissions over 40-year project lifetime

11 Risk mitigation

A complete risk register for the development of the proposed heat network at Inverness west bank is provided in the accompanying Appendix J. However, a summary of the key project risks and proposed mitigations is provided below.

1. **Location of the alluvial aquifer**
   - The location of the alluvial aquifer thought to be present in the west bank area of Inverness could not be confirmed as part of this feasibility study. However, it's understood that previous geotechnical investigation has been carried out into the area that confirms it's presence.
   - A project similar to that proposed here at the Glen Mhor hotel makes use of an alluvial aquifer on the opposite bank of the river Ness.
   - Further investigation by a geotechnical engineer is required to determine if the aquifer is beneath the west bank
2. **Accessing the alluvial aquifer**
   - If it's confirmed that the alluvial aquifer is present beneath the west bank there is a risk that the aquifer cannot be accessed due to geotechnical difficulties associated with drilling the required boreholes to access it.
   - A suitable geotechnical engineer should be consulted at the next project design stage to minimise the risks associated with drilling and accessing the aquifer.
3. **Capital cost**
   - The proposed heat network is particularly sensitive to CapEx costs. Further engagement with a Quantity Surveyor should take place to accurately forecast equipment and material costs to adequately capture inflation. Due to the delayed connections of Phase 2.
4. **Ground source heat pumps efficiency**
   - Manufacturer SCOP has been used as a basis for the performance of the GSHPs. Further engagement with manufacturers required to mitigate the risk of poorer than expected performance on the NPV of the heat network.
5. **Electricity network capacity**
   - The closest nearby SSEN electrical substation to the west bank area at Dalneigh is currently unconstrained.
   - However, as substation capacity can be quickly taken up by other developments in the area it is recommended that SSEN be contacted as part of a full formal application in determining network capacity in the area.
6. **Capital cost - building operating temperatures**
   - Operating the heat network at lower temperatures, 75°C flow/55°C return implies carrying out enabling works on the buildings that currently operate at high temperatures to ensure heating system compatibility. Further information regarding current operating temperatures can be found in Section 4.
   - Enabling works may include design and contractor works to replace existing heat emitters (radiators and fan coil units) to operate at lower temperatures

12 Heat network development stages

The development process for a public sector sponsored district heating scheme typically has a number of stages:

- **Development** – this includes feasibility (the current stage) and Outline Business Case (OBC) once the feasibility has been established. This will ultimately lead to the completion of a business case for the scheme. This stage would typically take up to 12 months.
- **Tendering and procurement** – following a decision to proceed on the business case. Finance for the project would be procured and contracts negotiated. This stage would typically take 12 months.
- **Delivery** – this would include the final detailed design of the scheme, construction and commissioning. This would typically take 18 to 24 months.

Based on the assumed timeline, it's assumed that the heat network will be operational by Q1 of 2026. It would be recommended that the Outline Business Case for the scheme is developed as soon as possible.

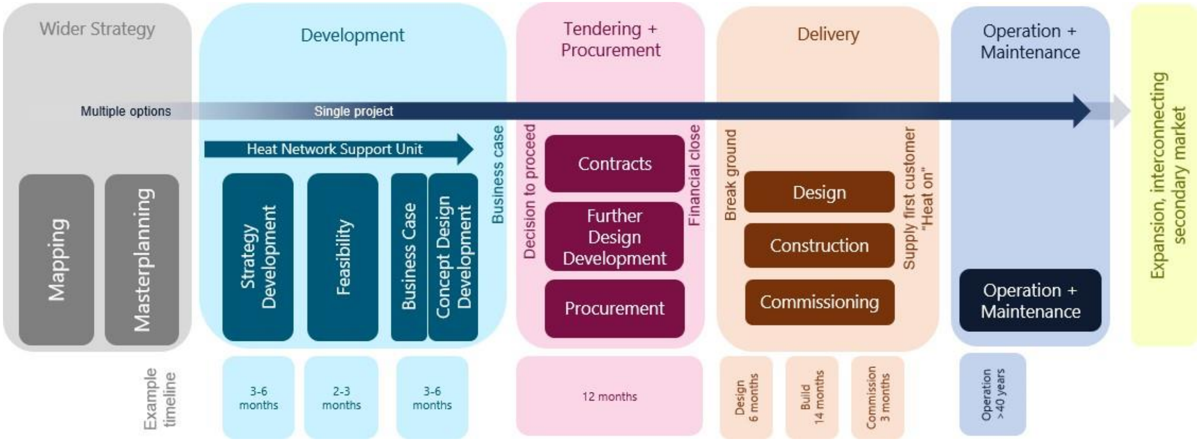

Figure 12-1: Heat network Project Delivery Timeline

12.1 Commercial options and delivery routes

This section provides a review of commercial options for delivering the Inverness west bank DHN, it aims to inform the Highland Council of possible routes to procurement for the preferred DHN option.

12.1.1 Commercial structures

The commercial case for the district heat network should demonstrate that the scheme will have a viable procurement and contractual strategy that provides a sustainable basis for the long-term operation of the system.

12.1.1.1 Objectives

A commercial strategy needs to ensure that the project delivers an optimal return while aligning with the Highland Councils drivers for a low-carbon development and ensuring fair energy/heat pricing for consumers. As such it needs to consider the commercial arrangements between principal parties including the council, any potential funders/investors, contractors, suppliers and customers.

Key roles to be allocated for the development of a district heat network are given in Table 12-1. The allocation of these roles is dependent on the allocation of risks, ability to fund and requirements for participation and control.

Table 12-1 Key roles associated with a heat network

Role	Explanation
Property developer	Often has a limited engagement with a decentralised energy project and is mainly concerned with delivery of a real estate project including compliance with planning conditions and net floor area for revenue generation.
Building owners	Building owners tend to focus on reliable heat supply and a heat sales price from a heat network that compares well with an alternative low-carbon approach
Asset owner	The party that owns the physical assets, such as the generation technology and associated infrastructure.
Operator	Responsible for the technical operation of the energy scheme.
Retailer	The party responsible for the retailing of energy, i.e., purchasing it from the generator, arranging transportation to the consumer and sale to the consumer.

12.1.1.2 Options available

The Highland Council will decide the formal role they will take in the design, installation, commissioning and long-term operation of the system. If no private sector involvement is possible (e.g., due to lack of commercial performance for private sector involvement) or desired, then the council can choose to self-deliver and operate the network. Councils have access to low-cost finance through the Public Works Loan Board as well as other potential sources of public funding such as the Heat Network Fund (HNF) and the Green Growth Accelerator and could benefit from the revenue generation of a heat network scheme.

The commercial structure options are outlined in Appendix O. This table, provided in the heat networks Code of Practice (CIBSE), shows that the system can be broken down as required.

The possible structures are summarised in Table 12-2.

Table 12-2 Potential commercial structures

Commercial structure	Description
Private ESCo	Common approach whereby a private ESCo company installs, owns, and operates the district heating network and acts as the energy service provider. Where the scheme is likely to be attractive to a private ESCo, this can remove any burden of operation and maintenance from the Council.
Council owned (direct involvement)	Council undertakes delivery and operation of the project in its entirety. This will include sourcing all necessary funds, undertaking procurement and owning and operating the scheme, including acting as heat supplier to end customers. Any capacity the Council does not have in-house would be contracted to third parties, e.g., through operating and maintenance contracts with equipment suppliers and billing and metering with a dedicated company. The Council gains more strategic control, but also takes on more risk.
Council owned (DBOM)	If there is no appetite for the Council to operate the network directly, this can be done via a Design, Build, Operate and Maintain (DBOM) contract in which a private entity is responsible for design and construction as well as long-term operation and maintenance. The public sector secures the project's financing and retains the operating revenue risk and any surplus operating revenue.
Council Joint Venture	Council enters into a formal agreement with a third party for supply of funding and / or operational and technical expertise. A Joint Venture can bring significant benefit by bringing expertise in the sector by managing delivery and operation however there needs to be a clear benefit to all JV partners.

The fundamental issue facing the Highland Council should they invest directly in the DHN will be around the relationship the council decides to have with the private sector. The suitability and applicability of the preferred commercial structure can be determined by the desired level of control, risk and return on investment. The relationship between control as well as risk and reward are summarised in Figure 12-2 for the various commercial structures.

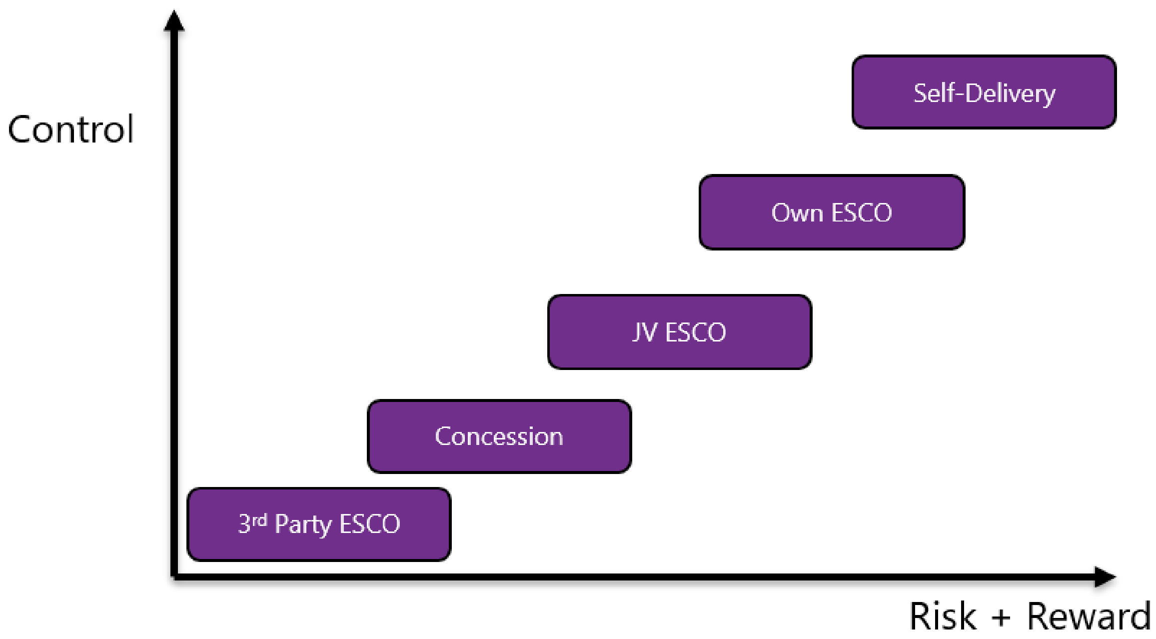

Figure 12-2 Risk/reward vs. level of control

The evaluation of the options usually revolves around a number of considerations, these are outlined in Table 12-3.

Table 12-4 Considerations for Council involvement

Consideration	Explanation
Control vs. risk	The tensions between the desire for control over project outcomes and the willingness to take on project risk.
Commercial attractiveness	The rate of return the project will actually support and whether this will be acceptable to the private sector.
Cost of raising capital	The recognition that the cost of raising capital for the private sector is generally greater than for the public sector which, on a capital-intensive project, has a major impact on viability and ultimately on cost of heat supply.
Availability of capital	The availability of capital to both public and private sector is limited but is also closely linked to the degree of risk involved and the organisations' understanding of the risks involved.

The amount of control that the council or the various stakeholders have over the scheme may be important in achieving their overall objectives. Similarly, drivers to participate may not be sufficiently strong to ensure agreements for connection are reached. For private sector developers, it is likely that some form of compulsion will be required to ensure connection, through planning conditions which require this and safeguard infrastructure and heating system types to enable future connection.

In relation to the preferred project vehicle, particularly whether or not to set-up a separate operating company (Special Purpose Vehicle), it is recommended that legal advice is obtained during the initial stages of design development prior to proceeding. Issues such as State Aid, legal authority for the council to undertake various activities, continued stakeholder engagement, flexibility and implications for an exit strategy will need to be considered. If a JV is preferred, it is likely that the establishment of an SPV would be the preferred route.

12.2 Financing options

There are a number of funding mechanisms which the council can explore to obtain both loan and grant funding to develop the Inverness west bank heat network.

These are described in more detail below:

12.2.1 District Heating Loan Fund

The District Heating Loan Fund provides low unsecured loans up to £1 million, with repayment terms of either 10, or 15 years. Loan terms for larger projects will be considered on a case-by-case basis. Typical interest loan rates of circa 3.5% are available. The scheme is managed by the Energy Saving Trust and is open to councils, registered social landlords, SMEs, and ESCOs with less than 250 employees.

12.2.2 Scotland's Heat Network Fund

The objectives of Scotland's Heat Network Fund are to:

- Stimulate and accelerate the delivery of zero emission heat network opportunities across Scotland through capital co-funding
- Help prepare the market for future regulations including the Heat Network (Scotland) Act 2021 and support meeting our deployment targets
- Support the reduction of our heat demand and ensure poor energy efficiency is no longer a driver for fuel poverty
- Create smart resilient heat networks that provide us with a reliable and affordable source of heat
- Support a secure supply chain with high value, local, sustainable jobs across Scotland and help people to transition to new, secure jobs as part of a just transition
- Support the delivery of heating systems that enable and efficiently use Scotland's renewable energy sources
- Support the delivery of heat networks that enable flexible and stable operation of our energy networks[11]

12.2.3 Green Growth Accelerator

Unlocking £200m of public sector investment (with further investment from the private sector also anticipated), the Green Growth Accelerator (GGA) programme is an outcome-based funding model that requires a Local Authority to commit to agreed economic, environmental and social value goals[12].

The GGA aims to help deliver Scotland's just transition to a net-zero emissions economy. In this funding model, the Scottish Government makes regular payments over a set period, reflecting the value associated with the goals achieved. The set period is typically 25 years. The focus of outcomes for the GGA will include carbon emissions reductions, unlocking net zero and just transition opportunities and targeting growth in green jobs.

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[11] https://www.gov.scot/publications/heat-network-fund-application-guidance/#:~:text=The%20objectives%20of%20Scotland's%20Heat,support%20meeting%20our%20deployment%20targets

[12] https://www.gov.scot/news/accelerating-green-growth/ (Accessed November 2022)

13 Conclusion

In conclusion

This heat network feasibility study report was prepared by the Buro Happold Cities Energy Team on behalf of Zero Waste Scotland (ZWS) for the Highland Council. This study follows on from a pre-feasibility study carried out in 2021 that considered opportunities for an air source heat pump led heat network(s) in the west bank area of Inverness.

Key findings

There is an opportunity for a low-carbon Heat Network (HN) in the west bank study area in Inverness, using an open loop, alluvial aquifer fed Ground Source Heat Pump system (Figure 13-1).

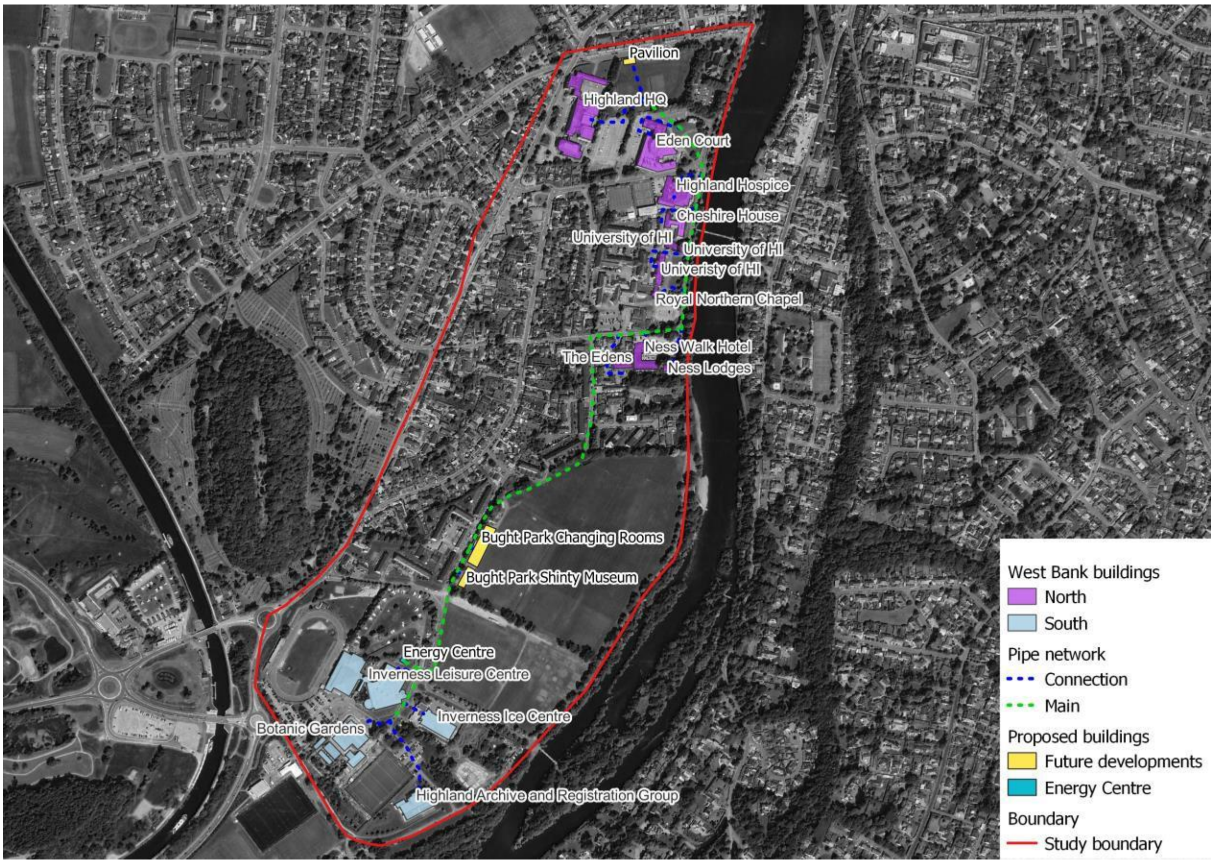

Figure 13-1 Proposed energy centre location and heat network route

As part of this study, the opportunities for heat networks connecting different areas in the west bank were considered. The Linear Heat Density (LHD) was estimated for each, giving an early indication of suitability for a heat network. The higher the LHD, the more likely a heat network is to be economically viable:

a) Entire study area, all buildings considered for connection to a heat network (HN), LHD: 4.80 MWh/a/m

b) North area, with buildings near the Council HQ connecting to HN, LHD North area, with buildings near the Council HQ connecting to HN, LHD: 2.79 MWh/a/m

c) South area, with buildings near the leisure centre connecting to the HN, LHD: 12.60 MWh/a/m

The Council's preference was to consider the entire west bank study area for heat network connection, due to the driver to decarbonise heating for buildings.

Entire west bank study area

A heat network at the castle site is likely to require capital funding. High-level, pre-tax, techno-economic model of the proposed solution indicated a Net Present Value (NPV) of £0.03M and Internal Rate of Return (IRR) of 3.6% at the end of the 40-year period considered in this study, with additional capital cost funding of 50% (£7.43M). These values are indicative only and not financial advice.

Carbon savings of 91% were estimated for the proposed heat network when compared to the business-as-usual scenario of each of the buildings continuing to use their current gas-fired boiler, gas-fired boiler/CHP unit (or Ground Source Heat Pumps in the case of the future developments) heating technologies.

A heat network in the area could consist of:

- Energy centre, on Highland Council land adjacent to Inverness Leisure Centre
- Heat network Flow & Return Temperatures, 75°C and 55°C, respectively.
- Equipment at the energy centre, comprising:
    - Open Loop Ground Source Heat Pumps fed via an alluvial aquifer, 2,100 kW
    - Top-up electric boilers, 5,800 kW
    - Thermal stores, 60 m^3
- Heat network, 2,731 m, connecting the following building typologies:
    - Leisure Centre
    - Office Space
    - Care Homes
    - Storage facilities
    - Hotels
    - Public Buildings
    - Performing arts centre

Key next steps

It is recommended to progress this study to the business case stage with an Outline Business Case (OBC). Preparing a business case involves:

- Inverness High School should be engaged to assess the feasibility of the school connecting to a heat network in the area. Inclusion of an additional high heat demand user could improve the prospects of a potential heat network in the area.
- A five-case Outline Business Case (OBC) presenting the strategic, management, commercial, economic, and financial cases
- As part of the OBC, there is a component of design development, to approximately a RIBA stage 2, Concept Design level.
- Heads of Terms for heat network connections (agreements to connect to the heat network)

At the next stage, it is recommended to consider phasing the building connections (e.g., year assumed for building connections), starting with the energy centre and the leisure centre, and building out from there.

The council may also be interested to revisit the opportunity for a heat network in the south area of the west bank where the LHD is estimated to be the highest, compared to the entire study area or the northern part of the study area. When considering phasing, the south area could be considered as the first phase.

Elements to be addressed in the next stages of work:

Management

- Consider management of the construction, installation, operation, and management of the heat network
- Consider customer management and metering and billing services

Technical

- Engagement with the Distribution Network Operator (DNO) - to understand possible grid constraints, electrical connection budget application for a new supply, and an indication of costs. To minimise risk of extensive grid infrastructure upgrades, alternative resilience strategies should be considered to work around potential grid constraints and peak lopping from thermal stores could also be considered to minimise electric boiler capacity.
- Building condition surveys – secondary system temperature strategy and connection costs.
- Updated energy demands and plant sizing - accounting for updated plans to buildings or new construction(s) etc. -also considering future expansion with buildings

Economic

- Explore grant funding options - that could be available for the heat network, including Scotland's Heat Network Fund and the Green Growth Accelerator.
- Assessment of the economic and carbon benefit of completing enabling works and expansion of Network - in the buildings to achieve a lower operating temperature, e.g., increasing radiator size
- Confirming costing with a Quantity Surveyor

Commercial

- Explore commercial model - for the scheme and consideration of the most suitable connection charge strategy.
- Assess opportunity to split the heat network into two areas – Northern (Highland HQ, Eden Court etc) and Southern (Inverness Leisure Centre, Botanic Gardens etc)
- Further engagement with Inverness High School to assess opportunity for them to connect to a heat network.
- Engagement with developers to gain engagement for proposed new buildings

Feasibility Study