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Bromsgrove Heat Network Feasibility

Final report – Appendices

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The information provided in this report is for general information only and should not be relied on to inform investment decisions or technical design specifications.

It is not intended that the content and analysis in this report should be relied upon as the basis for commercial bids; bidders are expected to carry out their own due diligence and form their own technical and commercial solutions.

Table of contents

Appendix 1. Energy mapping

Heat mapping methodology

The heat mapping is conducted by utilizing data from various sources including:

- Primary consumption data for existing consumers, where it was made available by stakeholders.
- Filed EPC and DEC records
- Planning information
- Open source information (e.g. Google Maps)

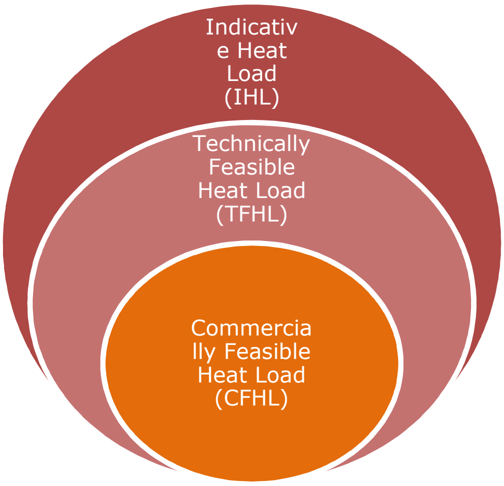
Primary consumption data and details on building energy systems were collected using data collection sheets where the consumer filled out details of their consumption and

Additional demands were identified in the area by engagement with the local authority. Where actual metered data or filed EPC and DEC records were not available, benchmarking analysis was used to estimate heat, electricity and cooling loads. The benchmarking methodology is described in the sections below.

Identifying appropriate loads

The figure below illustrates the various classifications of the energy load assessments that are used. Typically, the first, Indicative Heat Load (IHL) is determined from current energy use to provide heat, e.g. gas used in a boiler to provide heat. Where available, actual consumption information is used to determine the heat load. If actual consumption information is not available, then benchmarking is conducted, or where this is not possible, then other secondary data such as data from Energy Performance Certificates (EPCs) or Display Energy Certificates (DECs) could be used. Benchmarking and use of secondary data brings inaccuracies and uncertainty, and so metered data is always preferable but is frequently unavailable, particularly during early-stage investigations.

The second classification is Technically Feasible Heat Load (TFHL) which is arrived at by adjusting IHL to account for non-displaceable loads, i.e. those that cannot be substituted by a heat network using hot water. Reasons could include that energy is required in the form of steam or at temperatures that are unsuited to a hot water network. At an early stage of analysis, this level of detail would typically only be considered for major consumers.



The final classification is Commercially Feasible Heat Load (CFHL), which is determined by excluding those loads for which supply from a heat network supply is unlikely to be commercially viable, e.g. an existing low-cost supply is available, or the cost of the transmission pipework required would be excessive. Commercial issues might also include phasing of the replacement of existing plant, the relative cost of connection, the loss of other potential revenues, e.g. from power generation where local CHP is being considered. CFHL is the thermal load that would ideally be modelled to determine the overall load required within a heat network. It is not always possible, for all prospective consumers, particularly at early stages of feasibility, to arrive at reasonable estimates for CFHL and this can subsequently be dealt with through risk and sensitivity analyses.

The methodologies used to analyse the heat loads of different building categories are presented in the following sections.

Existing buildings

Metered consumption

Where available, actual consumption information is used to determine the heat load. Actual consumption data varies from half-hourly/hourly, monthly or annual level data.

The consumption data, typically gas consumption data, was used to calculate the heat demand under the assumption of thermal efficiency of 80% for traditional Heat-Only-Boiler (HOB) systems across the whole data set.

If the consumption data was available at monthly or annual level, the data was time-profiled against assumed building occupation hours and heating degree days, to arrive at hourly consumption profiles.

Benchmarking

Annual consumption for all energy consumption is estimated through benchmarks based on property use, type of building, estimated internal floor area and number of dwellings. In order to reflect the energy performance of modern buildings, where applicable, good practice values from published benchmarks such as BEES and NEED for existing properties. Benchmark assessments are weather-corrected against local degree-days to match the number of annual heating degree days in the local area.

The BEES benchmarks define heating, hot water, cooling and electricity demands. NEED benchmarks define gas and electricity consumption per dwelling (the data can be sorted to by e.g. property type and property age). A typical boiler efficiency of 80% is then applied to arrive at a heat consumption estimate.

Annual heating demand was then also time-profiled against assumed building occupation hours and heating degree days based on external temperature variations in the local area. For occupied periods a heating degree day reference temperature of 15.5°C is assumed and during unoccupied hours 10.5°C. The analysis is used to generate estimated peak demands and consumption profiles for hot water and heating.

Hourly electricity demand is generally calculated by allocating standard winter (October-April) and summer (May-September) billing profiles for non-domestic buildings to the annual consumption data. Where electricity consumption demand profiles for a particular type of building is available then these were applied.

New development

Future energy demand has been estimated and profiled (on an hourly basis) for new development. A variety of planning, master planning and design-stage information has been used. The methodology for the analysis is as follows:

1. Sites have been split out into the different building use types (space types), so that each consumption type may be modelled separately.
2. Energy consumption benchmarks have been applied to each space type, using an appropriate benchmark. This calculation is done within an in-house energy demand modelling tool.
3. The total heat and electricity demand for the site are then mapped onto an hourly energy demand profile, using an energy profiling tool which incorporates energy demand profiles for different use types.
4. The total demand and demand profiles have been adjusted to account for degree day variations.

The following energy consumption benchmarks have been utilised:

1. BEES benchmark data was used to model the energy demand of the commercial use areas.
2. Building Regulations 2013 standards were applied to model benchmark data used to examine residential development.
3. NEED provides primary heat benchmarks for dwellings. A boiler efficiency of 80% was assumed to convert this figure into heat demand.
4. Existing hourly energy demand profiles have been used based on space type.
5. Heating benchmarks were adjusted according to any variation in Degree Days between the site and the UK average. A base temperature of 15.5^{o}C was assumed for heating.

Appendix 2. Prospective consumers

Map no	Site	Type	Agent	Peak Heat (MW)	Heat Load (MWh)	Power Load (MWh)	Source	Connection year	Notes
1	Princess of Wales Community Hospital and other HACW buildings	Hospital	NHS	0.77	2,317	-	Actual bills	3	
2	Asda Bromsgrove	Retail	ASDA	0.64	1,137	-	Metered data	11	
3	HOW College - Bromsgrove Campus	Education	HOW College	0.52	870	-	Metered data	3	
4	North Bromsgrove High School	Education	BAM PPP	0.34	590	-	Actual bills	3	
5	Burcot Lane low-rise flats, BDHT	Residential (BDHT)	BDHT	0.32	584	-	NEED	3	
6	Parkside Civic Centre	Council	Council	0.28	474	-	Actual bills	2	
7	Windsor Gardens sheltered housing, BDHT	Residential (BDHT)	BDHT	0.25	401	-	NEED	2	
8	Breme Residential Care Home	Care Home	Sanctuary Housing	0.13	365	-	BEES	2	
9	Bilberry Place Retirement Living	Residential (Private)	McCarthy and Stone	0.12	353	-	BEES	2	
10	Housman Park retirement housing	Residential (Private)	Amica Care	0.12	347	-	BEES	3	
11	Meadows First School	Education	BAM PPP	0.17	285	-	Actual bills	2	
12	Parkside Middle School (County)	Education	BAM PPP	0.16	264	-	Metered data	2	

Map no	Site	Type	Agent	Peak Heat (MW)	Heat Load (MWh)	Power Load (MWh)	Source	Connection year	Notes
13	Life After Stroke Centre	Charity Offices	Stroke Association	0.17	213	-	NEED	11	
14	Maple House, Bromsgrove School junior (independent)	Residential		0.17	201	-	NEED	3	
15	Shenstone Court, BDHT	Residential (BDHT)	BDHT	0.17	201	-	NEED	3	
16	Housman Court Care Home	Care Home	Amica Care	0.06	182	-	BEES	3	
17	7 School Drive Care Home (Dimensions UK)	Care Home	Dimensions UK	0.15	170	-	NEED	3	
18	Wendron Centre (Bromsgrove Day Services)	Council	Council	0.09	156	-	Metered data	2	
19	Brook Court	Residential (Private)	Kingsdale	0.14	146	-	NEED	3	
20	Bromsgrove Methodist Centre	Church	Bromsgrove Methodist Church	0.08	144	-	BEES	2	
21	Parkside Court (previously BDHT housing for older people)	Residential (BDHT)	BDHT	0.12	109	-	NEED	2	
22	Artrix Theatre	Leased from Council	Artrix	0.06	98	-	Actual bills	3	
23	Blue Light Centre	Government buildings	Place Partnershio	0.03	88	-	Metered data	3	
24	South Bromsgrove High School	Education	BAM PPP	0.25	436	643	Actual bills	1	
25	1 Conway Road	Resi - Detached	Bromsgrove School	0.01	24	6	Metered data	1	Updated consumption data

Map no	Site	Type	Agent	Peak Heat (MW)	Heat Load (MWh)	Power Load (MWh)	Source	Connection year	Notes
26	12 Conway Road	Resi - Mid-terrace	Bromsgrove School	0.01	20	2	Metered data	1	Updated consumption data
27	Cobham - (Prep. School)	Education	Bromsgrove School	0.32	758	418	Metered data	1	Updated consumption data
28	Academic - ADT Block	Education	Bromsgrove School	0.04	85	40	Metered data	1	Updated consumption data
29	Academic - Humanities Block	Education	Bromsgrove School	0.04	104	865	Metered data	1	Updated consumption data
30	Academic - School Library	Education	Bromsgrove School	0.00	-	202	Metered data	1	Updated consumption data
31	Academic - Science Labs	Education	Bromsgrove School	0.12	290	68	Metered data	1	Updated consumption data
32	Boarding - Elmshurst	Resi - p.b. flat	Bromsgrove School	0.31	706	-	Metered data	1	Updated consumption data
33	Boarding - Mary Windsor	Resi - p.b. flat	Bromsgrove School	0.01	30	68	Metered data	1	Updated consumption data
34	Boarding - Page House (Prep. School)	Resi - p.b. flat	Bromsgrove School	0.11	256	11	Metered data	1	Updated consumption data
35	Boarding - Wendron Gordon House	Resi - p.b. flat	Bromsgrove School	0.04	83	338	Metered data	1	Updated consumption data
36	Bromsgrove School - 18 Conway Road	Resi - Mid-terrace	Bromsgrove School	0.02	42	-	Metered data	1	Updated consumption data
37	Bromsgrove School - Lyttleton House	Education	Bromsgrove School	0.14	320	-	Metered data	1	Updated consumption data
38	Bromsgrove School - Millington	Education	Bromsgrove School	0.05	114	-	Metered data	1	Updated consumption data

Map no	Site	Type	Agent	Peak Heat (MW)	Heat Load (MWh)	Power Load (MWh)	Source	Connection year	Notes
39	Bromsgrove School - Music / Routh Concert Hall	Education	Bromsgrove School	0.03	75	162	Metered data	1	Updated consumption data
40	Bromsgrove School - Oakley	Education	Bromsgrove School	0.01	25	-	Metered data	1	Updated consumption data
41	Bromsgrove School - School House	Education	Bromsgrove School	0.17	408	-	Metered data	1	Updated consumption data
42	Bromsgrove School - Thomas Cookes/Hazledene	Education	Bromsgrove School	0.10	244	-	Metered data	1	Updated consumption data
43	Bromsgrove School - Webber House	Education	Bromsgrove School	0.01	19	-	Metered data	1	Updated consumption data
44	Dayhouse - 6 Conway Road	Resi - Mid-terrace	Bromsgrove School	0.01	20	4	Metered data	1	Updated consumption data
45	Dayhouse - 8 Conway Road	Resi - Mid-terrace	Bromsgrove School	0.01	30	7	Metered data	1	Updated consumption data
46	Dining Hall (Bromsgrove)	Education	Bromsgrove School	0.25	587	491	Metered data	1	Updated consumption data
47	Pastoral - Health Centre (Bromsgrove)	Education	Bromsgrove School	0.01	15	11	Metered data	1	Updated consumption data
48	Pastoral - The Chapel (Bromsgrove)	Education	Bromsgrove School	0.00	-	75	Metered data	1	Updated consumption data
49	Police Station	Education	Bromsgrove School	0.09	213	68	Metered data	1	Updated consumption data
50	Sports - Sports Hall (Bromsgrove)	Education	Bromsgrove School	0.45	1,066	58	Metered data	1	Updated consumption data
51	Staff - 171 Worcester Road	Resi - Detached	Bromsgrove School	0.01	11	3	Metered data	1	Updated consumption data

Map no	Site	Type	Agent	Peak Heat (MW)	Heat Load (MWh)	Power Load (MWh)	Source	Connection year	Notes
52	Staff - 1a Conway Road	Resi - Mid-terrace	Bromsgrove School	0.01	19	7	Metered data	1	Updated consumption data
53	Staff - 20 Conway Road	Resi - Mid-terrace	Bromsgrove School	0.00	8	1	Metered data	1	Updated consumption data
54	Staff - 22 Conway Road	Resi - Mid-terrace	Bromsgrove School	0.01	16	2	Metered data	1	Updated consumption data
55	Staff - 26 Conway Road	Resi - End-terrace	Bromsgrove School	0.01	14	4	Metered data	1	Updated consumption data
56	Staff - 5 Conway Road	Resi - Detached	Bromsgrove School	0.02	39	6	Metered data	1	Updated consumption data
57	Staff - 7 Conway Road - Thatcholme (Headmasters House)	Resi - Detached	Bromsgrove School	0.03	76	11	Metered data	1	Updated consumption data
58	Walters house	Education	Bromsgrove School	0.02	46	16	Metered data	1	Updated consumption data
59	Bromsgrove Sports and Leisure Centre	Leisure Centre	Everyone Active	0.42	1193	-	Metered data (inc. CHP) - CHP portion excluded	3	Included without CHP consumption, CHP 25 kWe
60	David Lloyd Bromsgrove	Leisure Centre	David Lloyd	0.56	699	-	Metered data + CHP modelling	3	Included without CHP consumption, CHP 125 kWe
61	Chandler Court Care Home	Care Home	Care UK	0.09	123	-	Metered data + CHP modelling	2	Included without CHP consumption, CHP capacity unknown, modelled as 14 kWe
62	Westminster Court	Resi - p.b. flat	First Port	0.11	91	-	BEES	2	New consumer

Map no	Site	Type	Agent	Peak Heat (MW)	Heat Load (MWh)	Power Load (MWh)	Source	Connection year	Notes
63	Cypress Court (prev. Cypress House)	Resi - p.b. flat	First Port	0.17	207	-	NEED	2	New consumer
64	Alten Court 19 New Road (flats)	Resi - p.b. flat	Private	0.06	156	-	NEED	2	New consumer
65	Guardian Court, New Road	Resi - p.b. flat	Anchor HA	0.04	97	-	BEES	2	New consumer
66	Lupton Court, New Road	Resi - p.b. flat	Private	0.19	255	-	NEED	2	New consumer
67	Sunningdale, 28 New Rd (flats)	Resi - p.b. flat	Private	0.02	47	-	NEED	2	New consumer
68	Raglan Court, New Rd (flats)	Resi - p.b. flat	Private	0.04	96	-	NEED	2	New consumer
69	Fernleigh, New Rd	Resi - p.b. flat	Private	0.04	100	-	NEED	2	New consumer
70	Nailers Court, Ednall Lane	Resi - p.b. flat	Private	0.24	377	-	BEES	2	New consumer
TOTAL				**9.73**	**19,334**	**3,587**			

Schedule of excluded consumers

Site	Type	Notes
Old Council House/Burcot Lane: council-owned redevelopment site	Development (residential)	Excluded from WP2 due to construction timing being incompatible with heat network build-out.
Windsor St private development site	Development (residential)	Developer confirmed that they intended to take a conventional approach with resistive electrical heating
Bromsgrove Healthcare Innovations (BHI) Parkside	Clinic	Biomass boiler, recently installed
Lowes Court retirement housing	Residential (BDHT)	Location
Birmingham Road Retail Park	Retail	No consumer interest
Aldi Birmingham Road	Retail	Uses heat recovery
Wayside Care Home	Care Home	Location
Phebe Bell Court retirement housing	Residential (private)	Scale & location
Churchfields Court, Spires View	Residential (private)	Location
Kathleen Fields Court retirement housing	Residential (private)	Scale & location
Bryson Place	Residential (private)	Recently built
St. James Court retirement housing	Residential (private)	Location
1-5 Exmoor Drive Care Home	Care Home	Scale & location
Iceland Bromsgrove	Retail	Scale
Amphlett Hall	Council	Scale
The Victoria Ground	Leisure	Scale
New Road Doctors Surgery	Clinic	Location
Ryland Centre (Sandwell Leisure Trust)	Leisure	Location

Appendix 3. Heat network infrastructure – general notes

Included in appendix: Heat network pipework; Trenches; Testing and commissioning of pipe welds; Valves and valve chambers; Routing Principles and Key Constraints; Heat Interface Units (HIUs); Electrical network

Heat network pipework

It is assumed the network would constructed with pre-insulate steel pipework. The pipe assemblies will consist of a steel service pipe, rigid polyurethane foam insulation and an outer casing of polyethylene. The pipe assembly would also include the following additional elements: measuring wires, spacers and diffusion barriers. Measuring wires are used to monitor moisture inside the polyurethane insulation to predict corrosion. An upper limit for thermal conductivity is typically set at 0.033W/mK but modern applications often reach a level of 0.026-0.029 W/mK.

The steel heat network is typically designed to withstand a maximum operating temperature of ≤120 °C (flow), however, 90 °C is rarely exceeded and flow will typically vary between 80-85°C most of the year. The standard maximum nominal design pressure for the pipes is 16 bar or 25 bar (typically shown as PN16 or PN25). Actual pressure level will typically vary between 5-10 bar (including static and dynamic pressure), depending on operating conditions in the network.

Recommended pipe material for the underground DH pipeline is carbon steel P235GH for pressure level of PN 16 and for the pipe dimensions less than DN 500. P265GH is recommended for PN 25 (typically used in deep underground tunnels or areas with large topographic differences) and where pipe diameters are greater than DN 500.

DH circulation water is de-mineralised water with oxygen removal; hydrazine (oxygen removal chemical) is fed into the DH network to prevent corrosion.

Properties of pre-insulated polyurethane bonded district heating pipes are governed by the following European standards:

- EN 253 for pipe assemblies
- EN 448 for fitting assemblies
- EN 488 for valve assemblies
- EN 489 for joint assemblies
- EN 13941 for design and installation
- EN 14419 for surveillance systems.

Trenches

The figure below shows a typical construction detail for a heat network mains pipe trench in the public highway, using a pair of pipes for flow and return; this is the recommended pipe system in this case. The minimum distance from the top of the pipes to ground level is 600mm. Pipes can be located within road structures as defined under NRSWA[1], but care should be taken with design and construction. The dimensions of the excavation depth (d) and width (w) and the separation distance between pipes (a) and from the excavation edge (b) depend on the size of pipe and the highway construction. The figure below provides the suggested relevant trench dimensions for typical pipe diameters. Additional space at welding points, corners, valve locations and spurs will be required.

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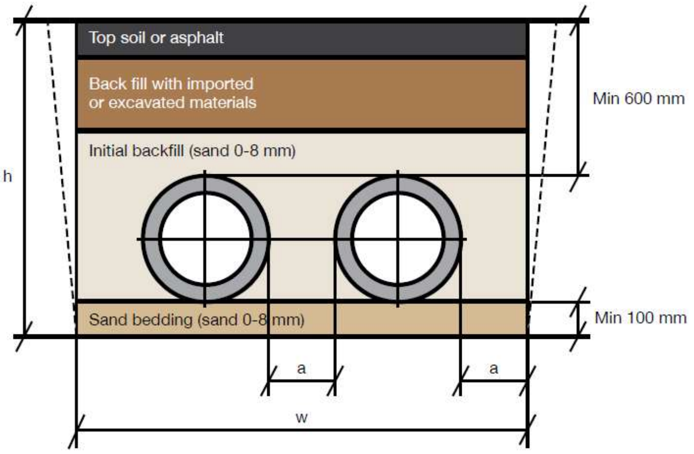
[1] New Roads and Street Works Act



Typical installation arrangement for separate flow and return pipes (source: London Heat Network Manual, GLA, 2014).

DN (carrier/ casing)	a (mm)	b (mm)	w (mm)	h (mm)
DN80/160	150	150	770	860
DN80/160	150	150	770	860
DN100/200	150	150	850	900
DN125/225	150	150	900	925
DN150/250	150	150	950	950
DN250/400	200	200	1400	1100
DN300/450	200	200	1500	1150
DN400/560	200	200	1720	1260
DN500/630	200	250	1910	1330
DN600/800	250	300	2400	1500
DN700/900	250	300	2600	1600

Table 1. Trench minimum dimensions.

When the trench is located within the public highway the depth, surround, backfill and reinstatement of the trench must comply with the NRSWA (New Roads and Street Works Act 1991) specification for the reinstatement of openings in roads. When backfilling, the initial surround (a minimum of 100mm) above the heat network pipes should use specified, imported and screened sand.

The excavated trenches should be surveyed to determine high and low spots of the installed bonded pipe network. This information should be used to inform where the optimum positions for air release valves and drainage valves are to be located.

Where a heat network is installed in proximity to other existing utility and service apparatus, the installation of the heat pipes should endeavour to comply with the principles of separation from other apparatus. Separation will depend upon the congestion of the area and consultation with owners of the existing apparatus is recommended.

Where a heat network is installed in new developments where no other apparatus exists, the installation should endeavour to comply with the principles within the National Joint Utilities Group Guidelines on the Positioning of Underground Utilities Apparatus for New Development Sites.

Testing and commissioning of pipe welds

Pipe work should be tested as detailed in EN 13941. Typical requirements which should be included in the works specification are:

- All steel pipe welding is to be undertaken by certified coded welders. Certification must be in compliance with current British and European Standards. Welders may be subjected to a welding test with at least the same acceptance criteria as the criteria for the finished work, with reference to EN 25817;

- A testing regime must be established for welded joints e.g. non-destructive testing of 10% of welds as detailed in EN 13941. Visual inspection of welds is required;
- All pipework installations should be hydrostatically pressure tested, witnessed, and signed off by a competent engineer. All equipment used for testing should be fully calibrated and the test procedures and monitoring proposals must be agreed before the tests commence;
- Following completion of a satisfactory pressure test the site closures must be made in strict accordance with the pipework manufacturer's specification;
- The leak detection system must be tested and certified; and
  Systems must be flushed and treated prior to being put to service.

In terms of case joint welds, typical requirements to be included in the works specification are:

- Joint assemblies for the steel pipe systems, polyurethane thermal insulation and outer casing of polyethylene shall comply with BS EN 489. The joint assemblies shall be installed by specially trained personnel according to the instructions given by the manufacturer. Fusion-welded insulation joints shall be implemented to join the pre-insulated steel pipe systems;
- All joint assemblies must be manufactured by the same manufacturer as the steel pipe systems and/or approved by the steel pipes systems' manufacturer for use with their pipes;
- The joint should be pressure tested to confirm it is airtight;
- Polyethylene welders shall possess evidence of valid qualifications, which document their ability to perform reproductive welding of the quality specified.

Valves and valve chambers

All valves on a heat network should be pre-insulated and of the same manufacturer as the pre-insulated pipe system. Where necessary spindle extensions must be provided to enable operation of the valves buried at depth or located within manholes where it is otherwise unnecessary to enter.

Where valves are housed in specific chambers then these chambers should be sized to accommodate the apparatus within them and to enable easy operation of the valves. The valve chambers and associated items must be designed to withstand the likely traffic loads applicable to their location. Valve chambers should be clearly marked such that the location and contents of the pipes are easily identifiable.

Routing Principles and Key Constraints

Heat network routing has been developed to connect key heat loads efficiently (shortest distances) and has been influenced by constraints identified during site inspections (route walk-throughs). Where possible, the network route takes advantage of 'soft dig' land, to minimise installation costs (e.g. removing and reinstalling pavement/roadways). Pre-insulated pipes would be directly buried, thermal expansion being accommodated by the friction between the surrounding compacted soil and the outer polyethylene casing of the heat network pipeline. Where land constraints are an issue, e.g. contamination, then over-ground sections could be considered. No compensators are proposed because they are prone to leakage and breakages over time.

Where possible, it is recommended that construction of the heat network be integrated into other construction works to deliver savings in construction costs and ensure in-building costs, such as boilers, are fully displaced and correctly accounted for.

Heat network heat losses

Heat conduction is directly proportional temperature difference. In district heating pipelines, heat is conducted from the pipeline to ground and consequently to the environment. A portion of the heat is conducted from flow pipe to return pipe. This portion is not counted as losses, as it is returned to the energy centre.

Heat loss calculations have been performed for each month of operation, taking account of estimated variations of heat demand, flow, return, and ground temperatures. The heat loss percentage is calculated for the whole year and presented in the report.

The heat networks code of practice advises network-side heat losses not to exceed 15% of the heat supplied up to the point of connection of each building, while the losses are typically expected to be less than 10%. Heat losses from a secondary heat distribution system within a multi-residential building shall not exceed 10% while losses less than 10% would constitute best practice.

Substations and Heat Interface Units (HIUs)

When connecting a building or dwelling to a heat network, the connection arrangement is a fundamental design choice. The options are either indirect (a heat exchanger is used as a physical barrier between the primary and secondary sides) or direct connection (where water from the heat network flows directly through the heating circuits of the building). System cost and operating temperatures are both affected by the design choice. Indirect connections are more prevalent, but both connection types have been used in UK heat networks.

In the indirect connection, heat consumers (non-domestic buildings and dwellings) are connected to the district heating network indirectly using prefabricated units comprising of the necessary heat exchangers and control valves in a compact unit called a substation or in the case of dwellings a heat interface unit (HIU). Indirect connection benefits from the following:

- Due to the hydraulically separate primary and secondary systems (which have a limited volume), leaks within the building or dwelling have limited potential for damage and impact on other customers.
- Building heating systems do not need high pressure ratings as they are not subject to higher heat network pressures and transients. Heat network pressure ratings are not limited by the building's heating systems.
- Separation between the building and network water, leading to less potential to contractual disputes over contamination or loss of system water, if systems are owned by different parties.

Indirect connections can be arranged to use a mixing control valve, allowing the secondary flow temperature to be set lower than the primary flow temperature, and to be varied with the outside air temperature. Direct connection is generally used for smaller systems, especially within apartment blocks. Direct connection benefits from the following:

- Less complexity and fewer components, leading to potentially lower costs
- No increase in primary return temperatures across a heat exchanger
- More compact system requiring less plant room space

Substations and comprise of heat metering equipment and isolation valves on the supply side, and heat exchangers, and circulation pumps on the consumer's side. For small building (e.g. individual residential consumers), these usually come packaged in a single unit, some of which are a similar size to wall-hung boilers. For larger buildings, the equipment is larger but is generally easily accommodated in existing boiler rooms. If the consumer has existing gas-fired boilers, these can usually be replaced directly with the district heating HIU, providing the operating temperatures are compatible. In comparison with boiler plant, HIUs require a smaller space, are quicker and easier to install and are easier to maintain.

An important aspect of the design of substations, is that they may be constructed with two or more heat exchangers in the heating circuit in addition to the domestic hot water heat exchanger, with each sized at for example 60% of the building's peak demand. If one of the heat exchangers is isolated for maintenance, the provision of heat to consumers may continue. Normally when multiple heat exchangers are used for the heating circuit, it is not necessary to size the heat exchangers based on 100% redundancy, but for special cases such as hospitals or care homes, the requirements for redundancy may be considerably different to that of a commercial property or residential building.

The diagram below shows a typical connection and metering arrangement.

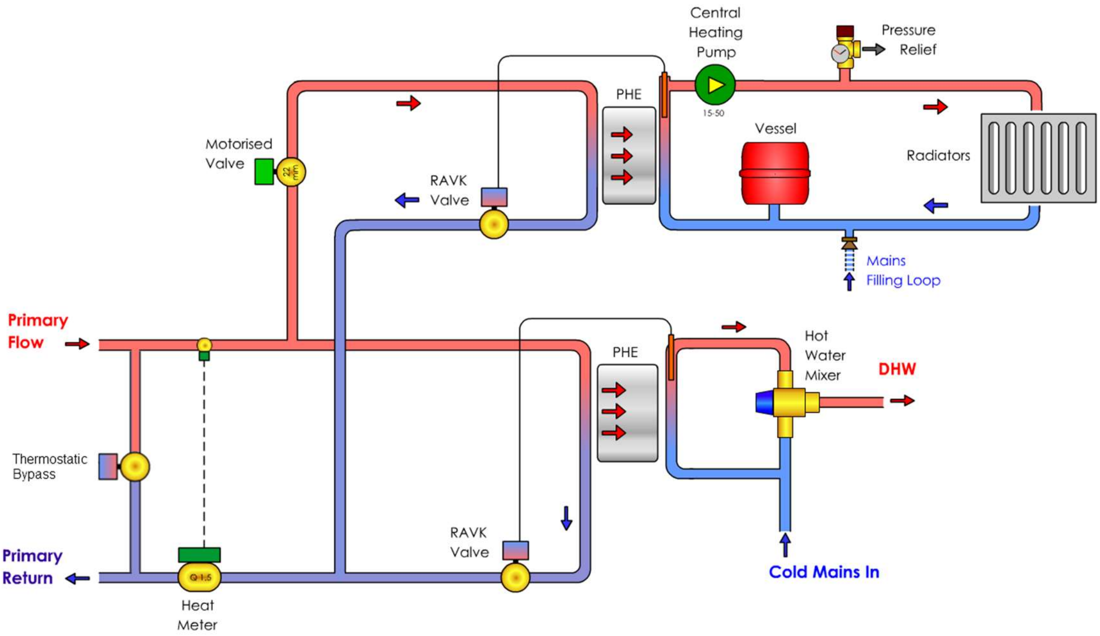


*Figure **Error! No text of specified style in document.**-1. Diagram illustrating a DH consumer's Heat Metering Equipment and Substation.*

Typical substations and HIUs have automatic temperature controls such that the heating circuit is adjusted in relation to outdoor temperature and the required indoor temperatures via a thermostatic control, outdoor sensor and/or indoor sensor; this enables optimisation of water flow and temperatures which will improve system efficiency.

The substations used in larger buildings are typically free-standing units (opposed to wall mounted for smaller buildings), as is the case with the unit shown below. HIUs are typically delivered as ready-to-install packages and as such are relatively easy to install, as seen in Figure Error**! No text of specified style in document.**-3 below. Modern units can be controlled and monitored remotely using a standard PC with an internet connection or by an operator panel.

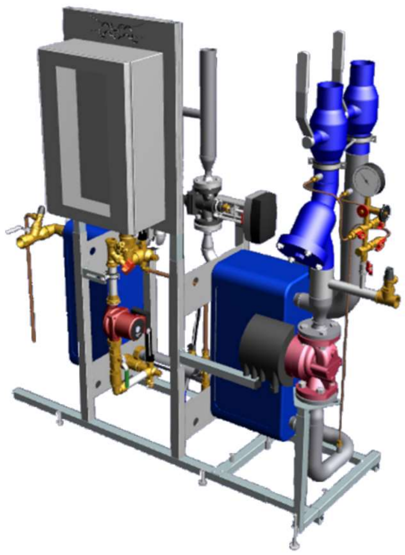


*Figure **Error! No text of specified style in document.**-2. Typical substation suitable for larger consumers (reproduced courtesy of Alfa-Laval Ltd).*

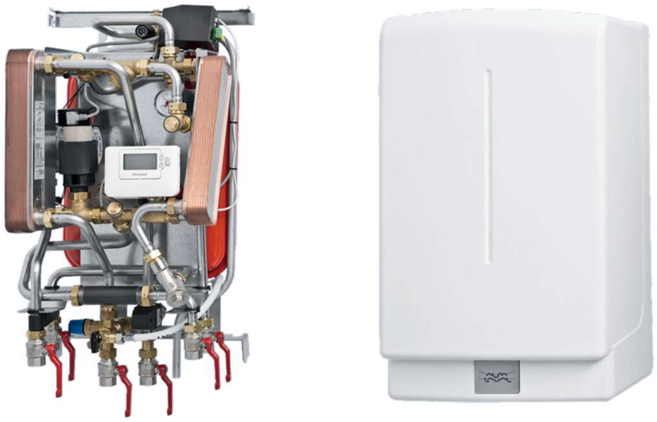


*Figure **Error! No text of specified style in document.**-3. Typical HIU suitable for individual dwellings shown with cover on and removed (reproduced courtesy of Alfa-Laval Ltd).*

If the heat network operator is contracted to operate and maintain the substation or HIUs, they would need to be provided with a means of access to fulfill this obligation. Access rights are commonplace and are normally agreed at the time of contracting the service.

Secondary systems within buildings should be designed with the following guidance[2] in mind.

- Existing buildings designed for 82-71 °C can be rebalanced to 80-60 °C, and potentially even as low as 50 °C return temperature while using existing radiator systems.
- New secondary systems should be designed for maximum temperatures as presented in Table 2.
- Heat exchanger approach temperature (difference between primary return and secondary return temperature across a plate heat exchanger) shall not exceed 5 °C, less than 3 °C is considered best practice
- Heat losses from secondary heat distribution system installed within a multi-residential building shall not exceed 15%, less than 10% is considered best practice.

Circuit	Flow temperature (°C)	Return temperature (°C)
Radiators, Air Handling Units	Max 70	Max 40
Fan-coil units	Max 60	Max 40
Underfloor heating	45 typical	Max 35 typical
DHW, instantaneous heat exchanger on load	65 typical min flow 55 typical min delivery	Max 25
DHW, cylinder with indirect coil	70 typical min flow 55 min storage	Max 45
DHW, calorifier with external plate heat exchanger	70 typical min flow 60 typical storage 55 min recirculation	Max 25

Table 2. Design temperatures for new secondary systems (HNCP).

Heat metering

Individual heat meters for dwellings are a requirement under the Energy Efficiency Directive (EED) for all new building as well as buildings undergoing major refurbishment. Building-level meters are also a requirement under EED for all multi-apartment/multi-purpose buildings connected to a heat network.

Heat meters must comply with the Measuring Instruments Directive (MID) with Class 2 accuracy. The minimum frequency of data collection and billing is quarterly for residential and micro-businesses and monthly for non-residential customers. Best

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[2] Heat Networks Code of Practice

practice would be to meter and monitor heat consumption profiles on a half-hourly basis, which may enable both parties to identify control modifications that would reduce or shift peak demands.

The components of a heat meter include a flow meter, temperature sensors and a heat calculator. The flow meter is used to measure the volume of circulating heat network water. The temperature sensor pair constantly monitors the flow and return temperatures. Based on the metering signals, the heat calculator determines the amount of heat used by the building.

The meter installation should be designed to the manufacturer's specifications of orientation and minimum length of straight pipe before and after the meter. Ease of access for maintenance, calibration and reading should be possible.

Heat meters will normally be owned, installed and maintained by the heat supplier (as with electricity and gas networks). New heat meters incorporate automatic meter reading (AMR) systems that communicate with a central database for billing and analysis. Communication is facilitated wirelessly or via optical fibre.

Electrical network

An important revenue opportunity for heat networks is the possibility to introduce Combined Heat and Power (CHP) systems. The total efficiency of a CHP heat network system is much higher (about 85%) compared with separate heat and power production (ranging between 55-65%), with commensurate fuel savings and environmental benefits.

From a financial viability point of view, it is important that the revenue from power generation can be maximised as this will contribute to the payback of the network investment. The value of CHP electricity depends on the trading arrangements and the degree to which power generated can be consumed on site, where it will command the greatest value. Electricity exported to the 'grid' yields significantly lower value compared to utilising it on site (end consumer or as an input for heat pump systems) or selling it through a private wire network, both of which can achieve values close to retail tariffs, which will vary between £95/MWh to £125/MWh for non-domestic consumers[3]. Sale or 'spill' to the 'grid' will typically achieve a value below the wholesale electricity market price which is dynamic but will typically be in region of £45/MWh to £50/MWh.

Minimising export to 'grid' is achieved by correct sizing of CHP plant and effective generation scheduling. Since the heat demand profile will not be truly known until the heat network is fully operational and "bedded-in" it is important to be conservative, since additional CHP could be added at a later stage, whereas oversized plant will lead inefficient operation with increased modulation and periods of shut down. On-site power storage (via batteries) or diversion to other uses such as vehicle charging could also be considered.

Power will also still be required to be purchased via the regional power network to fill the gap between demand and the CHP supply.

The operational power demands for the main energy centre, which would be located with the CHP plant, would be covered from the CHP generation or, during non-operating periods, from the grid.

The CHP plant arrangement would also include a step-up transformer and switching equipment for the generator and a grid connection facility, assuming the regional power network is able to accept the exported power.

Approvals for connections on to regional power network for the proposed CHP plan is a key issue. In some locations, regional electricity networks need reinforcement to allow new generation to connect on to them and this can be exacerbated by other new generation being developed, such as solar farms, seeking to connect on to the same network. Minimising export capacity through appropriate sizing and operation of CHP plant can mitigate this risk. In addition, Distributed Network Operators (the organisations operating regional electricity networks) are actively considering dynamic grid connection arrangements would prevent export when the network is constrained, and therefore potentially allow larger capacities able to export at unconstrained times.

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[3] Quarterly energy prices, BEIS

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

Operational parameters

In this study, the district heating network layout and pipework has been optimised and dimensioned using TERMIS district heating/cooling hydraulic modelling software. The design parameters used for dimensioning are presented in the table below.

Parameter	Value	Source
Maximum design temperature Maximum operating temperature	140°C 120°C	HVAC TR/20, 2003
Upper dimensioning supply temperature – Flow (plant outlet)	90°C	HNCP[4], BEIS report: Assessment of the costs and performance of HNs (Bulk schemes, max value)
Lower dimensioning temperature – Return (consumer HIU)	55°C 45°C (new developments)	HNCP
Maximum design gauge pressure	16.0 bar	HVAC TR/20, 2003
Pressure loss guideline to be used in design Main lines Branches	 100 Pa/m 250 Pa/m	 London Heat Network Manual London Heat Network Manual
Minimum pressure difference at consumer HIU	60 kPa	HNCP
Pipe series	2	Greenfield analysis

Design parameter assumptions used for hydraulic modelling of the heat network.

The Heat Networks proposed are dimensioned with a source (or flow) temperature of 90°C at peak demand. It is proposed that the network would operate on a variable flow and variable temperature basis, with changes in both responding to the instantaneous consumption needs. Higher loads will require greater water flow (controlled at the 'consumer substations' or 'Heat Interface Unit') and higher source (often called 'flow') temperatures.

The flow temperature would typically reside around 80-85°C until an outdoor temperature of below 0-5°C occurs. With colder weather, the flow temperature is gradually increased towards the maximum temperature. Return temperature is dependent on correct/optimum design and operation of consumer substations and building heating systems, varying normally between 45-55°C.

Pipe dimensions and capital costs

Pipe dimensions (shown in map form and tables) and capital cost breakdowns are presented in the below for the network options considered.

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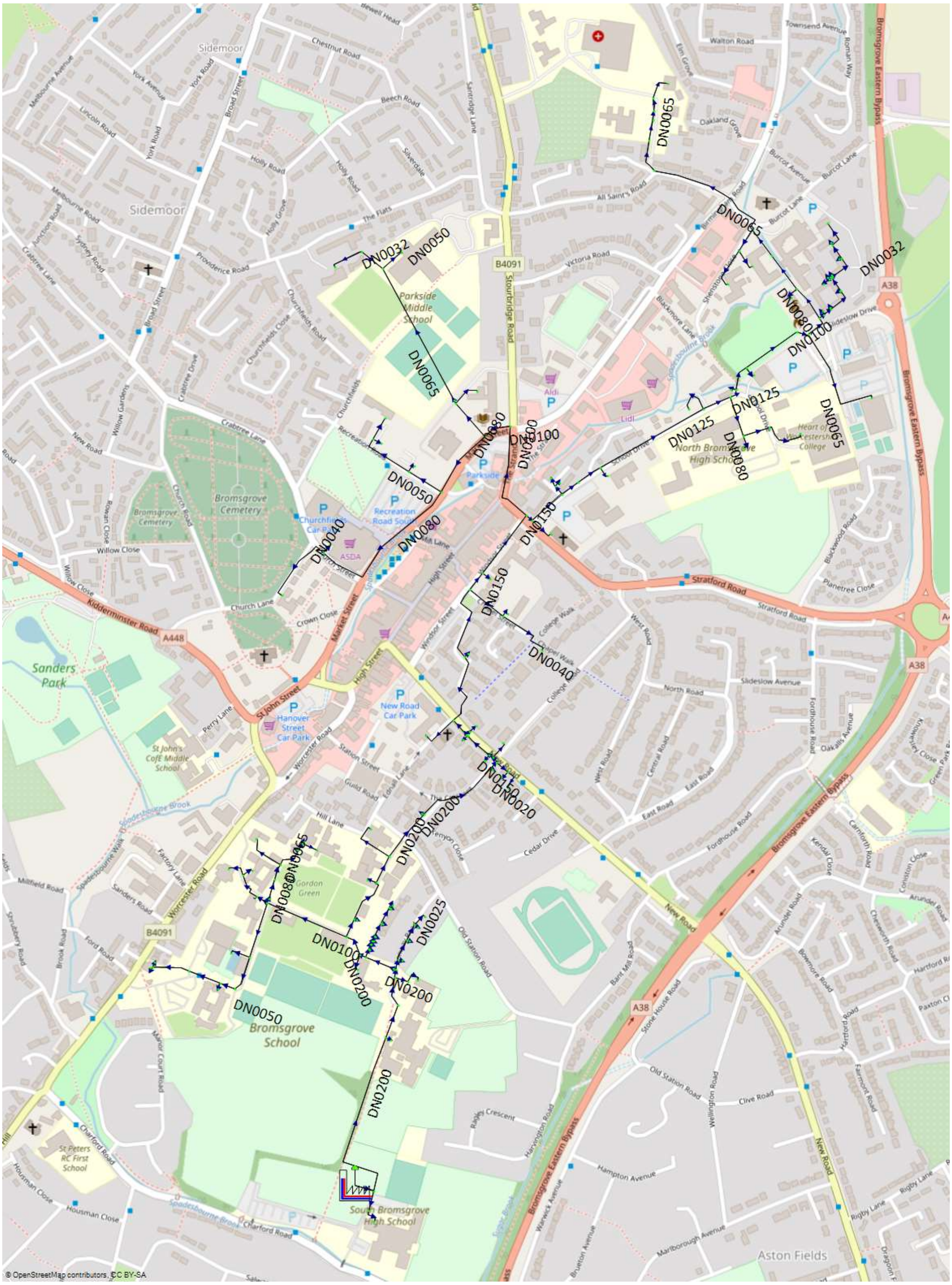
[4] *Heat Networks Code of Practice*



Bromsgrove heat network pipe dimensions.

	Trench length (m)	Pipe only supply and installation cost (£k)	Trenching and civils cost (£k)	Total cost (£k)
DN20	540	100.4	212.6	313.0
DN25	245	45.3	107.3	152.5
DN32	556	104.0	300.1	404.1
DN40	548	116.2	346.2	462.4
DN50	908	212.4	536.3	748.7
DN65	751	188.6	438.3	626.9
DN80	446	140.9	301.8	442.7
DN100	1,033	444.3	696.6	1,140.9
DN125	434	197.9	289.6	487.5
DN150	431	224.1	329.7	553.7
DN200	991	563.0	763.7	1,326.7
DN250	609	392.6	376.0	768.5
Subtotal	7,492	2,729.5	4,698.1	7,427.6
Contingency (10%)		273.0	469.8	742.8
Total	7,492	3,002.5	5,167.9	8,170.3

Bromsgrove heat network pipe dimensions and capital costs

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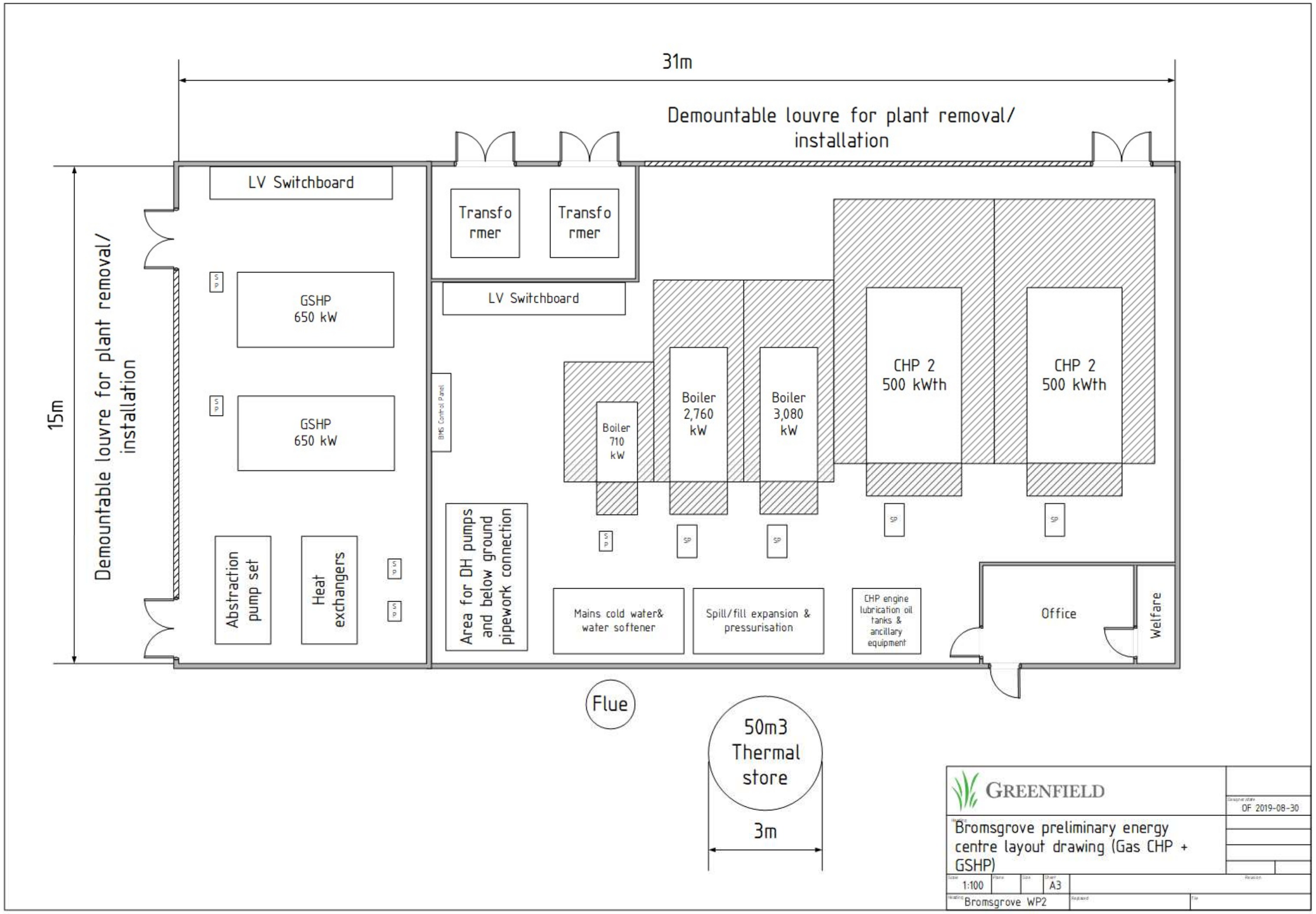
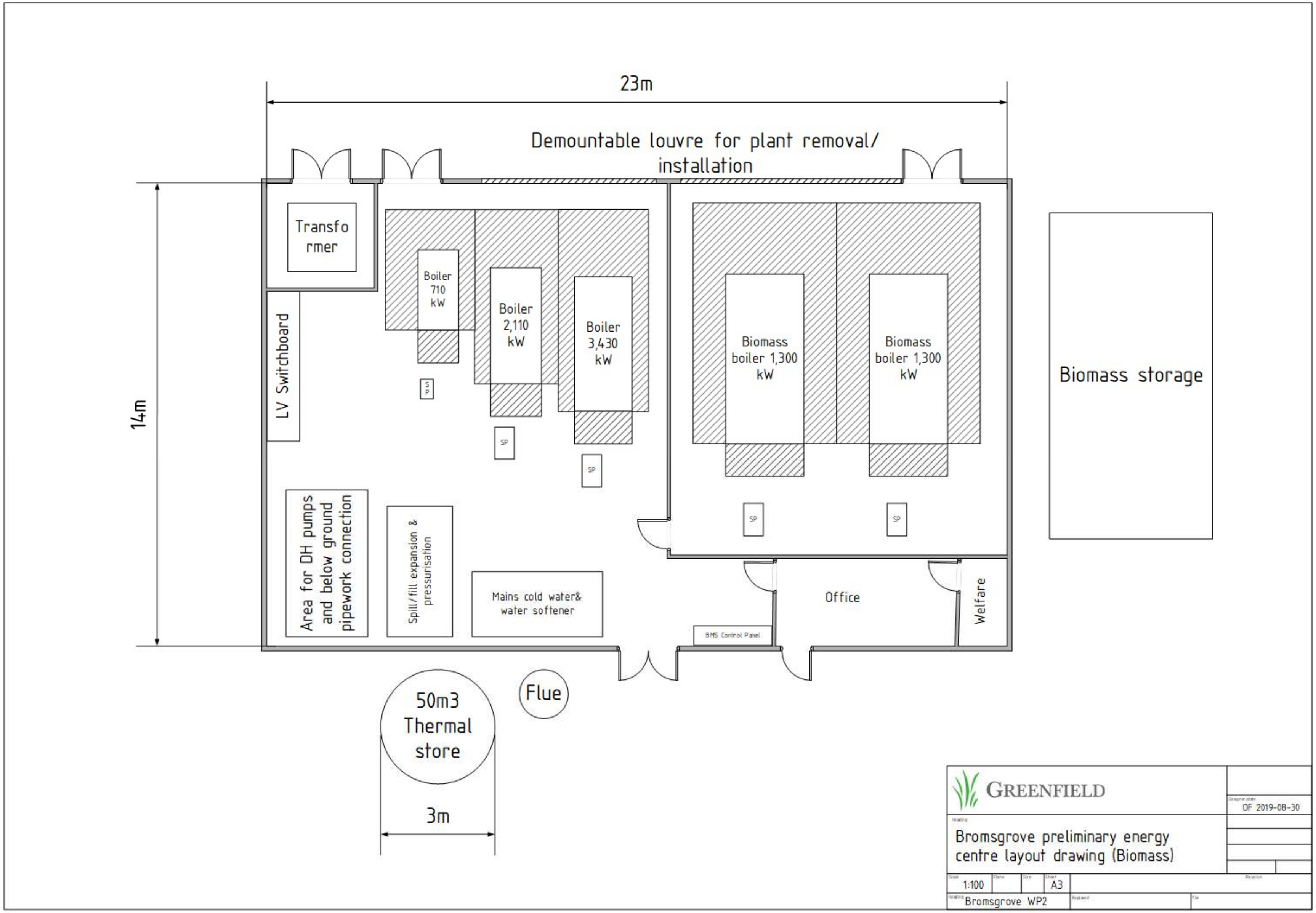
Appendix 5. Preliminary Energy Centre layout and flow diagrams



Preliminary layout drawing - Bromsgrove GSHP/CHP energy centre.



Preliminary layout drawing - Bromgrove biomass energy centre

Appendix 6. Carbon reduction analysis

CO_2 emissions have been calculated for the preferred energy supply solutions taking account of the efficacy of the various supply plant, system losses and parasitic consumption, e.g. pumping and the impact of displacing grid-supplied power in the CHP options. Carbon factors have been applied to each supply option and then this has been compared against a 'business as usual' scenario for each property that assumed to be connected to the network. The 'business as usual' scenario assumes gas boilers supply all existing and new buildings. Typical assumptions for boiler efficiencies have been applied. All buildings are assumed to be supplied with grid power. Where power generation is included in the supply mix, e.g. with CHP plant, carbon savings associated to power supply is attributed to the heat supply to enable comparison between heat networks. The emission factors for gas, biomass, and, grid-supplied electricity shown in the table below have been used.

Emission Factors		
Gas[5]	tCO_2 / MWh	0.205
Biomass	tCO_2 / MWh	0.039
Grid Electricity (2020)[6]	tCO_2 / MWh	0.290

CO_2 emissions for each heat network option and for the 'business as usual' solution is calculated based on static 2018 factors. Subsequently, the report goes on to show the impact of accounting for future projections for carbon emissions as estimated by HM Treasury[7], whilst also taking account of the specific carbon reductions that can be attributed to decentralised power generation from CHP as estimated by BEIS[8]. It is important to account for this since the carbon factor for electricity is forecast to significantly change over coming decades as the UK government seeks to decarbonise power supply, which would reduce the carbon benefits of locally generated electricity (when relative to grid power). The changes in electricity carbon factor predicted requires significant transformation of the UK power supply system which relies on major investment into new nuclear power, renewables and other low carbon technologies. Whilst it cannot be said with certainty that the rate of change predicted will be achieved it is a risk for a heat network scheme using CHP (whether gas, fuel cell or biomass) for baseload supply. Where carbon reduction is a key objective and stakeholders wish to apply the government's future grid carbon factors projections then the lower figures should be utilised to interpret the analysis results.

From a long-term perspective, it should be noted that supply technology can vary within a heat network; this is one of its key advantage. This may mean it acceptable for stakeholders to initially adopt more cost-effective technologies even where they do not deliver significant carbon savings because the implementation of the network infrastructure then enables lower carbon technologies to be introduced at later, perhaps at which point they will be more cost-effective.

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[5] *BEIS: "Government emission conversion factors for greenhouse gas company reporting" (August 2017)*

[6] *BEIS: "Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal" (April 2019)*

[7] *"Grid Average, consumption-based" emission factor for electricity has been used from Valuation of energy use and greenhouse gas (GHG) emissions - supplementary guidance to the HM Treasury Green Book on Appraisal and Evaluation in Central Government, HM Treasury, April 2019.*

[8] *"CHP exporting" and "CHP onsite" emission factors have been used from Emission factors for electricity displaced by gas CHP, Bespoke natural gas CHP analysis, Department of Energy & Climate Change, December 2015.*

Appendix 7. Detailed capital cost breakdowns

Investment 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 (ex. Utility connection, storage and design/development costs) – see next table		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 investment costs	***£k***	**20,061**	**15,408**

Bromsgrove heat network capital cost summary

	Trench length (m)	**Pipe only supply and installation cost (£k)**	**Trenching and civils cost (£k)**	**Total cost (£k)**
DN20	540	100.4	212.6	313.0
DN25	245	45.3	107.3	152.5
DN32	556	104.0	300.1	404.1
DN40	548	116.2	346.2	462.4
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DN80	446	140.9	301.8	442.7
DN100	1,033	444.3	696.6	1,140.9
DN125	434	197.9	289.6	487.5
DN150	431	224.1	329.7	553.7
DN200	991	563.0	763.7	1,326.7
DN250	609	392.6	376.0	768.5
Subtotal	7,492	2,729.5	4,698.1	7,427.6
Contingency (10%)		273.0	469.8	742.8
Total	7,492	3,002.5	5,167.9	8,170.3

Bromsgrove heat network pipe dimensions and capital costs

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

Energy Centre cost breakdown			
Baseload supply technology		**CHP + GSHP**	**Biomass Boilers**
Land	£k	-	-
Energy Centre Building (shell and core) plus civils	£k	1,053	1,248
Energy generating technology costs	£k	2,182	1,337
CHP units	£k	970	-
Ground-Source Heat Pumps	£k	983	-
Biomass Boilers	£k	-	1,118
Gas Boilers	£k	229	219
Boreholes for GSHP system[10]	£k	1,216	-
Energy Centre items, or refurbishment of existing plant areas, as applicable	£k	-	-
Thermal storage	£k	139	139
Electrical export switchgear and transformers	£k	662	-
Gas connection	£k	45	45
Electrical connections (export by Private Wire or export to grid)	£k	340	-
Water connection	£k	30	30
Drainage connection	£k	30	30
Telecoms connection	£k	2	2
Other Energy Centre capex (e.g. piping, valves, pumps, water treatment, cabling, electrical panels, etc.)	£k	929	1,124
Energy centre subtotal (exc. thermal store and connections)	**£k**	**6,042**	**3,709**
Energy centre subtotal (inc. thermal store and connections)	**£k**	**6,629**	**3,955**
Detailed engineering costs	£k	994	593
Professional fees	£k	331	198
Project Management	£k	199	119
Project Development	£k	200	200
Contingency (10%)	£k	835	506
Energy Centre total	**£k**	**9,188**	**5,571**

Energy Centre – detailed cost breakdown

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[10] Adding lining to the boreholes increases the capex by approx. £1.2m

Appendix 8. Energy tariff and other revenue assumptions

Heat sales tariffs for all consumer types are presented in the table below. Heat tariffs are assumed to inflated in line with BEIS gas and electricity cost projections (as also used for heat network fuel costs).

	Annual heat demand	Assumed seasonal efficiency	Unit rate for gas	Annual maintenance cost	Annual replacement cost	Total heat tariff	Total heat tariff inc. 5 % discount
	MWh	%	£/MWh	£	£	£/MWh	£/MWh
BAM schools	1,575	75 %	31.5	£13,662	£8,280	53.8	51.1
Bromsgrove School	5,485	75 %	27.5	£34,838	£21,114	45.0	42.8
Bromsgrove Sports and Leisure Centre	1,193	75 %	25.1	£6,178	£3,744	40.2	38.2
Care Home	1,053	75 %	25.8	£8,851	£5,364	46.2	43.9
Council offices	630	75 %	25.8	£5,450	£3,303	46.6	44.2
David Lloyd	699	75 %	25.1	£8,257	£5,004	50.8	48.3
Emergency services	88	75 %	40.8	£475	£288	60.3	57.3
Hospital	2,317	75 %	30.5	£11,494	£6,966	46.6	44.3
HOW College	870	75 %	25.8	£7,781	£4,716	47.0	44.7
Place of Worship	144	75 %	40.8	£1,188	£720	64.9	61.6
Retail	1,137	75 %	25.8	£9,489	£5,751	46.1	43.8
Theatre	98	75 %	40.8	£832	£504	65.3	62.0

Heat sales tariffs for non-residential consumers.

Residential consumers follow the same principle as above. Estimated costs are presented below per dwelling. Heat tariffs are assumed to inflated in line with BEIS gas and electricity cost projections (as also used for heat network fuel costs).

	Annual heat demand	Assumed seasonal efficiency	Unit rate for gas	Annual maintenance cost	Annual replacement cost	Total heat tariff	Total heat tariff inc. 5 % discount
	kWh/ dwelling	%	£/MWh	£/dwelling	£/dwelling	£/MWh	£/MWh
BDHT, flats	6.2	75 %	42.1	£205.3	£138.9	108.9	103.4
Bromsgrove School, staff and student houses[11]	25.2	75 %	42.1	£205.3	£138.9	77.6	73.7
Private residential, flats	6.0	75 %	42.1	£205.3	£138.9	111.1	105.5

Heat sales tariffs for residential consumers.

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[11] One house is accounted as one dwelling in energy modelling.

Power revenues, within gas CHP options, is based upon sales of power to the consumers at a 5% discount to their recently billed costs, accounting time-of-day changes in their tariff.

			Source
Electricity sales (grid)	£/MWh	52.2	BEIS (electricity wholesale, reference scenario) Price is inflated annually according to BEIS predictions
Electricity sales (private wire)			
Bromsgrove School	£/MWh	153.2 (peak) / 105.4 (offpeak)	Reported power costs
South Bromsgrove High School	£/MWh	158.4 (peak) / 108.9 (offpeak)	QEP (small/medium)

Power revenue assumptions.

Details on RHI revenue assumptions are shown in the table below.

		Rate	Term	Source
Heat pumps			20 years	Office of Gas and Electricity Markets: Tariffs and payments: Non-Domestic RHI
Tier 1 (15 % of heat load)	£/MWh	95.6		
Tier 2 (85 % of heat load)	£/MWh	28.5		
Biomass				
Tier 1 (35 % of heat load)	£/MWh	31.1		
Tier 2 (65 % of heat load)	£/MWh	21.8		

RHI revenue assumptions.

Appendix 9. Operational cost assumptions

			Source:
Fuel costs – gas	£/MWh	20.3–25.1 (inflated based on BEIS projections)	BEIS QEP: Tables Annex, June 2019, non-domestic, medium to large, excl. VAT, incl. CCL
Fuel costs – electricity (for heat pumps and energy centre)	£/MWh	147.6 (inflated based on BEIS projections)	BEIS QEP: Tables Annex, June 2019, non-domestic, small, excl. VAT, incl. CCL
Fuel cost – biomass	£/MWh	30.0 (inflated based on BEIS gas projections)	Supplier quote
Metering and billing cost	£/consumer/yr	90	Quote from heat network operator
Network management (”Account Manager”)	£/yr	18,000	Quote from heat network operator
Utility costs and overheads (water, data, etc.)	£/yr	1,500	Greenfield experience from prior projects
Insurance		0.1% of CAPEX	Quote from heat network operator
Heat Trust	£/dwelling	4.5	Quote from heat network operator

Operational cost assumptions.

			Source:
Variable costs			
Gas CHP variable	£/MWh$_{\text{fuel}}$	2.4	Quotes from equipment manufacturers
GSHP variable	£/MWh$_{\text{fuel}}$	3.0	
Biomass boiler variable	£/MWh$_{\text{fuel}}$	2.0	
Gas boiler variable	£/MWh$_{\text{fuel}}$	1.3	
Annual fixed costs			
Gas CHP		3.5 % of CAPEX	Quotes from equipment manufacturers
GSHP		3.5 % of CAPEX	
Biomass boiler		3.5 % of CAPEX	
Gas boiler		2.0 % of CAPEX	
Other energy centre equipment		1.0 % of CAPEX	
Heat network fixed maintenance	£/m, trench	1.3	Greenfield experience from prior projects
Heat network replacement/repair	%-of HN capex/yr	0.5%	
Substation & HIU servicing	£/unit/yr	50	Quote from heat network operator

Maintenance cost assumptions.

			Source:
Gas boilers lifetime	*yrs*	25	Greenfield experience from prior projects
Gas CHP lifetime	*yrs*	15	
GSHP lifetime	*yrs*	20	
Biomass boiler lifetime	*yrs*	15	
Other energy centre equipment lifetime	*yrs*	35	
Heat network, steel lifetime	*yrs*	50	
Substations & HIUs lifetime	*yrs*	20	
REPEX		70% of Balance of Plant original CAPEX	

REPEX / lifetime assumptions.

Appendix 10. Financial modelling results

Project viability		Gas CHP + GSHP	Biomass boilers
NPV @ Discount rate:	3.5 %		
25 yr	£k	96	-3,562
30 yr		-807	-4,961
40 yr		-1,873	-6,872
LCOE (heat consumption) @ Discount rate:	3.5 %		
25 yr	£/MWh	75.8	90.2
30 yr		71.9	87.4
40 yr		70.5	86.5
IRR			
25 yr	%	3.5 %	1.1 %
30 yr		3.1 %	0.2 %
40 yr		2.6 %	-1.5 %
MIRR			
25 yr	%	3.5 %	2.0 %
30 yr		3.3 %	1.7 %
40 yr		3.1 %	1.6 %
Simple Payback (yr)	yr	26.4	NA
Discounted Payback (yr) @ Discount rate:	3.5 %	NA	NA
Economic viability (including socio-economic benefits)			
NPV @ Discount rate:	3.5 %		
25 yr	£k	-171	-1,531
30 yr		1,008	-649
40 yr		1,759	201
IRR			
25 yr	%	3.4 %	2.5 %
30 yr		3.9 %	3.1 %
40 yr		4.2 %	3.6 %
Simple Payback (yr)	yr	24.5	32.7

Detailed financial modelling results.

Gap funding required to reach		Gas CHP + GSHP	Biomass boilers
IRR 5.0 %	£m	3.2	5.6
	% capex	16.2 %	36.5 %
IRR 7.0 %	£m	5.5	6.6
	% capex	27.5 %	43.0 %
IRR 10.0 %	£m	7.5	7.4
	% capex	37.2 %	47.7 %

Gap funding required to reach investment thresholds set out by HNDU.

Appendix 11. Risk register

Version	Date	Notes
0.2	4/9/19	Second issue

Key: Risk phase	
Project Development (PD)	Risks occurring prior to construction
Construction (C)	Risks occurring during construction
Operational & Mngt (O)	Risks occurring during operation period
Key: Risk theme	
Project Development	Risks associated due to scheme management (project development and construction phases)
Demand	Risk of loads to materialise or loads are lost over time, e.g. construction delays, efficiency programme, errors in initial analysis
Supply	Risk of out of insufficient generation and other EC and network failures/limitations of the required supply of energy
Financial/Commercial	Risks of increases in operational costs and depressed revenues beyond business case modelling assumptions, e.g. interest rate hike, inflation, reduced reference fuel costs
Regulatory	Risk with of legislative change (during development and operation), e.g. change in planning requirements, emissions standards, customer protection

Risk theme	Phase: PD, C, O	Network / option relevance	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
Demand	**PD, C**	**General**	**Demand for heat and power is lower than expected due to not being able to sign up consumers**	As is typical at feasibility stage there is limited certainty over consumers connections, i.e. there are no MOUs/HOTs/contracts in place and there is some reliance on estimated demand for smaller consumers. The impact of losing consumers can be significant but some are more important than others (scales and proximity to others). Loss of consumers could be for a range of reasons, including (1) the scheme not being able to provide an attractive offer to stakeholders (site operators, end-consumers, developers) or (2) because the scheme is not available when required (although few require early connection). In addition, revision of estimates may decreases demand.	4	4	16	1. Liaise with key stakeholders as scheme move through feasibility to investable proposition 2. Ideally establish MoU/HoTs with key/large consumers in near future 3. Refine understanding of programme / milestone issues and adjust scheme phasing and consider temporary solutions, where necessary 4. Seek to find additional heat demand that could connect, particularly in town centre through promotion of the project 4. Revise scheme design based on secured consumers (allowing for expansion capacity)
Supply	**PD**	**GSHP option**	**GSHP potential and acceptability**	There is some uncertainty over heat potential and construction costs for the GSHP boreholes and Bromsgrove School will need to give explicit approval for this solution	3	4	12	1. Further examine ground conditions and borehole design to improve certainty and costs information 2. review solution with school 3. consider alternative locations, e.g. Bromsgrove Leisure Centre or DPoW hospital
Demand	**PD, C**	**General**	**Non connection of BDHT properties**	Whilst engage was positive at the end of feasibility study there is some uncertainty over compatibility and cost of connection.	3	4	12	1. Liaise with BDHT to explore interest/rationale 2. Explore alternative consumers to replace them if they are to be excluded
Demand	**PD, O**	**General**	**Demand for heat is lower than expected, due to poor data or change in**	Heat demand data for some properties is based on metered consumption data so provide high confidence. Other data including is based on benchmarking and realised energy demand could be lower or higher than expected. Energy demands may also change over time as buildings are	4	3	12	1. Highlight data weaknesses and seek to improve over time 2. Update consumption estimates (and update scheme design) as new data becomes available (at least at key decision points during the scheme development

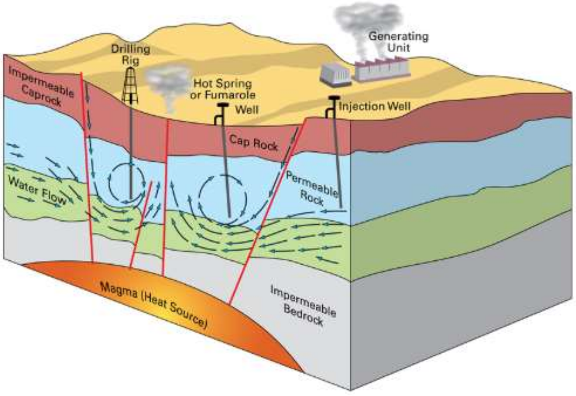
Risk theme	Phase: PD, C, O	Network / option relevance	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
			consumption profiles	updated / operated differently. For example, refurbishment.				process) 3. Use new data to revise scheme design prior to project investment 4. Address consumption changes to through operational management
Project Development	**PD, C**	**General**	**Devlopment skills / resources (to deal with investment planning, project/contract management, technical appraisal)**	Insufficient capacity and capability to act as an informed client to contract to market (install & operate). Could lead to higher costs, delays and system not fit for purpose.	4	3	12	Once their is a "live" project with good stakeholder support and appointed lead entity: 1. Formalise / Initiate project and establish project management structure and agreements between project champion and key stakeholders 2. Conduct skills audit 3. Recruit key resources (some will be external) 4. Up-skill decision makers and internal managers
Regulatory	**PD, C**	**General**	**Planning + consenting**	Energy Centres will need to planning permission and regulatory approvals	4	3	12	Once indicative scheme is established liaise with planners to review key information required and adaptations that may support a positive outcome
Supply	**PD**	**General**	**Energy Centre location - Bromsgrove school**	The location of the energy centre at Bromsgrove School has been confirmed but will need to be further proved.	4	3	12	1. Review concept design solution with school Bursar / estate manager 2. Explore alternative location options with stakeholders, if school is deemed to be uncertain
Supply	**O**	**General**	**Poor reliability and performance of consumer heat supply**	Poor design, construction or operational standards leading to poor service and/or non-service at times and a loss of trust in the system which could result in disconnections. The feasibility stage has developed an appropriate design solution but care will need to be taken to conduct design,	4	3	12	1. Apply best practice design, construction and operational standards, e.g. UK Code of Practice 2. Ensure specification meets longevity standards required 3. Ensure scheme revenues are sufficient to

Risk theme	Phase: PD, C, O	Network / option relevance	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
				installation and operation in compliance with the National Heat Code of Practice (and subsidiary guidance).				support O&M and meeting re-investment requirements 4. Transfer risks and incentives to operator to maintain optimal performance 5. Give careful consideration for interfaces between design, build and operation
Supply	**PD**	**Renewable supply only**	**No access to RHI**	RHI is close by end of Q1 2021 and as such these heat network options will not be able to access it. It may be replaced or extended but this has not been confirmed by government	4	3	12	1 Develop solutions (technical/financial) in WP2 that do not rely on RHI
Supply	**PD**	**Biomass option**	**Suitability of biomass options**	Biomass, which has been identified as a second option, needs to be further examined to explore energy centre, fuel handling and access design, where GSHP proves not to be deliverable (and the project still proceeds)	3	3	9	1. Consider exploring biomass as an option in parallel to GSHP (or keep as fall back) 2. explore access arrangement through Bromsgrove High access road 3. develop design solution
Demand	**C**	**General**	**Construction delays**	This refers to delays once a detailed construction plan is resolved which is likely to be linked to consumer and/or supply plant milestones. Delays may cause commercial impact but in the worst case result in loss of supply option and/or consumers	3	3	9	1. Develop realistic programme 2. Explore risks with stakeholders and development joint mitigation plans
Supply	**PD**	**General**	**Energy Centre utility constraints**	Technical or commercial constraint to connect energy centre servicing infrastructure, e.g. gas and power connections - response awaited from Cadent and WPD	4	2	8	1 review responses from Cadent and WPD when received
Financial /Commercial	**PD**	**General**	**Sufficient funding is not available amongst key stakeholders**	A heat network scheme involves significant capital expenditure, which will be compensated by long term returns	2	4	8	1.Switch to 3rd party network ownership, where they bring finance 2. Seek PWLB, soft loan or grant support (e.g. HNIP, LEP/EU funds)

Risk theme	**Phase: PD, C, O**	**Network / option relevance**	**Risk name**	**Risk description (and mitigation)**	**I**	**L**	**RV**	**Proposed action**
Financial /Commercial	**C**	**General**	**Overspend on capital budget**	Failure to deliver project within the estimated capital costs and contingency. Likelihood is low since costs have been benchmarked against major UK suppliers and a 20% contingency is added. However, there are risks such as greater construction and construction management for the network infrastructure and the water sourced heat pump installation in relation to location and discharge / abstraction arrangements.	4	2	8	1. Use effective project management framework/process 2. Produce clear specification of requirements and systematically de-risk 3. Use PM and advisers with experience of heat networks 4. Pass on risks, e.g. Design, Build & Operate council 5. Manage budget, making adjustments to capital allocation and finding balancing cost reduction, as necessary
Supply	**C, O**	**General**	**Energy Centre & network: Poor end-consumer service delivery**	Poor service provision leads to user dissatisfaction and, in worst-case, to disconnection	4	2	8	1. Ensure design, construction and commissioning are of a high standard and at least compliance against Code of Practice 2. Provide effective operational management, including annual consumer satisfaction surveys 3. Structure incomes/profits to management performance 4. Establish arbitration solution, e.g. Heat Trust or council operated scheme
Supply	**O**	**General**	**Energy Centre and network: Inadequate maintenance**	Poor maintenance leads to system failures which will cause dissatisfaction and increased costs as backup measures are required	4	2	8	1. Ensure design, construction and commissioning are of a high standard and at least compliance against Code of Practice 2. Design effective monitoring and management capabilities 3. Provide effective asset management, and ensure sufficient budget (O&M and repex) for planned and un-planned maintenance / replacement 4. Structure O&M contracts to performance

Risk theme	Phase: PD, C, O	Network / option relevance	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
Supply	**PD**	**Air quality constraints**	**Air quality impacts of energy centre(s) lead to perceived or real risk with respect to air quality**	Air quality impact may lead to regulatory constraints or may created public protest against development	4	2	8	1 At detailed design stage, review this issue further and engage with regulatory bodies
Financial /Commercial	**O**	**General**	**Operating costs and revenues outside business case tolerances**	O&M costs exceed, and revenues fall short, of the modelling tolerances. Modelling has been conducted an a conservative basis and so as are considered reasonable at this point.	3	2	6	1. Conduct independent due diligence 2. Monitoring costs and revenues during operation and develop operational responses 3. Pass risks on to operators, where possible
Financial /Commercial	**PD, O**	**General**	**Energy prices (general) vary on the medium/long-terms basis**	The financial modelling uses long terms price forecasts from BEIS and so retain inherent uncertainty, although there is a clear trend towards increasing energy costs over time. Changing energy prices will both affect costs of energy supply and the operation of the heat network, e.g. pumping, but will also affect consumer tariffs since these will either be linked to UK energy or consumer price indices. These will typically act against one another to mitigate overall impact.	3	2	6	1. Carefully negotiate energy centre fuel/electricity contracts 2. Establish heat supply contracts that link tariffs to energy/consumer indices 3. Adjust business case accordingly
Supply	**PD, C**	**General**	**Network route constraints**	Various highway and junction constraints and existing buried services will present route constraint issues. These are likely to be surmountable but solutions will need to be developed.	2	3	6	1. Conduct Liase with owner/operators of existing utility infrastructure 2. Survey other network constraints 3. Develop engineering solutions and the examine capital costs impact
Supply	**C**	**General**	**Runs beyond programme**	Construction delays leading to possible cost increases	3	2	6	1. Use project management framework/process 2. Use experienced PM

Risk theme	Phase: PD, C, O	Network / option relevance	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
Supply	**O**	**General**	**Future proofing network capacity**	A decision will need to made regarding the sizing of the network infrastructure and the energy centre(s) based on estimated demand, which clearly could increase costs. Whilst there is significant capacity within the proposed network to allow for expansion, it is finite.	3	2	6	1. Make decision for initial network sizing based on reasoned opinion of future expansion and compare against investment into secondary supply lines. 2. Consider grant support for initial oversizing network.
Regulatory	**PD, O**	**General**	**National legislation introduces new costs, e.g. taxation**	New carbon taxation of the heat network may add additional costs.	2	2	4	1. Due diligence against the possible changes 2. Make operational adjustments as required
Regulatory	**PD, O**	**General**	**Heat supply becomes regulated**	Currently unregulated, the supply of heat can be treated as any unregulated services. This is unlikely to be a major issues since heat sales are internal or as part of the tenant arrangements.	2	2	4	1. Review implications in further detail



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