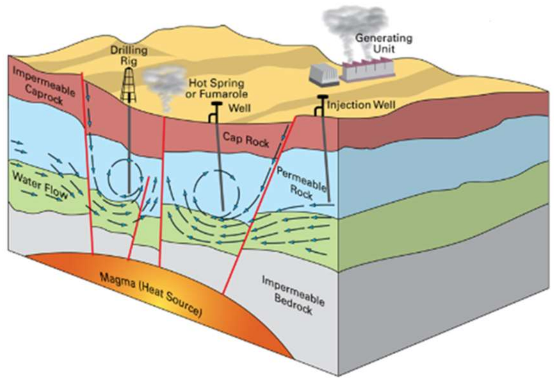
[redacted]

Heat Network Feasibility Study for **Bromsgrove**

Final report

November 2019



Electric Works, Sheffield Digital Campus, Sheffield, S1 2BJ
info@greenfieldgroup.co +44 7789248432

Report information:

Filename	Bromsgrove heat network feasibility_v02 (ci)		
Version	0.1	Client issue of WP2 final report	4 September 2019
	0.2	Revision based on comments received	12 November 2019
Author(s)	Robert Clark		
Contributors	Oskari Fagerström, Jussi-Pekka Kuivala, Sami Sihvonen		
Contract Reference			

Table of contents

Figures and Tables

Glossary

AHU Air handling unit

ASHP Air Sourced Heat Pump

BDC Bromsgrove District Council

BDHT Bromsgrove District Housing Trust

BGS British Geological Survey

BEES Building Energy Efficiency Survey

BEIS Department of Business, Energy and Industrial Strategy

BMS Building Management System

BDHT Bromsgrove District Housing Trust

CCL Climate Change Levy

CHP Combined Heat and Power

CIU Cooling Interface Unit

CO_2 Carbon dioxide (emissions arising from energy use)

CoP Coefficient of Performance (of heat pumps)

CRC Carbon Reduction Commitment

Delta T Temperature difference between two side of heat exchange device

DH District Heating

DHW Domestic Hot Water

DN Nominal diameter in mm (Diametre Nominal)

DNO Distribution Network Operator

EU ETS European Union Emission Trading Scheme

EED EU Energy Efficiency Directive

GCV (HHV) Gross Calorific Value (also referred to as Higher Heat Value)

GIS Geographic Information System

GSHP Ground Sourced Heat Pump

HIU Heat Interface Unit

HOB Heat-only boiler

HN Heat Network

HNCP CIBSE Heat Network Code of Practice

HNDU Heat Network Delivery Unit (BEIS)

HNIP Heat Network Investment Project

IRR Internal Rate of Return

JV Joint Venture

LCOE Levelised Cost of Energy

LPHW Low Pressure Hot Water

MDPE Medium Density Polyethylene (a form of plastic pipe)

MTHW Medium Temperature Hot Water

NEED National Energy Efficiency Database

NCV (LHV) Net Calorific Value (Lower Hear Value)

NPV Net Present Value

O&M Operation and Maintenance

PWCH Princess of Wales Community Hospital

PWLB Public Works Loan Board

PWN Private Wire Network

QEP Quarterly Energy Prices (BEIS dataset)

RHI Renewable Heat Incentive

ROC Renewable Obligation Certificates

RSL Registered Social Landlord

SPV Special Purpose Vehicle – a company created for a specific purpose

VAT Value Added Tax

WACC Weighted Average Cost of Capital

WCC Worcestershire County Council

WSHP Water Sourced Heat Pump

1 Executive summary

This report presents the analysis conducted to consider a range of heat network options for the town of Bromsgrove.

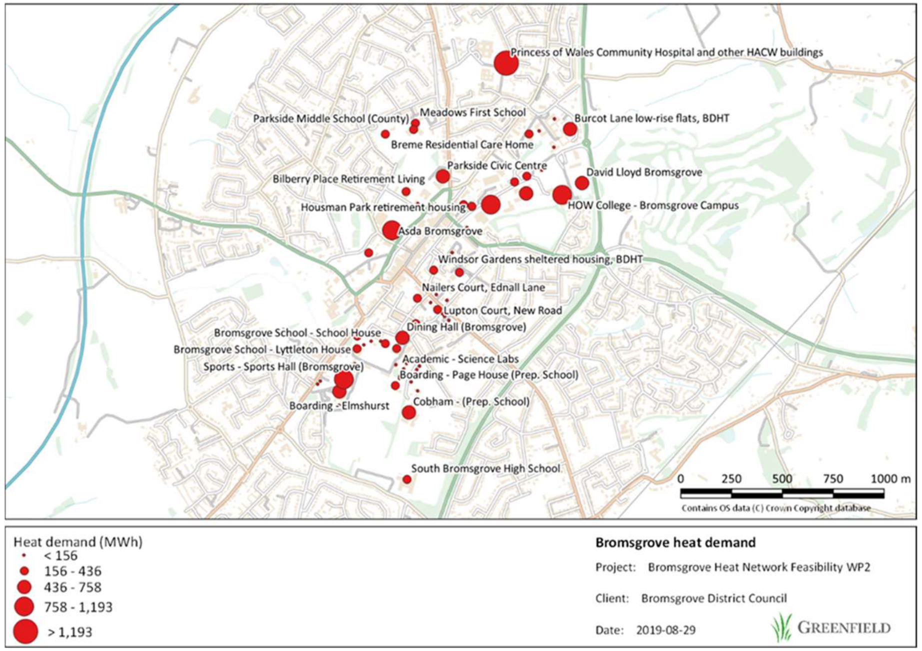
A heat network would connect multiple consumers, including public buildings, offices, schools (Bromsgrove School and others), residential properties (including assisted living facilities), Princess of Wales Community Hospital and several leisure centres. It would supply heat and power from a centralised energy centre, with the express aims of reducing energy costs and carbon emissions. Decarbonising heat supply is generally challenging and a heat network is an important opportunity that can deliver deep and sustained carbon reduction in an area, particularly as it facilitates future expansion and the inclusion of alternative technologies over time.

The work, part-funded by BEIS, Bromsgrove District Council and Worcestershire LEP, support their goals of developing solutions to decarbonise heat supply. The intended outcome of the work is to provide an evidence base for preferred project such that the council and other stakeholders can move to a next stage of development where the project is deemed to be viable.

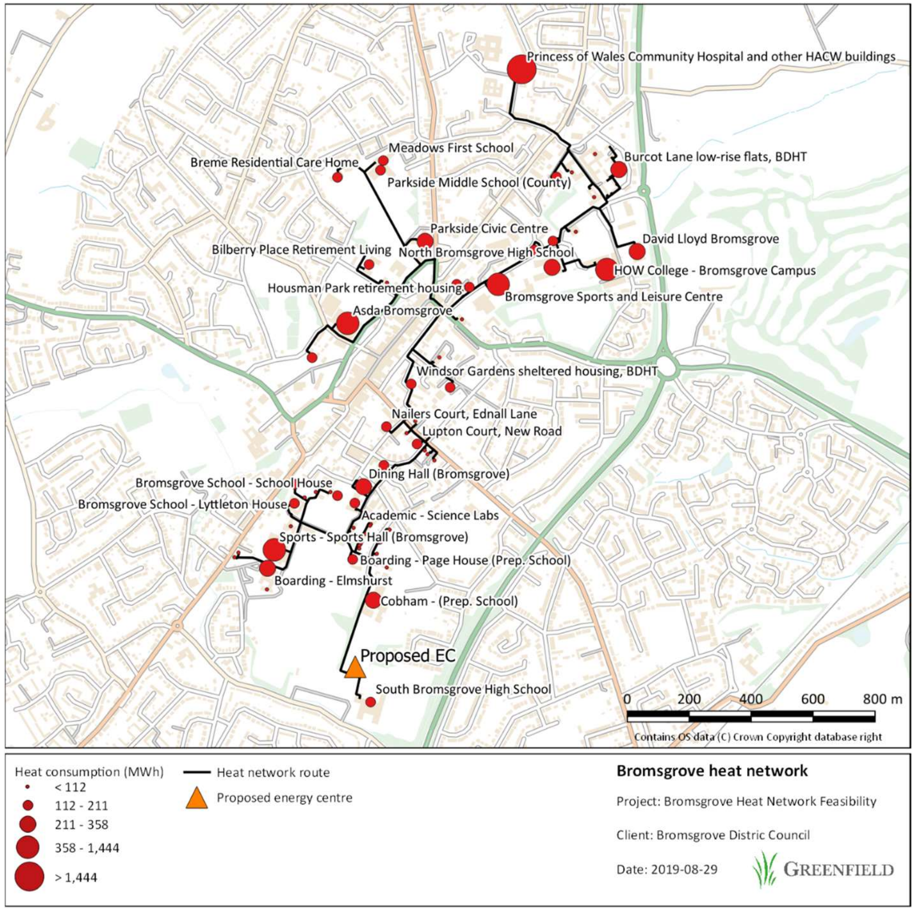
The work is defined as a detailed feasibility study and involves mapping of loads (energy demands), and, identification, initial concept design, and, techno-economic testing of heat network solutions.

Energy mapping and selection of network opportunities

Energy mapping was completed, focusing initially on consumers and areas identified by Bromsgrove Council. During the process of data collection for these consumers, additional properties were also identified. The map below shows all potential consumers included within the analysis.



The initial stage of investigation (work package 1) identified two principal heat network opportunities: Bromsgrove Town Centre and Bromsgrove School. Development and testing of these opportunities subsequently identified that the economic performance with a variety of energy supply technologies were very poor. Consequently, the second stage of investigation (work package 2) focused on a revised solution combining the two sets of consumers (with additions) with a single energy centre, as shown in the map below.



For this heat network solution the following supply options were examined: an open-loop ground-sourced heat pump (GSHP) system combined with gas CHP, and, biomass boilers. The GSHP system is a renewable energy technology involving the drilling of a series of boreholes to the depth of approximately 200m. These would abstract (and discharge) water at constant ambient temperature (approx. 12°C) from the underlying aquifer. The water is then essentially upgraded to a temperature useable for heating and hot water within buildings by an electrically driven heat pump device.

Ground source heat pumps, utilising groundwater extracted through a borehole array and combined with gas CHP is the preferred primary supply solution. Biomass boilers would be a fallback option. The following table summarises the two options.

	GSHP/CHP	Biomass
Economic performance	Good (considered fundable)	Marginal (considered fundable)
Carbon performance	Good. Improved if gas CHP is excluded	Very good
Environmental performance (non-carbon)	Low impact operation. Presents risk of marginal increase in localised (and town-wide) emissions to air, which can be reduce by exclusion of gas CHP.	Change in localised / town-air air emissions due to switch for property-level boiler to centralised energy centre. Particulate emissions will require further examination/mitigation measures Results in additional road transport to deliver fuel to site
Delivery risk	High: requires 'proving' of borehole array.	Medium: requires addressing risks around air emission and the fuel delivery

As shown on the map, the energy centre is proposed to be located at Bromsgrove School (with land near Bromsgrove Leisure Centre or the Princess of Wales Community Hospital as fall-back options).

Rationale for development and estimated performance

In general terms rationale for the development of the heat network is as follows:

1. Reduction in consumer energy costs (5% savings on estimated existing costs has been modelled)
2. Operational benefits for property owners/operators, including reduced plant liability and releasing property floor space

3. Reduction in carbon emissions which have been calculated to be between 32% (GSHP/CHP hybrid) and 61% (biomass) for connected properties[1]. Over a 25-year calculation period this is estimated to deliver the following carbon savings: 39,000 TCO_2 (GSHP / CHP hybrid option) and 69,000 TCO_2 (biomass option)
4. Ability to deliver deep and sustained carbon reduction for the town through further expansion and incorporating other lower carbon technologies in future.
5. Inward investment into the town of between £15.5m to £20m (construction costs) with consequent short term employment of construction staff
6. Training and the educational support opportunities for development staff and students, e.g. Bromsgrove School and HOW college
7. Development of a local energy generation / supply entity which could be fully or partially publicly owned. The entity could develop and operate support subsequent local energy ventures
8. Reputation benefits for the town, local authority and other stakeholders
9. Encourage commercial/residential tenant retention in the town (due to the consumer and reputation benefits)

The capital cost of the heat network is estimated at approximately £15.5m and £20m, depending on supply technology.

The techno-economic analysis completed shows a marginal economic performance for the GSHP / CHP hybrid option with a 3.5 % IRR (25-year) for the base case, with a worse result for the biomass option at 1.1%. Both demonstrate an improvement on the initial results for the discrete town centre, Bromsgrove School heat networks. The table below shows a summary of the results of economic modelling.

	unit	GSHP/CHP	Biomass
Total CAPEX (full scheme)	£m	20.1	15.4
Total REPEX (full scheme)	£m	8.7	6.8
Total OPEX (full scheme)	£m/yr.	1.2	1.3
Annual revenue (full scheme)	£m/yr.	2.2	1.8
Gross margin (full scheme)	£m/yr.	1.0	0.5
Consumer heat tariff costs (full scheme[2])	£/MWh	57.5	57.5
Total connection fees	£m	2.4	2.4
NPV (25 yr @ 3.5 %)	£m	0.1	-3.6
IRR (25 yr)	%	3.5 %	1.1 %
Social IRR (25 yr)[3]	%	3.4 %	2.5 %
LCOE (25 yr)	£/MWh	75.8	90.2

Table 1-1. Economic modelling results.

Whilst there are potential opportunities to improve economic performance there are also risks to it. As such, it is anticipated that grant support, notably from HNIP, will be required if the project is to proceed. For the GSHP / CHP hybrid option £2.6m grant would be required to achieve 5% IRR, £5m for a 7% IRR and £7m for a 10% IRR.

It is anticipated that these values would fall below state-aid constraints and that the project, in principal, could be structured as a publicly or privately funded project (or a combination). Project structuring options have not been explored and this would need to be considered in future work.

In principal, it is considered that the project could be supported by HNIP, but it should be noted that this is an open and competitive process and is time-limited.

[1] Calculated of the first 25 years of the project
[2] Average across all consumers to the wider community and society as a whole. The calculation includes net impact on heating costs, carbon emissions and air quality.
[3] Social IRR accounts for impacts accrued to the heat network operator and those connected to the networks, as well as

It is Greenfield's recommendation that the council seeks executive and member support to take the project forward, focusing GSHP/CHP hybrid option, with the biomass solution as a fall-back.

If the council is able and willing to pursue the project and the key stakeholders (particularly Bromsgrove School) are supportive then it is recommended that that the project is moved on to a Detailed Project Development (DPD) or commercialisation phase. This could be part-funded by HNDU, BEIS under a similar arrangement that has supported this investigation. DPD would involve developing a detailed business case, investment strategy, review and resolve key legal, resolve key technical and risk issues (see risk register in Appendix 11), and, initiate commercial actions, such resolving governance/ownership arrangements, fund-raising and procurement.

Aside from commercial and legal issues the following issues will need further consideration to address the key risk items:

1. Seek council executive and member sign-off for the specific recommendations to proceed, including any resource requirements and establishment of efficient decision-making and project governance (including establishment of a Project Board with senior representation).
2. Establish internal arrangements and necessary resources (financial and expertise) for effective project management (funding may be available from HNDU, BEIS)
3. Secure Bromsgrove School's support for the project (as a key consumer and host of the proposed energy centre), e.g. through a Memorandum of Understanding. In addition certainty over consumption data should be improved.
4. Secure other key consumers including schools, council properties, leisure centre and the hospital, e.g. through signing of Memoranda of Understanding, and further understand any connection timing issues. In addition certainty over consumption data should be improved for all assumed consumers.
5. Consider the the connection of the coucils development on Burcot Road. The imminent delivery of this development is at odds with the schedule of the a heat network scheme. Howevre, if the scheme proceeds prior to heat network being available, a retrofit connection should be considered and the properties should be designed to enable this. On a broader point the council should consider wheter other future development could be connected to the proposed heat network or that independent network are considered for these.
6. Identify and engage with additional prospective consumers, to address the risks of losing currently assumed consumers, through local promotion of the project and direct engagement.
7. Further examine the GSHP borehole design and costing.
8. 'Prove' network route, by investigating highways and existing underground service constraints.
9. Explore eligibility and timing issues for HNIP funding.

2 Introduction

The initial investigation into heat network options in the town resulted in the development of the two discrete solutions: Bromsgrove Town Centre and Bromsgrove School as illustrated in Figure 2-1.

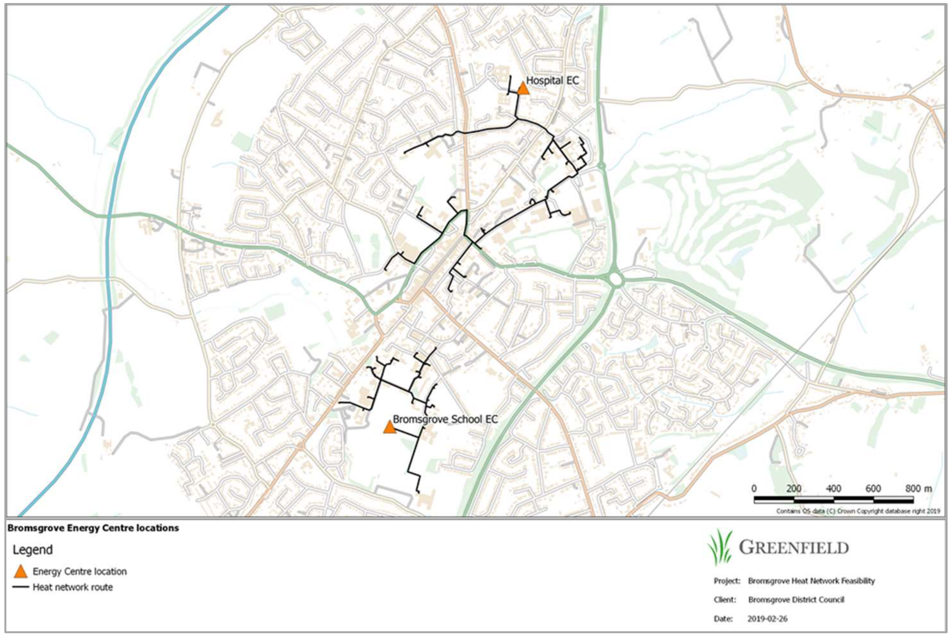


Figure 2-1. Initial heat network options

For these networks a range of the technology options were tested: Gas CHP, Ground-sourced heap pumps (closed-loop) and biomass boilers. In each case the network and supply solutions where developed and economic and carbon modelling was conducted. This results from this analysis are summarised in Table 2-1 and Table 2-2.

The results showed negative or marginal returns: Town Centre: Project IRR (25-year) up to 1.3%; Bromsgrove School cluster: Project IRRs (25-year) up to 0.5%. The result also illustrated that it would be difficult to support either project even with grant support.

Baseload supply		**CHP**	**GSHP**	**Biomass**
Total investment	£m	10.2	11.0	10.0
NPV (25yr) @ 3.5 % discount rate	£m	-3.2	-4.9	-2.2
IRR (25yr)	%	0.5	-0.9	1.2
Grant support to achieve IRR-25yr (as % of capital cost)				
IRR - 3.5%	%	31.3	44.7	22.1
IRR - 12.0%	%	53.4	59.3	48.5
Carbon reductions				
25 yr (savings against BAU)	%	1.8	36.9	74.5

Table 2-1. Analysis results of initial heat network options – Town Centre

Baseload supply		**CHP**	**GSHP**	**Biomass**
Total investment	£m	9.2	7.9	7.1
NPV (25yr) @ 3.5 % discount rate	£m	-3.6	-5.5	-2.2
IRR (25yr)	%	-0.3	-3.7	0.5
Grant support to achieve IRR-25yr (as % of capital cost)				
IRR - 3.5%	%	38.9	69.9	31.8
IRR - 12.0%	%	59.5	73.3	57.8
Carbon reductions				
25 yr (savings against BAU)	%	2.6	35.4	73.3

Table 2-2. Analysis results of initial heat network options – Bromsgrove School

Whilst it was recognised that either network could provide benefits through reduced energy costs, carbon reduction and provision of a managed ‘energy service’ neither were considered economically viable.

As a consequence further investigation / design-development (work package 2) focused on the following potential improvements:

- Examining an open-loop ground source heat pump solution (rather than the closed-loop solution explored initially) and the considering the use of hybrid heat pump / CHP arrangement. The main advantage of an open-loop system is that fewer boreholes are required to produce the same amount of heat, which should lower costs, whilst energy harvesting performance should increase. Adding CHP to this arrangement could also potentially deliver increased revenues, particularly where generated power was supplied both to the heat pump systems and directly to larger consumers, such as Bromsgrove School.

- Examining opportunities for additional consumers, particular assisted-living properties on the south side of the town centre, and existing consumers with gas CHP, which were excluded. Both could increase revenue whilst only adding limited capital costs

- Interconnecting the two networks, which could result in requiring a single main energy centre, making a significant reduction in capital costs.

- Exploring specific capital cost reduction opportunities, including reducing peak demands through adjusted consumer demand profiles

- Improving certainty around key issues, including energy demand estimates, capital costs and project risks

The analysis conducted is consistent with requirement of the UK Heat Network Code of Practive (CP1).

3 Energy demands and consumer selection

In the first stage of work (WP1) Bromsgrove District Council (BDC) provided a list of prospective heat network consumers from prior work and the following data sources were reviewed during the heat mapping exercise, enabling a review of potential heat network consumers within the study area:

- BDC databases for council-owned non-residential/residential buildings
- Planning documents
- Open source information (e.g. Google maps, OS OpenMap Local)
- Filed EPC/DEC reports
- Extensive direct contact with potential consumers (by Greenfield and BDC)

From the conclusions drawn in WP1 to focus on a single heat network (rather than two discrete networks) the prospective consumers were reconsidered, additional consumers were added and information regarding the key ones was collated. During the process it was also possible to examine further how likely consumers were to connect, to a heat network. This has resulted in retaining key consumers including Bromsgrove School, Princess of Wales Community Hospital and BDHT social housing. Notably new consumers were the David Lloyd and Bromsgrove Leisure Centres (operated by Everyone Active).

Figure 3-1 illustrates the distribution of the prospective consumers and heat demand (the size of each 'bubble' giving an indication of heat demand).

Figure 3-2 also shows the location and scale of consumers who would also receive power from an energy network (where gas CHP is included as a supply technology). Power supply is restricted to Bromsgrove School and South Bromsgrove High, to limited distance for a private wire network and to reduce complexity, i.e. only two power supply contracts.

This section goes on to describe key aspects of the principal consumers and schedules the total loads identified.

Appendix 1 includes for detail on the energy demand analysis methodology and data sources and Appendix 2 provide further data on all prospective consumers , including those excluded.

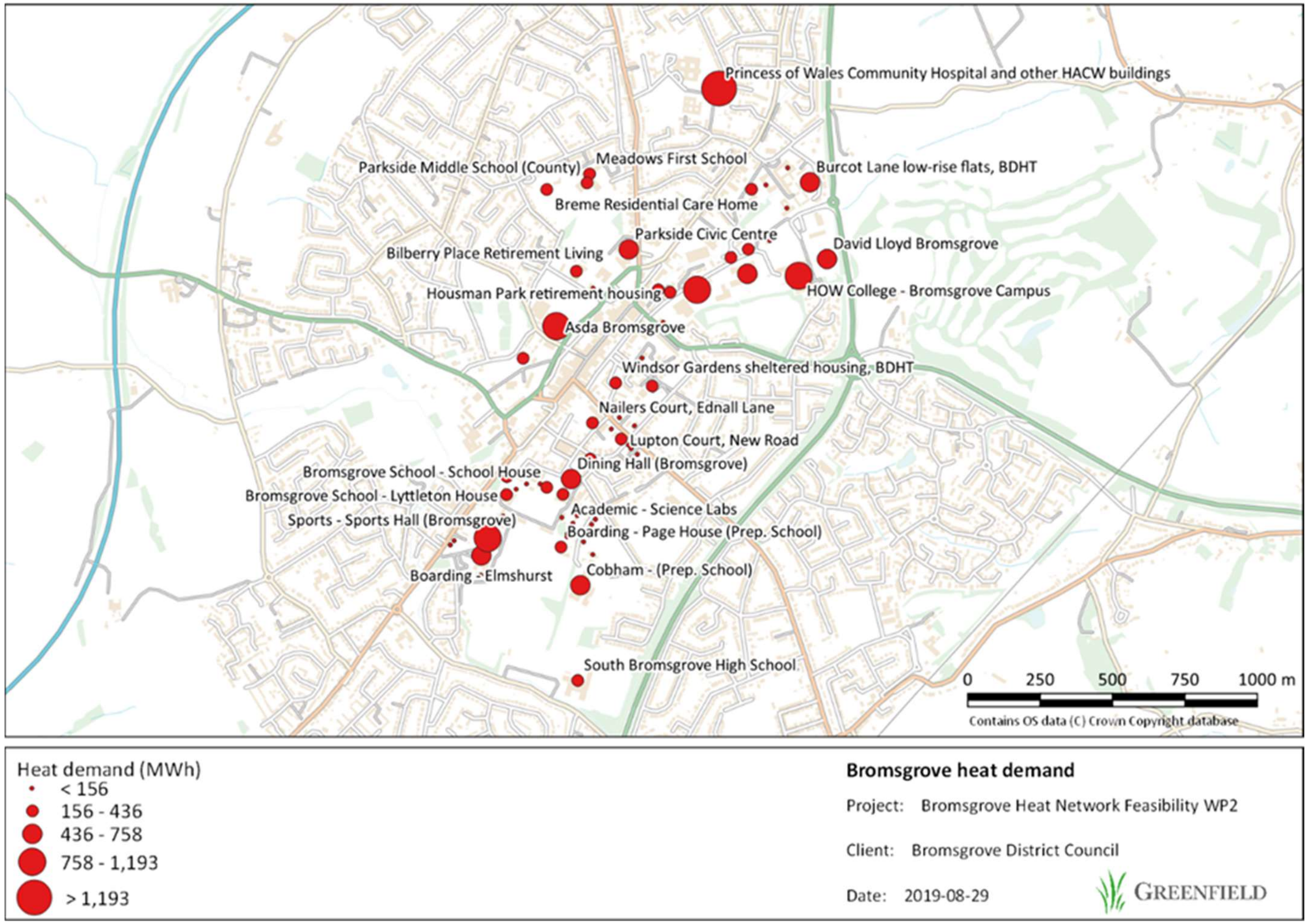


Figure 3-1. Proposed heat consumers

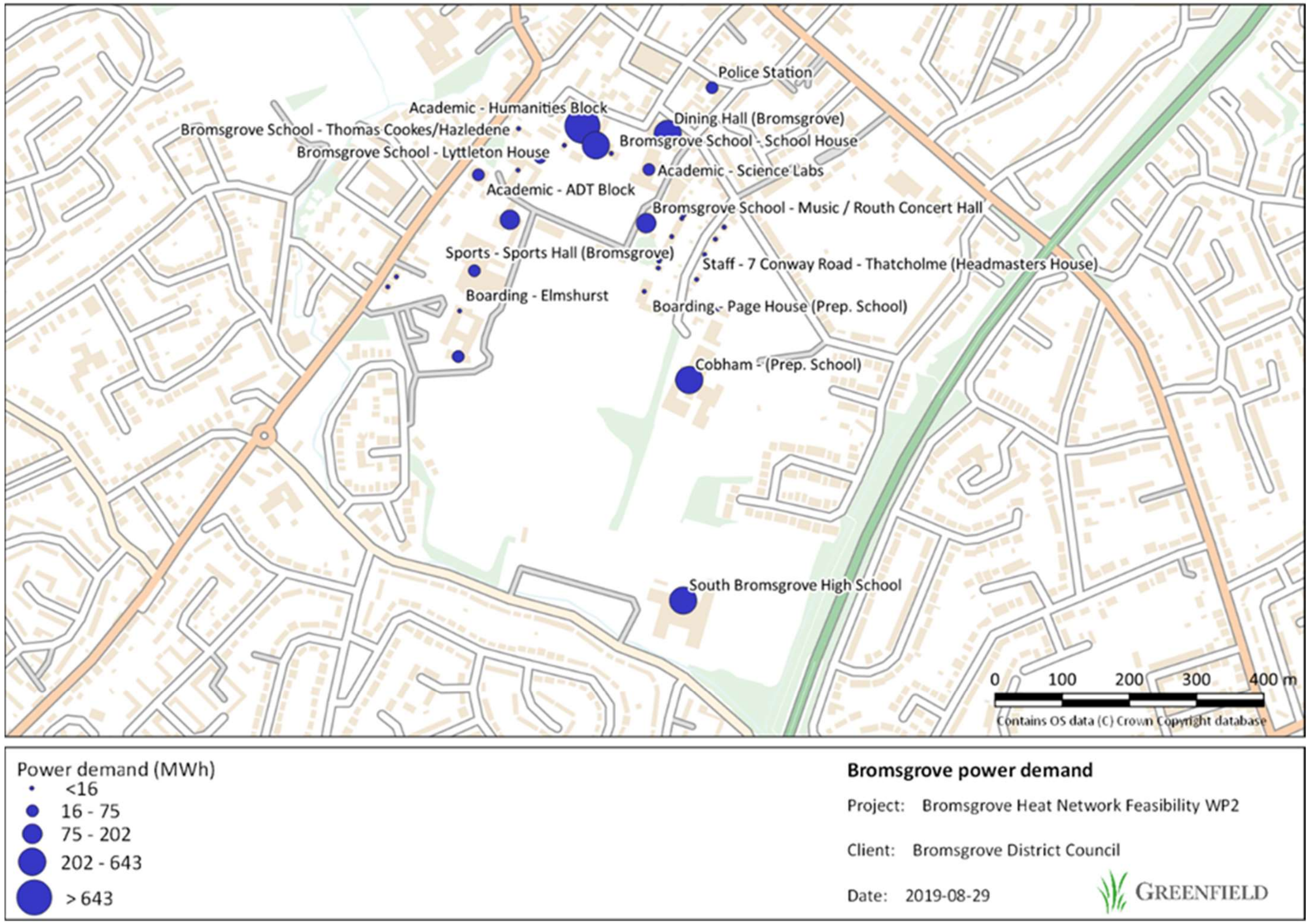


Figure 3-2. Proposed power consumers

3.1 Key consumers and total demand

The key consumers proposed for the heat network are as follows:

Bromsgrove School

- Bromsgrove School is a large private school with 200 staff and 1,660 pupils spread across 50+ buildings
- The school campus includes residential facilities and boarders and staff
- Majority of buildings are heated by gas boilers
- Gas and electricity metering and billing data was provided via the school's energy management consultant
- Included as a private wire network (power) consumer (close proximity to proposed energy centre)
- All consumption data has been updated from WP1, which has seen some significant changes for the earlier data which was largely based on accounting data rather than metered data. This has seen heat consumption drop by approximately 25%. But is considered to be much more reliable than data used in the earlier analysis.
- Engagement with the school has been positive, and, subject to a heat network solution achieving commercial requirements, the school are keen to further pursue this option. They anticipate it would support their goal of reducing operational costs, reducing carbon emissions and also support their educational objectives.

Princess of Wales Community Hospital and other HACW buildings

- Community hospital and Older Adults Mental Health Unit, including inpatient facilities
- Worcestershire Health and Care NHS Trust
- The hospital has provided gas and electricity data and billing information
- Currently heat is supplied by three gas boilers in a central plant room located on the hospital site. No CHP is present on site
- The heat network connection is proposed to be located within the existing plant room
- Further engagement with the health trust has confirmed their interest in connecting to a heat network and also highlighted the need for them to take action with the next few years since existing boiler plant will need to replaced. The trust also confirmed no concerns over resilience/reliability risks with heat network supply, although they would need further detail to fully evaluate this. They would also welcome this as an opportunity to reduce their carbon emissions.

Bromsgrove Sports and Leisure Centre – not previously included in WP1

- Council-owned leisure centre operated by Everyone Active featuring a swimming pool, climbing centre, exercise studios, fitness suite and spa, opened in 2017
- The centre has an 25 kWe (50 kWth) gas CHP unit installed
- Everyone Active was not able to provide historical operating data of the CHP, heating boilers and gas-fired water heaters
- Following further engagement, within the heat network modelling (see later) it is assumed that the on-site CHP would have precedence for supply to the building, i.e. only the proportion of heat demand presently supplied by boilers and gas-fired water heaters is assumed to be supplied the heat network, which is reflected in the consumption figures presented.
- Everyone Active confirmed their interest in receiving heat from a heat network, which they consider could be recharged through existing contract arrangements to the council.

David Lloyd Bromsgrove – not previously included in WP1

- Leisure centre operated by David Lloyd Clubs featuring a swimming pool, gym, club facilities and spa
- A 125 kWe CHP is due to be installed on site during 2019
- As per the Bromsgrove Leisure Centre only the proportion of heat demand forecast to be supplied by boilers and gas-fired water heaters is assumed to be supplied by the heat network
- David Lloyd Clubs provided historical operational data from their other facilities with similarly sized CHP systems and this was used within the modelling.
- David Lloyd confirmed their interest in taking heat from a heat network.

Chandler Court Care Home – not previously included in WP1

- Recently built care home operated by Care UK
- Site employs a gas CHP system, however, no detail on capacity was provided
- As per the Bromsgrove Leisure Centre only the proportion of heat demand forecast to be supplied by boilers is assumed to be supplied by the heat network
- A 14 kWe (28 kWth) CHP was modelled based on typical heat and power consumption profiles for care homes

Heart of Worcestershire (HOW) College

- Further education college with modern building stock (less than 10 years old)
- Buildings heated by gas boilers
- Gas consumption data was provided
- College staff confirm interest in a heat network connection where it provides monetary savings

North Bromsgrove High School

- Local Authority (WCC) maintained school, operated under BAM PPP arrangement
- Buildings heated by gas boilers, circa 15 years old. Full BMS controls in place
- Consumption and billing data provided
- BAM confirmed their interest in connecting to a heat network.

South Bromsgrove High School

- Local Authority (WCC) maintained school, operated under BAM PPP arrangement
- Buildings heated by gas boilers, circa 15 years old
- Consumption and billing data provided for gas and electricity
- Included as a private wire network (power) connection
- BAM confirmed their interest in connecting to a heat network.

ASDA Bromsgrove

- Large supermarket
- Consumption data provided directly by ASDA
- The bulk of heat demand is supplied by recently installed Air Sourced Heat pumps (ASHP).
- Following engagement with ASDA it was agreed to assuming a heat network connection at the end of the estimated lifetime of current ASHP system expires (in 2033)

BDHT social housing

- Following BDHT properties were included as heat network connections: Burcot Lane, Windsor Gardens, Shenstone Court, Parkside Court
    - Parkside Court: Approx. 26 sheltered apartments, built in 2017. Current energy system: communal heating with gas boiler.
    - Burcot Lane low-rise flats: 8 blocks of 12 general purpose flats. Some may be in private ownership. Current energy system: (assumed) individual gas boilers.
    - Cedar Court Flats: Approx. 7 general purpose flats owned by BDHT, a local RSL. Some flats may be in private ownership. Current energy system: Electric storage heaters.
    - Shenstone Court: Approx. 33 older people's retirement 1 bedroomed flats, built 1986. Current energy system: communal heating with gas boiler.
    - Windsor Gardens sheltered housing: Approx. 80 older people's apartments (largely 2 storey with individual gas boilers). Some may be in private ownership.
- Demands were modelled based on NEED benchmarking

Energy demand for each prospective consumer is shown in Table 3-1, ranked by scale (illustrating relative significance). The new development load figures shown represent estimated demand after full build-out.

Site	Peak Heat (MW)	Heat Load (MWh/yr)	Power Load (MWh/yr)	Source	Year	New ?
Bromsgrove School (18 properties)	1.85	4,369	2,473	Metering	1	
Princess of Wales Community Hospital and other HACW buildings	0.77	2,317	-	Actual bills	3	
Bromsgrove School staff and student residential (16 properties)	0.62	1,393	471	Metering	1	
Bromsgrove Sports and Leisure Centre	0.42	1,193	-	Metering + CHP modelling	3	✓
Asda Bromsgrove	0.64	1,137	-	Metering	11	
HOW College - Bromsgrove Campus	0.52	870	-	Metering	3	
David Lloyd Bromsgrove	0.56	699	-	Metering + CHP modelling	3	
North Bromsgrove High School	0.34	590	-	Actual bills	3	
Burcot Lane low-rise flats, BDHT[4]	0.32	584	-	NEED	3	
Parkside Civic Centre	0.28	474	-	Actual bills	2	
South Bromsgrove High School	0.25	436	643	Actual bills	1	
Windsor Gardens sheltered housing, BDHT[4]	0.25	401	-	NEED	2	
Nailers Court, Ednall Lane[5]	0.24	377	-	BEES	2	✓
Breme Residential Care Home	0.13	365	-	BEES	2	
Bilberry Place Retirement Living[4]	0.12	353	-	BEES	2	
Housman Park retirement housing[4]	0.12	347	-	BEES	3	
Meadows First School	0.17	285	-	Actual bills	2	
Parkside Middle School (County)	0.16	264	-	Metering	2	
Lupton Court, New Road[5]	0.19	255	-	NEED	2	✓
Life After Stroke Centre	0.17	213	-	NEED	11	
Cypress Court (prev. Cypress House)[5]	0.17	207	-	NEED	2	✓
Maple House, Bromsgrove School junior (independent)	0.17	201	-	NEED	3	
Shenstone Court, BDHT	0.17	201	-	NEED	3	
Housman Court Care Home	0.06	182	-	BEES	3	
7 School Drive Care Home (Dimensions UK)	0.15	170	-	NEED	3	
Wendron Centre (Bromsgrove Day Services)	0.09	156	-	Metering	2	
Alten Court 19 New Road (flats)[5]	0.06	156	-	NEED	2	✓
Brook Court[4]	0.14	146	-	NEED	3	
Bromsgrove Methodist Centre	0.08	144	-	BEES	2	
Chandler Court Care Home	0.09	123	-	Metering + CHP modelling	2	✓
Parkside Court (previously “BDHT housing for older people”)	0.12	109		NEED	2	
Fernleigh, New Rd[4]	0.04	100		NEED	2	✓
Artrix Theatre	0.06	98		Actual bills	3	
Guardian Court, New Road[4]	0.04	97		BEES	2	✓
Raglan Court, New Rd (flats)[4]	0.04	96		NEED	2	✓
Westminster Court[5]	0.11	91		BEES	2	✓
Blue Light Centre	0.03	88		Metering	3	
Sunningdale, 28 New Rd (flats)[5]	0.02	47		NEED	2	✓
Total	**9.73**	**19,334**	**3,587**			

Table 3-1. Summary of included loads, data source and assumed year of connection

[4] *Requires conversion from individual gas boilers*
[5] *Requires conversion from electric heating*

3.2 Aggregated consumer demands and profile

Demand data for each consumer identified has been profiled on an hourly basis. For estimated consumption (where metered data wasn't available typical property typr profiles have been used). These aggregated loads have then been further adjusted to take account of anticipated load diversification, to represent the effects of bringing together a set of independent consumers. In order to optimise heat network pipe sizes and energy centre capacity, the heat profile developed has also be adjusted to extend the moning heat-up period, to limit the maximum peaks that would be experienced.

The resulting aggregated loads are shown graphically in Figure 3-3 to Figure 3-9 and in Table 3-2. Further detail on the energy modelling methodology is presented in Appendix 1.

	Heat	Power
Consumption	19,336 MWh	3,509 MWh
Production (inc. losses)	22,588 MWh	3,579 MWh
Peak demand		
Undiversified[6]	8.0 MW	1.0 MW
Diversified[7]	6.8 MW	NA
No. of consumers		
Non-residential (buildings)	38	35[8]
Residential (buildings)	32	-
Residential (dwellings, included in above)	601	-

Table 3-2. Aggregated consumer demands

Adjusting 'heat-up' periods, in practice, will require some investigation into to specific needs of each consumer building. It will require adjustment to property management arrangements and potentially investment into internal property level heating systems (secondary network) and/or improvement of heat loss. This would also be the case for adjusting flow and return temperatures (see discussion in section 4.3).

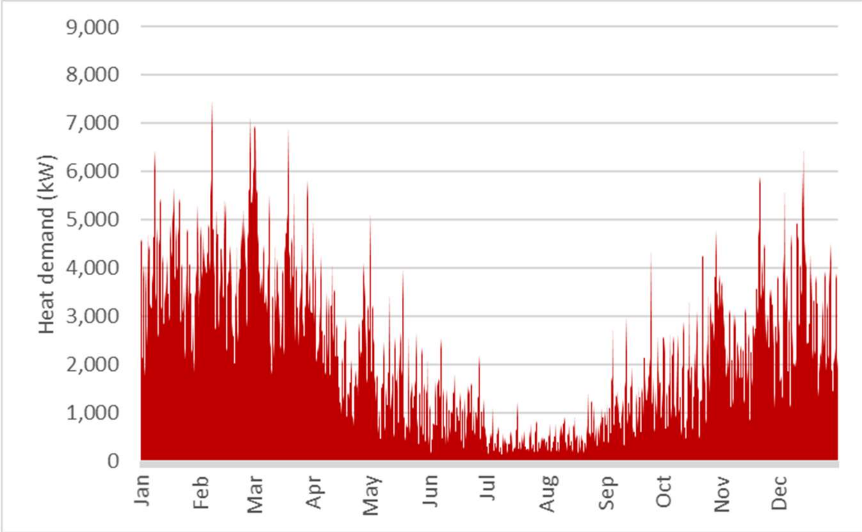


Figure 3-3. Annual hourly heat demand profile

[6] *Undiversified = simple aggregation of the profiled loads*

[7] *Diversified = adjusted to account for fact that consumer heating and hot water loads could be adjusted such that peaks do not occur at the same time. A 'flattened' peak would lead to reduction in the total network and energy centre capacity required*

[8] *Includes Bromsgrove School boarding*

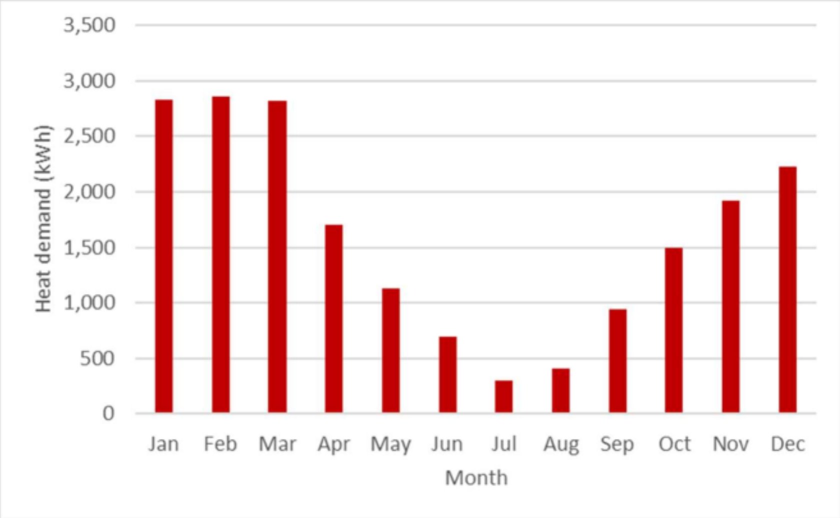


Figure 3-4. Annual monthly heat demand profile

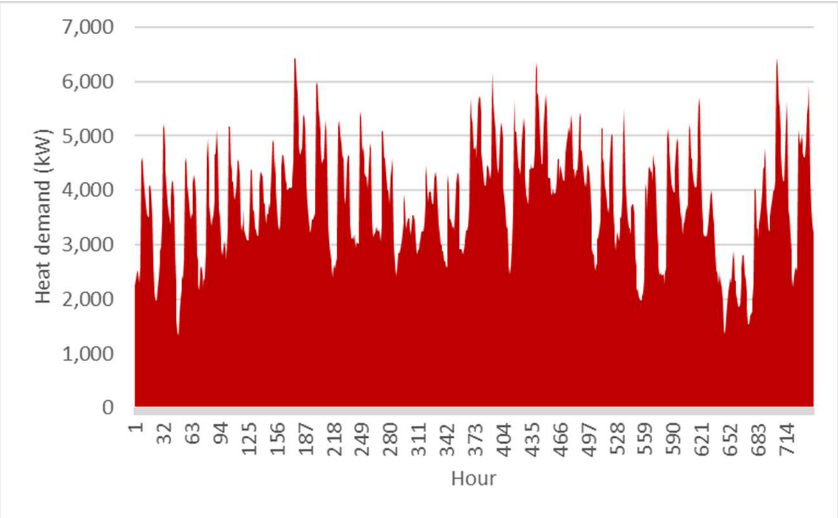


Figure 3-5. Example month heat demand profile - January

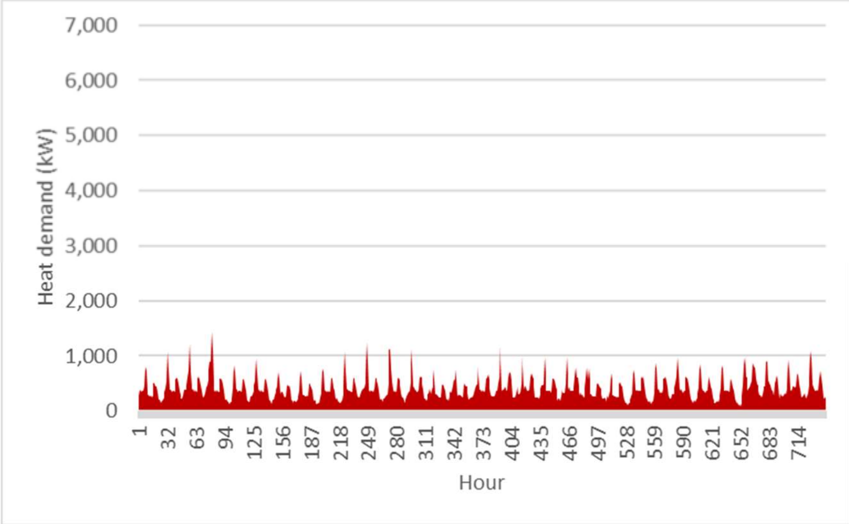


Figure 3-6. Example month heat demand profile -July

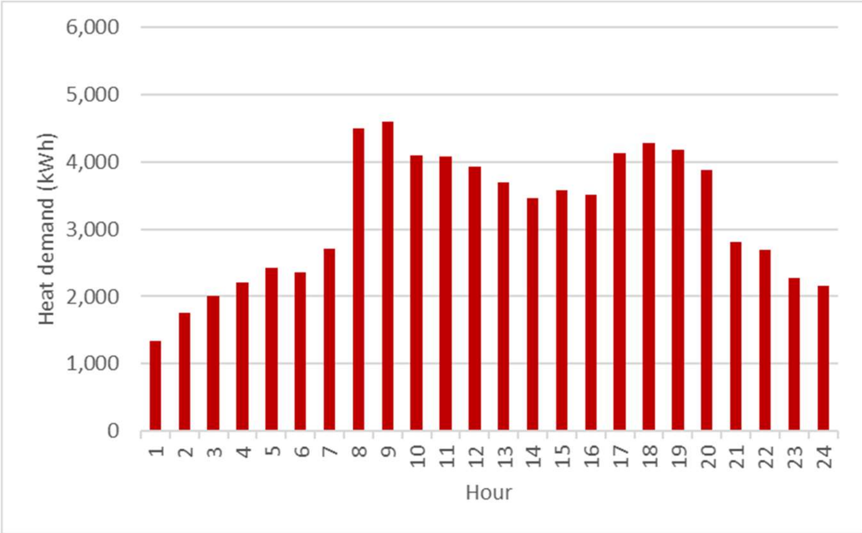


Figure 3-7. Example day profile - 3rd of January

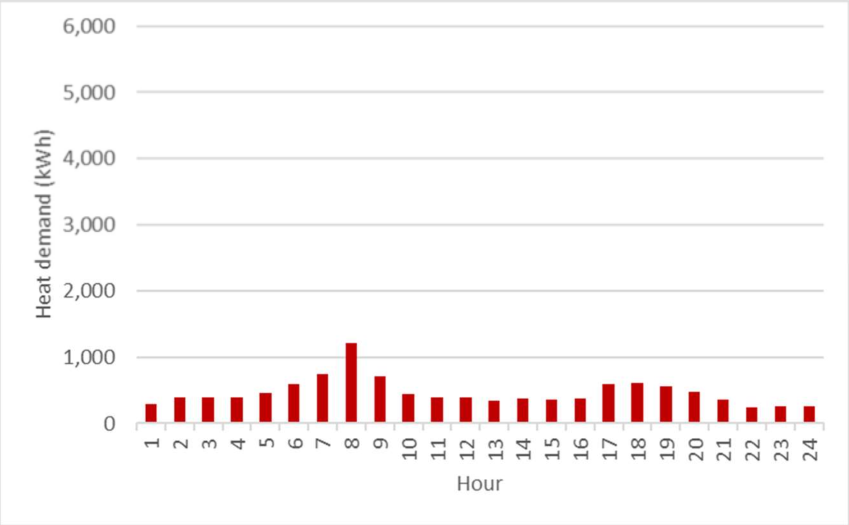


Figure 3-8. Example day profile - 3rd of January

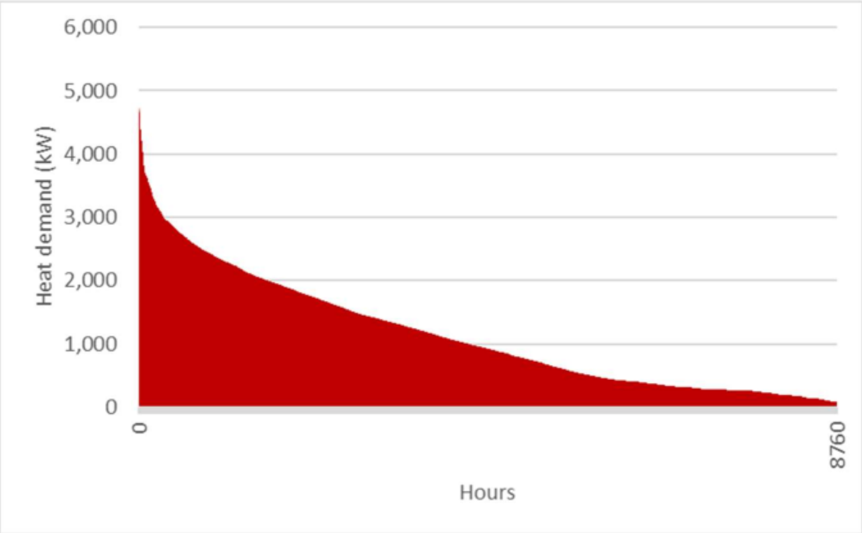


Figure 3-9. Load duration curve

4 Heat Network infrastructure

This section of the report summarises the infrastructure issues and conclusions for the Bromsgrove heat network project. Further detail is also provided in the following appendices:

Appendix 3. Heat network infrastructure – general notes
Appendix 4. Heat network design parameters, pipe sizes and capital costs

4.1 Network route

Based on review of the revised schedule of potential consumers and spatial constraints (including discussions with Worcestershire County Council highways staff and the Bromsgrove District Council planners), the heat network route has been revised as shown in Figure 4-1.

Key adaptations to earlier versions of the network are as follows:

- A single energy centre is proposed. This is anticipated to be a key advantage compared to the two heat networks identified and tested previously (where each had its own energy centre). This single energy centre will be circa 465m^2 for the GSHP/CHP solution.
- Energy Centre location:
    - Proposed location: "Piggery Field" on the south edge of Bromsgrove School estate (near to South Bromsgrove High School – also a consumer). A location on the Bromsgrove School estate was the preferred solution because the school will be the largest single heat consumer and the largest single power consumer. The school's Bursar and Estate Manager have proposed "Piggery Field" as their preferred location since it would have little conflict with normal operations.
    - This location is at the southern-most part of the proposed network as shown in the map, which is not ideal from an efficiency perspective (greater heat losses) but it is considered that availability of land and the proximity to the school is most important.
    - Alternative options include the development site adjacent to Bromsgrove Leisure Centre and the estate of the Princess of Wales Community Hospital.
    - With reference to the hospital, which would be the furthest consumer from an energy centre at Bromsgrove School, with a significant load, it is assumed that new boilers will be installed at this location to reinforce local supply capacity and system resilience.
- Various new connections between Bromsgrove School and the town centre required routing the network via The Crescent
- The heat network branch to Parkside Middle School, Meadows First School and Breme Residential Care Home has been re-routed through school grounds (behind Parkside Civic Centre) to enable lower cost 'soft-dig' construction
- Connection added Bromsgrove Sports and Leisure Centre, David Lloyd Bromsgrove as new connections (on School Drive)
- Chandler Court Care Home added as a new connection on Recreation Road

In general terms, the heat network route is designed to take advantage of land where 'soft dig' construction is possible and use of council-owned land where possible. In essence, the network route mainly follows the highway network. 'Soft dig' construction is mainly identified on the Bromsgrove School site, near to HOW College and David Lloyd, near Princess of Wales Community Hospital and for the connection to Parkside Middle School and surrounding buildings. It is eastimated that 34% of the network can be constructed on 'soft dig' land.

Heat Network infrastructure

No major network constraints such as canals, railways or motorways exist, but main roads (highlighted in green and orange on the map) are avoided where possible to limit traffic disruption during installation and servicing.

Discussions with highways staff at Worcestershire County Council identified planned upgrades to the road network around the intersection of Birmingham Road and Stourbridge Road. This intersection presents a critical traffic problem for the town (hence the planned upgrade). In order to exacerbate traffic problems, installation of the heat network in this area should be completed at the same time as the highway upgrade, where possible and even if the pipework is left unconnected for a period. This would also deliver a minor cost reduction.

The route will need to surveyed, considering land rights and existing underground services, and this may lead to some adjustments.

Further detail on network design parameters is presented in Appendices 3 & 4.

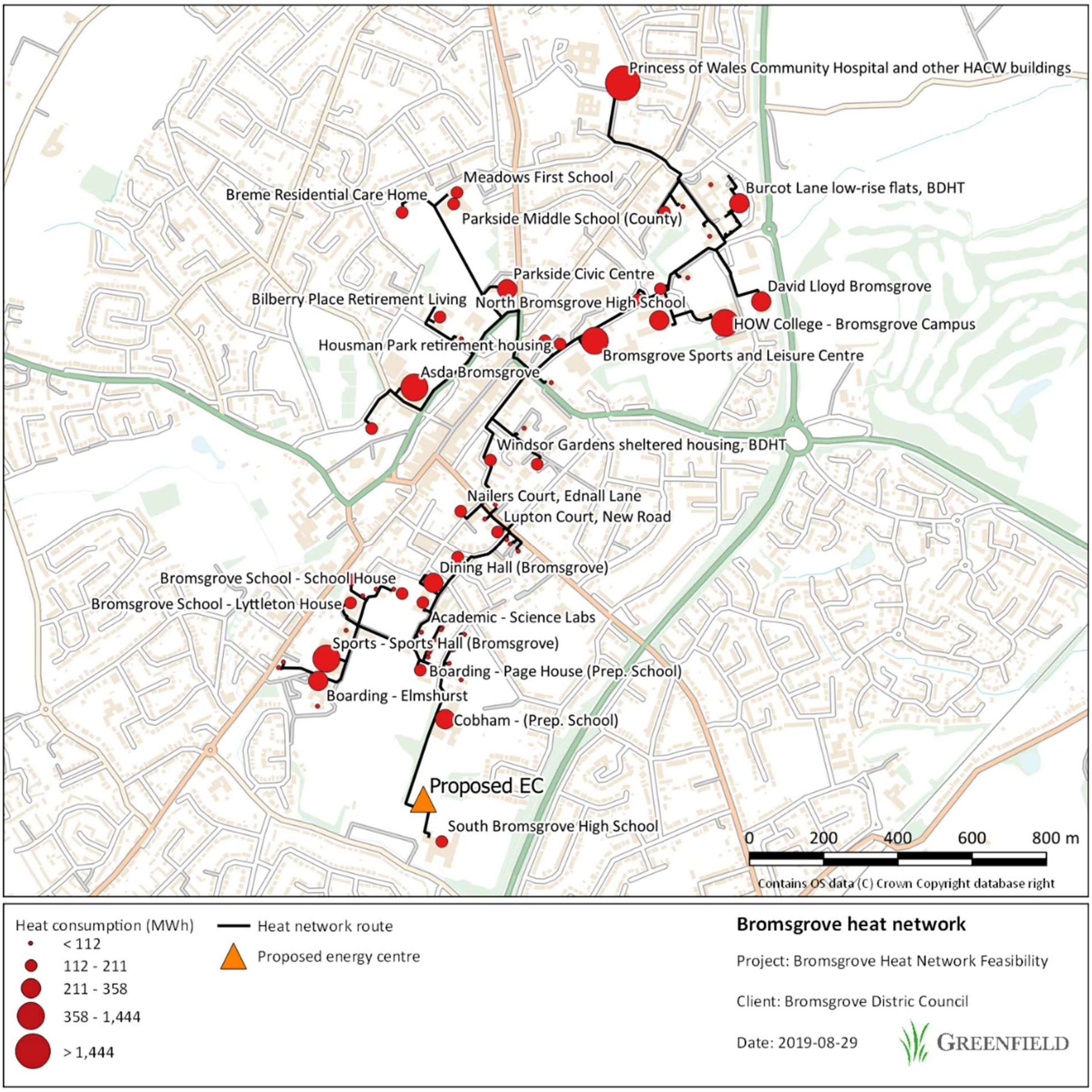


Figure 4-1. Bromsgrove heat network – route plan

4.2 Heat network build-out / phasing

The heat network is planned to originate from the Bromsgrove School site where the energy centre is proposed to be located. The main network build-out is proposed over three years period really to present a relatively pessimistic roll-out for the school. Phasing is shown spatially in Figure 4-3. The associated change in heat demand (peak and consumption) is shown in Figure 4-2.

In practice, build-out will need to account for the needs of individual consumers and, where possible, respond to their needs to avoid losing them. Except in the case of failure of existing heating systems, heat network connection dates can typically be flexible. Clearly, it would be better to deliver the network quicker (to maximise revenues) and; phasing should be reviewed on an ongoing basis with the objective in mind.

It is assumed that Bromsgrove School and South Bromsgrove High School are connected in Year 1. Year 1 refers to the first year of construction which may not be possible before 2021, due to the preceding planning stages which may take 18 months to 2 years. Year 2 sees expansion into the southern part of the town centre and then Year 3 sees expansion to the Leisure Centres, Hospital and other consumers in the northern part of the town centre. It is important to reach the hospital as soon as possible (since they need to resolve the resilience of ageing boiler plant). This may require them to install new boiler plant prior to the connection to the heat network. This could potentially be installed by the heat network operator in lieu of the planned connection, with the plant then be co-opted as addition supply plant feeding the network, once the hospital has connected.

The last buildings to connect are assumed to be the ASDA store and adjacent properties, in year 11. This is linked to the planned retirement of the Air Source Heat Pumps currently used at the store.

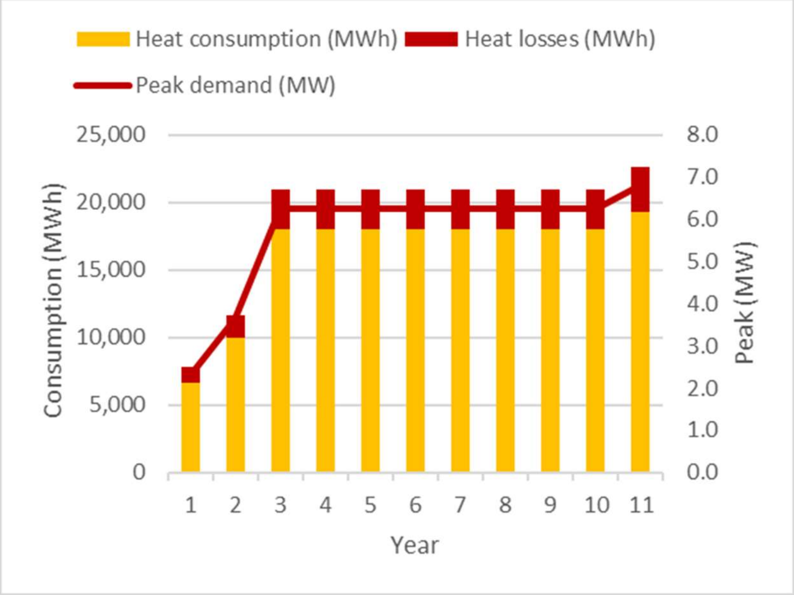


Figure 4-2. Heat network demand growth over time (peak demand and annual consumption)

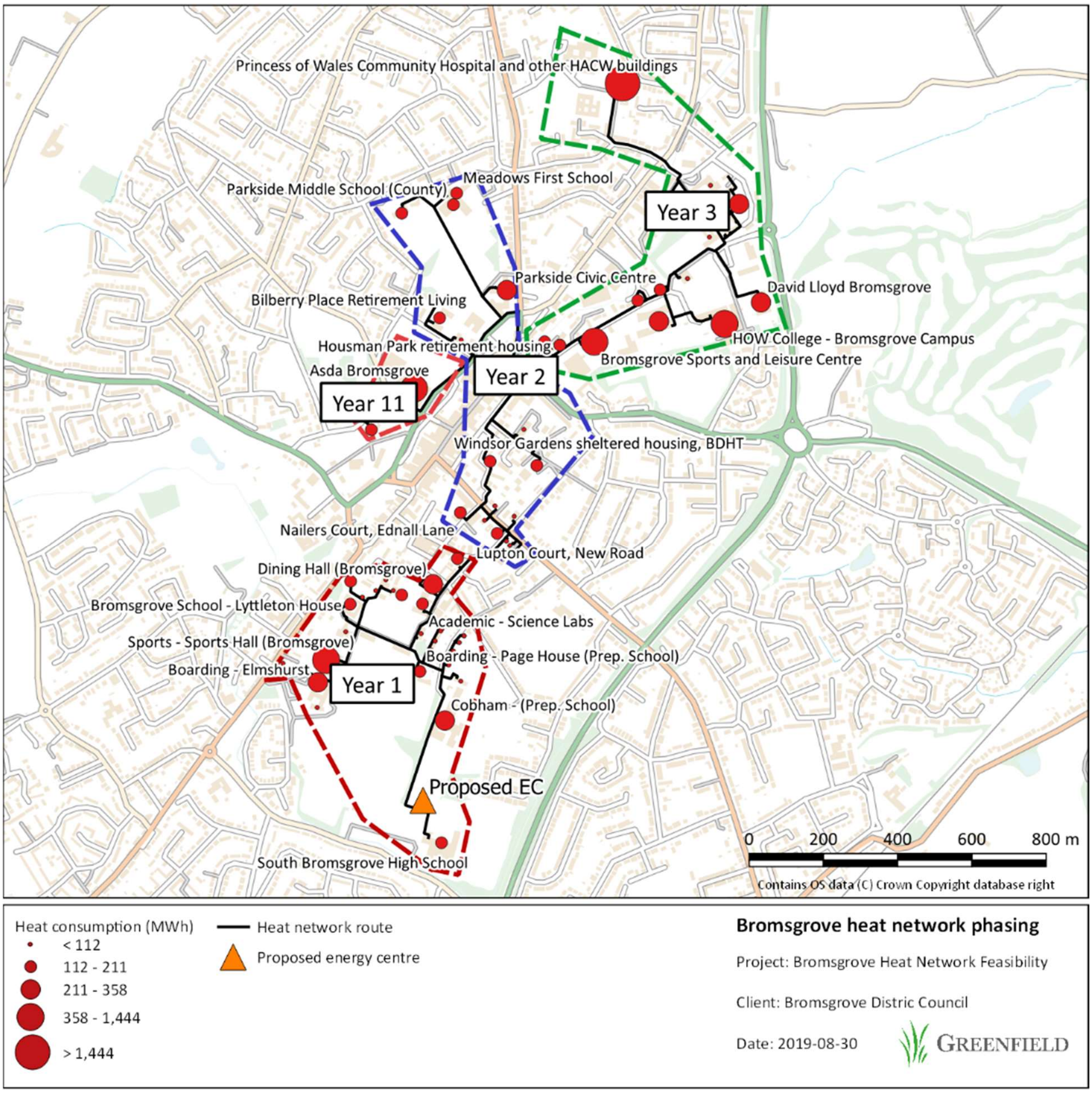


Figure 4-3. Bromsgrove heat network – proposed phasing arrangement

4.3 Key network parameters and capital costs

Based on consumer loads and the phasing plan a preferred design for the heat network has been developed with key parameters shown in Table 4-1.

The network is assumed to utilising Class 2 pre-insulated steel pipework to minimise heat losses whilst managing capital costs. Plastic pipework could be considered at the detailed design stage to seek to deliver reduce costs but this is likley to undermine long-term resilience so is not recommended.

The table highlights the network flow and return temperatures that have been used to size the network through hydraulic modelling. It is assumed however that the heat network would be designed to operate on a variable temperature, variable flow basis such that it can efficiently respond to the ambient temperatures conditions (and subsequent variation in consumer demands). The majority of consumers on the network are existing and existing heat will be managed to different degrees by the property operators. In the worst case we would anticipate some buildings operating on the (CIBSE) standard operating basis of (internal) flow temperatures at 82ºC and internal return temperatures of 71ºC. In order to maximise the performance (and advantages of a heat network compared to other options) the difference between these temperatures should be maximised and hence it is assumed that existing buildings are rebalanced to internal (secondary) network temperatures of 80/60.

Further detail on network design parameters is presented in Appendices 3 & 4.

Based on the heat network design, costs of the pipework and private wire network (for power distribution to Bromsgrove School and South Bromsgrove High School) have been developed. They are summarised on in Table 4-2, with further detail available in Appendix 4.

	Units	
Demand		
Heat demand	*GWh/yr*	19.3
Peak demand	*MW*	9.7
Number of connections		
Non-residential	*No.*	38
Residential (dwellings)	*No.*	601
Total	*No.*	639
Network		
Network trench length	*km*	7.5
Linear heat density	*GWh/yr/km*	2.6
Main pipe size	*DN*	250
Heat losses	*%*	11 %
Design temperatures (Flow / Return)	*°C*	90 / 55
Soft dig / Hard dig	*%*	34 / 66

Table 4-1. Bromsgrove Heat Network key heat network parameters

Heat network		
Pipe only supply and installation	£k	2,730
Trenching and civils	£k	4,698
Private wire network	£k	942
Heat substations and HIUs	£k	1,143
Heat metering	£k	373
Total	£k	9,886
Contingency (10 %)	£k	987
Grand total	£k	10,873

Table 4-2. Bromsgrove Heat Network distribution capital costs

5 Energy supply

This section of the report covers the proposed energy supply arrangements for the Bromsgrove heat network project.

5.1 Introduction

From the initial analysis of options (under work package 1) a hybrid ground source heat pump solution was identified as the preferred energy supply solution. Biomass boilers were also identified as a fall-back solution.

Both have been further assessed accounting for the changes to the heat network which is now intended to supply a larger number of consumers from a single energy supply facility (energy centre). Design detail and costings have been developed.

The hybrid gas Combined Heat and Power (CHP) plant and ground source heat pump (GSHP) system would be operated such that heat, at the required network temperatures (up to 90°C), would be provided by the central heat pump plant, CHP units and gas boilers (designed to meet peak loads). The individual plant would be automatically controlled to supply heat to optimise both carbon and costs performance. Thermal storage will be included to optimise operation, i.e. allowing lowest cost/lowest carbon plant to operate, even when demand does not exist on the network. This will enable a dynamic system able to deal with changing costs, e.g. electricity prices (which will change based on the time of day). The gas CHP will also provide power to run the GSHP system and supply directly to those consumers proposed to be connected to a Private Wire Network (the two schools). Gas boilers will provide additional capacity react to peak demands and also provide system resilience, dealing with planned and unplanned plant outage.

The fall-back biomass boiler system would operate in combination with gas boiler and thermal storage in a similar way but CHP is assumed to be excluded. This will reduce both capital costs and system complexity. The economic advantage of on-site power generation used in the heat pump supply strategy does not existing where biomass is the primary fuel source.

As described earlier (see section 4.1), the location for the primary energy centre has been reviewed against spatial arrangement of assumed consumers and engagement with Bromsgrove School. A location to the southern edge of school knowns as 'Piggery Field', has been proposed.

This location would facilitate the construction of an energy centre and a ground borehole array (with boreholes located within the Bromsgrove School estate) or biomass fuel handling facilities.

5.2 Energy technologies

5.2.1 Ground Source heat pump / Gas CHP hybrid

Gas CHP

CHP systems capture heat released during power generation, resulting in reduced energy losses and increased energy efficiency, when compared to individual boiler plant and grid-supplied electricity. Typical technology for small mixed-used heating systems (<5 MW) and medium scale (<20 MW) district heating systems are reciprocating gas-fired engine CHP systems. Overall efficiency in such systems is in the range of 80 to 90% with heat to power ratios of between 1.1 to 0.9.

Gas-fired CHP is a proven low carbon technology that can provide heat to district networks with additional revenue generated from power sales. Appropriate dimensioning of the CHP capacity is critical. Capital and operating costs are relatively high and CHP plant is not suited to modulation (turning down) and as a consequence, utilisation (or load factor) needs to be high to generate sufficient value from energy supply whilst minimising maintenance costs. Typically, gas CHP will be a baseload supply, operating for a minimum of 5,000 hours per year, with gas boilers/thermal storage are providing top up and back up.

A well-designed gas CHP can modestly reduce carbon emissions due to its higher efficiency compared to the alternative case of conventional gas boiler and grid electricity produced mostly by large distant "power only" power stations. Over time, the carbon reduction available is assumed to diminished as grid sourced electricity is forecasted to continue to decarbonise, which leads to the need to replace or supplement the technology with lower carbon technologies (GSHP in this case).

Ground-Source Heat Pumps

Ground-source heat pumps (GSHPs) are a well-established technology that can economically heat buildings in most locations by absorbing heat from the ground and/or ground water.

The system consists of a heat pump system (heat pump units and ancillary equipment including pumps, heat exchangers, pipes etc.) and a ground heat exchanger system or groundwater boreholes.

Ground source heat exchangers systems can be divided into two main groups. Shallow (1.0–2.5 m) horizontal heat exchangers and deep (15–200 m) vertical systems. Shallow horizontal heat exchangers are commonly used for small or residential installations. Due to the relatively low temperature of shallow ground layers during the heating season, efficiency is relatively low. Deep vertical systems are not dependent on the heat retained in the top layer of the ground rather they rely on migration of heat from surrounding deeper geology, where the temperature is almost constant during the year. As a consequence, they are more efficient and result in a lower cost of energy.

A vertical closed-loop field is composed of pipes that run vertically in the ground. This would consist of an array of boreholes, commonly filled with bentonite grout surrounding the pipe to provide a good thermal connection to the surrounding soil or rock to improve the heat transfer. Thermal conductivity of the soil will influence system performance.

In this case, an open-loop system appears to be possible. This would utilise groundwater abstracted from an aquifer (as per Injection well shown in image). In such a system, groundwater is directly abstracted and pumped through the heat exchanger (evaporator) inside the heat pump, and water is returned (discharged) through a separate re-injection borehole or soakaway back to the aquifer, meaning zero net abstraction. Abstraction and discharge of groundwater would require Environment Agency licensing, for flow rates greater than 20 l/s.

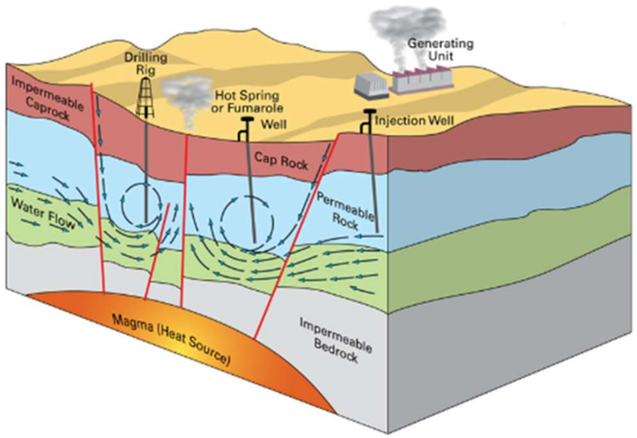


Figure 5-1. Geothermal energy systems – illustrating the range of energy extraction points

In this study, GSHPs are assumed to be of an industrial scale solutions based on centrifugal compressor units with a vertical open-loop system abstracting and discharging water from/to the underlying aquifer. The Coefficient of Performance (COP) of the heat pump is typically at the level of 2.5 to 3.0, depending on the ground loop and heat network operating temperature.

Local ground conditions and possible groundwater availability

A geothermal borehole/water abstraction report from the British Geological Survey (BGS) for Bromsgrove was commissioned to support the design and costing of a GSHP solution. The report provides information on geology at the site and an evaluation of the expected geological sequence and geological formations in terms of aquifer potential for groundwater abstraction beneath the site. Information in the report is based on available data from existing boreholes and geological maps.

Based on the BGS report, the main ground type in the area is sandstone (Helsby Sandstone and Wilmslow Sandstone formations up to 150 m and Chester formation for >50 m below that). BGS estimates annual mean soil temperature of 10.6°C and ground temperature of 13.7°C at 200 m depth (ground temperature gradient is thus 1.55°C/100m). Thermal conductivity of the ground (sandstone) is estimated as 3.1 W/mK and thermal diffusivity as 0.125 m^2/day for 100 – 150 meter deep boreholes. A 200 m deep borehole may terminate in the Chester formation which has slightly lower thermal conductivity and diffusivity values (2.4 W/mK and 0.1048 m^2/day respectively). Ground temperatures at the site are relatively low but they are offset by good thermal conductivity values.

Sandstone can be problematic for borehole construction because it can fracture and the reduce to sandy material during the drilling process and over time with as a result of water flowing. The water-saturated sand will flow into the void created by drilling which consequently led to subsidence of the surrounding ground. Water-based mud drilling techniques can be used to combat running sands and to maintain borehole integrity during drilling. This drilling technique would add to construction costs. In order for the boreholes to remain stable if bands of running sands are present, 'filter packs' and a lining (typically stainless steel) and larger diameter boreholes will be required. This further increases borehole costs. Understanding the likelihood of this and associated design solutions will require further hydrological desk-top investigation and ultimately test boreholes. In addition, the number of abstraction and discharge boreholes will be dependent on the specific ground conditions that are determined. At this stage, the uncertainty of borehole costs are dealt with by exploring variants with and without a lining arrangement and also proposing a worst-case number of boreholes.

There is a major aquifer beneath the proposed heat network location (Sherwood Sandstone Group aquifer), which has some potential for open-loop GSHP systems based on the BGS report. Borehole records in the area indicate that mean a mean yield of 11.5 l/s could be attained at the site from a single borehole. The aquifer lies just some 10 m beneath the surface but to increase chances of better yields and higher temperatures, deeper boreholes (200 m) are recommended. Mean hydraulic conductivity of the aquifer varies depending on location but according to the BGS report, it is likely in the range of 0.14 to 5.9 m/day. For the purposes of this study, it is assumed that water temperature in a 200 m deep borehole is the same as the ground temperature at that depth.

Proposed GSHP solution

Based on the evidence provided in the BGS report, open-loop GSHP was investigated as a supply option. Despite the relatively low flow rates of available water for abstraction from the aquifer (compared to other aquifers in the UK), the number of boreholes required for an open-loop GSHP is significantly less than the number required for a closed-loop GSHP system of the same scale. Modelling of the GSHP solution has indicated that a large optimal GSHP capacity is required. An indicative borehole arrangement for a borehole field consisting of 5 abstraction boreholes and 6 discharge boreholes is shown in Figure 5-2. The boreholes would house submersible pumps within them and trenched pipework would connect the abstraction and discharge sides of the system, enable the existing sports fields to be freely utilised.

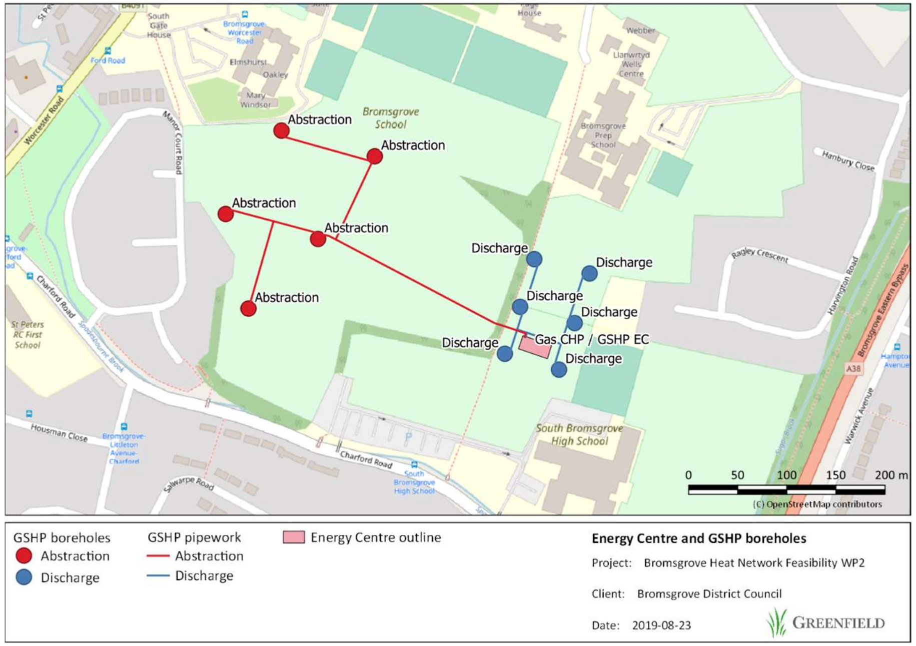


Figure 5-2. Indicative borehole arrangement for GSHP/CHP arrangement

5.2.2 Biomass Boilers

Using biomass boilers would achieve CO_2 emission savings and could also gain financial support in the form of the Renewable Heat Incentive (RHI). Capital costs would be higher than a gas-fired boiler of comparable output due to ancillary fuel storage and handling facilities.

Based on the scale of fuel supply required and the location of the energy centre the use of virgin woodchip is recommended. Pelletised biomass fuel is generally suited to boilers under 200 kW and wood-waste fuels will bring additional complication for fuel management and handling on a relatively constrained site.

The virgin wood chip fuel supply chain is not as mature as either pellet or waste wood in the UK, but it is possible to source. The industry standard for virgin wood chip is Woodsure, which is critical for smaller sized biomass boilers 200kW to 1MW but becomes less important for larger size boilers, capable of handling a greater variation in fuel quality. Virgin wood chip will generally have a moisture content of 30% and a calorific value of 3.5MWh/tonne and a bulk density of 4-5 cubic metres/tonne.

In general, the need to bring bulk fuel material on-site, typically by road, requires energy centres to be located at sites with easy access by lorries (typically articulated lorries). Biomass systems require a greater land-take than other energy supply alternatives as the plant is larger and additional space is required for fuel storage and to enable fuel lorry deliveries.

Consistent supply of fuel, appropriate to the specific energy plant installed, is essential to ensure reliability of the energy supply. Hence, it is necessary to secure fuel supply on long-term contract arrangements.

The biomass boiler option presents a localised air pollution risk. However, this is can be mitigated through the use of modern boiler technology (which will need to be licensed under the Medium Combustion Directive), and appropriate siting of the boiler plant/energy centre. Evidence would need to be prepared, including flue gas dispersal modelling, to enable licencing by the Environment Agency, as it would for the other options considered. See also discussion below on air quality.

5.2.3 Secondary issues

Gas Boilers

Gas-fired boilers are common generation plant for individual heating systems as well as for centralised district heating. Gas is a fossil-based energy source that has low capital costs and flexibility to be used at different operating temperatures and it reacts quickly in load variations. Gas boilers would be used as back-up (as a fall-back to cover periods of planned and unplanned plant outage) and peak supply in district heating systems.

Heat Storage Systems

In addition to the energy supply options considered above, heat storage can be a useful addition to a heat network. The optimum use of the capacity mix can be enhanced by including heat storage which is used to even out momentary demand variations and most importantly, can increase the use of base-load capacity, maximising carbon reduction and use of the least-cost supply option. During periods of low heat demand (e.g. during night periods and at weekends) the excess base-load capacity can be used to ‘charge’ the heat storage and correspondingly, during high heat demand the storage ‘discharges’ partially replacing peak supply plant (gas boilers).

In addition, heat storage brings other operational benefits by reducing the need for short-term modulation of heat production from CHP, heat pumps or boiler systems; this helps to ensure higher efficiency and will also reduce the maintenance needs. Other operational benefits also include production optimisation with energy price hourly variations. This concerns mainly on Gas CHPs and heat pumps; CHP electricity generation can be scheduled at the times when the electricity price is high and GSHP when the electricity price is low, respectively.

Combustion emissions

All heat generation technologies that utilise combustion present a localised air pollution risk particularly in terms of NOx and particulates. This can be mitigated through the use of modern boiler technology (which is likely be required under Medium Combustion Directive licensing) and appropriate siting of the boiler plant/energy centre. Where energy centres are to be developed, evidence would need to be prepared, including flue gas dispersal modelling, to enable licencing by the Environment Agency.

Discussions with Worcestershire Regulatory Services did not highlight particular concerns (for any of the technology options considered) and should be seen in the context of transport derived air pollution which is the principal concern for the town. Air Quality management for the town currently focuses on specific areas, for which Air Quality Management Plans are in place but none of these include the areas proposed for energy centres. It is suggested, going forward, that an area-wide approach will be introduced, seeking to strategically address air quality across the town, which may have implications for future air pollution sources such at the proposed energy centre.

However, in general terms, a heat network would displace existing or planned (in the case of new development) property-level boilers. The impact of a heat network will therefore be to reduce the total volume of combustion gases entering the atmosphere and to reduce air pollution overall. This benefit is compounded by that fact that the displaced boilers will be less efficient and more polluting than the highly managed energy plant within a heat network energy centre.

Where gas CHP is used within a heat network energy supply strategy it may lead to an increase in overall emission to air since it would use gas locally to generate power (as well as heat). Without this local power supply, the power consumed would be delivered through the 'grid' which supplies power from mix of power generation plant across the UK (and outside the local area). Any increase in emissions to air will be mitigated by reduction in emission for individual property-level gas boiler plant that will not longer be used and also through the specification of abatement systems within the energy centre.

Renewable Heat Incentive payments

Renewable Heat Incentive (RHI) tariff payments are available for ground source heat pumps and biomass boiler plant (see Appendix 8 for tariff assumptions). However, currently this is only up until March 2021, pending any further announcement on how the UK government will support low carbon / renewable heat supply technologies. It is widely anticipated that the RHI programme will be extended or alternative arrangements will be put in place to support the UK's heat decarbonisation targets.

5.3 Supply plant sizing

Two supply scenarios were examined for the Bromsgrove Heat Network:

1. Hybrid CHP/Ground-sourced heat pump (GSHP) solution
   - Energy centre located at Piggery Field on Bromsgrove School premises
   - Gas CHP feeding power to GSHP units and specific properties (via private wire network)
2. Biomass (heat only)
   - Energy centre located at Piggery Field with fuel delivery via the local road network through the Bromsgrove High School entrance – presumed to be outside school hours.

Plant capacity modelling for the supply options was conducted to determine the economically optimal sizing through analysis of hourly demand profiles. The following principles/assumptions were used in the analysis:

- Gas CHP
  - The CHP plant is modelled to produce heat and electricity with a heat-to-power ratio of 1.08 and efficiency of 83 % i.e. it produces 1 MWh of heat and 0.93 MWh of electricity while consuming 2.33 MWh of fuel.
  - Power produced is distributed (by Private Wire) to Bromsgrove School . Excess electricity is assumed to be exported to the regional power network.
  - Availability: 8,592 hours per annum (accounting for annual shut-down and maintenance for a one-week period during summer). Maintenance of the units is sequential (multiple units are proposed).
  - Gas CHP modelling accounts for time-of-day variations in power prices (peak and off-peak) for PW electricity and invariable income tariff for grid export.
- Ground Source Heat Pumps
  - Availability: 8,592 hours per annual (accounting for annual shut-down / maintenance for a one-week period (during summer). Maintenance of the units is sequential (multiple units are proposed).
  - Heat pump operation is calculated with a delta T of 3°C between inlet and outlet heat source flows (this could potentially increase)
  - The Coefficient of Performance (CoP) of the heat pumps varies based on water temperatures at condenser and evaporator. Annual average CoP based on modelling results is 3.02 (above RHI requirement of 2.8)
- Biomass boiler
  - Availability: 8,592 hours per annum (accounting for annual shut-down and maintenance for a one-week period during summer). Maintenance of the units is sequential (multiple units are proposed).

  - Biomass boilers produce heat with an efficiency of 83 %. Efficiency of biomass boilers generally varies between 80% to over 90% depending on the type of biomass fuel used.
- Gas boilers are dimensioned for back-up and reserve capacity.
- Thermal storage sizing for a unit located in the Energy Centre is included in the optimisation.

For the purposes of economic modelling, targeted sizing of the supply plant has been set above the thresholds set by the EU Energy Efficiency Directive (EED) definition of efficient heat networks. This is a requirement for Heat Network Investment Project (HNIP) funding, which may be required to make the project viable. For GSHP and Biomass installations the threshold is set at 50% of annual heat supply and for Gas CHP the threshold is set at 75%.

5.3.1 Results of supply modelling

Supply optimisation modelling was conducted to identify the least-cost sizing of the individual supply systems. This has resulted in the following supply capacities:

GSHP / Gas CHP hybrid

- 1,000 kW Gas CHP
- 1,300 kW open-loop GSHP
- 6,550 kW Gas Boilers
- 50 m³ thermal storage

Biomass boiler

- 2,600 kW Biomass Boilers
- 6,250 kW Gas Boilers
- 50 m³ thermal storage

Figure 5-3 and Figure 5-4 shows the load duration curve (illustrating modelled operational across a year) for the fully built-out network for each supply option, illustrating the important contribution of thermal storage (estimated at 50m³ for both supply options).

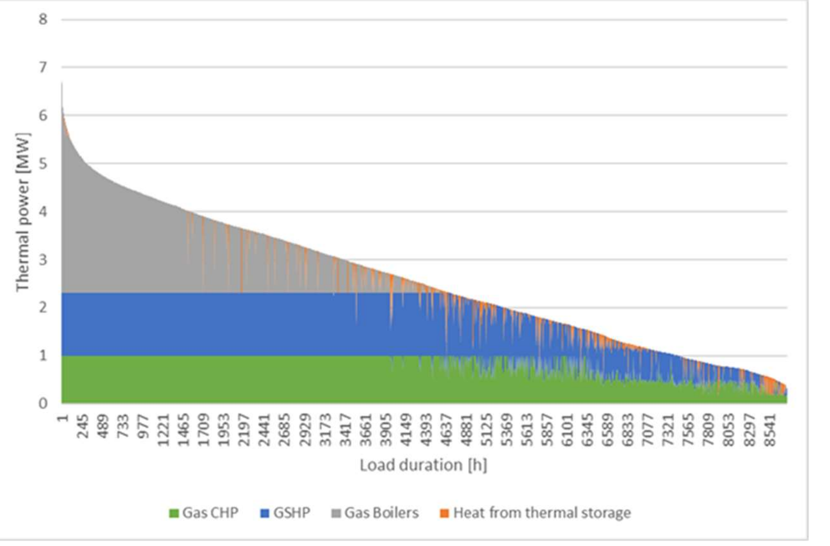


Figure 5-3 Load duration curve for the network with GSHP/CHP

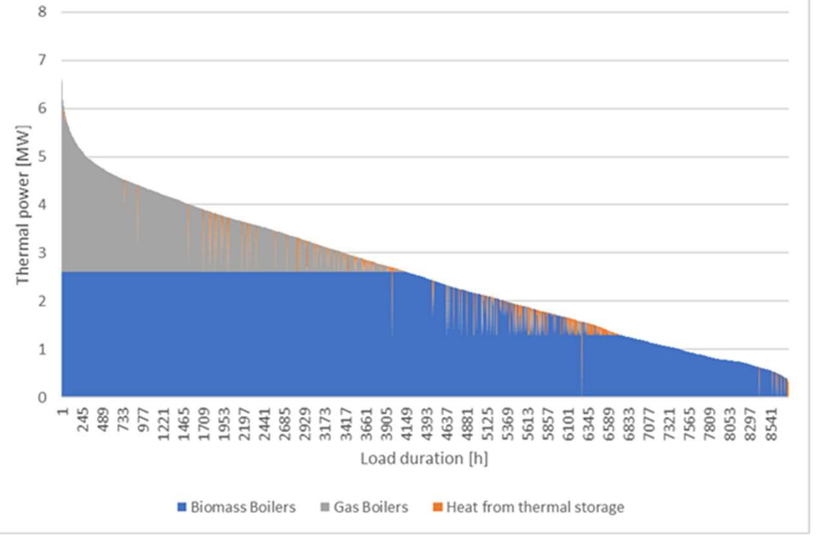


Figure 5-4 Load duration curve for the network with biomass boiler

Table 5-1 presents the summary of the plant supply capacities and energy production conclusions from the analysis for each network and supply option.

	Supply option:	Gas CHP + GSHP	Biomass Boilers
Supply capacity			
Ground source heat pumps	*kWth*	1,300	-
Gas CHP	*kWth*	1,000	-
Biomass boilers	*kWth*	-	2,600
Gas boilers	*kWth*	6,550	6,250
Thermal storage	*m³*	50	50
Heat production share			
Heat production	*MWh/yr*	22,588	22,588
GSHP	*MWh/yr*	9,382	-
	%	41.5 %	-
Gas CHP	*MWh/yr*	7,112	-
	%	31.5 %	-
Biomass boilers	*MWh/yr*	-	17,756
	%	-	78.6 %
Gas boilers	*MWh/yr*	6,095	4,833
	%	27.0 %	21.4 %
Gas consumption	*MWh/yr*	23,309	5,370
Electricity consumption (purchase)	*MWh/yr*	1	-
Biomass consumption	*MWh/yr*	-	20,889
CHP electricity			
CHP electricity production	*MWh/yr*	6,614	-
Consumed by EC site	*MWh/yr*	225	-
To GSHPs	*MWh/yr*	3,106	-
	%	46.9 %	-
To Private Wire	*MWh/yr*	2,806	-
	%	42.4 %	-
To grid	*MWh/yr*	478	-
	%	7.2 %	-
Biomass boilers	*kW_{th}*	-	-
Gas boilers	*kW_{th}*	6,540	6,020
Thermal store	*m^3*	-	100
Total heat production capacity	*kW_{th}*	6,840	6,840

Table 5-1. Heat production technologies capacities & energy production

5.4 Carbon performance

Carbon Dioxide emission savings have been estimated for the network options considered, against a counterfactual or 'business-as-usual' scenario based on existing energy consumption within each of the connected properties (largely gas boilers). See Appendix 6 for further details including the carbon factors used.

Figure 5-5 shows, graphically, the annual CO_2 savings against the counterfactual case, using projected carbon factors over a 40-year period. The variations beyond 2027 are principally a result of the projected changes in carbon factors. The biomass and heat pump schemes maintain emission savings throughout the calculation period, while the savings rates of Gas CHP options start to rapidly reduce over time as the grid electricity carbon factor diminishes.

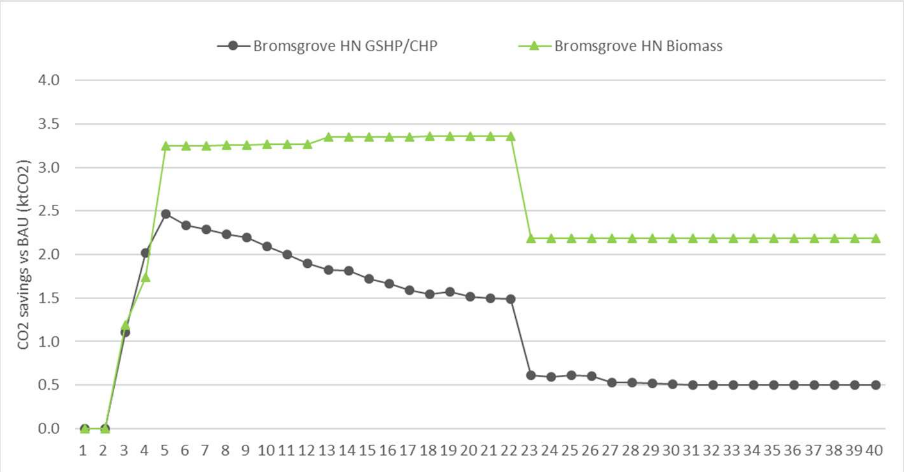


Figure 5-5. Variation of annual CO_2 emission savings vs. Business as Usual

As Table 5-2 shows, carbon emission reductions over a 25-year period, compared against the counterfactual case (accounting for BEIS projections of carbon factors) range from 32% to 61% and between 39,000 and 69,000 Tonnes.

The biomass option achieves the greatest carbon savings and the lowest cost per tonne of carbon saved. Combining the ground source heat pump system with gas CHP, which improves economic performance, constrains carbon performance.

Clearly, establishing the heat distribution infrastructure unlocks the possibility of using alternative lower carbon technology. For example, at the end of the useful life of the CHP plant (typically 12-15 years) this soculd be replaced with additional heat pump plant, biomass boilers or another technology such as a solar thermal ground array.

		GSHP/CHP	Biomass
	units		
CO_2 savings over 25 yr.	*$kTCO_2$*	38.7	69.1
CO_2 savings over 25 yr.	*%*	32.2 %	61.4 %
Cost of carbon saving (over 25 years)	*£/TCO_2*	£520	£222

Table 5-2. Carbon emission savings against business as usual

6 Economic Viability

Economic modelling has been conducted for each heat network option. The methodology and results are summarised in this section whilst the following appendices provide further detail: Appendix 7 (Detailed capital cost breakdowns); Appendix 8 (Energy tariff and other revenue assumptions); Appendix 9 (Operational cost assumptions) and Appendix 10 (Detailed financial modelling results).

6.1 Capital costs

Estimated capital costs (£20.1m for the GSHP/CHP hybrid option and £15.4m for the biomass boiler option) are illustrated in Figure 5-4 and summarised in Table 6-1. Appendix 7 provides detailed capital cost breakdowns for the heat network infrastructure and for the planned energy centre.

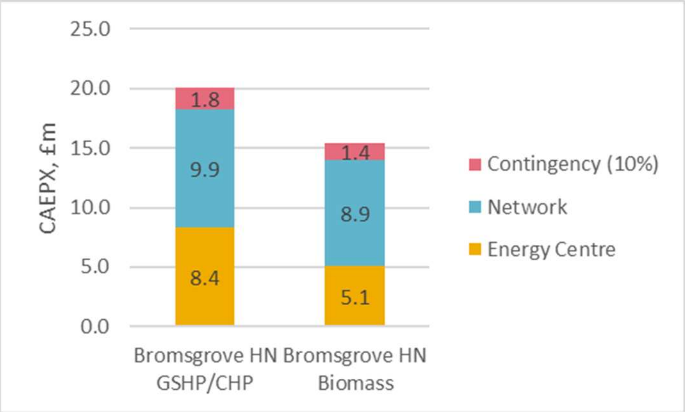


Figure 6-1 Summary of capital costs

Baseload supply technology		CHP + GSHP	Biomass Boilers
DH Network (steel)	£k	7,428	7,428
Heat substations, HIUs & metering		1,515	1,515
Private Wire network		942	0
Energy Centre		6,042	3,709
Utility connections (gas, power, water, drainage, telecoms)		447	107
Thermal Store		139	139
Development costs[9]		1,725	1,110
Contingency (10%)		1,824	1,401
Total capital costs	**£k**	**20,061**	**15,408**

Table 6-1. Capital cost summary (whole system)

6.2 Energy tariffs, other revenue and operating costs

In terms of revenues (or income) for the heat network, consumer tariffs are based on a 5% reduction of a calculated counterfactual cost, i.e. cost of the alternative energy supply solution (assumed to be building-level gas boilers in all properties and grid-supplied power).

Tariffs will vary between consumer types, with domestic consumers paying more (per unit of energy delivered) than commercial properties, as per counterfactual costs.

All heat and power sales prices to consumers are based on the consumers' counterfactual energy costs. Heat and power sales tariff components include a 5% discount to incentivise the consumers to connect to the heat network.

[9] *Including detailed engineering costs, professional fees, project management, and project development*

The heat sales tariff has been split into three components; unit rate for heat, annual maintenance cost, and annual replacement cost. The unit rate for heat is estimated based on counterfactual gas cost and applying the appropriate BEIS retail gas price projection in the cash flow model.

Boiler maintenance costs, life expectancy, and investment/replacement costs reflect the centralised gas boiler solution and are based on the Heat Trust Heat Cost Calculator and boiler manufacturer data.

A worked example for the calculation of the heat sales tariff for Bromsgrove School is presented below:

Unit rate for heat:

Unit rate for gas = 27.47 £/MWh
Assumed seasonal efficiency of gas boiler = 75 %
Unit rate for heat = 27.47 / 75 % = 34.80 £/MWh

Annual maintenance cost:

Assumed at 11 % of boiler investment = 11 % * 90 £/kW = 9.9 £/kW
Peak demand = 2,346 kW
Boiler capacity required (incl. reserve) = 2,346 kW * 1.5 = 3,519 kW
Cost of boiler maintenance per year = 3,519 kW * 9.9 £/kW = £34,838
Cost of boiler maintenance per MWh = £34,838 / 5,485 MWh = 6.35 £/MWh

Annual replacement cost:

Boiler capacity required (incl. reserve) = 3,519 kW
Cost of boilers = 3,519 kW * £90/kW = £367,710
Cost of boilers per year = £316,710 / 15 yrs = £21,114
Cost of boilers per MWh = £21,114 / 5,485 MWh = 3.85 £/MWh

Total cost of heat: 34.80 + 6.35 + 3.85 = 45.00 £/MWh

Heat tariffs are assumed to inflated in line with BEIS gas and electricity cost projections (as also used for heat network fuel costs).

Connection fees would also be levied against each property when it connects to the network and this is assumed to be a 5% reduction of the calculated counterfactual cost of installing gas boilers. On this basis, connection fees would vary based on the heat capacity required by each consumer.

Revenue is also assumed to be available from the Renewable Heat Incentive (RHI) for the renewable energy options (heat pumps), although it should be noted that the current RHI programme is due to close in Q1 2021 and a replacement or extension has yet to be proposed (a financial sensitivity has been modelled with the exclusion of RHI). The sensitivity analysis shown in section 2 shows the impact of having no RHI income. RHI contracts are available on a 20-year term, after which time no RHI income is assumed within the modelling.

Appendix 8 shows proposed tariffs/connection fees for each consumer or consumer type, along with estimated operating costs and RHI revenues.

Key operating costs assumptions are shown in Appendix 9, covering key issues such fuel/electricity costs (which are inflated based on BEIS projections), plant lifetimes (used to calculate replacement costs) and plant/equipment maintenance.

A summary of operational costs and revenues at full build-out is shown in Figure 6-2. Operational costs range from £1,188k for the GSHP/CHP hybrid option to £1,292 for the biomass boiler option.

Electricity cost for operation of heat pumps is effectively zero, as electricity (as modelled) is largely estimated to be largely supplied directly from the gas CHP plant.

Revenues range from £2,182k for the GSHP/CHP hybrid option and £1,761k for the biomass boilers option. Where the source of energy is renewable (GSHP or biomass), Renewable Heat Incentive (RHI) income is assumed although it should be noted that this is due to close to applications from April 2021. The sensitivity analysis shown in section 6.4 illustrates the worst-case impact where this income is not available (assumes the renewable energy technical systems are not re-sized to account for loss of this revenue).

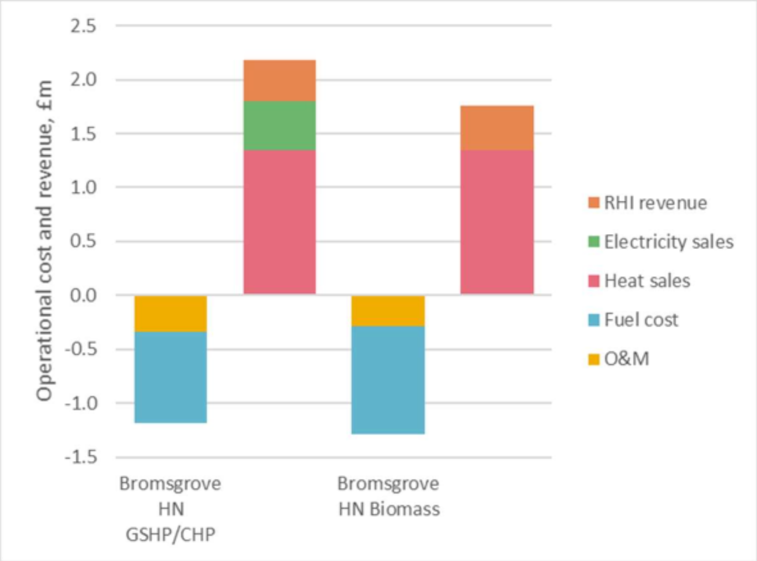


Figure 6-2 Summary or operational costs and revenues

6.3 Economic analysis

Economic analysis has been conducted with a bespoke discounted cashflow model covering time-periods of 25, 30 and 40 years, which recognises the long-term nature of heat network infrastructure. The model includes discrete versions for each network scenario (different baseload supply technology) and scenario-testing of key parameters.

Outputs from the modelling include a range of financial parameters including Internal Rate of Return (IRR) and Net Present Value (NPV). The results of the base-case economic model for a 25-year period are summarised in Figure 6-3, Figure 6-4 and Table 6-2, with carbon savings also shown (see section 5.4). Further detail is also shown in Appendix 10. Figure 6-5 also shows the discounted cash flow graphs on an annual basis, illustrating the positive balance of revenue and costs (accounting for the effect of discounting at 3.5%) throughout the period.

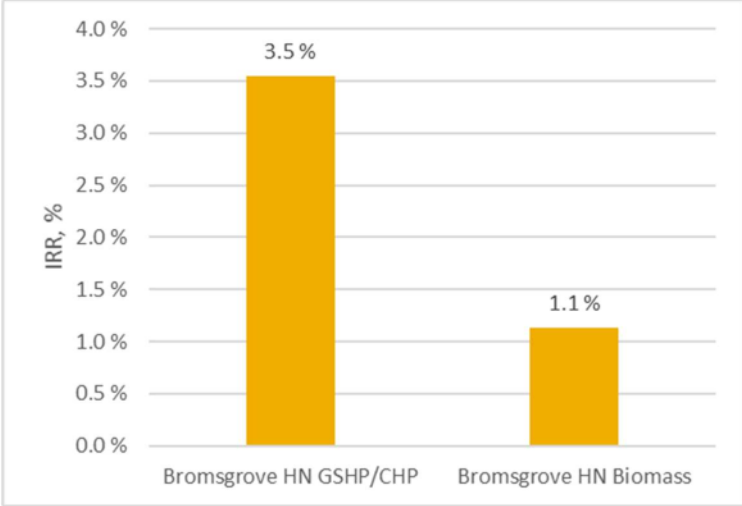


Figure 6-3. IRR (25 years)

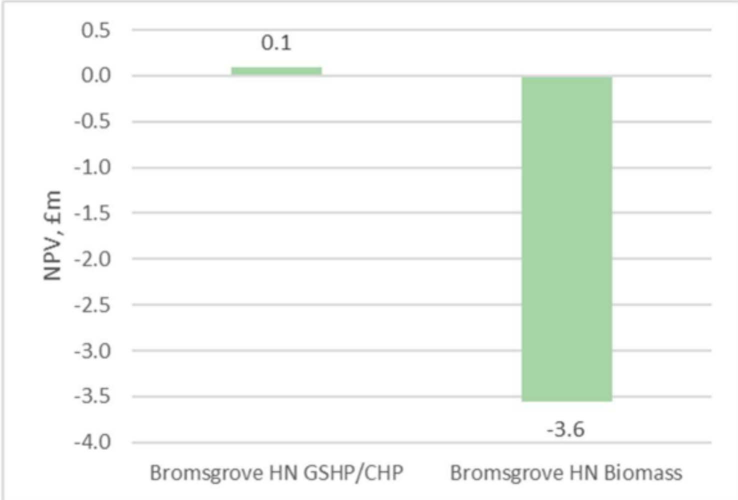


Figure 6-4. NPV (25 years @ 3.5 %)

	unit	GSHP/CHP	Biomass
Total CAPEX (full scheme)	£m	20.1	15.4
Total REPEX (full scheme)	£m	8.7	6.8
Total OPEX (full scheme)	£m/yr.	1.2	1.3
Annual revenue (full scheme)	£m/yr.	2.2	1.8
Gross margin (full scheme)	£m/yr.	1.0	0.5
Consumer heat tariff costs (full scheme[10])	£/MWh	57.5	57.5
Total connection fees	£m	2.4	2.4
NPV (25 yr @ 3.5 %)	£m	0.1	-3.6
IRR (25 yr)	%	3.5 %	1.1 %
Social IRR (25 yr)[11]	%	3.4 %	2.5 %
LCOE (25 yr)	£/MWh	75.8	90.2

Table 6-2. Economic modelling results.

In summary, the GSHP/CHP option achieves a Project IRR (25-year) of 3.5% (or 3.4% when accounting for social costs of climate change as per HM Treasury guidance). The biomass option is estimated to deliver a Project IRR (25-year) of 1.1%.

Potential variance of the economic performance is discussed in section 6.4, which explores sensitivities of key parameters and potential scheme changes that could impact performance, including external grant support.

[10] *Average across all consumers to the wider community and society as a whole. The calculation includes net impact on heating costs, carbon emissions and air quality.*

[11] *Social IRR accounts for impacts accrued to the heat network operator and those connected to the networks, as well as*

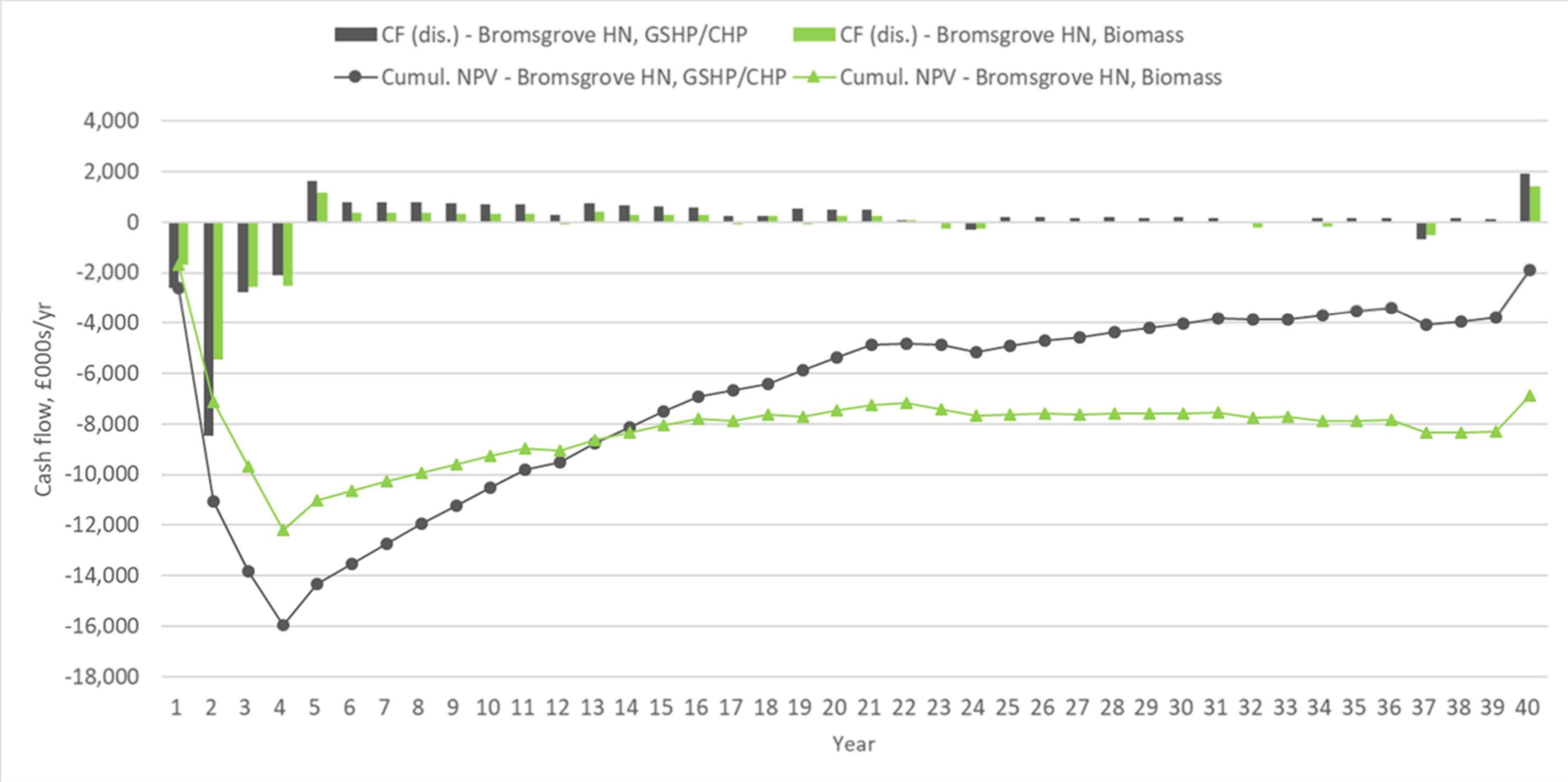


Figure 6-5. Discounted cash flow graphs for Bromsgrove heat network options.

6.4 Potential variations to economic performance

It is important to recognise at this stage of project development, a number of conservative assumptions have been used to counter optimism-bias, meaning it is possible that improvements in economic performance are possible after further investigation / design development. Equally, there are multiple parameters that could worsen economic performance. In both cases, changes could happen simultaneously to compound impact on economic performance.

Further investigation/refinement could deliver improvement in economic performance, for example:

1. **Adding additional consumers** along the proposed network routes. This would improve heat load density and essentially increase revenues with limited additional costs. To achieve this will require both securing the existing consumers (ultimately resulting in contract arrangements) and implementing a campaign to recruit additional consumer so far unidentified. Clearly, this would be made easier if the project moves beyond feasibility and stakeholders promote it.
2. **Value engineering and design optimisation**. Incremental improvements to the proposed systems may yield cost savings such that budget tolerances and contingency can be removed. This covers both capital and project development costs, which are not insignificant. Technical improvements may also boost performance (3°C delta T currently assumed), e.g. increased energy yield from boreholes and reduced heat losses from lower temperature operation and use of more efficient technology
3. Securing **lower operating costs**, particularly the purchase of fuels/electricity which is largely a function on market pricing but is also balanced by influencing consumer tariffs (assumed to be linked to gas price)
4. **Increasing tariffs and connection costs**. Presently these costs are notionally discounted (by 5%) against for all consumers against estimated counterfactual costs. This discount be lost, but it could be reasonable to increase cost to account for the added-value of a heat network being a 'service' offering (removing on-site liabilities for building operators), and, also to acknowledge the social value of the scheme (addressing climate change, mitigating future energy costs increases, addressing fuel poverty and localising energy supply)

Numerous risks are also present that could worsen economic performance:

1. **Losing anticipated consumers / reducing heat load** density (may be mitigated by adapting the project design, e.g. adjusting network routes and re-sizing infrastructure and supply plant, where possible). Associated with this is the need to verify demand data which in some cases is estimated at this stage.
2. **Increasing capital costs** as unknown/uncertain cost issues become apparent, for example:
    a. increase in borehole construction costs and infrastructure construction
    b. addition of property conversion cost such as switching from electrically heated flats – presently this is assumed to site with building operators / owners
3. **Higher operating costs**, particularly the purchase of fuels/electricity which is largely a function on market pricing but is also balanced by influencing consumer tariffs (assumed to be linked to gas price)
4. **Decreased tariffs and consumer connection fees**, for example, where further discounting is necessary to secure consumers
5. **Loss of RHI income.** This is plausible since the current programme is due to close in Q1 2021 and no replacement has been announced by government.

Sensitivities of key parameters have been analysed in the base-case economic model and are shown graphically in Figure 6-6 and Figure 6-7.

Key findings (in order of impact):

- **Change in capital costs (capex)** will have a material impact. A 30% change (up or down) results in an IRR change to between +6% and 2.0% (above 3% and 0% for biomass).

- **Energy demand** is the most significant independent factor. This reinforces the need to secure anticipated and additional consumers. A 30% increase in heat consumption takes Project IRR for GSHP/CHP option to above 5% (2% for biomass). Reducing consumption by the same percentage result in the IRRs of near to 1% and 0% respectively.
- **Fuel prices** will have a material impact with a limited ±1% variation in the IRR for gas in the GSHP/CHP option (nb. gas is primary fuel source since gas-fired CHP provides the primary power demand). Within the biomass supply option (which uses both gas and biomass) change in gas and biomass prices have a significant impact at circa ±2% in IRR. NB. The modelling incorporates BEIS forecasted increases for gas and electricity prices and the Biomass price has been assumed to inflate based on Bank of England 2% CPI target (in the absence of the BEIS price projections).
- The impact of **consumer heat sales tariffs** on its own sees significant change in IRR with a ±2.5 percentage-point variation. A large (±30%) change has been assessed. The assumed link between heat sales tariffs and fuel costs will, in practice, mitigate this impact.
- **Loss of RHI** has a significant impact on both options the GSHP/CHP option to 1% IRR and the -2% IRR for the biomass option options, with IRRs reducing by 2-3%.
- **Private wire electricity sales tariffs** affect the IRR significantly in the gas CHP powered network options. A small shift of +/- 5% to the tariff is tested and this has a marginal impact to IRR.
- The inclusion of **flat conversion costs** in the capital costs of the heat network reduces IRR in both options by approximately 1% (IRR). In the base economic model it is assumed that the cost associated to installing internal pipework/radiators (the flat conversion cost) in dwellings that currently use electrical heating is met by properties owners.
- Adding the estimated additional cost of £1.2m for **GSHP boreholes lining** (see notes on borehole design) has a marginal impact of reducing IRR by less than 1% (GSHP/CHP options only)

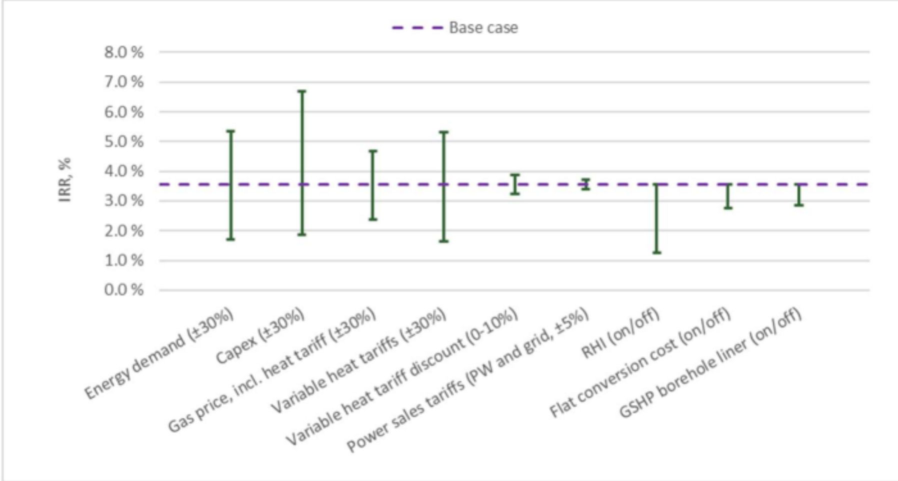


Figure 6-6. Investment return sensitivities – GSHP/Gas CHP hybrid

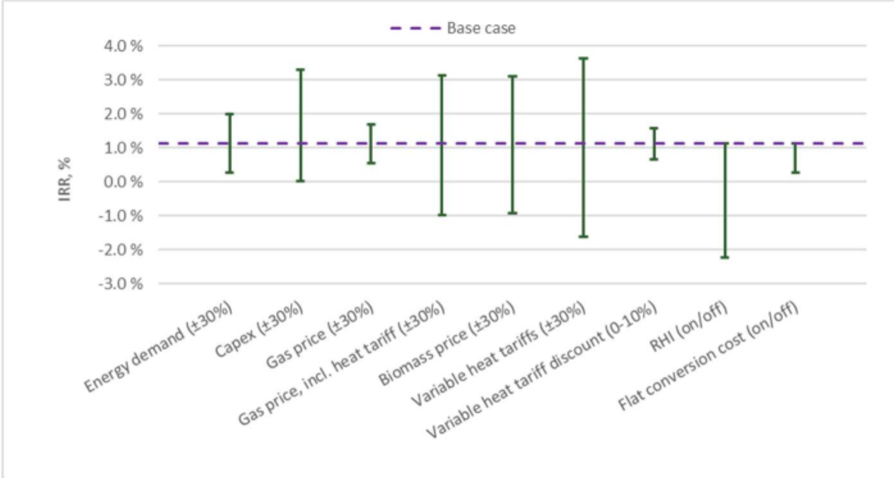


Figure 6-7. Investment return sensitivities – Biomass boilers

6.4.1 Grant contributions

As shown in the cash flow graphs (Figure 6-5) for both options there is an upward cashflow trajectory; revenues exceed operating costs. Hence, in the modelled base case, if initial capital costs are reduced through grant contributions (or costs reduction) either option could be profitable. Depending on the level of grant contributions specific rates of return could be targeted to fit with funder investment return requirements. These requirements will vary depending on the development model/ownership structure used and the aggregated cost of capital. For a solely publicly funded scheme, this might be as low as 3-5%. A solely privately funded scheme is likely to need upwards of 10%. A public-private joint venture with blended investment is therefore likely to need a return between these figures.

Grant (or soft loan support) is available from numerous sources including the Heat Network Investment Project which launched in February 2019 and is intended to provide gap-funding for heat network projects, ECO 3 programme (e.g. social housing connections) and EU Funds (e.g. through the LEP). Each source will apply different conditions and will have spending constraints, e.g. State Aid rules (restricting the overall percentage of public funding) and restrictions on combining with other sources of revenue, such as Renewable Heat Incentive. In respect of the Heat Network Investment Project, it is anticipated that the Bromsgrove scheme could present a case against its core objectives:

- Scale: the project intends to connect a large number of consumers across a dense urban area with potential for expansion
- Deliverability: whilst there are project risks (as with all heat network schemes) the network, based on evidence to date, is considered deliverable
- Carbon: use of ground sourced energy or biomass is estimated to deliver significant carbon savings

As designed, both projects would be able to achieve the HNIP low carbon technology energy supply percentage of 50% as dictated by the European Energy Efficiency Directive. The GSHP / CHP option is estimated to deliver 73% of supplied energy from the two technologies and biomass is estimated to deliver 79%.

Table 6-3 indicates the level of non-repayable grant funding that would be required (assuming no other economic improvements are achieved) to achieving project returns (IRR-25yr) of 5%, 7% or 10%, which, are used as short-hand to represent cost/thresholds:

- Typical local authority investment threshold: 5%
- Public-private joint ventures: 7%
- Private: above 10%

Assuming a 50% limit for grant support[12] Table 6-3 shows that both options could achieve returns likely to be suitable for commercial investment (10% IRR).

As the best performing option, the GSHP/CHP option requires less grant support. It would require between a minimum of £2.6m (13% of capital costs) to achieve the public funding threshold, and, £7m (35% of capital costs) to achieve the private funding threshold.

The biomass option would require between a minimum of £5m (32% of capital costs) to achieve the public funding threshold, and, £7m (45% of capital costs) to achieve the private funding threshold.

		GSHP/ CHP	Biomass
IRR 5.0 %	£m	2.6	4.9
	% capex	12.7 %	32.0 %
IRR 7.0 %	£m	5.0	6.1
	% capex	24.7 %	39.5 %
IRR 10.0 %	£m	7.0	6.9
	% capex	35.1 %	45.1 %

Table 6-3. Grant contribution required to achieve specific Project IRRs.

[12] *Assumed threshold for HNIP funding due to state-aid rules.*

7 Conclusions & next steps

This report presents the analysis conducted to develop and test an optimised heat network solution for Bromsgrove, building on earlier investigations into two discrete schemes.

This heat network solution developed would connect a number of consumers, including public buildings, offices, schools, and, residential properties, supplying heat and/or power from a centralised energy centre, utilising low carbon energy systems. Notable consumers include Bromsgrove School, Princess of Wales Community Hospital, council properties, and, two leisure centres.

Ground source heat pumps, utilising groundwater extracted through a borehole array and combined with gas CHP is the preferred primary supply solution. Biomass boilers would be a fallback option. The following table summarises these two options.

	GSHP/CHP	Biomass
Economic performance	Good (considered fundable)	Marginal (considered fundable)
Carbon performance	Good. Improved if gas CHP is excluded	Very good
Environmental performance (non-carbon)	Low impact operation. Presents risk of marginal increase in localised (and town-wide) emissions to air, which can be reduce by exclusion of gas CHP.	Change in localised / town-air air emissions due to switch for property-level boiler to centralised energy centre. Particulate emissions will require further examination/mitigation measures Results in additional road transport to deliver fuel to site
Delivery risk	High: requires 'proving' of borehole array.	Medium: requires addressing risks around air emission and the fuel delivery

There are a range of economic, environmental and social benefits that would be derived from the project, including:

1. A general 5% reduction in consumer energy costs (the basis for revenue modelling)
2. Operational benefits for property owners/operators, including reduced plant liability and releasing property floor space
3. Reduction in carbon emissions[13] between 32% (GSHP/CHP hybrid) and 61% (biomass) for connected properties. Over a 25 year period this

[13] *Calculated of the first 25 years of the project*

would equate to the following carbon savings: 39,000 TCO_2 (GSHP / CHP hybrid option) and 69,000 TCO_2 (biomass option)

4. Ability to deliver deep and sustained carbon reduction for the town through further expansion and incorporating other lower carbon technologies in future. Delivering decarbonisation of heat would be difficult to achieve in the town, at scale, through alternative measures
5. Inward investment into the town of between £15.5m to £20m (construction costs) with consequent short term employment of construction staff
6. Training and the educational support opportunities for development staff and students, e.g. Bromsgrove School and HOW college
7. Development of a local energy generation / supply entity which could be fully or partially publicly owned. The entity would develop and operate the heat network, employing staff, returning business rates and supporting other energy initiatives
8. Reputation benefits for the town, local authority and other stakeholders
9. Encourage commercial/residential tenant retention in the town (due to the consumer and reputation benefits)

The techno-economic analysis shows a marginal economic performance for the GSHP / CHP hybrid option with a 3.5 % IRR (25-year) for the base case, with a worse result for the biomass option at 1.1%. Both demonstrate improvement on the initial results (for the split town centre Bromsgrove School heat networks).

Whilst there are potential opportunities to improve economic performance there are also risks to it. As such, it is anticipated that grant support, notably from HNIP, will be required if the project is to proceed. For the GSHP / CHP hybrid option £2.6m grant would be required to achieve 5% IRR, £5m for a 7% IRR and £7m for a 10% IRR.

It is anticipated that these values would fall below state-aid constraints and that the project, in principal, could be structured as a publicly or privately funded project (or a combination). This project structuring options have not been explored and this would need to be considered in any further work.

In principal, it is considered that the project could be supported by HNIP, but it should be noted that this is an open and competitive process and is time-limited.

It is Greenfield's recommendation that the council seeks executive and member support to take the project forward, focusing GSHP/CHP hybrid option, with the biomass solution as a fall-back.

If the council is able and willing to pursue the project and the key stakeholders (particularly Bromsgrove School) are supportive then it is recommended that that the project is moved on to a Detailed Project Development (DPD) or commercialisation phase. This could be part-funded by HNDU, BEIS under a similar arrangement that has supported this investigation. DPD would involve developing a detailed business case, investment strategy, review and resolve key legal, resolve key technical and risk issues (see revised risk register Appendix 11), and, initiate commercial actions, such resolving governance/ownership arrangements, fund-raising, and, procurement.

Aside from commercial and legal issues the following issues will need further consideration to address the key risks and opportunities:

10. Seek council executive and member sign-off for the specific recommendations to proceed, including any resource requirements and establishment of efficient decision-making and project governance (including establishment of a Project Board with senior representation).
11. Establish internal arrangements and necessary resources (financial and expertise) for effective project management (funding may be available from HNDU, BEIS)
12. Secure Bromsgrove School's support for the project (as a key consumer and host of the proposed energy centre), e.g. through a Memorandum of Understanding. In addition, certainty over consumption data should be improved.
13. Secure other key consumers including schools, council properties, leisure centre and the hospital, e.g. through signing of Memoranda of Understanding, and further understand any connection timing issues. In addition, certainty over consumption data should be improved for all assumed consumers.
14. Consider the the connection of the coucils development on Burcot Road. The imminent delivery of this development is at odds with the schedule of the a heat network scheme. Howevre, if the scheme proceeds prior to

heat network being available, a retrofit connection should be considered and the properties should be designed to enable this. On a broader point the council should consider wheter other future development could be connected to the proposed heat network or that independent network are considered for these.

15. Identify and engage with additional prospective consumers, to address the risks around losing assumed consumers, through local promotion of the project and direct engagement.
16. Further examine the GSHP borehole design and costing.
17. 'Prove' network route, by investigating highways and existing underground service constraints.
18. Explore eligibility and timing issues for HNIP funding.
19.

Appendices

Appendix 1. Energy mapping

Appendix 2. Prospective consumers

Appendix 3. Heat network infrastructure – general notes

Appendix 4. Heat network design parameters, pipe sizes and capital costs

Appendix 5. Preliminary Energy Centre layout and flow diagrams

Appendix 6. Carbon reduction analysis

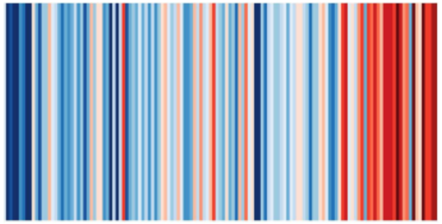
Appendix 7. Capital costs (whole system)

Appendix 8. Operational cost assumptions

Appendix 9. Revenue assumptions

Appendix 10. Detailed financial modelling results

Appendix 11. Initial risk register



Annual UK temperatures 1884-2018

GREENFIELD

Electric Works, Sheffield Digital Campus, Sheffield, S1 2BJ
info@greenfieldgroup.co +44 7789248432