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CITY OF WOLVERHAMPTON COUNCIL

Wolverhampton City Heat Network/Detailed Feasibility

Final Report – Appendices

July 2021

GREENFIELD

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GREENFIELD

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Appendix 1. Energy consumption estimation

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 85% for traditional gas boiler 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 the 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 85% is then applied to arrive at a heat consumption estimate.

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 is 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. Data from SAP assessment for new-build housing
3. NEED provides primary heat benchmarks for housing from a by date of construction. A boiler efficiency of 85% was assumed to convert this figure into heat demand.

4. Existing hourly energy demand profiles have been used based on space type.

Demand profiling

Metered gas consumption (half-hourly) was used to determine the peak heat demand where such data is available. Heat consumption is determined by treating the half-hourly gas metering with a typical boiler efficiency. The resulting heat consumption is normalised to a statistical reference year using heating degree days (HDD).

Where high-resolution consumption data is not available, peak demands and annual heat consumption was estimated using benchmarks. If annual heat consumption is known, only the peak demand will be estimated. Installed boiler capacity is used to sense-check the benchmarking results, as boiler capacity would need to larger than the actual peak demand.

The annual heating demand was time-profiled against building occupation hours (DHW), heating periods (space heating), typical DHW consumption patterns and external temperature variations in the local area (hourly weather data) using an in-house profiling model.

To arrive at the hourly heat demand profile required to be delivered the Energy Centre the individual profiles for each building are aggregated on an hourly level with appropriate diversity factors and heat losses (calculated based on hydraulic modelling).

Appendix 2. Prospective consumers (demand & other data)

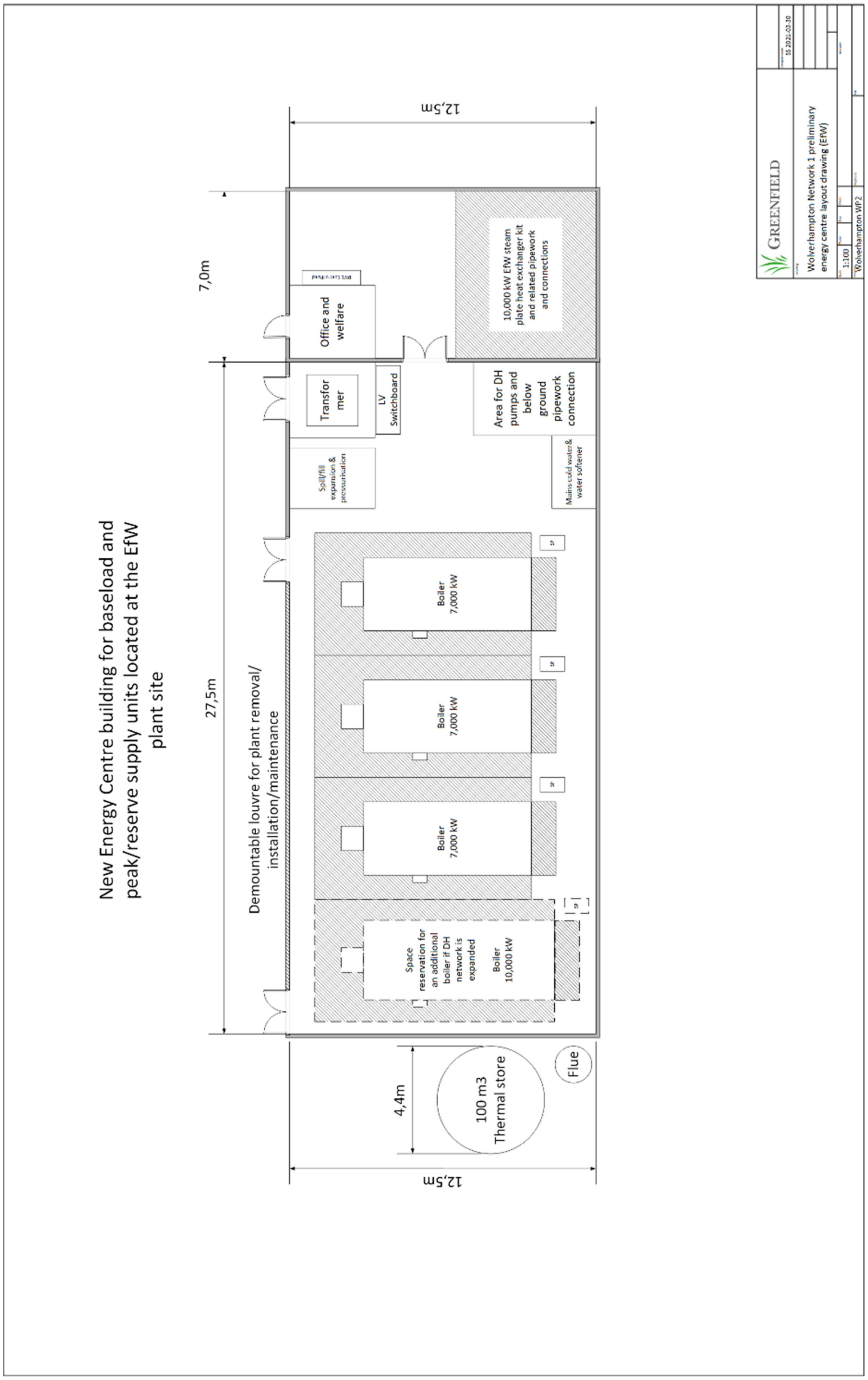
Ref	Site	Building type	Counterfactual heating system[1]	Consumer zone	Peak Heat (MW)	Heat demand (MWh/yr)	Electricity demand[2] (MWh/yr)	Source	Connect year
Existing properties									
E-01	Boscobel - Residential, existing	Flats	ESH / EI	Base	0.55	860	-	EPC data	3
E-02	WU - Molineux Campus	University	GB	Base	2.23	3,377	2,507	Metering	3
E-03	WU - Student Accommodation	Student Residential	GB	Base	1.23	1,983	-	Metering	3
E-04	WU - Wulfruna Campus (aka South Campus)	University	GB & CHP	Base	6.53	9,855	5,695	Metering	3
E-05	Wolverhampton Wanderers FC	Football Stadium	GB	Base	0.74	1,083	-	Metering	3
E-06	Wolverhampton Art Gallery	Art Gallery	GB	Base	0.48	656	-	Metering	3
E-07	Civic Centre	Office	GB	Base	2.87	2,795	4,345	Metering	3
E-08	Civic Hall	Venue	GB	Base	0.71	1,331	887	Metering	3
E-09	Magistrate Courts (old Town Hall building)	Court	GB	Base	0.55	634	452	Metering	3
E-10	Leisure Centre ("Baths")	Leisure	GB	Base	0.84	1,343	452	Metering	3
E-11	Molineux Hotel	Office	GB	Base	0.14	101	116	Metering	3
E-12	Regents House	Office	GB	Base	0.03	28	-	Metering	3
E-13	Redwings Lodge Hotel	Hotel	GB	Base	0.27	481	-	Benchmarked	3
E-14	Wolverhampton Britannia Hotel	Hotel	GB	East	0.47	463	-	Metering	3
E-15	Grand Theatre	Theatre	GB	East	0.87	309	-	Masterplanning	3
E-19	Central Library	Library	GB	East	0.17	152	-	Metering	3

[1] *ESH – Electric Storage Heater / Electric Immersion heaters; GB – Gas Boiler; CHP – Combined Heat and Power (Gas)*

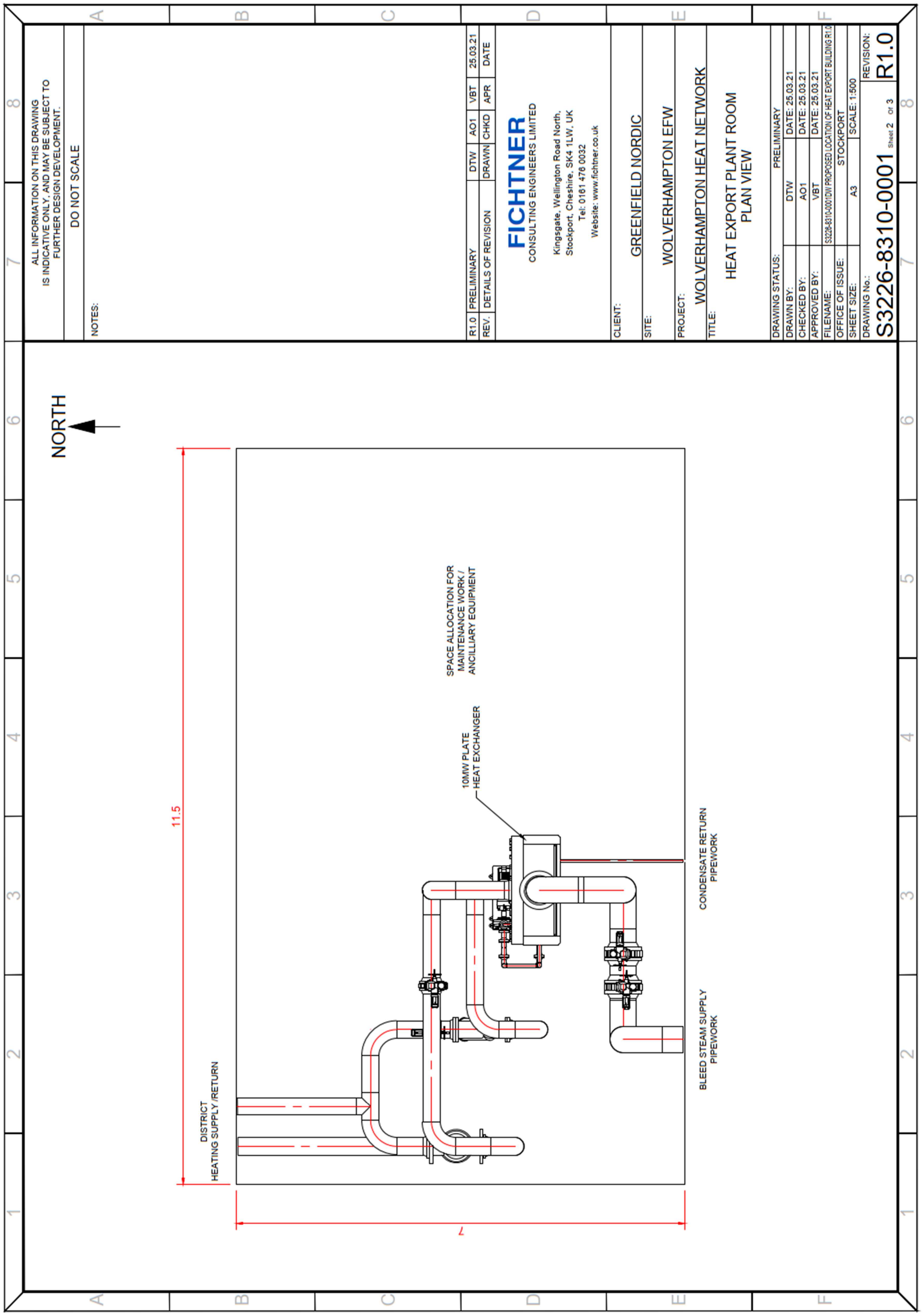
[2] *Shows only those buildings assumed to be connected to Private Wire*

E-20	Adult Education College	Education	GB	East	0.32	173	-	Metering	3
E-21	Police Station	Police Station	GB	East	0.30	965	-	DEC data	3
E-22	Wulfrun Shopping Centre (HVAC supply)	Retail	GB	East	0.23	130	-	Benchmarking	3
E-23	Job Centre	Office	GB	East	0.40	540	-	DEC data	3
E-24	Crown Court	Office	GB	East	0.61	704	-	Metering	3
E-25	Novotel	Hotel	GB	East	0.52	910	-	Benchmarking	3
E-26	St Davids Court	Office	GB	East	0.32	311	-	Benchmarking	3
E-16	Mander House	Office	GB	West	0.27	259	-	Benchmarking	3
E-17	Graiseley High Rise	Flats	GB	West	0.42	742	-	EPC data	3
E-18	Graiseley Low Rise	Flats	GB	West	0.65	1,301	-	EPC data	3
New Build									
D-03	Westside Phase 2	Flats & Hotel	GB & AWHP	West	1.20	2,468	-	Benchmarking	3
D-01	Broad Street Car Park	Mixed	GB & AWHP	East	1.45	1,546	-	Benchmarking	3
D-02	St George's	Flats	GB & AWHP	East	1.12	1,221	-	Benchmarking	3-5
D-04	Cornhill site	Offices	AWHP	East	0.09	103	-	Benchmarking	5-8
D-05	Canalside South	Houses	GB & AWHP	East	2.97	3,978	-	Benchmarking	3-7
	Total Demand				**29.54**	**40,802**	**14,435**		

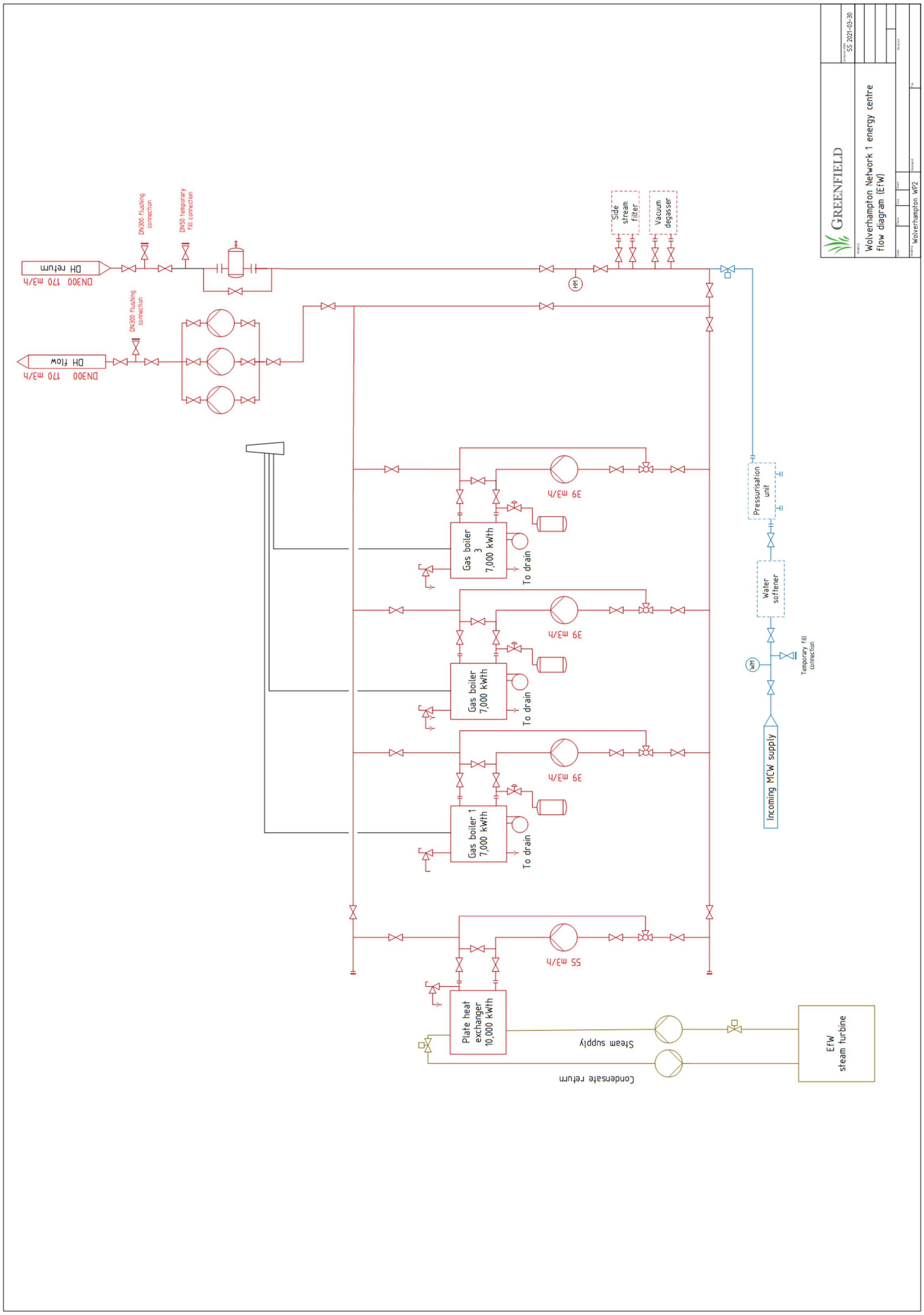
Appendix 3. Preliminary Energy Centre layouts and flow diagrams



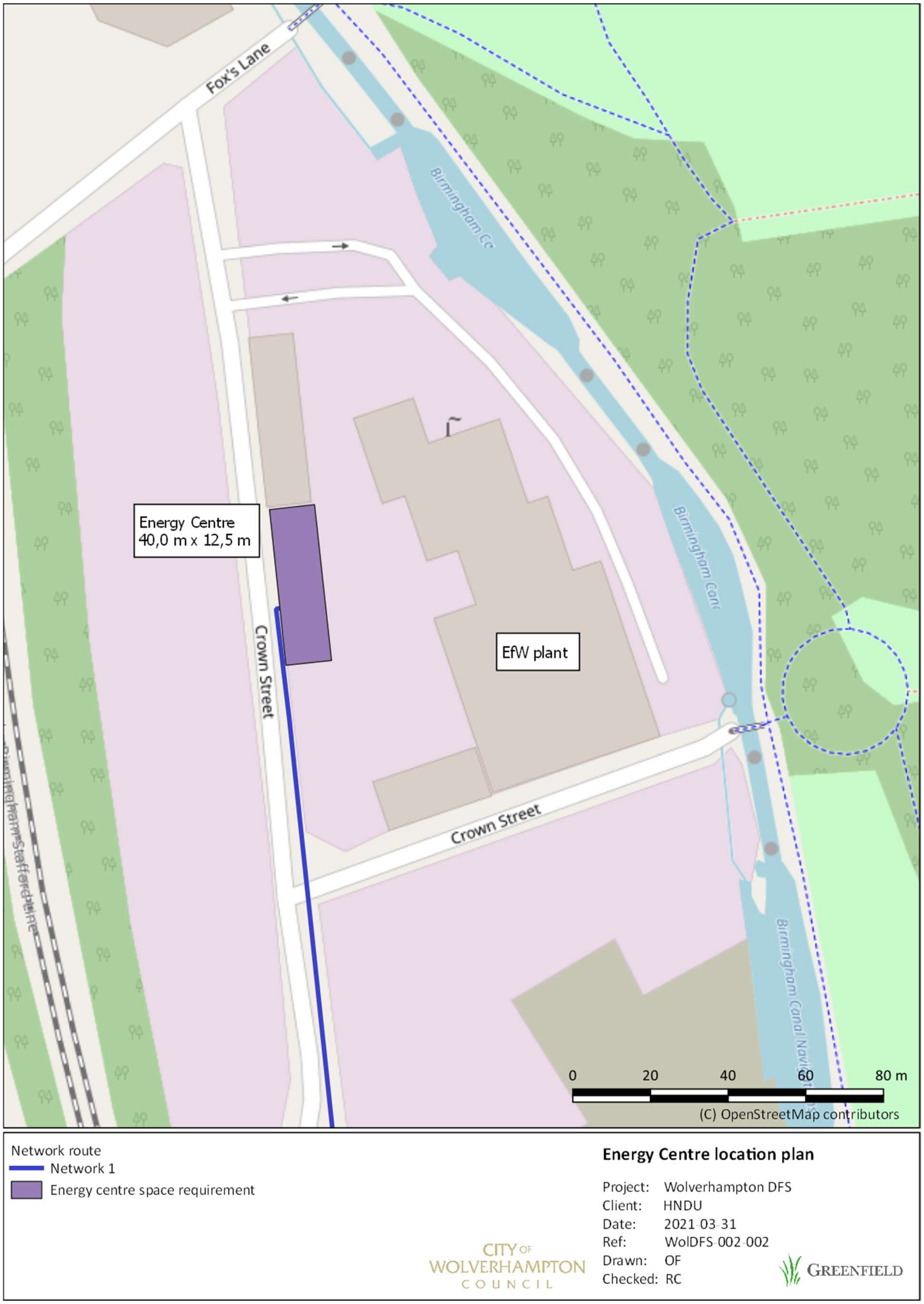
Preliminary Energy Centre layout drawing Network 1



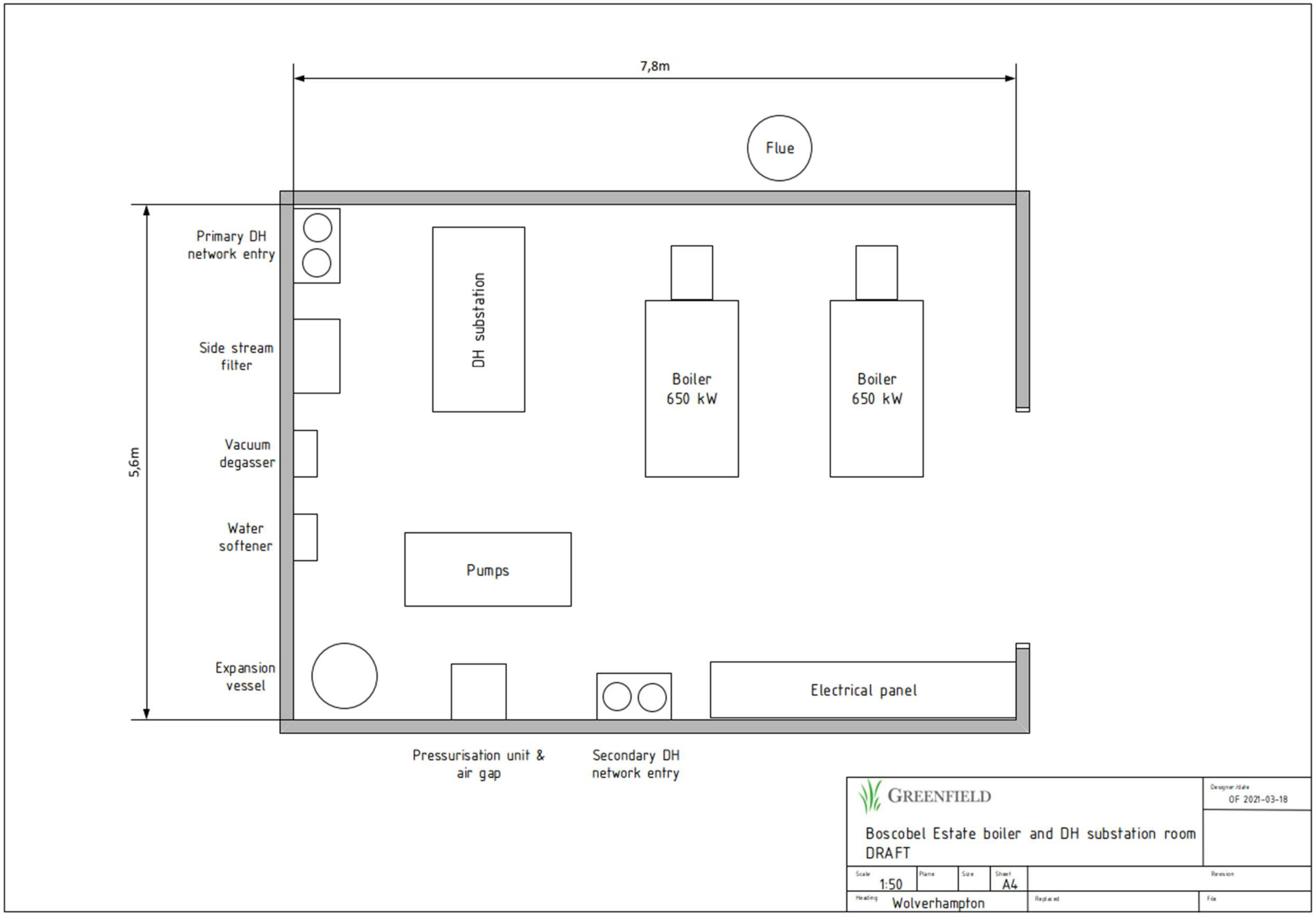
Detailed preiliminary layout of the EfW PHEx kit and connection shown in the EC layout drawing



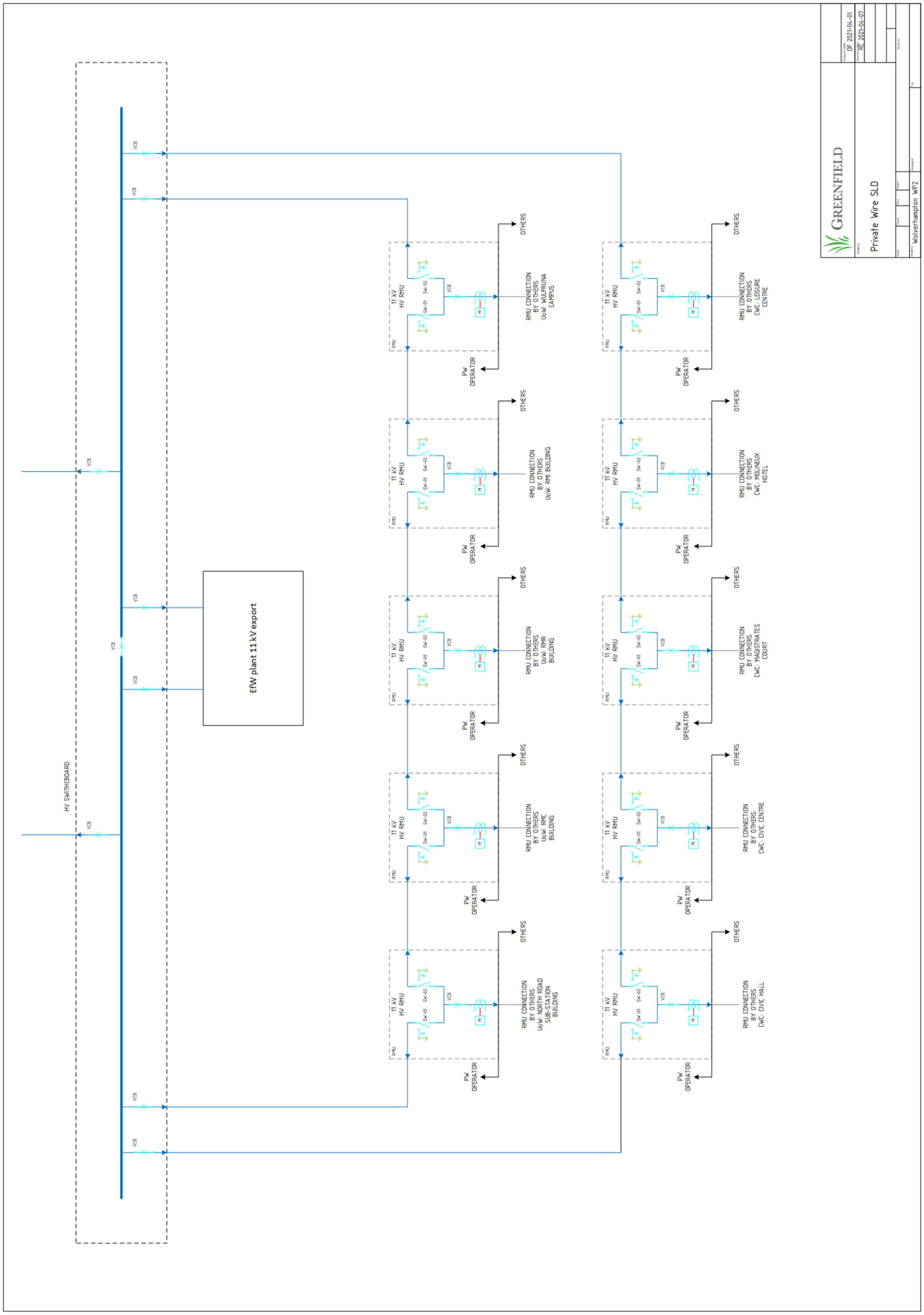
Preliminary process flow diagram Network 1



Indicative Heat Network Energy Centre Location plan



Indicative Boscobel flats substation layout



Private Wire SLD

Appendix 4. Heat network infrastructure

Heat network pipework

It is assumed the network would constructed with pre-insulated 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, 100 °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 a large topographic range) 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.

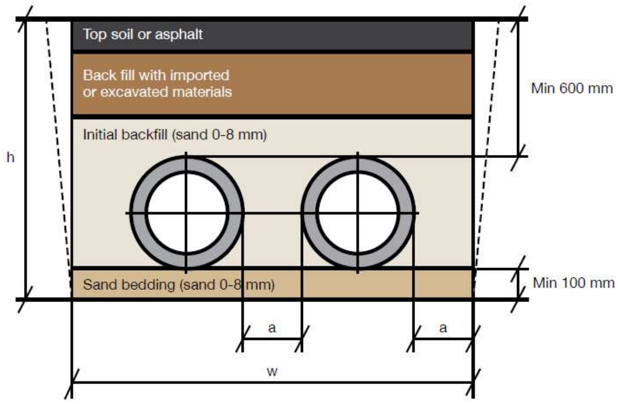
Properties of pre-insulated polyurethane bonded district heating pipes are governed by the following European standards:

- 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[3], 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.

[3] 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

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

Pipework should be tested as detailed in EN 13941. Typical requirements which should be included in a 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 a 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.

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, substations 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.

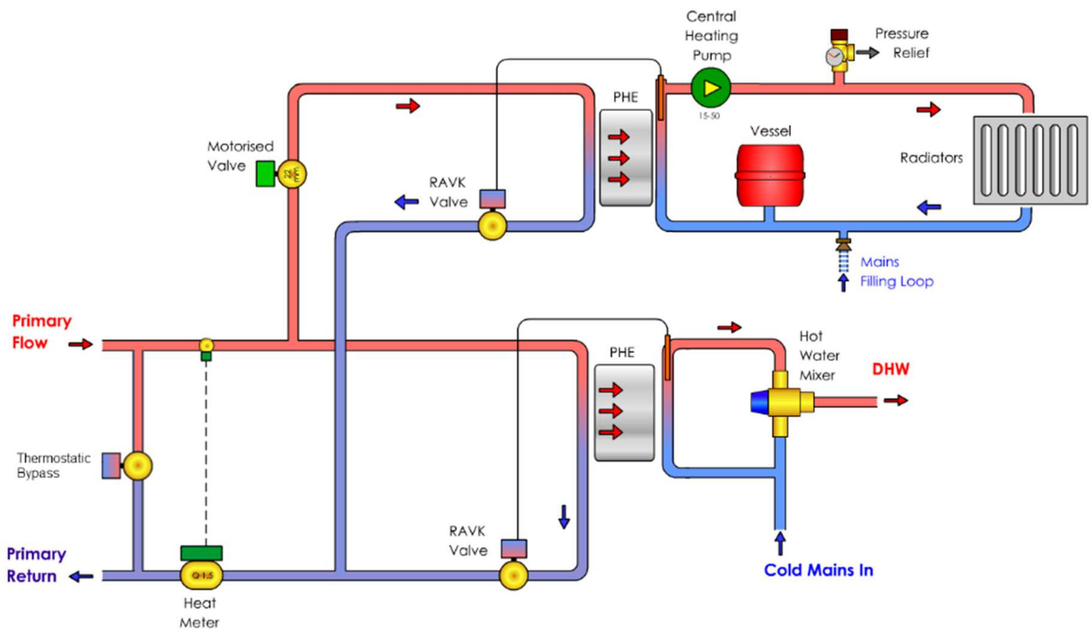
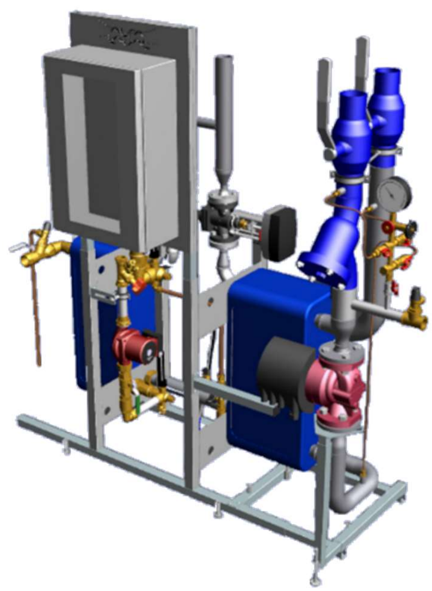


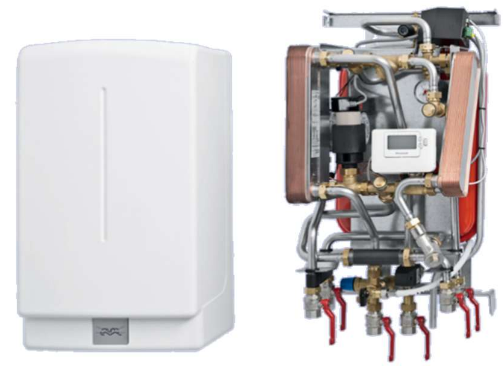
Diagram illustrating a DH consumer's Heat Metering Equipment and Substation.

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, see images below. Modern units can be controlled and monitored remotely using a standard PC with an internet connection or by an operator panel.



Typical substation suitable for larger consumers (reproduced courtesy of Alfa-Laval Ltd).



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 fulfil 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[4] in mind.

- Existing buildings designed for 82-71 °C can be rebalanced to 80-60 °C, and potentially even as low as 55 °C return temperature while using existing radiator systems.
- New secondary systems should be designed for maximum temperatures as presented in the table below. Generally, the delta-T should be minimum 25 °C for existing buildings and minimum 30 °C for new buildings.
- 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.

[4] Heat Networks Code of 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

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 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 ensured.

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.

Appendix 5. Pipe sizing analysis

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	Analysis based on consumer secondary system temperatures
Lower dimensioning temperature – Return (consumer HIU)	65 °C 45 °C (new developments)	Analysis based on consumer secondary system temperatures
Maximum design gauge pressure	16.0 bar	HVAC TR/20, 2003
Pressure loss guideline to be used in design	250 Pa/m	London Heat Network Manual
Minimum pressure difference at consumer HIU	60 kPa	HNCP
Pipe series	2	Heat loss analysis

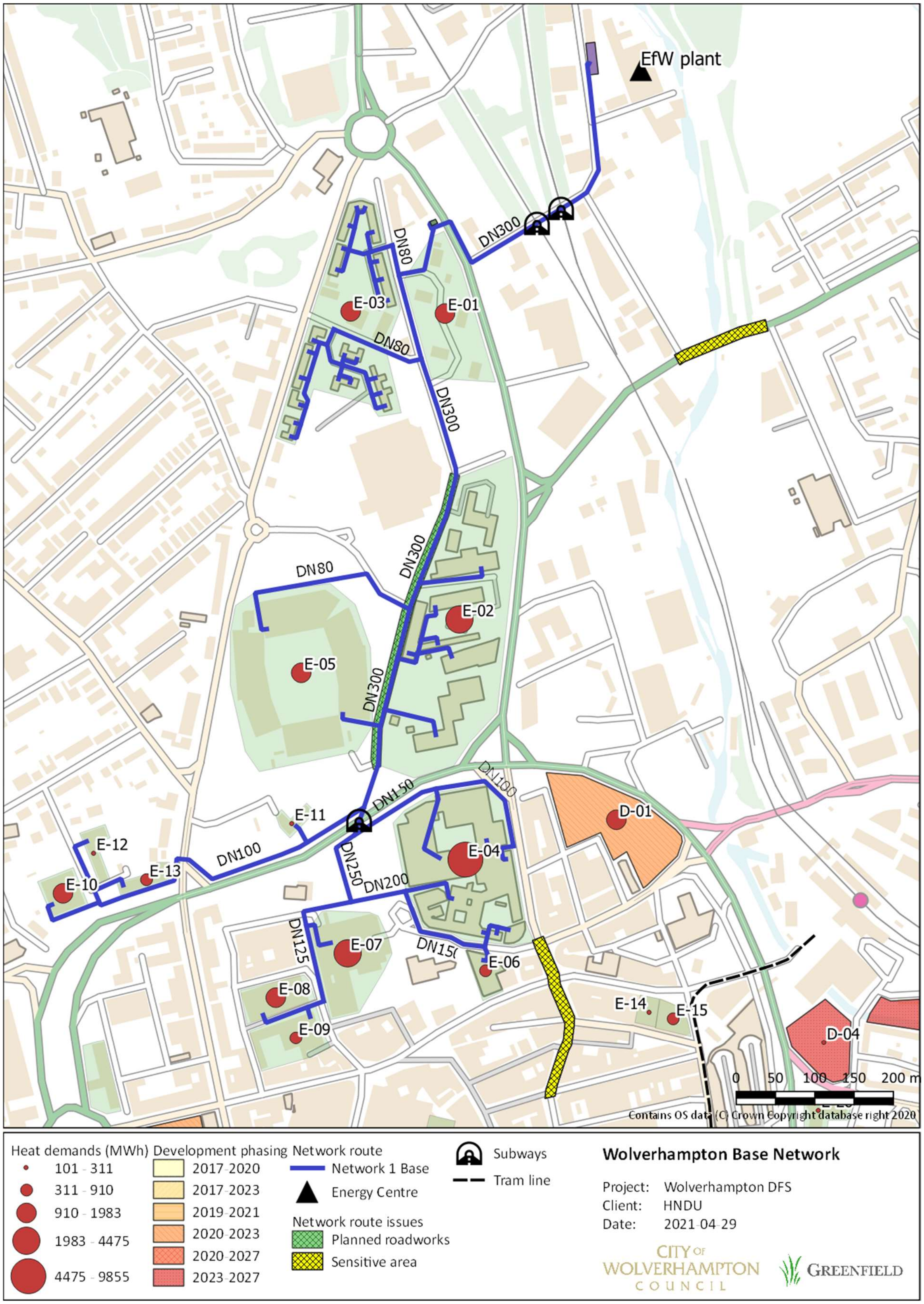
Design parameter assumptions used for hydraulic modelling of the heat network.

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.

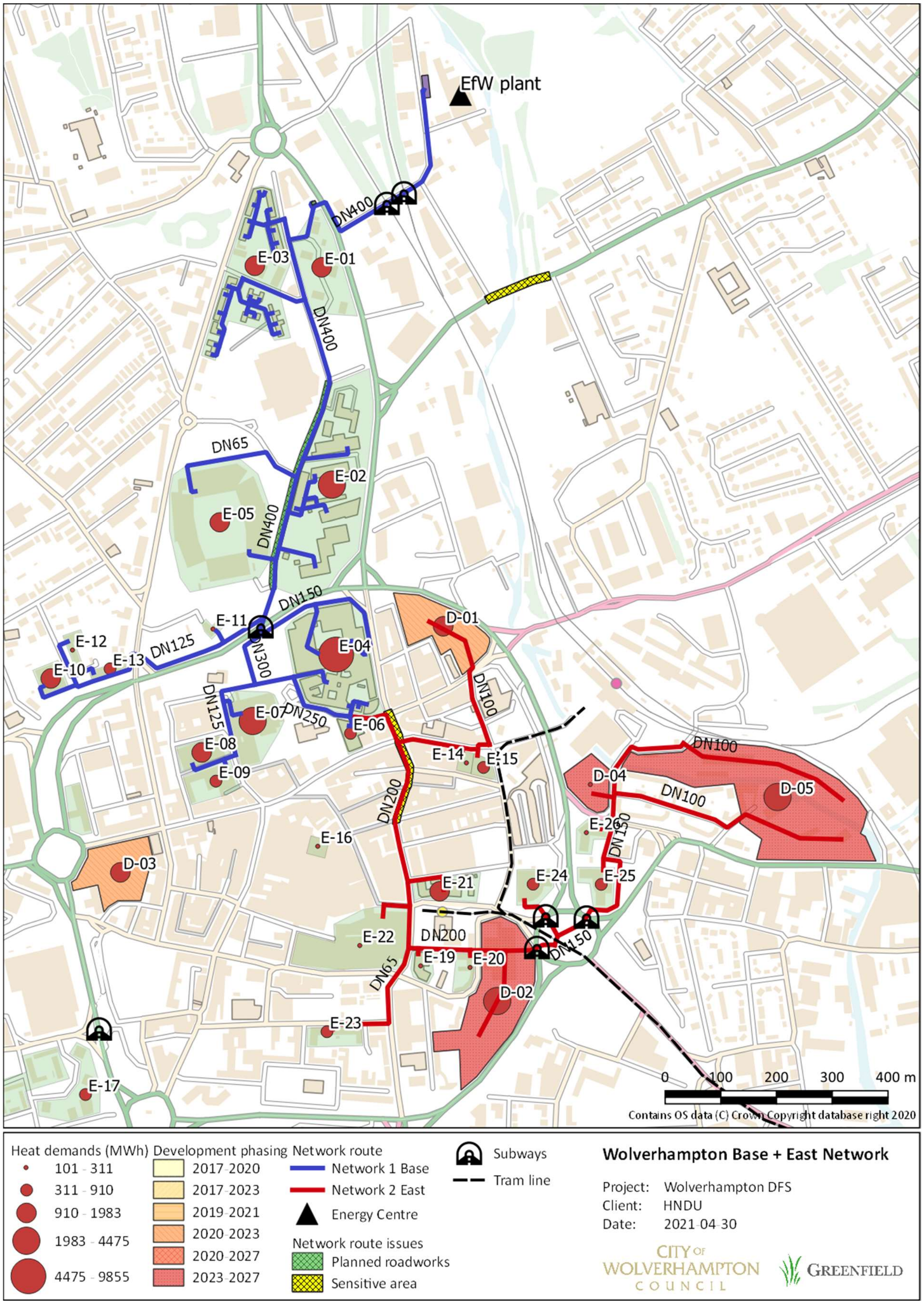
The flow temperature would typically reside around 80-85 °C until an outdoor temperature of below 0-5 °C occurs. With colder weather, the flow temperature is gradually increased towards the maximum temperature. Return temperature is dependent on correct/optimum design and operation of consumer substations and building heating systems, varying normally between 45-65 °C.

Pipe dimensions and capital costs

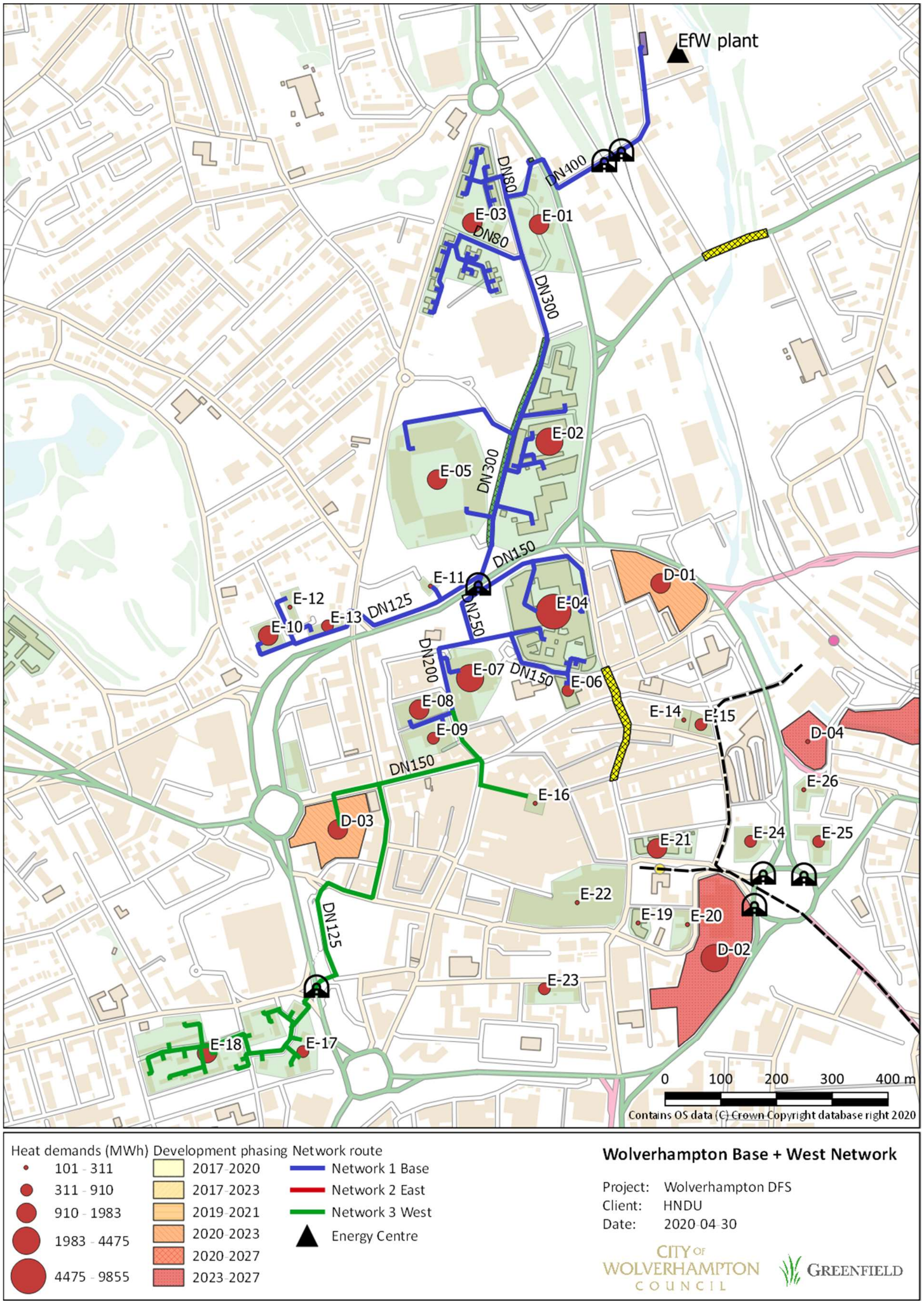
Pipe dimensions (shown in map form and tables) and capital cost breakdowns are presented in the figures below for the network options considered.



Network 1 Base – Network routes and pipe sizes



Network 2 East Extension – Network routes and pipe sizes



Network 3 West Extension – Network routes and pipe sizes

	Trench length (m)	Pipe only supply and installation cost (£k)	Trenching and civils cost – hard dig (£k)	Trenching and civils cost – soft dig (£k)	Total cost (£k)
DN20	-	-	-	-	-
DN25	78	14	39	-	53.7
DN32	320	59.8	113.4	87.9	261.0
DN40	108	22.9	42.3	28.3	93.5
DN50	178	41.5	120.5	-	162.1
DN65	814	204.6	562.1	11.3	778.0
DN80	569	180.1	407.2	-	587.3
DN100	342	147.0	246.7	-	393.7
DN125	510	232.4	382.5	-	614.9
DN150	299	155.7	229.1	-	384.8
DN200	151	85.7	120.6	-	206.3
DN250	137	88.2	112.9	-	201.2
DN300	1,159	768.2	982.4	-	1,750.6
Subtotal	4,666	2,000.5	3,359.2	127.4	5,487.1
Constraint mitigation					-
Contingency (10%)		200.1	335.9	12.7	548.7
Total	4,666	2,200.6	3,695.1	140.1	6,035.9

Network 1 Base – network pipe dimensions and capital costs

	Trench length (m)	Pipe only supply and installation cost (£k)	Trenching and civils cost – hard dig (£k)	Trenching and civils cost – soft dig (£k)	Total cost (£k)
DN20	6,436	1,196.0	-	2,072.5	3,268.4
DN25	78	14	39	-	53.7
DN32	368	68.9	113.4	118.6	300.9
DN40	108	22.9	42.3	28.3	93.5
DN50	255	59.6	173.0	-	232.6
DN65	1,180	296.5	819.7	11.3	1,127.5
DN80	850	268.8	492.6	115.3	876.7
DN100	1,583	680.9	710.3	432.4	1,823.5
DN125	537	244.8	402.9	-	647.6
DN150	636	330.8	411.3	75.4	817.5
DN200	740	420.2	536.9	54.8	1,012.0
DN250	260	167.4	214.3	-	381.7
DN300	170	112.8	144.2	-	257.0
DN400	1,196	894.9	1,046.3	-	1,941.2
Subtotal	14,398	4,778.9	5,146.4	2,908.5	12,833.7
Constraint mitigation					-
Contingency (10%)		477.9	514.6	290.8	1,283.4
Total	14,398	5,256.8	5,661.0	3,199.3	14,117.1

Network 2 East Extension – network pipe dimensions and capital costs

	Trench length (m)	Pipe only supply and installation cost (£k)	Trenching and civils cost – hard dig (£k)	Trenching and civils cost – soft dig (£k)	Total cost (£k)
DN20	1,000	185.8	-	322.0	507.8
DN25	395	73	95	103	271.7
DN32	500	93.6	161.1	154.0	408.7
DN40	170	36.0	58.8	52.0	146.8
DN50	250	58.6	153.4	16.5	228.5
DN65	1,065	267.5	738.4	11.3	1,017.2
DN80	638	201.8	456.5	-	658.3
DN100	564	242.8	333.8	73.6	650.1
DN125	973	443.4	729.8	-	1,173.2
DN150	585	304.0	447.2	-	751.2
DN200	168	95.2	134.1	-	229.3
DN250	181	116.9	149.6	-	266.4
DN300	741	491.2	628.2	-	1,119.4
DN400	455	340.2	397.7	-	737.9
Subtotal	7,686	2,949.8	4,484.1	732.6	8,166.5
Constraint mitigation					-
Contingency (10%)		295.0	448.4	73.3	816.7
Total	7,686	3,244.8	4,932.5	805.9	8,983.2

Network 3 West Extension – network pipe dimensions and capital costs

Network		**1**	**2**	**3**
Variant		Base	East Extension	West Extension
Thermal rating, non-residential	kW	16.6	21.5	17.4
Thermal rating, residential	kW	0.6	5.5	2.3
Non-residential buildings connected	no.	13	42	17
Dwellings connected	no.	198	1,485	734
Substations - non-residential	£k	611	1,030	697
Substations - residential	£k	39	435	158
Heat Interface Units - residential	£k	0	541	0
Heat meters - non-residential	£k	115	199	127
Heat meters - residential	£k	14	590	162
Subtotal	£k	779	2,795	1,143
Contingency (10 %)	£k	78	279	114
Total	£k	**857**	**3,074**	**1,258**

Network 3 West Extension – network pipe dimensions and capital costs

Appendix 6. Carbon analysis

CO_2 emissions for delivered heat have been calculated based on assumed steam turbine power losses associated to heat offtake within the EfW plant, and the forecasted power carbon factors (Long term grid marginal emission projection used published by BEIS, over the assumed operation period. Carbon emissions for the heat supply have been compared against a counterfactual scenario for each assumed property connection. Typical performance assumptions for gas boilers and other counterfactual supply options have been applied. The emission factors for gas and heat from the EfW plant are shown in the table below have been used.

Emission Factors			Source
Natural gas	gCO_2/kWh	184	UK Government GHG Conversion Factors for Company Reporting (June 2020)
EfW heat offtake – refurb (2-line)	gCO_2/kWh	13.86	Analysis based on 'displaced power' as per Green Heat Network Fund guidance (v1.1)
EfW heat offtake – refurb + expand (3-line)	gCO_2/kWh	12.88	
Grid Electricity (2020)	gCO_2/kWh	138	Source: Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal, Table 1, Grid average (March 2020)

Note regarding the exclusion of carbon emissions associated to power generation

The carbon emission performance of the project only accounts for the emissions associated to the delivery of heat. Within the project the provision of power via a private wire network to the two anchor consumers (University of Wolverhampton and CWC) is an important source of revenue which supports the project business case. However, there is uncertainty regarding how these carbon emissions should be attributed. In summary, EfW plant is considered to be a waste management process with power generation as a direct bi-product, i.e. these are its primary purposes. Heat recovered from the plant is considered to be 'waste' and as such it is reasonable to assume zero carbon emissions but also to allocate the associated emissions linked to lost power generation which is then replaced by grid-sourced power.

It is reasonable to assume that the overall carbon emissions of the EfW facility (the combustion process + ancillary energy uses) could then be attributed to the power generation minus that already attributed to the heat extracted (for the heat network). The resulting power emissions would typically be higher in comparison to grid-sourced power (which is rapidly de-carbonising).

Equally, it may be argued that a carbon factor for grid-sourced power is used for the power supplied since this is what is displaced by power distributed directly from the EfW to the 'private wire' consumers.

Calculation of the emissions for the project, i.e. accounting for both heat and power, are summarised in the tables below using both of these approaches.

Further to this, the carbon associated to the EfW plant may also reasonably take account of alternative waste management options, e.g. landfill. This would significantly discount the emissions, potentially resulting in the negative emissions. This has not been calculated within the study as it outside the scope of the work.

		Network 1 (Base)		Network 2 (East Extension)		Network 3 (West Extension)	
		2 Line	3 Line	2 Line	3 Line	2 Line	3 Line
15 yr.							
CO_2 emission savings	$kTCO_2$/yr	3.8	4.1	3.6	4.3	3.9	4.4
	%	83 %	90 %	65 %	78 %	78 %	87 %
CO_2 intensity	gCO_2 /kWh	34	20	56	35	40	24
40 yr.							
CO_2 emission savings	$kTCO_2$/yr	4.2	4.5	3.9	4.7	4.3	4.8
	%	83 %	90 %	65 %	78 %	78 %	87 %
CO_2 intensity	gCO_2 /kWh	34	20	57	36	40	24

Carbon emission savings vs. counterfactual (heat and power) – using grid-sourced power carbon factors[5]

		Network 1 (Base)		Network 2 (East Extension)		Network 3 (West Extension)	
		2 Line	3 Line	2 Line	3 Line	2 Line	3 Line
15 yr.							
CO_2 emission savings	$kTCO_2$/yr	1.2	1.6	1.2	1.9	1.4	1.9
	%	20%	26%	16%	27%	21%	29%
CO_2 intensity	gCO_2/kWh	209	194	178	156	188	170
40 yr.							
CO_2 emission savings	$kTCO_2$/yr	0.6	1.0	0.4	1.2	0.7	1.3
	%	10%	17%	5%	17%	12%	20%
CO_2 intensity	gCO_2/kWh	208	192	176	154	186	169

Carbon emission savings vs. counterfactual (heat and power) – using carbon factors of EfW plant (see below)

The calculated carbon factors of the power supplied, based on EfW combustion minus extracted heat emissions (using GHNF method) are:

		Network 1 (Base)	Network 2 (East Extension)	Network 3 (West Extension)
3 - Refurbished/3-line	gCO_2/kWh	312.97	317.16	314.93
4 - Refurbished/2-line	gCO_2/kWh	316.23	320.57	318.58

[5] *Long term grid marginal emission projection used (GHNF) (15 year average, 2025-2040)*

Appendix 7. Costings and financial assumptions

Capital costs (whole system)

Investment costs							
Network		1 Base	1 Base	2 East Extension	2 East Extension	3 West Extension	3 West Extension
Supply		EfW refurb	EfW refurb + expand	EfW refurb	EfW refurb + expand	EfW refurb	EfW refurb + expand
Heat network	£k	5,487	5,487	12,834	12,834	8,167	8,167
Private wire network		1,081	1,081	1,081	1,081	1,081	1,081
Heat substations, HIUs and metering		779	779	2,795	2,795	1,143	1,143
Private wire connection and metering		954	954	954	954	954	954
Energy Centre		5,117	5,117	7,094	6,805	5,117	5,117
EfW retrofit		880	960	880	960	880	960
Thermal store		0	0	200	0	200	0
Utility connections (gas, electricity, water, drainage, telecom)		1,637	1,637	1,836	1,836	1,681	1,681
Development costs[6]		1,956	1,974	2,496	2,408	2,006	1,984
Contingency (10%)		1,789	1,799	3,017	2,967	2,123	2,109
Total investment costs	**£k**	**19,680**	**19,789**	**33,187**	**32,641**	**23,351**	**23,196**

Capital costs breakdown

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

Energy Centre cost breakdown[7]							
Network		1 Base	1 Base	2 East Extension	2 East Extension	3 West Extension	3 West Extension
Supply		EfW refurb	EfW refurb + expand	EfW refurb	EfW refurb + expand	EfW refurb	EfW refurb + expand
Land	£k	-	-	-	-	-	-
Energy Centre Building (shell and core) plus civils	£k	2,499	2,499	3,475	3,332	2,499	2,499
Energy generating technology costs	£k	1,293	1,373	1,433	1,493	1,293	1,373
EfW retrofit	£k	880	960	880	960	880	960
Gas Boilers	£k	413	413	553	533	413	413
Energy Centre items, or refurbishment of existing plant areas, as applicable	£k	-	-	-	-	-	-
Thermal storage	£k	-	-	173	-	173	-
Electrical export switchgear and transformers	£k	-	-	-	-	-	-
Gas connection	£k	167	167	367	367	211	211
Electrical connections (export by Private Wire or export to grid)	£k	1,408	1,408	1,408	1,408	1,408	1,408
Water connection	£k	30	30	30	30	30	30
Drainage connection	£k	30	30	30	30	30	30
Telecoms connection	£k	2	2	2	2	2	2
Other Energy Centre capex (e.g. piping, valves, pumps, water treatment, cabling, electrical panels, etc.)	£k	2,205	2,205	3,066	2,940	2,205	2,205
Energy centre subtotal (exc. thermal store and connections)	£k	5,997	6,077	7,974	7,765	5,997	6,077
Energy centre subtotal (inc. thermal store and connections)	£k	7,634	7,714	9,984	9,601	7,851	7,758
Detailed engineering costs	£k	1,145	1,157	1,498	1,440	1,178	1,164
Professional fees	£k	382	386	499	480	393	388
Project Management	£k	229	231	300	288	236	233
Project Development	£k	200	200	200	200	200	200
Contingency (10%)	£k	959	969	1,248	1,201	986	974
Energy Centre total	**£k**	**10,549**	**10,657**	**13,728**	**13,211**	**10,843**	**10,716**

Energy Centre cost breakdown

[7] *Costs derived from supplier quotes and Greenfield experience from prior projects*

Tariffs and other revenue assumptions

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.

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.

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.

The heat sales tariff has been split to three components; energy fee, fixed annual fee, and connection fee. The energy fee is estimated based on counterfactual gas cost and applying the appropriate BEIS retail gas price projection. The fixed annual fee accounts for counterfactual boiler O&M costs, and annualised boiler replacement cost. The connection fees are based on counterfactual boiler investment cost (or in the case of existing consumers counterfactual boiler replacement cost).

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.

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

	BAU heating system	Annual heat demand	Peak heat demand	Input energy type	Input energy consum-ption	BAU heating system CAPEX	BAU heating system mainte-nance	BAU heating system repla-cement	BAU input energy unit cost	BAU heating energy cost	Tariff discount vs. BAU	Connect-ion fee	Fixed tariff	Variable tariff	Variable tariff
		MWh	MW		MWh	£	£/yr.	£/yr.	£/MWh	£/yr.	%	£	£/yr.	£MWh	£/yr.
Boscobel - Residential, existing	GB	860	0.55	Power	1,012	286,520	5,455	19,101	33.7	52,877	5 %	272,194	23,328	37.7	50,234
WU - Molineux Campus	GB	3,377	2.23	Gas	3,973	401,222	22,067	26,748	41.9	166,480	5 %	381,161	46,375	46.8	158,156
WU - Student Accommodation	GB	1,983	1.23	Gas	2,333	221,364	12,175	14,758	41.9	97,759	5 %	210,296	25,586	46.8	92,871
WU - Wulfruna Campus (aka South Campus) - without CHP	GB	5,599	3.77	Gas	6,587	677,927	37,286	45,195	41.9	276,016	5 %	644,031	78,357	46.8	262,216
WU - Wulfruna Campus (aka South Campus) - CHP	GB	4,256	2.77	Gas	5,007	498,069	27,394	33,205	41.9	209,810	5 %	473,166	57,568	46.8	199,319
Wolverhampton Wanderers FC	GB	1,083	0.74	Gas	1,274	133,980	7,369	8,932	27.7	35,312	5 %	127,281	15,486	31.0	33,547
Wolverhampton Art Gallery	GB	656	0.48	Gas	772	86,880	4,778	5,792	27.7	21,386	5 %	82,536	10,042	31.0	20,317
Civic Centre	GB	2,795	2.87	Gas	3,288	516,517	28,408	34,434	22.9	75,356	5 %	490,691	59,701	25.6	71,588
Civic Hall	GB	1,331	0.71	Gas	1,566	126,937	6,982	8,462	27.7	43,398	5 %	120,590	14,672	31.0	41,228
Magistrate Courts (old Town Hall building)	GB	634	0.55	Gas	746	98,621	5,424	6,575	27.7	20,687	5 %	93,690	11,399	31.0	19,653
Leisure Centre ("Baths")	GB	1,343	0.84	Gas	1,580	151,658	8,341	10,111	27.7	43,792	5 %	144,075	17,529	31.0	41,603
Molineux Hotel	GB	101	0.14	Gas	119	25,834	1,421	1,722	53.0	6,287	5 %	24,542	2,986	59.3	5,973
Regents House	GB	28	0.03	Gas	32	5,220	287	348	53.0	1,718	5 %	4,959	603	59.3	1,632
Redwings Lodge Hotel	GB	481	0.27	Gas	566	49,032	2,697	3,269	27.7	15,692	5 %	46,580	5,667	31.0	14,907
Total		24,527	17.18		28,855	3,279,782	170,084	218,652		1,066,571		3,115,792	369,300		1,013,242

Heat sales tariffs for ***Network 1 Base***

	BAU heating system	Annual heat demand	Peak heat demand	Input energy type	Input energy consum-ption	BAU heating system CAPEX	BAU heating system mainte-nance	BAU heating system repla-cement	BAU input energy unit cost	BAU heating energy cost	Tariff discount vs. BAU	Connect-ion fee	Fixed tariff income	Variable tariff	Variable tariff income
		MWh	MW		MWh	£	£/yr.	£/yr.	£/MWh	£/yr.	%	£	£/yr.	£MWh	£/yr.
Network 1 Base consumers	GB	24,527	17.18	Gas	28,855	3,279,782	170,084	218,652		1,066,571	5 %	3,115,792	369,300		1,013,242
Central Library	GB	152	0.17	Gas	179	29,700	1,634	1,980	53.0	9,483	5 %	28,215	3,433	59.3	9,008
Wolverhampton Art Gallery	GB	656	0.48	Gas	772	156,240	8,593	10,416	27.7	10,073	5 %	148,428	18,059	31.0	9,569
Grand Theatre	GB	309	0.87	Gas	363	84,060	4,623	5,604	27.7	15,102	5 %	79,857	9,716	31.0	14,347
Wolverhampton Britannia Hotel	GB	463	0.47	Gas	545	57,060	3,138	3,804	53.0	10,764	5 %	54,207	6,595	59.3	10,226
Adult Education College	GB	173	0.32	Gas	203	54,201	2,981	3,613	27.7	31,469	5 %	51,491	6,265	31.0	29,895
Police Station	GB	965	0.30	Gas	1,135	92,753	5,101	6,184	27.7	29,684	5 %	88,115	10,721	31.0	28,200
Novotel	GB	910	0.52	Gas	1,071	109,620	6,029	7,308	27.7	22,948	5 %	104,139	12,670	31.0	21,801
Crown Court	GB	704	0.61	Gas	828	41,777	2,298	2,785	53.0	8,119	5 %	39,688	4,829	59.3	7,713
Wulfrun Shopping Centre (centre HVAC)	GB	130	0.23	Gas	153	58,330	3,208	3,889	27.7	10,150	5 %	55,414	6,742	31.0	9,642
St Davids Court	GB	311	0.32	Gas	366	72,215	3,972	4,814	27.7	17,592	5 %	68,604	8,347	31.0	16,713
Job Centre	GB	540	0.40	Gas	635	29,700	1,634	1,980	53.0	9,483	5 %	28,215	3,433	59.3	9,008
ND1 - Former British Steel site	ASHP	1,790	1.27	Electricity		1,953,900	48,848	130,260	171.0	150,877	5 %	1,856,205	170,152	65.0	143,334
ND2 - Land to the East of Qualcast Rd	ASHP	1,193	0.95	Electricity	716	1,302,600	32,565	86,840	171.0	100,585	5 %	1,237,470	113,435	65.0	95,556
ND3 - Former Crane Foundry site	ASHP	994	0.74	Electricity	398	1,085,500	27,138	72,367	171.0	83,821	5 %	1,031,225	94,529	65.0	79,630
ND4 - St. George’s	ASHP	1,221	1.11	Electricity	489	1,283,146	16,039	85,543	171.0	109,136	5 %	1,218,989	96,503	65.0	103,679
ND6 - Cornhill site	ASHP	103	0.09	Electricity	1,908	108,580	1,357	7,239	171.4	7,073	5 %	103,151	8,166	65.1	6,720
ND 5 - Broad St. Car Park	ASHP	974	0.56	Electricity	390	647,075	8,088	43,138	154.3	60,171	5 %	614,721	48,665	58.7	57,162
Total		36,032	27.00		37,073	11,432,498	358,396	762,167		1,815,990		10,860,873	1,064,535		1,725,190

Heat sales tariffs for ***Network 2 East Extension***

	BAU heating system	Annual heat demand	Peak heat dema nd	Input energy type	Input energy consum-ption	BAU heating system CAPEX	BAU heating system mainte-nance	BAU heating system repla-cement	BAU input energ y unit cost	BAU heating energy cost	Tariff discount vs. BAU	Connect-ion fee	Fixed tariff income	Variab le tariff	Variable tariff income
		MWh	MW		MWh	£	£/yr.	£/yr.	£/MW h	£/yr.	%	£	£/yr.	£MW h	£/yr.
Network 1 Base consumers	GB	24,527	17.18	Gas	28,855	3,279,782	170,084	218,652		1,066,571	5 %	3,115,792	369,300		1,013,242
Graisley high-rise	GB	742	0.42	Gas	873	186,419	25,047	16,645	33.7	40,974	5 %	177,098	39,607	37.7	38,925
Graisley low-rise	GB	1,301	0.62	Gas	1,531	326,997	43,935	29,196	33.7	71,873	5 %	310,647	69,475	37.7	68,279
Mander House	GB	259	0.27	Gas	305	48,562	2,671	3,237	27.7	8,450	5 %	46,134	5,613	31.0	8,027
ND7 – Westside Phase 2	ASHP	1,961	0.84	Electricity	784	966,704	12,084	64,447	173.2	135,762	5 %	918,369	72,704	65.8	128,974
Total		28,790	19.33		32,348	4,808,464	253,821	332,177		1,323,630		4,568,041	556,698		1,257,449

Heat sales tariffs for ***Network 3 West Extension***

Power revenue assumptions are shown in the table below.

			Source
Electricity sales to grid	£/MWh	[redacted]	Current grid export price of the EfW plant, MESE
Electricity sales to Private Wire (peak / offpeak) WU Civic Centre Civic Hall Magistre Courts Leisure Centre "Baths" Molineux Hotel	 £/MWh £/MWh £/MWh £/MWh £/MWh £/MWh	 140.1 / 99.6 138.4 / 98.4 149.7 / 106.5 162.3 / 115.4 162.3 / 115.4 162.3 / 115.4	 WU electricity price -5% QEP (medium) -5% QEP (small/medium) -5% QEP (small) -5% QEP (small) -5% QEP (small) -5%

Power revenue assumptions

Operational cost assumptions

			Source:
Energy centre fuel cost – gas	£/MWh	23.6 – 27.5	BEIS QEP: Tables Annex, non-domestic, small to medium, excl. VAT, incl. CCL, average of latest 4 quarters
Energy centre fuel cost – electricity (for energy centre parasitic load)	£/MWh	[redacted]	Current grid export price of the EfW plant, MESE
EfW heat cost refurb refurb + expand	 £/MWh £/MWh	 10.4 9.8	Analysis based on EfW material and energy flows
EfW power cost	£/MWh	[redacted]	Current grid export price of the EfW plant, MESE
Private wire maintenance	%-capex	1.50 %	Heat Network Electricity Revenues & Licencing Guidance
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 – annual maintenance			
Gas boiler variable	£/MWh_{fuel}	1.3	
Annual fixed costs			
Gas boiler		2.0 % of CAPEX	
Other energy centre equipment		1.0 % of CAPEX	
Sewage heat recovery equipment (H/X, pumps etc.)	£/yr	5,000	From sewage heat recovcery equipment manufacturer
Heat network fixed maintenance	£/m, trench	1.3	Greenfield experience from prior projects
Heat network replacement/repair	%-of HN capex/yr	0.5 %	
Private wire maintenance	%-of PW capex/yr	1.5 %	
Substation & HIU servicing	£/unit/yr	50	Quote from heat network operator

Maintenance cost assumptions

			Source:
Gas boilers lifetime (in energy centre)	*yrs*	25	Greenfield experience from prior projects
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 8. Detailed financial modelling results

		Network	Net 1		Net 2 East		Net 3 West	
Project viability		Supply	EfW refurb	EfW refurb + expansion	EfW refurb	EfW refurb + expansion	EfW refurb	EfW refurb + expansion
NPV (@3.5 %)								
	25 yr	£k	17,771	18,329	28,796	30,859	21,826	22,720
	30 yr	£k	20,536	21,174	32,311	34,627	24,879	25,886
	40 yr	£k	25,002	25,765	38,179	40,887	29,886	31,066
LCOE, heat (@3.5 %)								
	25 yr	£/MWh	22.1	20.7	43.0	39.3	27.1	25.2
	30 yr	£/MWh	20.3	18.9	41.6	38.1	25.8	23.9
	40 yr	£/MWh	18.0	16.5	39.6	36.0	23.8	21.9
IRR								
	25 yr	%	11.6 %	11.8 %	12.2 %	13.0 %	12.0 %	12.4 %
	30 yr	%	11.8 %	11.9 %	12.3 %	13.0 %	12.1 %	12.5 %
	40 yr	%	12.0 %	12.1 %	12.4 %	13.1 %	12.3 %	12.7 %
Simple payback		yr	9.9	9.7	9.4	9.0	9.6	9.4
Discounted payback (@3.5 %)		Yr	11.5	11.3	10.9	10.3	11.1	10.9
Economic viability (including socio-economic benefits								
Social NPV (@3.5%)								
	25 yr	£k	20,311	20,682	14,371	15,868	17,946	18,663
	30 yr	£k	26,346	26,825	16,820	18,611	22,687	23,565
	40 yr	£k	38,456	39,145	21,610	23,948	32,425	33,604
Social IRR								
	25 yr	%	11.0 %	11.1 %	7.6 %	8.0 %	9.5 %	9.8 %
	30 yr	%	11.5 %	11.6 %	7.7 %	8.2 %	10.0 %	10.2 %
	40 yr	%	12.0 %	12.1 %	8.1 %	8.6 %	10.5 %	10.7 %

Detailed financial modelling results – including Private Wire

		Network	Net 1		Net 2 East		Net 3 West	
Project viability		Supply	EfW refurb	EfW refurb + expansion	EfW refurb	EfW refurb + expansion	EfW refurb	EfW refurb + expansion
NPV (@3.5 %)								
	25 yr	£k	-7,207	-6,649	3,817	5,881	-3,152	-2,258
	30 yr	£k	-7,860	-7,222	3,915	6,232	-3,516	-2,510
	40 yr	£k	-8,694	-7,931	4,482	7,191	-3,810	-2,630
LCOE, heat (@3.5 %)								
	25 yr	£/MWh	86.5	85.1	86.8	83.2	81.0	79.1
	30 yr	£/MWh	85.1	83.6	85.7	82.1	79.9	78.0
	40 yr	£/MWh	83.1	81.6	83.8	80.2	78.3	76.4
IRR								
	25 yr	%	-0.6 %	-0.2 %	4.8 %	5.5 %	2.0 %	2.5 %
	30 yr	%	-0.7 %	-0.3 %	4.7 %	5.5 %	2.0 %	2.4 %
	40 yr	%	-0.9 %	-0.4 %	4.8 %	5.5 %	2.0 %	2.5 %
Simple payback		yr	40.0	40.0	18.1	16.5	31.0	28.8
Discounted payback (@3.5 %)		yr	40.0	40.0	31.0	26.4	40.0	40.0
Economic viability (including socio-economic benefits)								
Social NPV (@3.5%)								
	25 yr	£k	-2,700	-2,329	-8,640	-7,143	-5,065	-4,348
	30 yr	£k	-3,010	-2,531	-12,536	-10,745	-6,669	-5,792
	40 yr	£k	-3,127	-2,439	-19,973	-17,636	-9,158	-7,979
Social IRR								
	25 yr	%	2.0 %	2.3 %	0.3 %	0.8 %	1.1 %	1.4 %
	30 yr	%	2.0 %	2.2 %	-1.7 %	-0.9 %	0.3 %	0.8 %
	40 yr	%	2.0 %	2.4 %	-20.6 %	-18.1 %	-1.8 %	-0.8 %

Detailed financial modelling results – excluding Private Wire

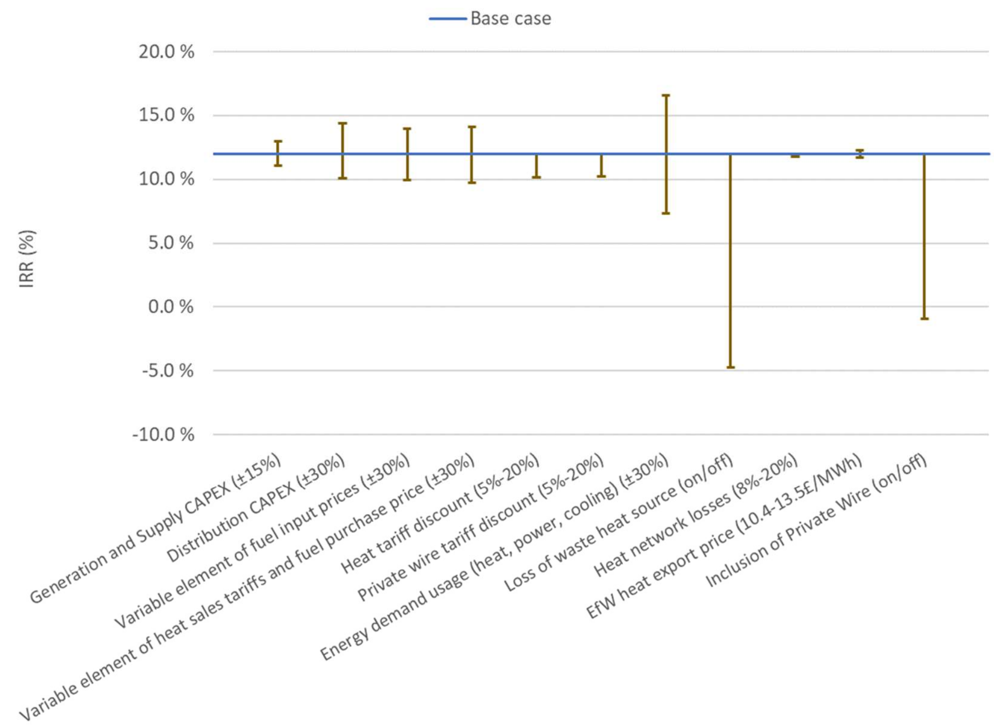
Network Supply	Unit	Net 1 EfW refurb	Net 1 EfW refurb + expansion	Net 2 East EfW refurb	Net 2 East EfW refurb + expansion	Net 3 West EfW refurb	Net 3 West EfW refurb + expansion
IRR 5.0 %	£m	0.0	0.0	0.0	0.0	0.0	0.0
	% capex	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
IRR 7.0 %	£m	0.0	0.0	0.0	0.0	0.0	0.0
	% capex	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
IRR 10.0 %	£m	0.0	0.0	0.1	0.0	0.0	0.0
	% capex	0.0 %	0.0 %	0.2 %	0.0 %	0.0 %	0.0 %

Gap funding required to reach investment thresholds set out by HNDU – including Private Wire

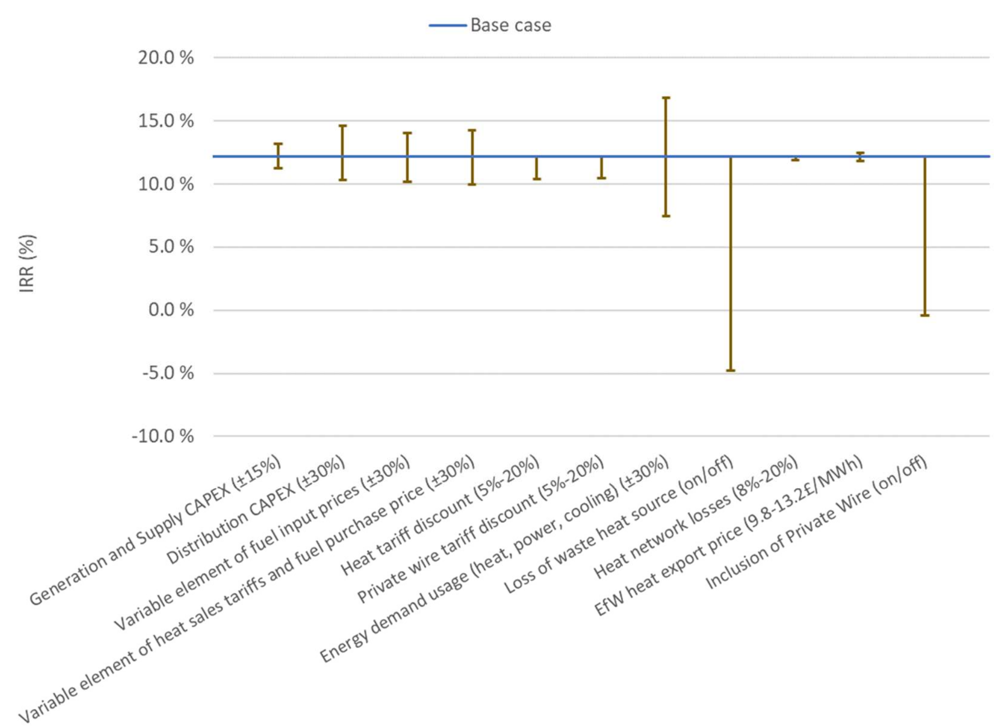
Network Supply	Unit	Net 1 EfW refurb	Net 1 EfW refurb + expansion	Net 2 East EfW refurb	Net 2 East EfW refurb + expansion	Net 3 West EfW refurb	Net 3 West EfW refurb + expansion
IRR 5.0 %	£m	8.4	8.0	0.5	0.0	5.5	4.7
	% capex	45.7 %	43.0 %	1.6 %	0.0 %	24.7 %	21.4 %
IRR 7.0 %	£m	9.5	9.1	4.5	3.0	7.6	6.9
	% capex	51.3 %	49.2 %	14.2 %	9.6 %	34.2 %	31.6 %
IRR 10.0 %	£m	10.3	10.0	8.2	7.0	9.4	8.9
	% capex	55.6 %	54.0 %	25.7 %	22.3 %	42.4 %	40.4 %

Gap funding required to reach investment thresholds set out by HNDU – excluding Private Wire

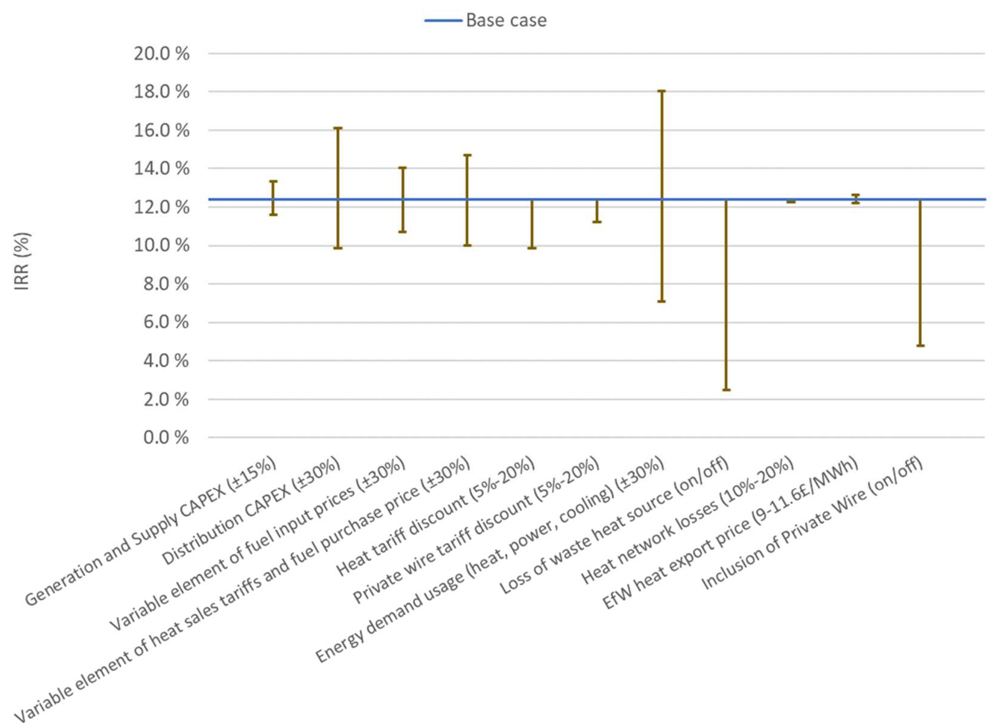
IRR sensitivity graphs



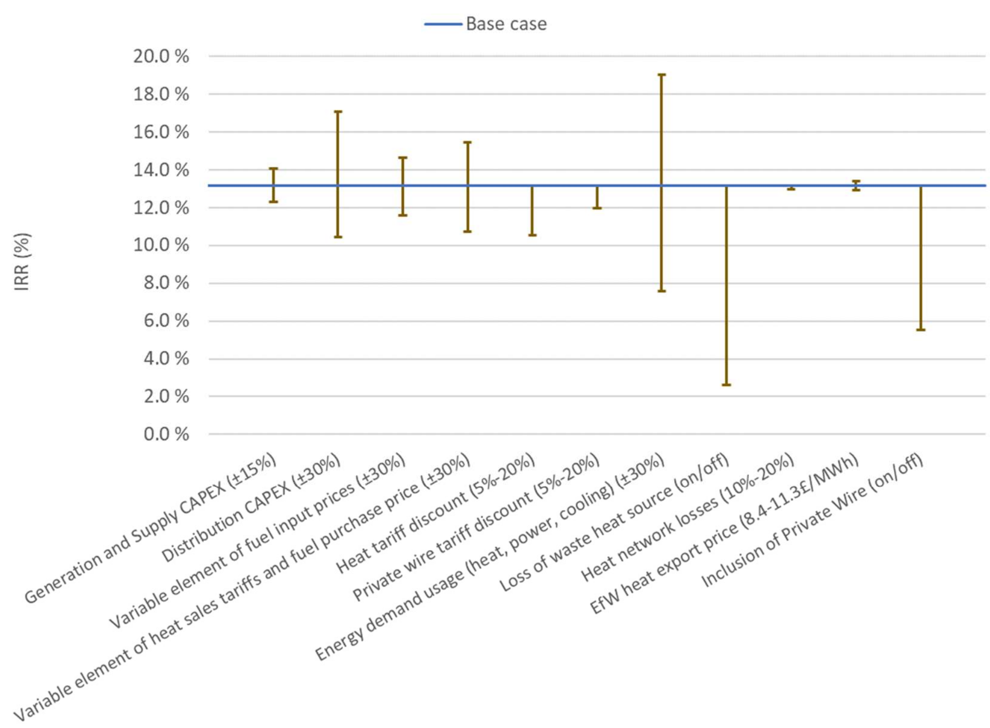
IRR sensitivities – Network 1: Base (EfW refurb)



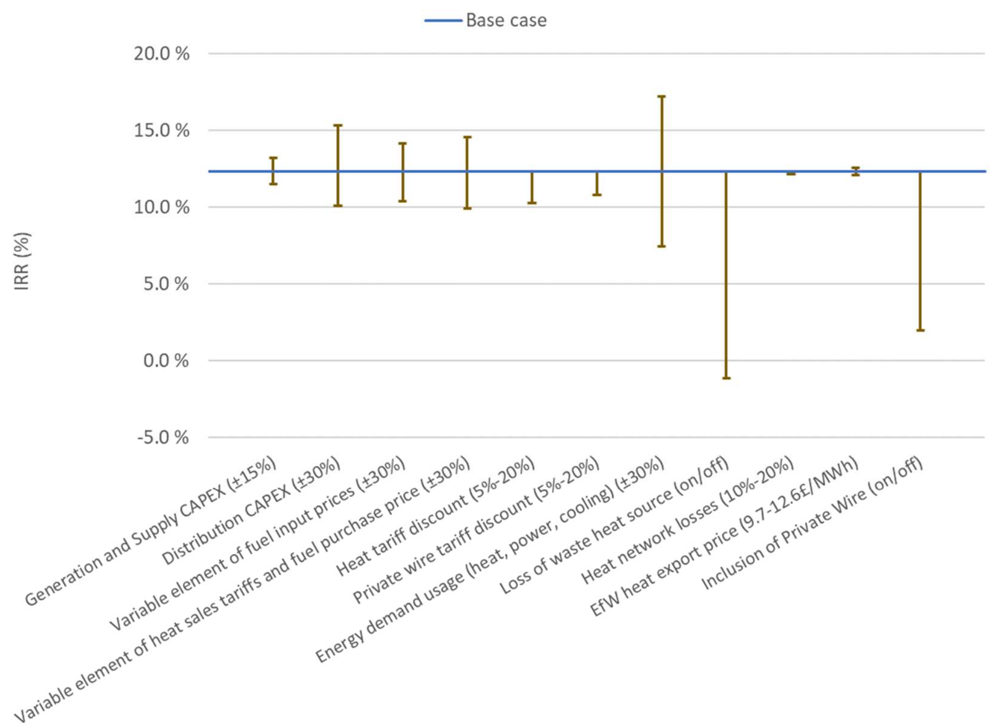
IRR sensitivities – Network 1: Base (EfW refurb & expand)



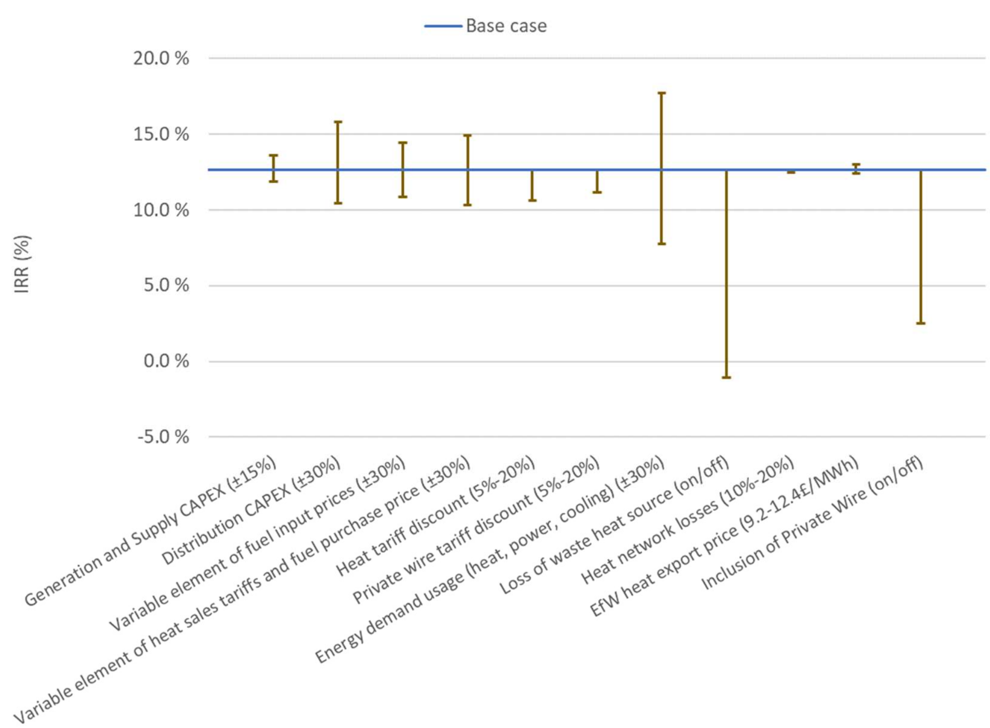
IRR sensitivities – Network 2: East extension (EfW refurb)



IRR sensitivities – Network 2: East extension (EfW refurb & expand)



IRR sensitivities – Network 3: West extension (EfW refurb)



IRR sensitivities – Network 3: West extension (EfW refurb & expand)

Annual UK temperatures 1884-2018

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