BUROHAPPOLD ENGINEERING

Hogsmill Heat Detailed Feasibility

Detailed Feasibility Report

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Glossary

Term	Definition
AD	Anaerobic Digestion
ASHP	Air Source Heat Pump
BEIS	Government department for Business Energy and Industrial Strategy
BoQ	Bill of Quantities
Capex	Capital Costs
CHP	Combined Heat and Power
COP	Coefficient of Performance
CRE	Cambridge Road Estate
DPD	Detailed Project Development
dT	Temperature difference
EC	Energy Centre
EMP	Energy Masterplan
FBO	Full Build Out
GLA	Greater London Authority
HIU	Heat Interface Unit
IRR	Internal Rate of Return
KH	Kingston Hospital
NPV	Net Present Value
O&M	Operation and Maintenance
Opex	Operational costs
PFS	Preliminary Feasibility Study
PHE	Plate Heat Exchanger
RBK	Royal Borough of Kingston upon Thames
Repex	Replacement costs
SAP	Standard Assessment Procedure
SOC	Strategic Outline Business Case
TEM	Techno-economic cashflow model
WSHP	Water Source Heat Pump
WWTP	Waste Water Treatment Plant

1 Executive Summary

Context to the Hogsmill Heat Network

The Hogsmill Heat network proposes to export low carbon resilient heat from multiple sources at the Thames Water Hogsmill Waste Water Treatment Plant (WWTP) to supply the Cambridge Road Estate development as a first stage of an expandable decarbonisation project. This will reduce gas consumption by ~50% vs. alternative CRE technology and provide up to ~95% of the heat with only 5% coming from onsite boiler plant.

The RBK commissioned detailed feasibility study finds that the [redacted] project could provide a commercially viable proposition for both RBK and Thames Water and would deliver long term low carbon heat and air quality improvements as well as a gateway for further decarbonisation across the borough through scheme expansion.

This report presents the findings from the detailed feasibility study and outlines the key risks and next steps for project implementation.

Benefits to RBK

In 2019 RBK declared a climate emergency, setting a target for the borough to be carbon neutral by 2038. This project could save an estimated 16,600tCO2e over 30 years compared to the CRE proposed solution and will likely be the single biggest intervention RBK can make to reduce carbon emissions in the borough.

Other benefits include:

- Potential **to create jobs** during construction phase and local upskilling for operation
- Alleviate fuel poverty and **improve air-quality** in the borough, with an estimated 80% reduction in carbon emissions at year 15 compared to the counterfactual
- Requires funding in the region of [redacted] **investment** and would qualify for the government backed £320m HNIP scheme.
- **Private sector investment:** The scheme could deliver returns within Thames Water hurdle rates and attract [redacted] of investment for Energy Centre operation and could attract further private sector investment on the heat network elements..

Heat demands and supply

The accelerated sense of urgency since the climate emergency declaration has led RBK to focus the scheme on the key anchor load of Cambridge Road Estate (CRE). CRE is a 2,170 residential unit social housing estate in Kingston. Its timely redevelopment and location near the Hogsmill WWTP presents an excellent opportunity to provide one of Kingston's most deprived areas with affordable, clean, low carbon heat.

WWTP final effluent and biogas CHP waste heat will supply the bulk of heat to the network. Gas boilers at CRE provide the peaking capacity.

The network route, key connections and heat supplies are shown in Figure 1-1. Along with CRE, the nearby Cambridge Gardens social housing and new Hampden Road residential development have been considered as additional heat loads.

Positive conversations held with Kingston Hospital have opened up the opportunity to integrate this large heat load as part of future network phases however this is not investigated in detail in the scope of this study.

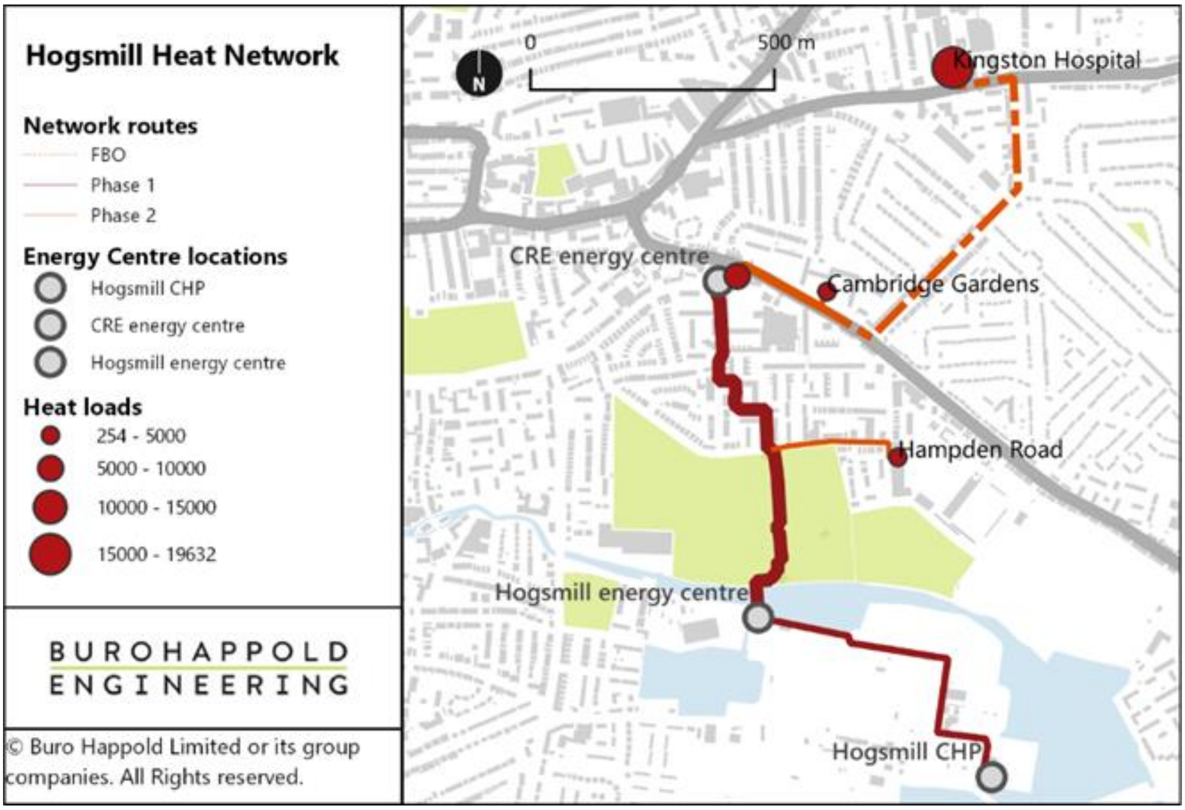


Figure 1-1 Hogsmill heat network

Effluent heat offtake and energy centre

BuroHappold have held monthly discussions with Thames Water, the operators of Hogsmill WWTP, to develop the technical requirements for heat offtake. The proposed solution is to extract heat from the effluent post tertiary treatment to minimise impact on WWTP operations.

It is proposed a new chamber is built with an offtake from the existing culvert. From here the effluent will be pumped to the Energy Centre (EC) where the low-grade heat will be compressed in a heat pump to the required 80°C for distribution in the network. Thames Water are currently undertaking further design and costing of the offtake solution.

Techno-economic performance

The capital costs of the proposed network total [redacted] (see Table 1—1). This includes [redacted] of additional interventions to the existing biogas CHPs to utilise the zero-carbon high grade heat currently being dumped. By reducing the reliance on peaking gas boilers at CRE, this intervention improves the carbon and economic performance of the network.

Modelling suggests the project can deliver a [redacted] IRR, depending on the level of funding that can be secured. This is well within the RBK internal hurdle rate of [redacted], suggesting significant benefit to RBK and any 3rd party wanted to invest.

[redacted]

Operational considerations

Different operational options have been investigated to understand the sensitivity to Thames Water involvement and potential payment for services provided. E.g. operation of the Energy Centre and Heat Pumps on TW land. The assessment suggests that the returns when funded would be adequate to meet both RBK and TW hurdle rates.

Required actions

This project has the potential to provide RBK with a secure revenue stream which can be reinvested into the community. It is therefore recommended that the study is taken forward further to Detailed Project Development (DPD) stage.

The key next steps are to:

- Stakeholder engagement
    - Continue Thames Water engagement to work towards an agreeable delivery model.
    - CRE design team integration of proposals
- Develop scheme through DPD
    - Technical development
    - Costing
    - TEM update
    - Operational model
- Produce the Outline Business Case (OBC)
- Proceed with funding applications and procurement
- Further investigate the Kingston Hospital network extension
- Surveys recommended:
    - Desktop C2 utility record survey and identify locations for GPR surveys
    - Ground investigation surveys at Thames Water site

2 Key drivers for the Hogsmill Heat Network

2.1 Aims and focus

Since 2018 the Royal Borough of Kingston upon Thames (RBK) have been investigating the opportunity to utilise the large waste heat source available at the Hogsmill Waste Water Treatment Plant (WWTP) to provide low carbon heat and hot water to RBK residents.

RBK declared a climate emergency on 25th June 2019, with the goal of making the borough carbon neutral by 2038[1]. This decision has accelerated the council's interest in the Hogsmill heat network project as likely the single largest intervention they can make to reduce greenhouse gas emissions in the borough. It has attracted the interest of the former Energy Minister and MP for RBK, Ed Davey who says of the CRE redevelopment:

> *"We need locally, nationally and globally, to make climate change a top priority because it is so urgent… Councils have got to work hard on energy efficiency… with the new homes programme on the Cambridge Road Estate, sustainability is really a much bigger aspect than it was under the last council… we have to tackle it, we have to act far more quickly than some people think…* ***Local authorities have an important role to play****"*

Ed Davey, Surrey Comet 22nd March 2019

This accelerated sense of urgency has led RBK to focus the scheme on the key anchor load of Cambridge Road Estate (CRE). The CRE development is a 2,170 redevelopment of an existing social housing estate in Kingston. It's timely redevelopment and location near the Hogsmill WWTP presents an excellent opportunity to provide one of Kingston's most deprived areas with affordable, clean, low carbon heat.

BuroHappold Engineering have been appointed as the main consultancy to progress this from Energy Mapping and Masterplanning (EMP) to Preliminary Feasibility Study (PFS) and Strategic Outline Case (SOC) to the current stage Detailed Feasibility as presented herein.

In December 2019, RBK submitted an application for funding of the Detailed Project Development stage, for a heat network scheme serving the Cambridge Road Estate area and the Kingston Hospital, to the UK Government's Business, Energy and Industrial Strategy (BEIS) department. At the time of writing no decision has been made.

2.1.1 Key drivers

A DHN can contribute to The Royal Borough of Kingston upon Thames (RBK) drivers and targets:

- Utilising waste heat at Hogsmill makes this likely **the largest single impact project** that RBK could participate in
- Potential **to create jobs** during construction phase and local upskilling for operation
- Alleviate fuel poverty and **improve air-quality** in the borough, with an estimated 80% reduction in carbon emissions at year 15 compared to the counterfactual
- Could deliver in the region of [redacted] **investment into CRE** towards the required low carbon heating system from the private sector

[1] https://www.kingston.gov.uk/info/200284/energy_climate_change_and_sustainability/1635/climate_change_-_news_and_events

- **Private sector investment:** The scheme could deliver returns to any operator in the range of 5% IRR before funding, which could bring revenue to RBK and also attract private sector investment.

2.2 Strategic vision

The borough wide opportunities presented in the PFS have been consolidated to focus on connecting Cambridge Road Estate (CRE) cluster.

Effluent waste heat at Hogsmill WWTP and biogas CHP heat will supply the bulk of heat to the network.

Positive conversations with Kingston Hospital (KH) have opened up the opportunity to integrate this network extension in the future.

Figure 2-1 illustrates the strategic vision in three phases:

- **Phase 1:** Cambridge Road Estate only
- **Phase 2:** additional connections of Cambridge Gardens and Hampden Road
- **Full Build Out (FBO):** network extension to Kingston Hospital

It is the intention that the scheme can be extended into Kingston Town Centre in the medium/long term.

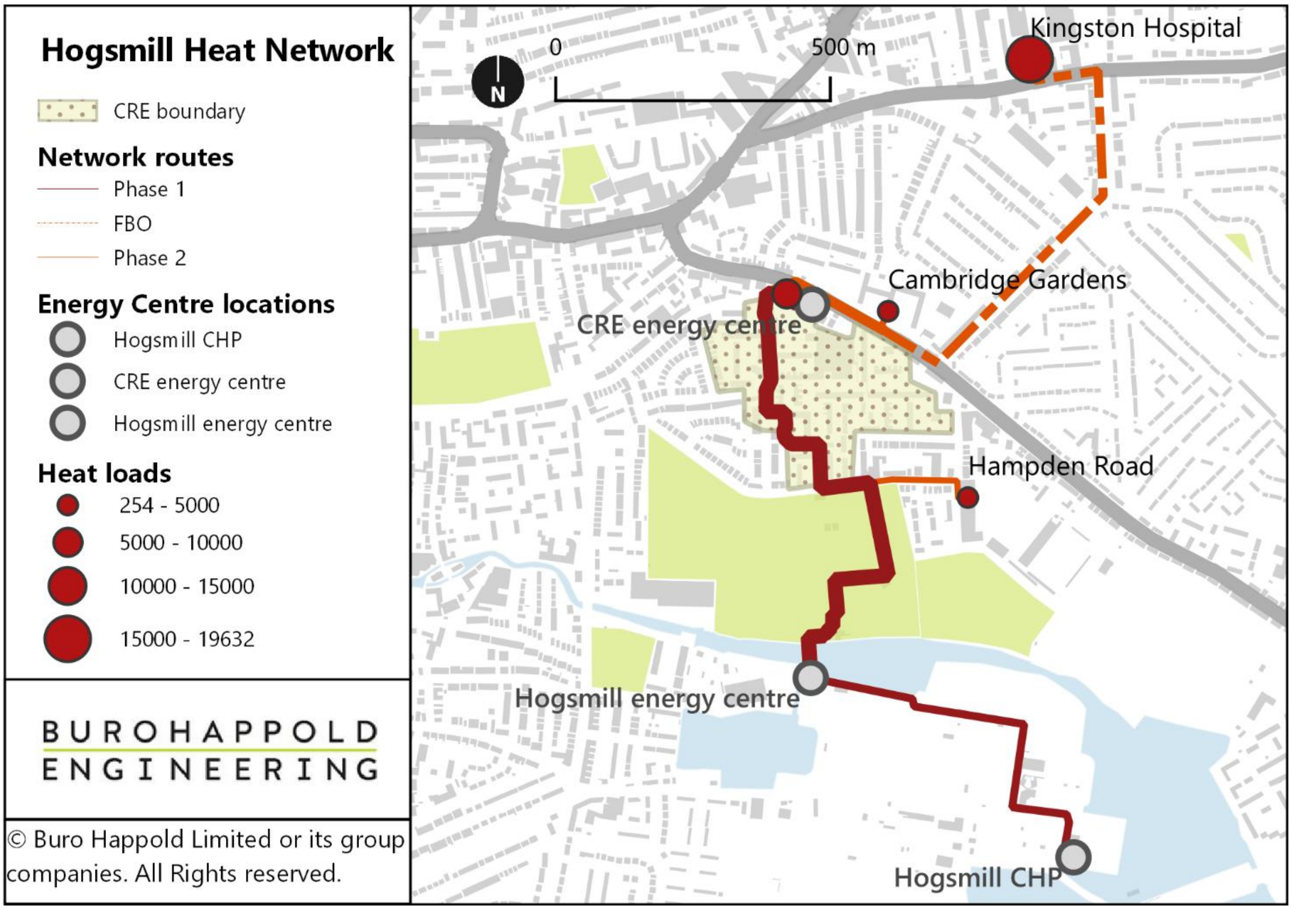


Figure 2-1 Strategic vision

2.3 Report structure

This report provides an update on the previous work BuroHappold have completed for RBK. Namely:

- The Energy Masterplan (2019)
- Strategic Outline Case (2019)
- RBK Heat Network Preliminary Feasibility Study (PFS) (2019)

As stated above, this report focusses on CRE and the surrounding connection opportunities. This is referred to as Phase 1 in the PFS.

The report is split into the following seven sections:

1. **Scheme update:** taking all lessons learnt from site visits and stakeholder engagement, this section detailed the proposed network
2. **Energy production:** summarises the available heat sources (including the final effluent, crematorium waste heat and onsite Thames Water Combined Heat and Power (CHP) heat)
3. **Energy Centre and plant:** provides the bill of quantities of all major plant on the network, along with the schematic and other drawings
4. **Network routing:** detailed the route and constraints as assessed by external consultant 3DTD. Network sizing and trenching specified is also specified in this section
5. **Carbon assessment:** Carbon dioxide equivalent (CO2e) modelling based on BEIS projections. The network's CO2e emissions is compared to the counterfactual CO2e emissions to assess potential savings
6. **Techno-economic modelling:** details of the capital and operation costs of the network, heat pricing, funding options and sensitivity testing
7. **Next steps and risk management:** the next steps for progression to Detailed Project Development (DPD) and beyond are detailed along with key risks.

3 Scheme update

Taking the learnings from the case studies and the stakeholder engagement, the proposed network design is detailed in the following section.

This report focusses on kick-starting the project through connection to Cambridge Road Estate. The extension to Kingston Hospital and the town centre (detailed in the PFS report) is not the focus of this study however, it is still considered a viable option for future phases of the network.

Due to positive engagement with the hospital, a high level review of the performance of the Kingston Hospital connection as a 'Plan B' for if the CRE ballot was rejected has been undertaken – this will be subject to further technical and commercial work at the next stage.

3.1 Load schedule

The load schedule for each connection is shown in Table 3—1. CRE consisted of 5 phases, built in 2-year intervals as per the phasing plan. All other key inputs and assumptions can be found in Appendix A.

Table 3—1 Load schedule

Connection name	Annual heat load	Peak heat load	No. resi units	Connection year	Option	Data source
	MWh/a	*MWth*	-	*Year*		
CRE phase 1	1,899	1.746	501	2024	Basecase	Annual and peak loads provided by Hodkinson. Estimated split over each phase based on phasing plan. Connection dates taken from phasing plan
CRE phase 2	1,579	1.453	417	2025	Basecase	
CRE phase 3	1,597	1.468	421	2027	Basecase	
CRE phase 4	1,555	1.430	410	2029	Basecase	
CRE phase 5	1,597	1.469	421	2031	Basecase	
Cambridge Gardens	2,155	0.754	164	2022	Sensitivity	Annual heat load estimated from EPC data (183kWh/m2). Peak load benchmarked
65 Hampden Road	254	0.424	79	2022	Sensitivity	Benchmarked based on info in planning documents
Kingston Hospital	19,632	5.751	n/a	2027	Sensitivity	Annual and peak loads provided by Kingston Hospital. Connection date assumed to align with new onsite EC from discussions with Kingston Hospital. Heat load includes the new residential development

3.2 Network schematic

The network schematic is shown in Figure 3-1. The following section details each heat supply and customer's connection requirements and configuration.

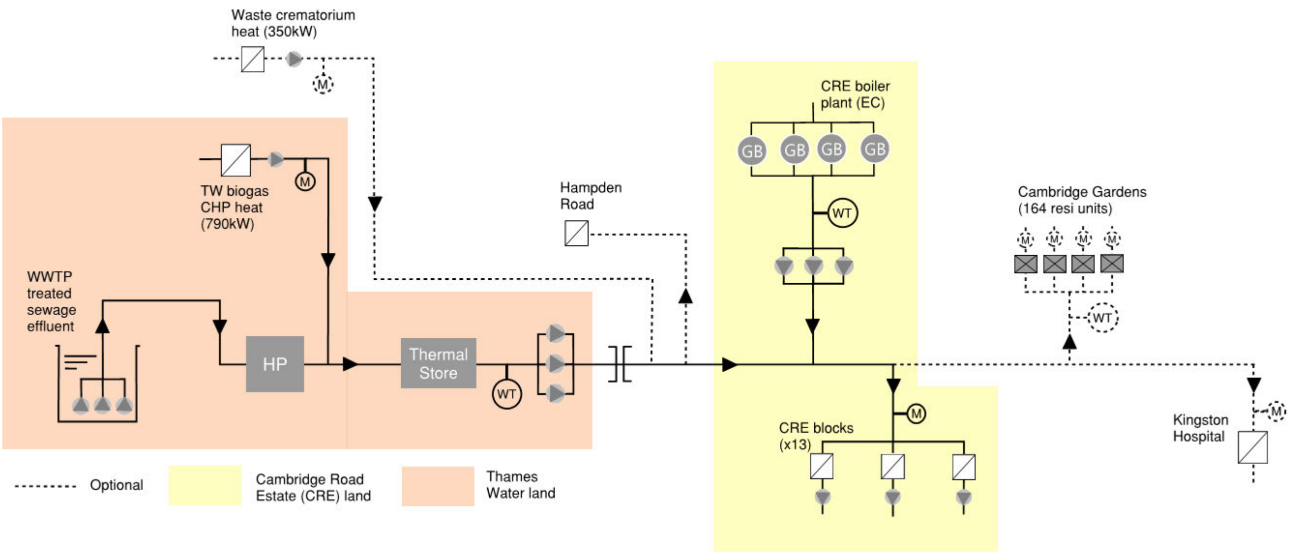


Figure 3-1 Network schematic

3.2.1 Heat customers

CRE

The key anchor load for the network is CRE. It's estimated annual heat load at the site EC of 8,227MWh/a and a peak of 7.6MW over the 2,170 resi unit development. Detailed plans of the redevelopment are yet to be seen. Based on the available information (see appendix) it has been assumed that at full build out there are 13 blocks, each requiring a Plate Heat Exchange (PHE) skid and pump set. These will supply residents through a direct Heat Interface Unit (HIU) at each flat as part of the secondary network.

It is assumed that Countryside will install the secondary network at CRE. Once connection is made, the network operator will take on the O&M and replacement costs of the PHE, pump sets, HIUs and all secondary network. Metering will be carried out at the HIU.

Hampden Road (sensitivity)

Hampden Road is a new 79-unit residential development. Identified in the EMP as a potential connection due to its proximity to CRE. Since the EMP, Hodkinson have written an energy addendum to the planning documents, stating the development will have an onsite heat network powered by ASHPs and top-up gas boilers. All dwellings to connect into a single plant room for ease of connection to the proposed heat network.

This is an considered an optional heat supply as it has a small heat load compared to CRE. It is proposed connection is made in the onsite plant room through installation of a PHE skid. Heat is supplied and metered at bulk point.

Cambridge Gardens (sensitivity)

As in the PFS report, it is proposed the existing 164-unit social housing at Cambridge Gardens is considered for connection to the network. The secondary system, currently individual gas boilers, will require retrofitting to become connection ready to the network.

Heat will be sold to the customer at HIU level. As none of the Cambridge Gardens blocks are high-rise indirect HIUs are considered appropriate, with no central thermal substation.

Kingston Hospital (optional – future phases)

Kingston Hospital's continued interest in connecting to the proposed heat network means it could act as an alternative heat customer should the CRE regeneration fall through due to the residential ballot. In this scenario is proposed that a single PHE skid is installed into the Hospital's EC to facilitate connection to the network. Low carbon heat will be metered at sold in bulk. It is assumed the Hospital will retain and operate its existing peaking plant as part of their secondary network.

4 Energy production

The sewage effluent heat offtake arrangement at Hogsmill WWTP is detailed in this section. Data on the available heat from the existing CHPs on the Hogsmill site is also summarised with indicative drawings and routing to connect into the new energy centre. Similarly, the indicative interventions required at Kingston Crematorium to connect into the network are shown in this section.

4.1 Heat supplies summary

Table 4—1 shows the peak and max annual heat supplies available from the three waste heat sources.

Gas boilers housed at the CRE EC will provide back-up and peak heat supply to the network. By locating the boilers here the network can make the most out of the existing plant space and reduce network losses. It is proposed that Countryside will provide boiler capacity to meet the peak load of the CRE. Once connection is made, the Operation and Maintenance (O&M) and replacement costs of these boilers and associated plant will be adopted by the network.

Table 4—1 Low carbon heat supplies summary

Heat supply	Peak heat (kWth)	Max. annual heat supply (MWhth)
Heat pump	1,523	12,000
Biogas CHPs	790	6,000
Crematorium	350	730

4.2 Hogsmill effluent offtake arrangement

The following section details the considerations made on location and design on the effluent offtake.

It is proposed the main energy centre, housing the heat pump(s), thermal stores, water treatment, distribution pumps and auxiliary plant is located on Thames Water land at the Hogsmill WWTP. Locating the heat near the final effluent abstraction will reduce pumping power and increase the overall efficiency of the network.

4.2.1 Basis of design

Investigation on the feasibility of each option is based on initial hydraulic considerations, ease of access and potential disruption to the site.

Table 4—2 shows the estimated water head in the culvert downstream of the tertiary treatment at different flow conditions, calculated with the Manning equation (subject to future investigation of roughness, slope etc.). The recommended minimum water depth in the pumping chamber for the abstraction pumps is 1m. Therefore intervention is required to ensure minimum depths in all flow scenarios.

Table 4—2 Water head at selected flow conditions

	Flow (l/s)	Normal Depth (m) Culvert
Minimum Flow	282	0.35
Average Flow	744	0.58
Maximum Flow	2258	1.13

4.2.2 Optioneering

Three options for effluent offtake were presented to Thames Water (locations shown in Figure 4-1).

- **Option A:** existing chamber upstream the tertiary treatment
    - Disregarded as the temperature drop is thought to affect the tertiary treatment process
- **Option B:** existing chamber downstream the tertiary treatment
    - Disregarded at this stage as a sluice gate would be required to increase water head in low flow scenarios which could interfere with upstream tertiary treatment
- **Option C:** offtake on existing outfall/manhole before the outfall in the Hogsmill River
    - Taken forward as has no impact on WWTP operations and located away from key plant

Figure 4-1 Offtake options – locations (edited from GoogleMaps)

4.2.3 Preferred design

The design of the offtake (Option C - Figure 4-2) has been developed based on an iterative design process with feedback from Thames Water. The design minimises the risk to Thames Water operations while also providing a reliable flow of water to the heat pump.

The existing chamber is to be modified or replaced to divert flows to a new pumping chamber. A new sluice gate is suggested to facilitate maintenance and access to the pumps. This also ensures complete control of the discharge flow should Thames Water require it. The cold return can be placed inside the existing culvert, downstream of the new offtake chamber. This has the added benefit of the chamber's proximity to the proposed EC location (see Section 0). This means it may be possible to create a separate compound with private access from the RBK Recycling Centre.

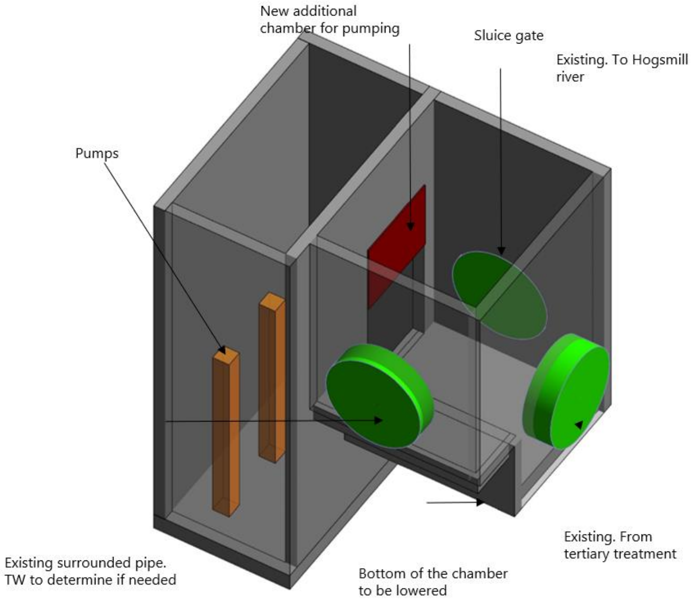


Figure 4-2 Option C Offtake drawing – BuroHappold initial proposal

Thames Water development of the design

Based on this work Thames Water have since taken forward their own design for costing of works onsite. This design is similar to that detailed here, however it uses hot tapping to the existing outfall to connect a pre-made cylinder to the existing culvert.

This option will likely reduce capital costs and construction tine on site compared to the solution detailed above. However, it is not possible to tell from the drawings if the existing culvert can maintain its water level at periods of low flow to ensure a constant flow into the heat pump.

Further development of the design and monitoring of flow conditions in the culvert is recommended before this design is taken forward.

4.3 Heat supply connection to network

See Appendix D for the schematic arrangement of the connections detailed below.

4.3.1 Hogsmill biogas CHPs

To utilise the waste heat from the CHP, it is proposed a plate heat exchanger (PHE) skid is installed before the existing heat-dump radiators in the South-East corner of the Hogsmill WWTP site (see Figure 4-3).

This PHE have been sized at 66% duty/assist to the combined peak thermal load of the three CHP units. This has been estimated at 1,547kWth based on data provided by Thames Water. It is assumed this is high-grade heat. This ensures that the maximum heat available from the CHPs can be utilised if not being used on site.

During normal operation, the average combined peak heat load from the three CHPs is 790kWth.

Assuming a 90/50degC flow and return from the CHP, the network size required to carry 1,547kW is DN125mm.

Figure 4-3 Indicative CHP routing across Hogsmill WWTP (image from GoogleMaps)

4.3.2 Kingston Crematorium

There is an estimated 350kW of available heat per cremation and Kingston Crematorium perform an average of 4 cremations per working day (Section 1). Assuming an average of two hours per cremation (i.e. the cremators are continually running over the 8-hour day) annual heat available with a 90% availability factor is ~730MWh/a.

Assuming a peak factor of 1.25, the peak power available is 460kW. The PHE required to connect this heat into the network is sized to this peak, with a 66% duty/assist configuration.

As a worse case estimate, it is assumed the heat is bought back to the Hogsmill EC (Figure 4-4). However, it is likely that the networks trunk pipe will pass directly adjacent to the Crematorium building and the heat can be injected directly into the network. The crematorium upgrades are also facilitating heat recovery for use in their buildings and therefore intervention should be straightforward, however mechanical drawings were not made available at this stage.

Assuming a 90/50degC flow and return from the Crematorium PHE, the network size required to carry 460kW is DN80mm.

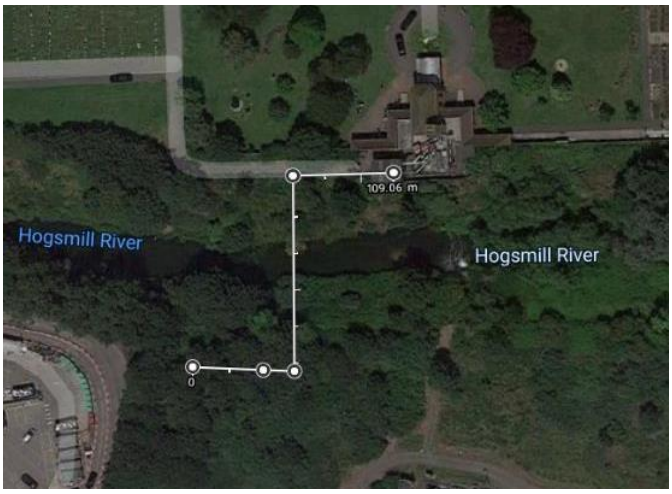


Figure 4-4 Crematorium network routing (image from GoogleMaps)

5 Energy Centre and plant

This section details the sizing and design of the main Energy Centre (EC) at Hogsmill WWTP. A bill of quantities is produced for all major plant along with EC layout, connection schematic, ventilation design and the electrical concept schematic.

5.1 EnergyPro modelling

Overview

The energy modelling software EnergyPro has been used to assess the annual heat flows of the network. Five scenarios have been modelled to determine plant sizing and heat fractions, as shown in Table 5—1.

This section outlines the methodology used for the modelling and presents the results with recommendations for heat pump and thermal store capacities at the energy centre.

Table 5—1 Scenarios modelled

Scenario	Heat supplies	Heat demands
1	Hogsmill final effluent heat	CRE
2	Hogsmill final effluent and CHP heat	CRE
3	Hogsmill final effluent and CHP heat	CRE and Cambridge Gardens
4	Hogsmill final effluent and CHP heat	CRE, Cambridge Gardens and Hampden Road
5	Hogsmill final effluent, CHP and Crematorium heat	CRE

5.1.2 Methodology and key inputs

Profiling

To build a model of the annual operating profile for the scheme, in order to size plant, a number of profiles were combined. The annual heat load of each connection was modelled. This data was distributed for each building across the year using a typical week hourly profile for a building of that typology. The profiles used are from a range of BuroHappold metered operational data and previous project experience.

These typical weekly profiles are then factored to the annual heat demand of each connection. The process for the core scheme connections is outlined in Figure 5-1. Figure 5-2 shows the hourly heat profile for the year for CRE, including 10% network losses applied as a flat profile across the year. The domestic hot water profile remains relatively constant throughout the year; the dip in the summer months is due to domestic hot water generation as minimal space heating is required in these periods.

Figure 5-1 Heat demand profiling method

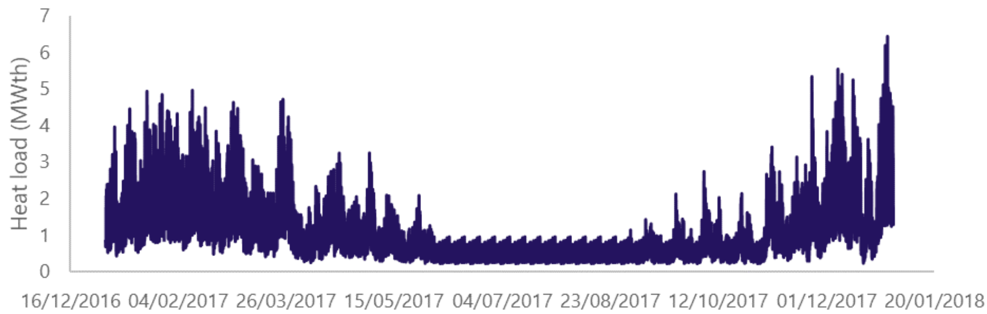


Figure 5-2 Combined annual hourly heat profile for CRE

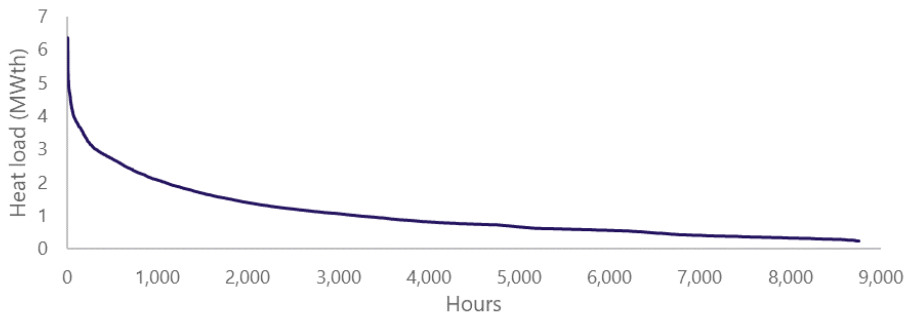


Figure 5-3 Combined heat duration curve for CRE

Heat pump modelling

The 1.5MWth heat pump has been set up to run at a minimal partial load of 50%, with a minimum run time of 1 hour (as per GEA specifications). The Coefficient of Performance (COP) varies with network temperature (assumed 80°C flow and 50°C return), effluent water temperature and load on the network. Partial load is achieved with constant flow rate and varying the dT and supply return temperatures. The COP varies from 3.5 to 4.1 depending on outfall temperature and load on the network.

Two days downtime per year for each heat pump unit for maintenance is assumed in the winter months, with an availability factor of 98% as per GEA guidance. Gas boilers are modelled at 89% efficiency and allow for part load.

CHP heat supply modelling

The waste heat supply from the three Hogsmill biogas CHPs has been modelled as three flat profiles totalling 790kW. Each CHP has an assumed 2 hours of downtime per day.

The operational strategy has been set to prioritise heat from the CHPs before the heat pump. With the remaining heat supplied by the gas boilers (Figure 5-4). In this case both the heat pump and CHP heat are used to charge the thermal store.

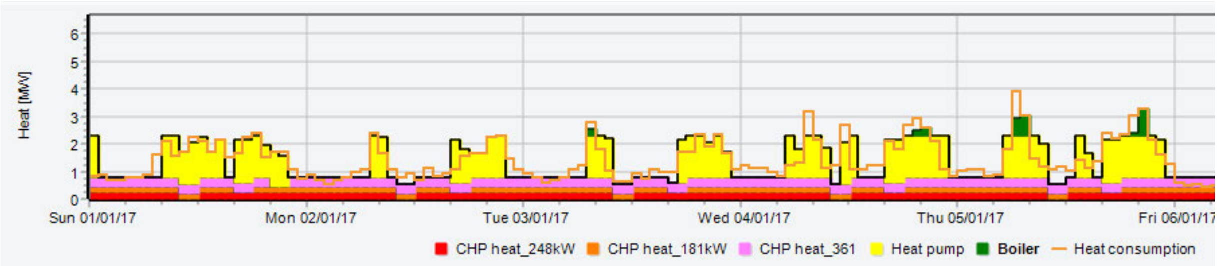


Figure 5-4 Typical winter week with CHP heat

Crematorium heat supply modelling

As with the CHP heat, the crematorium waste heat has been modelled as flat 350kW profile (see Section 4.3.2). It is assumed this heat is only available from 9am to 5:30pm Monday to Friday. At these times the crematorium heat is prioritised over the other heat sources

The resulting profile of a typical winter week is shown in Figure 5-5.

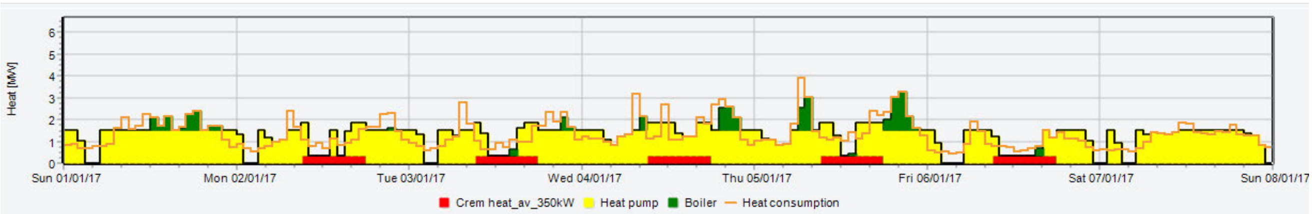


Figure 5-5 Typical winter week with Crematorium heat

Thermal store modelling

A thermal store, comprised of a large hot water tank, is used in order to maximise the operational hours of the heat pump unit to maximise carbon emission savings. Functions include:

- Smooths the daily variation in heat demand to reduce the use of peak boilers
- Enables plant to operate at full output for fewer hours rather than part load, which can be less efficient
- Reduces the number of starts of the low carbon plant.

The thermal store has been set up to allow charge from all heat supply except the gas boilers. Assumes a 90% utilisation factor and 20% minimum storage content.

Assessment of the thermal store capacity's impact on total heat load met by the heat pump with CRE heat load is shown in Figure 5-6. After approximately 50m^3 the percentage met by the heat pump is almost constant. A constant thermal store size of 100m3 has been incorporated to allow for the inclusion of CHP heat and will reduce load cycling on the heat pump in early phases and the summer months when load is low.

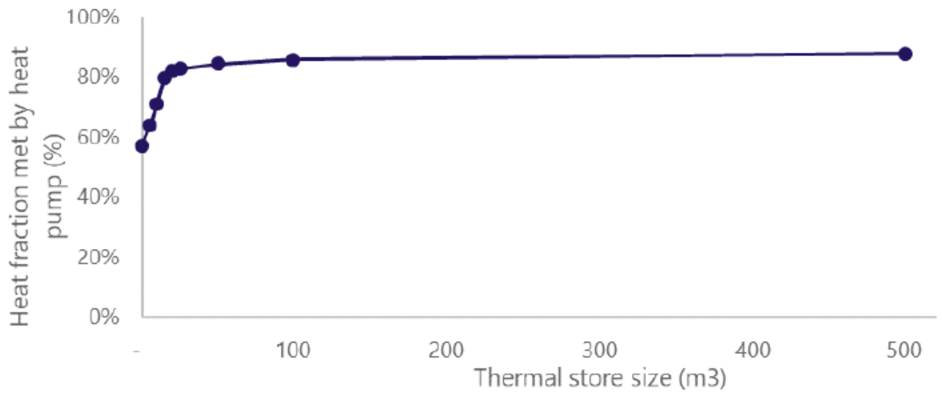


Figure 5-6 Thermal store sizing

5.1.3 Results

Table 5—2 details the results from the EnergyPro modelling for all five scenarios tested. The maximum percentage of annual heat demand met by the 1.5MW heat pump is 86%. Peaking gas boilers can provide the remaining 14% (Scenario 1).

The combined waste heat from the three biogas CHP engines at Hogsmill have the potential to provide over 60% of CRE's annual heat demand (Scenario 2). In this option the heat pump would provide the remaining 33% of heat load, with gas boilers operating during the top 5% of peak. As more heat load is added to the network (Scenarios 3 and 4), the percentage of heat delivered by the CHP reduces to around 50%, with the heat pump increasing its use to ~45%.

The modelling suggests the crematorium (Scenario 5) can provide approximately 8% of CRE's annual energy demand. Although this is a small amount, the heat is free and currently wasted. Techno-economic modelling will assess the financial viability of incorporating this heat source into the network.

Table 5—2 EnergyPro modelling results

Scenario	Annual heat load incl. losses (MWhth)	Peak heat load (kWth)	Annual heat demand met by… (% annual heat demand)			
			Heat pump	CHP	Crematorium	Gas boilers
1 – Effluent & CRE	9,050	6.4	86%	-	-	14%

2 – Effluent, CHP & CRE	9,050	6.4	33%	62%	-	5%
3 – Effluent, CHP, CRE & Cambridge Gardens	11,420	7.0	44%	51%	-	5%
4 – Effluent, CHP, CRE, Cambridge Gardens & Hampden Road	11,700	7.2	45%	50%	-	5%
5 – Effluent, CHP, Crematorium & CRE	9,050	6.4	30%	57%	8%	5%

5.2 Energy centre location

After discussions with Thames Water it is proposed that the EC is located on the large area of disused land near to the existing outfall and culvert (Figure 5-7). The western edge of the Hogsmill WWTP site borders an RBK Recycling Centre which is under ownership of RBK Environmental Services.

This location could provide access for external parties other than Thames Water, depending on who goes on to operate the scheme therefore avoid disruption to the Hogsmill WWTP operations and site entrances when the EC is being serviced. In this case it is recommended that a secure perimeter is built around the EC compound to separate it from existing Hogsmill operations. The other benefit of this location is reduced pumping losses as the heat pump is near the existing outfall where heat can be extracted. Its remote location (not near any housing) means disruption to the local area can be minimised both during construction and operation.

This location is also the opposite side of the WWTP to the CHP engines. Additional pipework must be laid to connect this heat into the EC; as explored in the techno-economic modelling section.

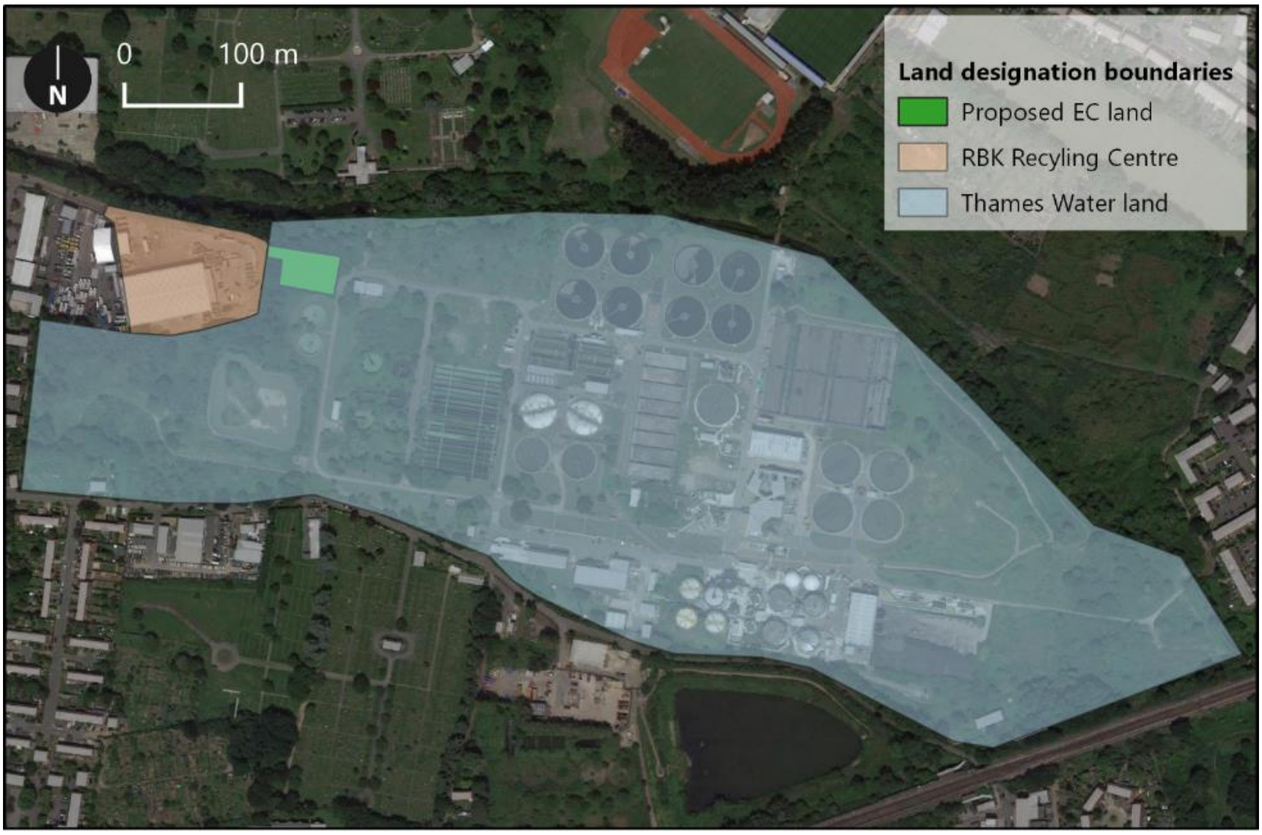


Figure 5-7 Energy Centre location

Earthworks and Flooding

Flood protection is likely to be a key consideration going forward, due to the proximity to the Hogsmill River. Although flooding maps suggest that this area is just outside of a flood zone area it is recommended that a flood protection survey is carried out as levelling of the existing abutment in this location will be required for access.

A site visit to Hogsmill WWTP in 2019 indicated the land proposed for EC development is mainly built up of excavated earth during the WWTP construction. The earth is covered in vegetation and shrubs.

In order to prepare the land for EC construction it is recommended the land is cleared of vegetation, with the excess earth excavated and disposed of. The earthworks can be disposed offsite using a tipper however Thames Water have suggested the earth could potentially be relocated to a disused area of the site.

The removal strategy and associated cost significantly depends on the make-up of the earth. Costs of disposal may increase due to the large amount of vegetation. If the organic carbon content high the cheapest option will be to relocate the earth to elsewhere onsite.

Similarly, if any contaminated land or invasive species are present costs of excavation will greatly increase.

Due to these risks, the following future surveys are recommended:

- Phase 1 desk study to provide details on site history and ground conditions
- Phase 1 ecological survey (required for planning): assessment of existing vegetation including invasive species (Japanese Knotweed, Giant Hogweed etc.) and any protected wildlife (bats, newts etc.)

- Flood risk assessment (required for planning) and air quality assessment
- Ground investigation: assessment of the physical and chemical nature of the ground. May include window samples, trial pits, boreholes and laboratory testing
- Topographical survey: a full 3D survey for setting out, plotting of constraints, establishing levels etc.

5.3 Air quality assessment

The overall air quality in the borough is likely to improve if this network is implemented as it will replace existing gas boilers at Cambridge Road Estate.

5.3.1 Hogsmill EC

The proposed location of the Hogsmill EC is on Thames Water land, far from any residential properties. The EC houses the heat pump with no gas boilers, making the impact on air quality minimal.

It is however important to consider leaking of the working fluid (ammonia) in the heat pump. Ammonia has a Global Warming Potential (GWP) rating of 0. This is significantly less harmful when compared to the common heat pump refrigerant R134a, which has a GWP of 1,430.

However, ammonia can be poisonous in high concentrations and an ammonia leak detection system should be installed. It is recommended by GEA, the heat pump manufacture that this is set at 450ppm for a low level alarm and 4,500ppm for a high level alarm.

At the high level alarm a signal would be sent out to a trip switch which would turn off power to the heat pump. The leak detection system would also be linked to the plantroom ventilation which would vent the plantroom away from personnel areas or to high level. It is recommended a DSEAR and plume dispersion model is carried out to assess the impact of any discharge to atmosphere.

5.3.2 CRE boiler plant

The boiler plant at CRE is being designed by Countryside. It is recommended that all plant comply with emissions standards as detailed in the GLA's Sustainable Design and Construction SPG. According to this document the two pollutants of specific concern in London are particulate matter (PM_{10} and PM_{25}) and nitrogen dioxide (NO_2). Nitric oxide easily converts into NO_2, therefore these are both generally referred to as NOx. NOx can be minimized by adhering to GLA NOX emission limits and use of effective abatement.

In order to ensure effective pollutant dispersion it is also necessary to consider the stack height and location. The energy centre stack should be as tall as possible, ideally at a level above all buildings in the vicinity of the site so as to minimise the building downwash effect (the increased vertical dispersion of plume emitted from stacks due to wind recirculation cavity areas created by buildings). It is also important to consider the proximity to sensitive receptors (particularly residential properties), which may be affected by pollutant emissions.

The use of thermal storage at the Hogsmill Energy Centre aims to maximise use of the heat pump and therefore the boilers are only anticipated to deliver around 15% of the annual heat demand at the CRE development.

5.4 Bill of quantities

The following section details the main plant and Bill of Quantities (BoQ) at Hogsmill and CRE as well as the possible additional network supply and demand connections.

The Energy Centre layout, detailed network schematic and electrical schematic can be found in Appendix D.

Table 5—3 Hogsmill energy centre BoQ

Hogsmill Energy Centre	
Effluent Abstraction	Grundfos submersible pumps (66% duty, assist, standby) SP 60-6 14A00006
	2no. 150m of DN225mm pipework and trenching to EC (uninsulated)
Energy Centre building	250m2 concrete slab. 80m2 office, new substation and storage facilities
Heat generation	1.5MWth GEA high temperature ammonia heat pump (externally housed)
	Taprogge ball heat exchanger cleaning system
Electrical substation	2MVA transformer (N+1 redundancy) 11/0.415kV, Dyn 11, 50Hz. Circuit breakers and batteries
	6.35/110kV 3 core 120mm and trenching 500m, looped cable (future proofed for FBO)
	HV Point of Connection (POC) for new 770kVA at LV (as per UKPN correspondence)
Distribution pumps	Grundfos CR 45-6 A-F-A-V-HQQV - 96122832 (66% duty, assist standby)
Water treatment	ENWA Water Treatment. EnwaMatic BS 300 and 1665 with associated break tank, dedicated circulation pump (Grundfos CRI 5-3)
Thermal stores	2no. Hartwell 50m3 (externally housed)
Other	CCTV, intruder alarm, fire protection, data, ammonia detection, ventilation and ductwork, fibre connection, cold water pipework, sewer, BMS, expansion and pressurisation units, LTHW pipework
Pipe bridge	Pipe bridge over the Hogsmill River (quote from Beaver Bridges)

Table 5—4 Cambridge Road Estate BoQ

Cambridge Road Estate	
CRE Energy Centre	

Boilers	3no. 500kW Hoval condensing boilers (steel heat exchangers). Sized to Cam Gardens and Hampden Rd peak with N+1 redundancy. Remaining CRE capacity provided by Countryside. Incl. heat meter and control valve
Gas upgrade	To allow for additional grid capacity to serve Cambridge Gardens and Hampden Rd
Other	All other plant provided by Countryside. Provision has been made for the distribution pumps (Grundfos NB 65-315/320 ASF2ABQQE (66% duty, 2x assist, standby)) to be included in the Opex and Repex payments of the network once connection is made. No thermal substation at CRE energy centre as assumed the boilers are rated to network pressure
CRE secondary network - for Opex and Repex only	
Block level Plate Heat Exchangers (PHE)	Armstrong PHE skid at each phasing block connection on CRE (assumed 13 in total) - sized to peak load 66% duty/assist.
Block level distribution pumps	Grundfos 66% duty/assist (13 in total)
Water treatment	EnwaMatic 1672
Heat Interface Units (HIUs)	Evinox ModuSAT XR Twin Plate 100A-10A (2,170 units)

Table 5—5 Optional connections BoQ

Optional connections	
CHP heat offtake	Armstrong PHE skid 1,547kW sized to 66% duty, assist (peak of all three biogas CHPs combined)
	Pumps: 66% duty, assist, jockey 10% pumps, Grundfos. 2no. Isolating valves, Logstor
	Logstor Series 2 795m DN125mm (hard dig) pipework and trenching from CHPs to EC
Crematorium heat offtake	Armstrong PHE skid 438kW sized to 66% duty, assist
	Pumps: 66% duty, assist, jockey 10% pumps, Grundfos. 2no. Isolating valves, Logstor
	Logstor Series 2 110m DN80mm (hard dig) pipework and trenching from Crematorium to EC
Cambridge Gardens	HIUs: Evinox ModuSAT XR Twin Plate 100A-10A (164 units)
	Secondary system retrofit from gas heating to DHN connection (see below)
	EnwaMatic 1260 water treatment and dosing
Hampden Road	Armstrong PHE skid 424kW sized to 66% duty/assist

6 Network route

3DTD, an external consultant specialising in district heat network routing, have performed a route assessment. Three options have been appraised from Hogsmill WWTP to CRE:

1. Over the Hogsmill River and through Kingston Crematorium
2. Along Chapel Mill Road, crossing the Hogsmill River at the existing road bridge. Reaching CRE along Villers Road
3. Through Hogsmill WWTP, crossing at the onsite bridge. Reaching CRE through Kingstonian Football Club Grounds

The preferred route is Option 1 and this has been taken forward for network design. The full route appraisal report and HAZIDs list can be found in Appendix C.

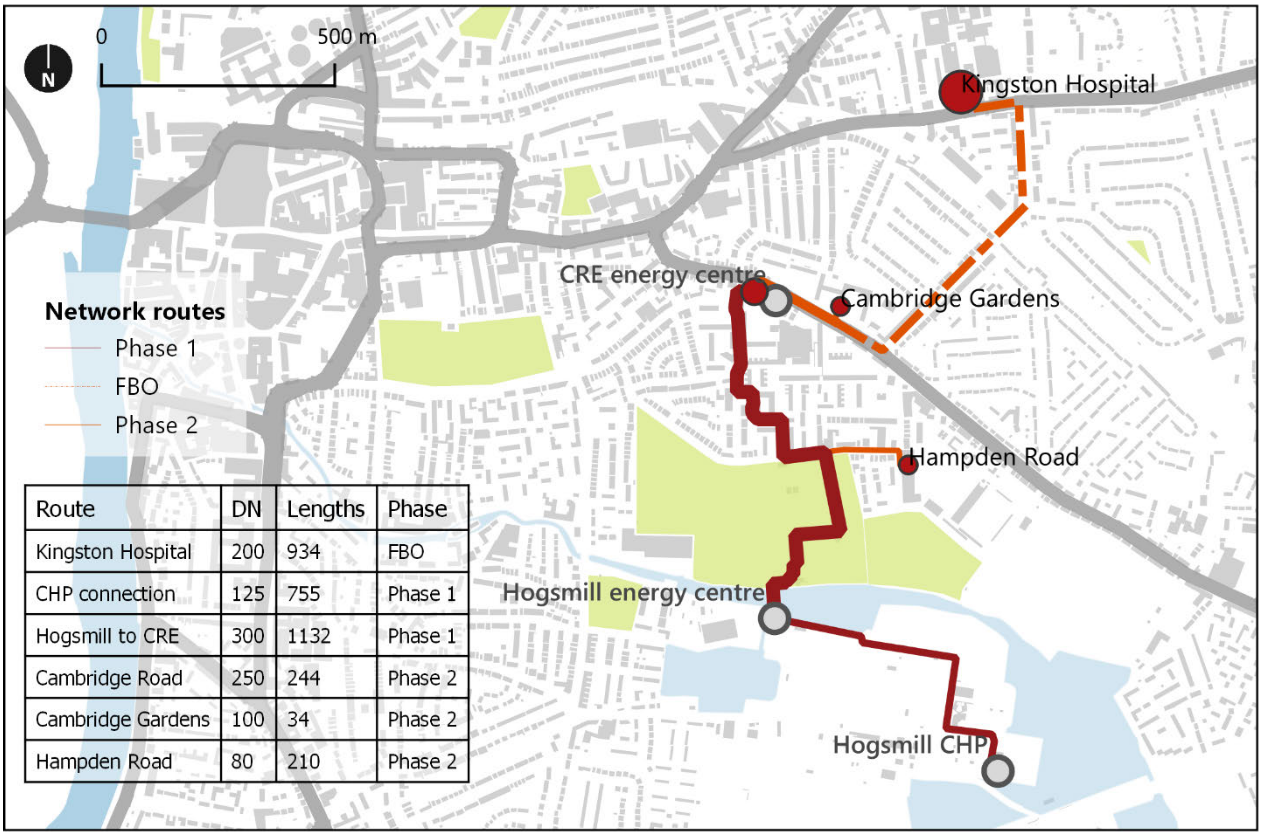
6.1 Network sizing

The network has been sized to allow for future expansion of the network to accommodation Kingston Hospital, Cambridge Gardens and Hampden Road. This provides a future proofed capacity of 14.5MW. A certain amount of oversizing is required to avoid having to replace pipework when the interconnection happens. Key inputs are shown in Table 6—1.

Table 6—1 Hydraulic modelling inputs

Input	Unit	Value
Delta T	ºC	30
Max allowable flow velocity	m/s	3
Water density	kg/m^3	1000
Max allowable pressure gradient	Pa/m	100
Kinematic viscosity	m^2/s	0.4091 x10^{-6}
Specific heat capacity of water	kJ/kgK	4.181
Pipe roughness factor	mm	0.05

Total network length at FBO (i.e. including Kingston Hospital) is estimated at 2,545m. The Phase 1 network to CRE is approximately 857m. There is an assumed 550m of soft-dig trenching through Kingston Crematorium. Network sizing results are shown in Figure 6-1 and Figure 6-2.



Route	DN	Lengths	Phase
Kingston Hospital	200	934	FBO
CHP connection	125	755	Phase 1
Hogsmill to CRE	300	1132	Phase 1
Cambridge Road	250	244	Phase 2
Cambridge Gardens	100	34	Phase 2
Hampden Road	80	210	Phase 2

Figure 6-1 Network sizing

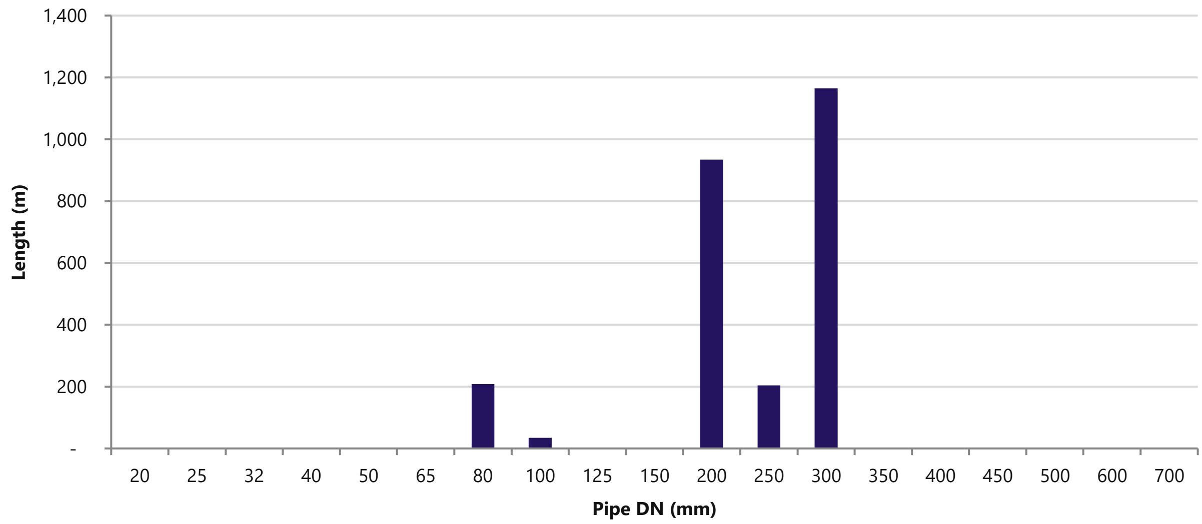


Figure 6-2 Network length by DN size (FBO)

7 Carbon assessment

The carbon emissions of the network have been calculated based on BEIS projections. The results are compared to the 'counterfactual' of not connecting CRE to the network. In this case this is assumed to be ASHPs with peaking gas boilers, housed at the CRE EC.

The heat fraction split for each scenario is as reported in Table 5—2 and assumes an average water-source heat pump COP of 3.8 (based on data provided by GEA) and gas boiler efficiency of 89%.

The biogas used in the CHP is being produced through onsite anaerobic digestion (AD). The Standard Assessment Procedure version 10.1[11] (SAP10.1) states a carbon factor of 0.011tCO2e/kWh for heat from biogas CHP (landfill or sewage). It is thought that the small associated carbon emissions reported in SAP10.1 derive from the biogas fuel stock transportation to the AD plant. Therefore, as the fuel stock for the Hogsmill biogas AD plant is produced onsite the associated carbon emissions are considered negligible and the carbon factor of the CHP heat has been modelled as zero.

Carbon emission factors for natural gas and electricity are based on the BEIS 2019 carbon factors of fuel[12]. The electricity grid carbon factor varies over time as predicted by BEIS.

7.1 Network carbon emissions

7.1.1 CRE counterfactual heat supply

Countryside have confirmed their counterfactual heat source if connection to the network is not secured will be ASHP led. While the exact annual heat fraction the ASHP will supply is not known, Countryside have indicated it will be between 50% and 75%.

The modelling presented below summarises the impact this has on the carbon emissions savings CRE can achieve by connecting the scheme. For this a 60% heat fraction ASHP counterfactual is assumed, with gas boilers providing the remaining annual demand.

7.1.2 Results

Table 7—1 Carbon results summary

Scenario	Unit	CRE (heat pump only)	CRE with CHP heat	CRE + Cam Gardens + Hampden Rd with CHP heat	CRE + Cam Gardens with CHP heat	CRE + CHP + Crematorium (heat pump only)
DH emissions saving @ year 15	%	52%	81%	79%	80%	81%

[11] https://www.bregroup.com/wp-content/uploads/2019/10/SAP-10.1-10-10-2019.pdf
[12] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2018

DH emissions saving @ year 30	%	55%	83%	81%	82%	83%
DH emissions saving (15yr total)	tCO2 e	4,586	7,493	9,988	9,727	7,544
DH emissions saving (30yr total)	tCO2 e	10,592	16,627	21,621	21,096	16,712
Energy centre emissions (30yr total)	tCO2 e	10,071	4,036	5,877	5,681	3,951

The key results are shown in Table 7—1. The heat pump only CRE network achieves an emissions saving of 10,590tCO2e over the projects 30 year lifetime. This represents a 55% saving at CRE compared to the alternative of ASHPs. This increases to an 83% saving if the waste heat from the biogas CHPs can be utilised on the network.

As the additional heat loads of Cambridge Gardens and Hampden Road are connected, the emissions savings continue to increase to a maximum of 21,620tCO2e over the 30-year lifetime.

Figure 7-1 shows the variation in carbon savings over the project lifetime. It clearly illustrates the CRE five stage phasing strategy. Once all heat loads are connected (in 2032) the annual carbon savings remain relatively constant, varying slightly with the BEIS electricity grid carbon intensity predictions.

The connection of Kingston Hospital in the future would see more significant savings as the counterfactual is currently CHP and gas boilers.

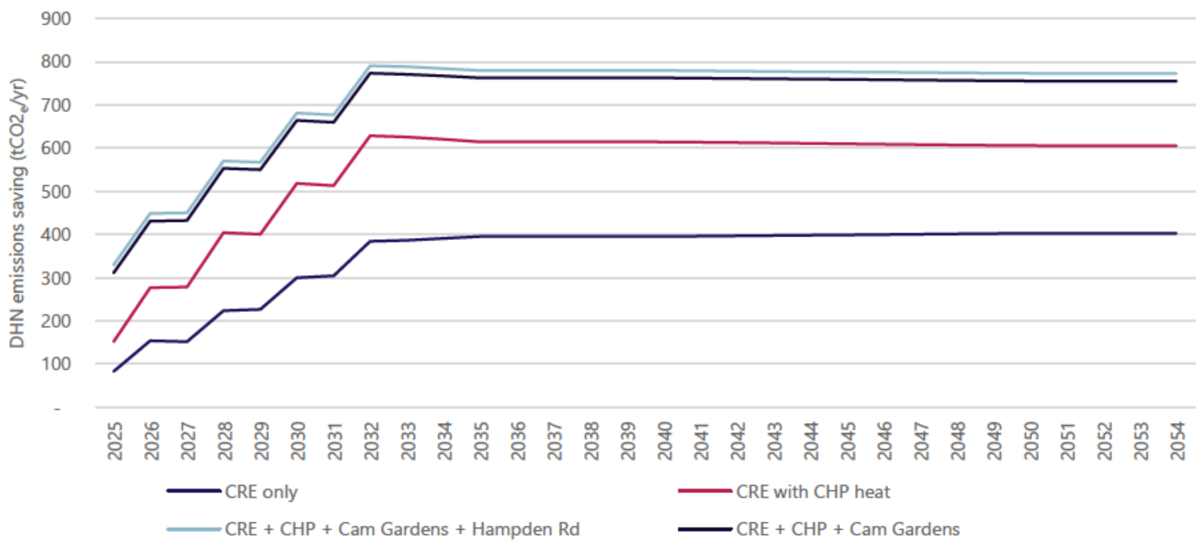


Figure 7-1 Carbon emissions saving across network lifetime

8 Techno-economic modelling

A techno-economic cashflow model (TEM) has been built to assess the possible return on investment the network can achieve over a 30-year time period. The model allows for key sensitivities to be tested, such as heat price, heat load, fuel prices and capital costs.

Multiple scenarios have been assessed including connections to Cambridge Gardens and Hampden Road, utilising the alternative heat sources of the Crematorium and Hogsmill CHPs and possible funding streams.

8.1 Methodology

A techno-economic cash flow model (TEM) was built in MS Excel combining the technical details of the scheme (capital and operational) with appropriate cost/price inputs to generate an annual cash flow. This enabled an assessment of viability (pre-tax) using Net Present Value (NPV) and Internal Rate of Return (IRR) as key indicators.

Key assumptions are detail in Appendix B and include:

- At Cambridge Road Estate it is assumed that Countryside pay for own energy centre, boiler capacity, network and HIU Capex and installation (as they would for own on-site solution). Provision is made within the energy centre for the DHN operator to install additional boiler capacity. The DHN operator will adopt the CRE plant and be responsible for OPEX and REPEX costs. Residents pay non-bulk rate for heat price
- Cambridge Gardens: building heat supply retrofit paid for by DHN project, including HIUs etc. Heat is supplied to each residential unit (i.e. non-bulk) with new peaking boiler capacity housed at the CRE plant room
- Hampden Road: a PHE interface is installed in the existing central plant room. Heat is sold at a bulk rate to whole development
- Crematorium heat is supplied to the network free of charge through a PHE skid and pump set integrated into the Crematorium by the DHN operator
- 5.4% parasitic electrical pumping power as a percentage of network heat load. 2% of which is attributed to distribution pumping (as per CP1). The remaining 3.4% is attributed to effluent abstraction pumps (as calculated by BuroHappold)
- 10% network losses (as per CP1)
- First heat load connected in 2024. CRE is assumed built out in five phases as per phasing plan provided. All other loads connected in year one.

The modelling boundary and key costing inputs are summarised in Figure 8-1.

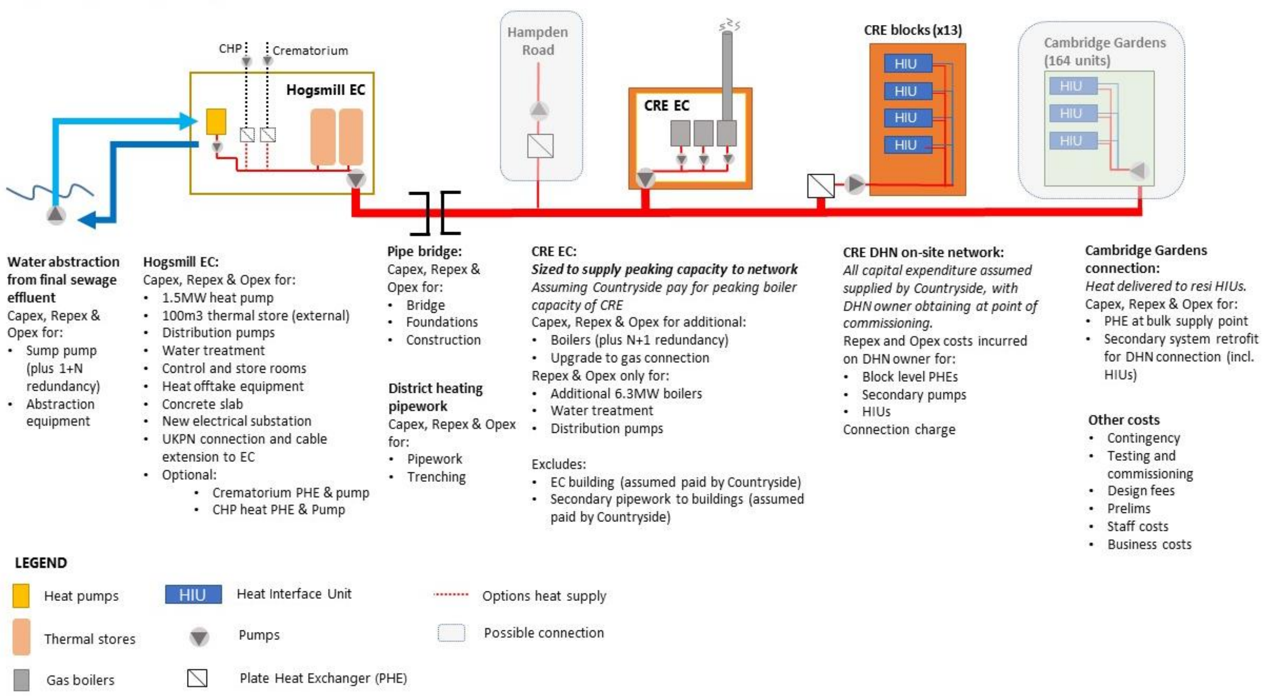


Figure 8-1 Modelling boundary and costing summary

8.2 Inputs

8.2.1 Capital costs

Industry quotes have been obtained for key plant including heat pump units, boiler, thermal stores, package substations at buildings and network pumps. Network costs have been determined using linear metre costs based on inner London pricing, as described in Appendix B.

The effluent abstraction has been costed for as described in Section 4.2.3. Additional costs have been included for expected earthworks [redacted] on the assumption that no contaminated land or invasive species are found.

15% contingency has been applied to all cost estimates, with an additional 5% for installation and delivery and 16% for prelims, design fees, testing and commissioning applied where not included in manufacturer quotes. The costs are subject change and future site investigation is recommended. A full cost breakdown can be found in Appendix B.

CRE connection charge

A connection charge of [redacted] is applied to CRE to take into account the avoided cost of installing the counterfactual ASHPs. This has been estimated based on an assumed sizing to meet 60% heat fraction, using a quote for a 890kW ASHP from Solid Energy, a supplier of heat pumps.

A summary of capital costs is shown in Table 8—1.

[redacted]

8.2.2 Operational costs

Table 8—2 presents the commercial assumptions made regarding the operation of the scheme. Gas, heat and electricity prices have been indexed over the project lifetime using BEIS projections. Opex costs have been included in the model based on a number of manufacturer quotes and other references.

For the purposes of this study, a discount rate of 3.5% has been applied to pre-debt cash flows. All other assumptions are detailed in Appendix B.

Table 8—2 Opex assumptions

	FBO	Unit	Reference and notes
Heat pumps and Taprogge ball cleaning	0.42	p/kWh	Heat pump O&M based on information GEA – applied to annual heat load of heat pumps
Top-up gas boilers	0.13	p/kWh	Boilers and PHX costs at CRE based on manufacture quotes – applied to annual heat load of boilers

Network ancillary equipment (TES, distribution pumps, water treatment, sump pumps)	0.048	p/kWh	Based on manufacture quotes and BuroHappold experience – applied to total annual heat load[13]
Pumps	0.03	p/kWh	Distribution and abstraction (sump) pumps – applied to total annual heat load. Grundfos
HIUs at Cambridge Gardens	0.90	p/kWh	Applied to the annual heat load of only residential connections where applicable[14]
CRE HIUs and PHEs	85,000	£ / yr	Operational cost of all HIUs, water treatment and block level PHEs at CRE
Metering and billing – bulk	1.1	p/kWh	
Metering and billing – non-bulk	65	£ / unit	
Staff costs	16,000	£ / yr	EC manned 2 days per week at £40k FTE
Business costs	0.60	p/kWh	Applied to total annual heat load[15]
Fuel charges			
Gas price at energy centre	2.37	p/kWh	BEIS UK gas and electricity prices in the non-domestic sector 2018[16] - medium consumer (incl. climate change levy)
Electricity price at energy centre	11.5	p/kWh	

8.2.3 Replacement costs

Replacement costs (Repex) are included for all pumps, heat pumps, thermal stores, boilers, PHXs, water treatment, HIUs, heat meters and associated components. As shown in the modelling boundary schematic (Figure 8-1), the TEM assumes that CRE pay for the initial Capex of their peaking boiler plant and HIUs. The DHN operator then takes over the O&M of the scheme up to each residential unit (i.e. including HIUs). This equates to a total capital expenditure of [redacted] to be added to the sinking fund.

An annual sinking fund is built up across the equipment lifetime to account for the Repex costs for 80% of the total energy centre capex in the TEM model.

Pipework replacement is excluded from the model as these typically last longer than the lifetime of the project.

[13] Department of Energy & Climate Change (DECC), 2015. *Assessment of the Costs, Performance, and Characteristics of UK Heat Networks*
[14] Department of Energy & Climate Change (DECC), 2015. *Assessment of the Costs, Performance, and Characteristics of UK Heat Networks*
[15] Sandvall, A. F. et al., 2017. Cost-efficiency of urban heat strategies – Modelling scale effects of low-energy building heat supply. *Energy Strategy Reviews,* Vol. 18, p. 212-223. Available at: https://www.sciencedirect.com/science/article/pii/S2211467X17300615
[16] https://www.gov.uk/government/statistical-data-sets/gas-and-electricity-prices-in-the-non-domestic-sector

8.2.4 Heat pricing

The assumed heat prices for residential bulk and non-bulk connections are shown in Table 8—3, split into standing charge and variable rate. Both rates are based on an average of several Heat Trust registered operational projects and quotes for schemes in London obtained by BuroHappold.

- The standing charge is a flat rate paid to the DHN operator for connection to the network. For heat network pricings, this is usually based on the avoided costs of connecting into the DHN compared to the counterfactual of gas boilers.
- The variable rate is the price paid per unit of heat consumed by each customer – again usually based on the fuel cost to deliver a kWh of heat compared to the counterfactual. E.g. cost of gas per kWh divided by the boiler efficiency.

The heat price at this stage is indicative and subject to change. There is currently no regulatory body for the supply of heat from DHNs however the heat pricing strategy will need to comply with the Heat Network (Metering and Billing) Regulations 2014[17]. All schemes BuroHappold have based the heat price are based on are Heat Trust compliant[18] - in-lieu of official regulation for heat networks the Heat Trust is a not for profit company focussed on customer protection for the district heating sector.

[redacted]

8.2.5 Thames Water waste heat pricing

The TEM allows for sensitivity testing around the heat price paid to Thames Water for their two waste heat sources:

- WWTP effluent: low-grade heat
- Biogas CHP: high-grade heat.

As the proposed scheme will be the first to capture waste heat from a Thames Water outfall, the rate charged for this resource greatly depend on the level of funding obtained and negotiations with Thames Water.

8.2.6 Funding

A summary of the available funding sources and potential Council funding sources is listed below:

- **Zero Carbon Homes and S106 /CIL –** Zero Carbon Homes (ZCH) is now being enforced in Kingston. Contributions are set at £1,800 per tonne of carbon
- **Connection charges –** It is assumed that developers of new buildings connecting to the scheme will pay a connection charge. This is to be treated as an offset against the capital costs of the scheme.

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[17] http://www.legislation.gov.uk/uksi/2014/3120/pdfs/uksi_20143120_en.pdf
[18] Heat Trust, 2018. *Heat Cost Calculator: Further information and background assumptions*. Available at: <http://www.heattrust.org/images/docs/HCC_Further_information_and_assumptions_Jan2019_update__v1.pdf>

- **Heat Network Investment Project (HNIP) –** HNIP funds are specifically offered as 'gap funding' through a combination of grants and loans and will be offered to eligible projects up till March 2022. This can be used for capital costs of energy centre, network and connections and will also cover some commercialization funding
- **Renewable Heat Incentive (RHI)** – Eligible installations receive quarterly payments over 20 years, with payments are made on a £/kWh of renewable heat generated basis. Available until March 2021.
- **The Mayor's Energy Efficiency Fund (MEEF)** – The fund will invest in capital funding of energy conversion measures and renewables, fabric improvements to buildings and innovation. The current interest rate is 1.2%, with the fund open to receive applications until March 2023.

8.3 Results

Results are presented for the CRE only 'core network' both with and without utilisation of the waste CHP heat at Hogsmill (Section 8.3.1). The performance of the network if 40% capital grant funding is secured through the Government's HNIP is also presented here.

Scenario testing on the additional heat loads, crematorium heat and RHI is shown in Section 8.3.3.

Disclaimer: Prospective information for revenue, capital expenditure and operating costs have been derived from information provided by different sources. BuroHappold does not accept responsibility for such information. BuroHappold emphasises that the realisation of the prospective financial information is dependent upon the continued validity of the assumptions on which it is based. BuroHappold accepts no responsibility for the realisation of the prospective financial information; actual results are likely to be different from those shown in the prospective financial information because events and circumstances frequently do not occur as expected, and the difference may be material.

8.3.1 Core network

Table 8—4 shows the core network's performance if supplied by:

1. Heat pump and gas boilers at CRE
2. Heat pump, CHPs and gas boilers at CRE

The results are shown for an unfunded network and a 40% grant funded scheme. These are the results if no payment is made to Thames Water for the waste heat sources.

- Table 8—4 shows that without any grant funding the network returns a positive IRR [redacted] with heat pump and gas boiler only. With 40% capital funding this increases to a [redacted] IRR; within the internal RBK hurdle rate o[redacted]
- If CHP heat can be secured to supply around 60% of the heat network annual demand the scheme with no funding could see IRRs of [redacted], increasing [redacted] with capital funding.
- Figure 8-2 and Figure 8-3 shows the 30-year unfunded cashflow for both these options. It is clear that securing the CHP heat would not only greatly improve the network's carbon savings (see Section 7) but also improve its economic viability.

[redacted]

[redacted]

8.3.2 Sensitivity testing

Tornado graphs

The sensitivity of the model to key inputs has been tested by changing each input in turn and assessing the impact on NPV. Figure 8-4 and Figure 8-4 show the impact of a ±10%, 20% and 30% change in the key variables noted on the vertical axis.

The purpose of undertaking this analysis is to establish which variables are key to project performance and therefore which need particular management focus in order to reduce and mitigate risk.

The standing charge is the most sensitivity variable tested for both the core network with and without CHP. This is followed by the variable heat sales price. As stated in DM2 of the Kingston Core Strategy[19], the CRE falls in one of the most deprived areas in the borough and it is anticipated that a significant proportion of the residential heat load connected may currently be in fuel poverty. This result highlights the importance of setting a heat price that will create a suitable return on investment as well as ensure affordable heat is delivered to those that need it.

Figure 8-4 indicates a variation it annual heat load has minimal impact on the networks NPV. This is due to the proportional increase in revenue through variable heat sales and Opex costs increasing by p/kWh. This effect is reduced in the CHP option (Figure 8-4) because the majority of the heat is considered 'free' (see following section); reducing the fuel import cost.

[redacted]

[19] https://www.kingston.gov.uk/downloads/file/1901/core_strategy

8.3.3 Scenario testing

As the network's economic performance improves significantly with CHP heat, the following sensitivities are for the core scheme with CHP heat and no payment to Thames Water.

Table 8—5 shows that with RHI funding the IRR increases to [redacted] within RBK's hurdle rate. As applications to the RHI scheme are closing in March 2021 and it is currently unknown if or what will replace it. It is therefore only included as a sensitivity in the model. If both RHI and 40% HNIP funding is secured, then IRR reaches [redacted]

If Cambridge Gardens can be connected the core scheme's IRR decreases from [redacted] It is likely this is due to the high cost of retrofitting the existing individual gas boiler heating supply in each flat. The addition of Hampden Road will improve this IRR by another [redacted] This highlights the importance of future network phasing and ensuring suitable low capital cost connections. There may be separate funds available to contribute towards the retrofit of Cambridge Gardens (e.g. RBK replacement funds for gas boilers in the individual dwellings) – these could help improve performance.

This also appears to be the case for the crematorium heat, which sees a slight drop in IRR [redacted] The additional network cost to transport the heat from Kingston Crematorium to the EC is too large to warrant the small increase in waste heat. However, if the network is routed through Kingston Crematorium (as in Section 6), then networks costs can reduce and capturing this heat becomes more viable.

Table 8—5 Scenario testing results

Scenario	[redacted]
Includes CHP heat	
Core network (for comparison)	
Core network with Cambridge Gardens	
Core network with Cambridge Gardens and Hampden Road	
Core network with Crematorium heat	
Core network with RHI	

9 Next steps

The section details the key next steps, risks and proposed timeline for project delivery.

9.1 Next steps

The study suggests that the scheme is able to achieve a positive IRR and meet RBK hurdle rates with grant funding. It is therefore recommended that the study is taken forward further to Detailed Project Development (DPD) stage.

Key next steps are therefore:

- Develop scheme through DPD
- Produce the Outline Business Case (OBC)
- Proceed with funding applications and procurement
- Further investigate the Kingston Hospital network extension

This will further develop the technical scheme but also develop the commercial case and develop a full financial model, plus obtain early legal involvement to ensure regulatory / policy / State Aid compliance of proposals.

Surveys recommended

- Desktop C2 utility record survey and identify locations for GPR surveys
- Ground investigation surveys at Thames Water site

Key Stakeholder engagement

- Thames Water
    - Continue development of offtake option and energy centre location
    - Agree commercial structure with Thames Water
- Kingston Hospital
    - Obtain technical data to inform the development of a scheme serving the Hospital and future demand forecasting
- CRE
    - Engagement with Hodkinson/Countryside for EC peak output and pipework configuration for DH adoption.
    - Performance specification for Energy centre requirements e.g. peak outputs, utility connection and pipework arrangements
- Recycling Centre
    - to review possible energy centre access from existing access road

- Cemetery / Crematorium
    - Review bridge and pipework routing options with cemetery operators and crematorium
- Environment Agency / South East Rivers Trust
    - Gain necessary approvals for the scheme
    - Look for coordination opportunities with renaturalisation of river
- Retain engagement with key connections outside of Phase 1 to ensure that investment decisions are not made in energy infrastructure that may impact ability to connect to the strategic heat network
- Engagement with RBK members including Highways, Housing and Planning.

9.2 Key risks

- CRE residential ballot: residents rejecting the CRE ballot. Mitigation for this can be made through securing the Kingston Hospital connection and retrofitting the existing CRE estate blocks to facilitate DHN connection
- No contaminated land or invasive species at Hogsmill: if these are found at Hogsmill, the land clearing costs for the Hogsmill EC will significantly increase. It is recommended a Phase 1 Habitat Survey is conducted to mitigate against this risk
- Flood protection at Hogsmill: a flood risk survey is recommended to ensure the proposed EC location is not at risk of flooding
- UKPN capacity is not secured: there is a risk of load being taken up by a different a user, increasing cost of supply. The mitigation for this is to pay to secure grid capacity once confident the project is going ahead
- Cambridge Gardens heat load: no data has been provided for heat load over the year and this has been estimated based on a review of EPCs. It is recommended half-hourly metered data is sought to verify heat load.

See Appendix A for full risk register.

Appendix A Risk Register

Item ref.	Risk description	Pre-mitigation			Mitigation measure	Lead by	Post-mitigation		
		Impact (I) 1-5	Probability (P) (1-5)	Risk level (I*P)			Impact (I) 1-5	Probability (P) (1-5)	Risk level (I*P)
1	**Technical**								
1.1	Heat consumption estimates vary vs actual consumption. If heat loads do not materialise (e.g. Cambridge Gardens) the scheme may become difficult to operate economically	4	3	12	No data has been provided for heat load of Cambridge Gardens over the year and this has been estimated based on a review of EPCs. It is recommended half-hourly metered data is sought to verify heat load.	BH / RBK	3	2	6
1.2	Heat load insufficient to justify running of LZC plant during the summer	4	3	12	Obtain hourly heat profiles where possible. Current sizing based on typical hourly heat loads profiles for clusters to ensure sufficient base load. Measure heat loads over long period of time for best possible design information. Provide large thermal store or heat pump modulation for lower summer loads	RBK	3	2	6
1.3	LZC technology availability - if the plant does not achieve the required availability it may impact running costs and carbon emissions. Significant plant failure may leave customers without heat	5	3	15	Transfer risk to operation and maintenance contractor via guaranteed minimum availability contract provisions and penalties. Back-up boilers (or alternative) provided for resilience and fuel flexibility	RBK	2	2	4
1.4	Large heat network distribution losses may lead to substantial loss in value if heat network is not adequately designed or insulated	3	2	6	Transfer risk to O&M contractor - specify high performance as per CP1 guidance and ensure detailed approval, inspection, testing and acceptance process including penalties for under performance. Minimise route lengths where possible in route proving process at detailed feasibility	RBK	3	1	3
1.5	UKPN capacity is not secured	5	3	15	There is a risk of load being taken up by a different a user, increasing cost of supply. The mitigation for this is to pay to secure grid capacity once confident the project is going ahead	BH / RBK	3	3	9
2	**Business case**								
2.1	**Funding**								

2.1.1	Failure to identify funding sources adequate to meet the capital costs of the scheme. Scheme performance reliant on grant funding	5	3	15	Continuous engagement with the GLA to ensure schemes meet requirements for HNIP funding. CP1 and HNDU checklists will be carried out to ensure scheme compliance. Do not proceed if adequate funding cannot be secured	RBK	2	2	4
2.1.2	Lack of interest from commercial developers	5	3	15	Establish what IRR/ NPV values would attract commercial investment through soft market testing	BH	4	2	8
2.2	**Capital costs**								
2.2.1	Budget overspend due to poor cost controls	4	2	8	Undertake design reviews with relevant stakeholders. Consider procurement via a contractors to cover energy centre and networks	RBK	2	2	4
2.2.2	Budget underestimated due to unforeseen issues	5	3	15	15% contingency added to cost estimates	RBK	4	2	8
2.3	**Revenues**								
2.3.1	Resulting cost of heat too high for residents	5	2	10	RBK required to provide additional capital funding over and above loan value in order to reduce heat cost. However, this will affect the schemes revenue performance. Tight control on scheme costs is required through detailed development	RBK	4	1	4
2.3.2	Uncertainty around access to the Renewable Heat Incentive (RHI) after March 2021	4	3	12	Access to RHI funding is ending in March 2021. It is not currently known if this will be replaced by a similar funding stream. Ensure schemes are viable without RHI funding – current base modelling excludes RHI	RBK	1	3	3
2.3.4	Changes to energy taxes could impose costs on the energy business	3	2	6	Any increase in tax will be transferred to customer - include change of law provision in heat contracts that adjusts charges to reflect new taxes	RBK	2	2	4
2.3.5	Heat sales price	3	5	15	As identified in the TEM, the agreed heat sales price has a high impact on the projects economic performance. As with all LA lead DHN projects, there is a trade off in benefits sought through increasing revenue to the council and providing value for money to customers and ensuring fuel poverty is minimised. A market study of typical energy prices should be conducted to ensure both residents and DHN owner/operator receives value for money	RBK	2	4	8
3	**Stakeholders**								
3.1	CRE residential ballot rejected	5	3	15	RBK to manage TFL interface through normal channels with assistance from RBK Highways	RBK	3	2	6
3.2	TFL oppose street-works or propose onerous requirements	4	2	8	RBK to manage TFL interface through normal channels with assistance from RBK Highways	RBK	3	2	6

3.3	Failure to gain resident support for the scheme	4	2	8	Structure proposal to make it attractive to residents and ensure a communications plan is enacted for local residents. Ensure residents are no worse off and bring savings where possible through the cost of heat	RBK	4	1	4
3.4	RBK lack of expertise to carry project forward	4	3	12	External project manager recommended to lead the scheme. Operation and maintenance can be contracted out	RBK	3	1	3
3.5	Low support from within RBK council	5	3	15	Identify a "champion" from within council to take project forward and increase awareness. RBK to manage ongoing discussions with BH input.	RBK	4	2	8
3.6	Thames Water do not agree to sell heat from Hogsmill Sewage Treatment Works at suitable price	4	3	12	TW have expressed interest in the scheme. Detailed financial modelling carried out to ensure best price is agreed during negotiations with Thames Water. Continued engagement at all stages of DHN development is required. CRE team already in contact with TW as adjacent land owners.	RBK	4	2	8
3.7	RBK's ability to invest in the 'leg work' in setting up a DHN	4	2	8	Involve relevant RBK internal departments from project outset to raise awareness of project. Apply for funding/support from GLA/BEIS	RBK	2	2	4
3.8	Third party negotiations (Thames Water, Crematorium)	4	3	12	Early stakeholder involvement in proposed schemes once identified. Discussions with third parties as to acceptable IRRs	RBK	3	2	6
4	**Planning consents, permitting and environment**								
4.2	High noise levels from energy centre	4	3	12	Acoustic impact managed through using proven compliant heat pumps and noise insulating casing	RBK	3	2	6
4.3	Flood protection at Hogsmill	4	3	12	A flood risk survey is recommended to ensure the proposed EC location is not at risk of flooding	BH / RBK	3	2	6
4.4	Planning permission required for heat network	3	2	6	RBK to confirm whether permitted development rights cover installation of heating pipework in the public highways	RBK	2	2	4
4.5	Air quality issues increase cost or result in restriction on operation of energy centre	4	2	8	Air quality impact managed by ensuring flues extend to a higher level than the surrounding buildings. Early consultation with planning team advised. De-risk by installing high efficiency gas boilers	RBK	3	2	6
4.6	Failure to negotiate use of Thames Water land for CRE energy centre	4	3	12	Continue engagement with Thames Water and continue to pursue a memorandum of understanding for use of land for energy centre and waste heat off-take. If land is not available, EC could possibly be located on the CRE	RBK	2	2	4
4.7	Kingston Hospital contracts for power/gas. Existing service contracts may limit options for extending heat supply to wider network	3	3	9	Early engagement with the hospital NHS Trusts. Get key dates of planned heating system refurbishments and ensure stakeholders are aware of plans for DHN in the area. Ensure planned site network is compatible with wider DHN connection	RBK	3	2	6

4.8	Failure to obtain planning permission for WSHP at HSTW due to environmental issues	5	3	15	Early engagement with the Environment Agency (EA) on acceptable discharge temperatures and flow rates. Not currently aware of a minimum discharge temperature into rivers set by the EA	RBK	5	1	5
5	**Construction and procurement**								
5.1	Contract choice inappropriate and prevents project aims from being delivered	5	3	15	Residents rejecting the CRE ballot. Mitigation for this can be made through securing the Kingston Hospital connection and retrofitting the existing CRE estate blocks to facilitate DHN connection	RBK	4	2	8
5.2	Redevelopment time windows missed	4	4	16	Early and continued engagement with all major stakeholders identified (e.g. Cambridge Road Estate, Kingston Hospital) to ensure they are aware of the project and potential to connect into a DHN. Promotion of work from within RBK and across the borough so that future developers are aware of proposed scheme	RBK	4	3	12
5.3	Contaminated land or invasive species at Hogsmill	4	2	8	If these are found at Hogsmill, the land clearing costs for the Hogsmill EC will significantly increase. It is recommended a Phase 1 Habitat Survey is conducted to mitigate against this risk	RBK	3	2	6
5.4	Level of intervention required at Hogsmill	3	4	12	If construction works are not fully costed and planned it will lead to overspending. Recommended that detailed schematics of existing infrastructure at HSTW is obtained at early stage of detailed development. 15% contingency included in the Capex schedule	RBK	2	4	8
6	**Operation and maintenance**								
6.1	Heat delivery failure	5	4	20	Design resilience into system including redundancy for pumping, boilers etc. Make plans and procedures for emergency boiler hire for connection at building level.	RBK	3	1	3
6.2	Lack of clarity over the department with RBK who is responsible for operation and maintenance	3	2	6	RBK to make a clear statement of responsibility as part of internal business case. Particularly important if energy is being supplied by third party (Thames Water)	RBK	2	2	4
6.3	High losses in primary or secondary network negate cost savings and create inefficient system	4	3	12	Commissioning and ongoing monitoring conducted to ensure performance is achieved	RBK	3	2	6

Appendix B TEM Inputs

B.1 TEM inputs

	Input / assumption	Value	Unit	Reference
Plant: Low-carbon technologies				
	Heat pump capacity	1,500	kW	Energy modelling
	Heat pump thermal efficiency	350%	%	GEA
	Heat pump fraction as a % of total generation	33-85%	%	Energy modelling – depending of if CHP/Crem heat incl.
	CHP peak thermal output to network	789	kW	Energy modelling
	CHP heat fraction as a % of total generation	0-62%	kW	Energy modelling – depending of if CHP heat incl.
	Crematorium peak thermal output to network	350	kW	Energy modelling
	Crematorium fraction as a % of total generation	0-3%	kW	Energy modelling – depending of if Crematorium heat incl.
Plant: Back-up boilers				
	Natural gas boiler capacity	9,049	MWth	Energy modelling
	Natural gas boiler efficiency	89%	%	Assumed
	Boiler heat fraction as a % of total generation	5-15%	kW	Energy modelling – depending of if CHP heat incl.
Equipment life expectancy				
	Heat pump	20	yrs	[20]
	Top-up technology	15	yrs	[21]
	DHN connections	20	yrs	[22]
	Cambridge Road Estate HIUs	20	yrs	[23]
	Abstraction and distribution pumps	20	yrs	[24]
	DHN network	longer than scheme life	yrs	Assumed
Network losses				
	Parasitic pumping power	5.4%	%	2% network losses (CP1) and calculated 3.4% abstraction pumping at HSTW
	District heating standing losses	10%	%	CP1
REPEX sinking fund				
	% of replacement expenditure incurred	80%	%	Assumed
Other				
	Discount rate	3.5%	%	Green Book
	Start year	2024		Assumed
	Modelling lifetime	30	yrs	Assumed
	Discount rate	3.5%	%	[25]

[20] Department of Energy & Climate Change (DECC), 2015. *Assessment of the Costs, Performance, and Characteristics of UK Heat Networks*
[21] Department of Energy & Climate Change (DECC), 2015. *Assessment of the Costs, Performance, and Characteristics of UK Heat Networks*
[22] Department of Energy & Climate Change (DECC), 2015. *Assessment of the Costs, Performance, and Characteristics of UK Heat Networks*
[23] Department of Energy & Climate Change (DECC), 2015. *Assessment of the Costs, Performance, and Characteristics of UK Heat Networks*
[24] Department of Energy & Climate Change (DECC), 2015. *Assessment of the Costs, Performance, and Characteristics of UK Heat Networks*
[25] HM Treasury, 2018. *The Green Book, Central Government Guidance on Appraisal and Evaluation*

[redacted]

[redacted]

[redacted]

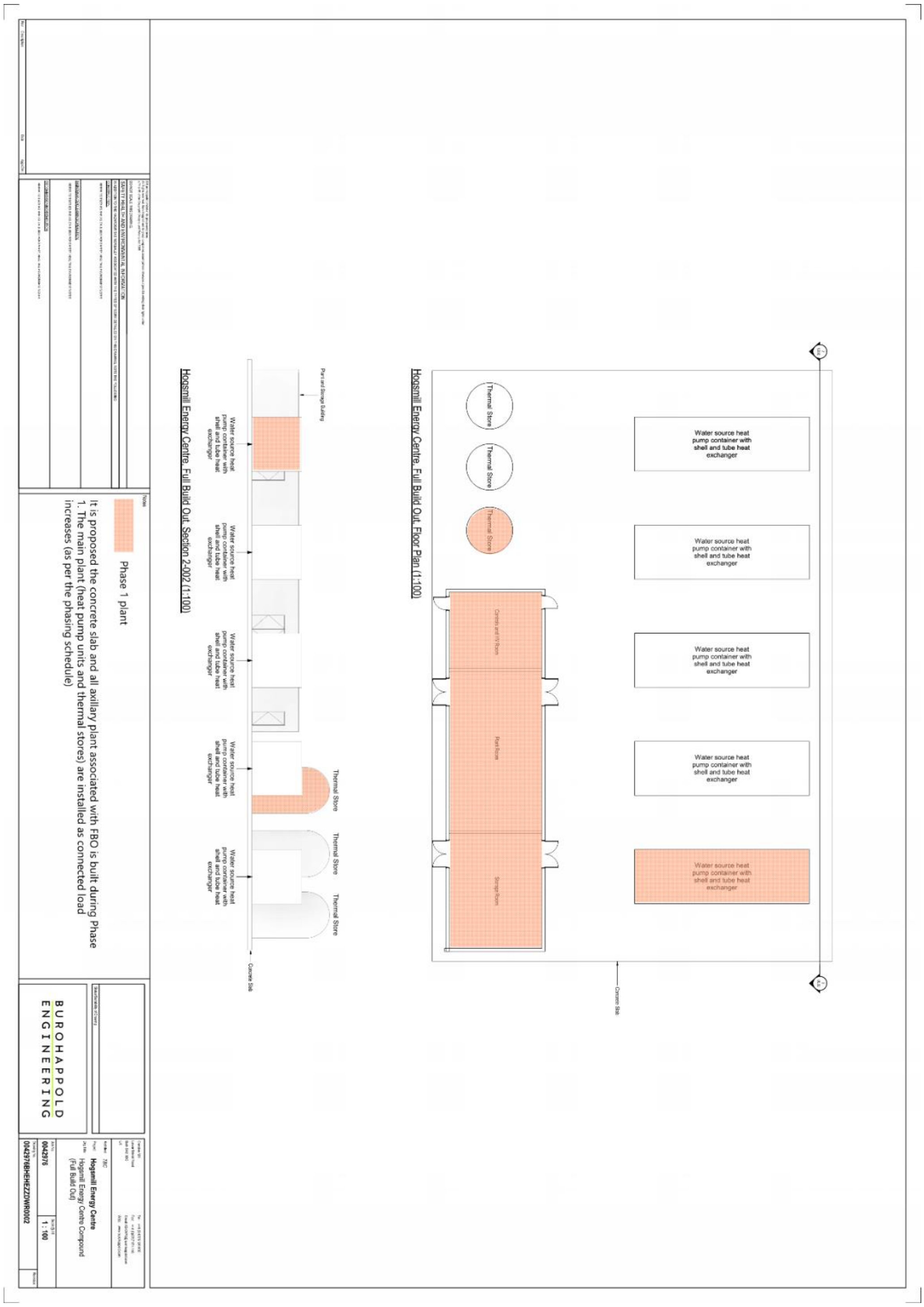
[redacted]

Appendix C 3DTD network report

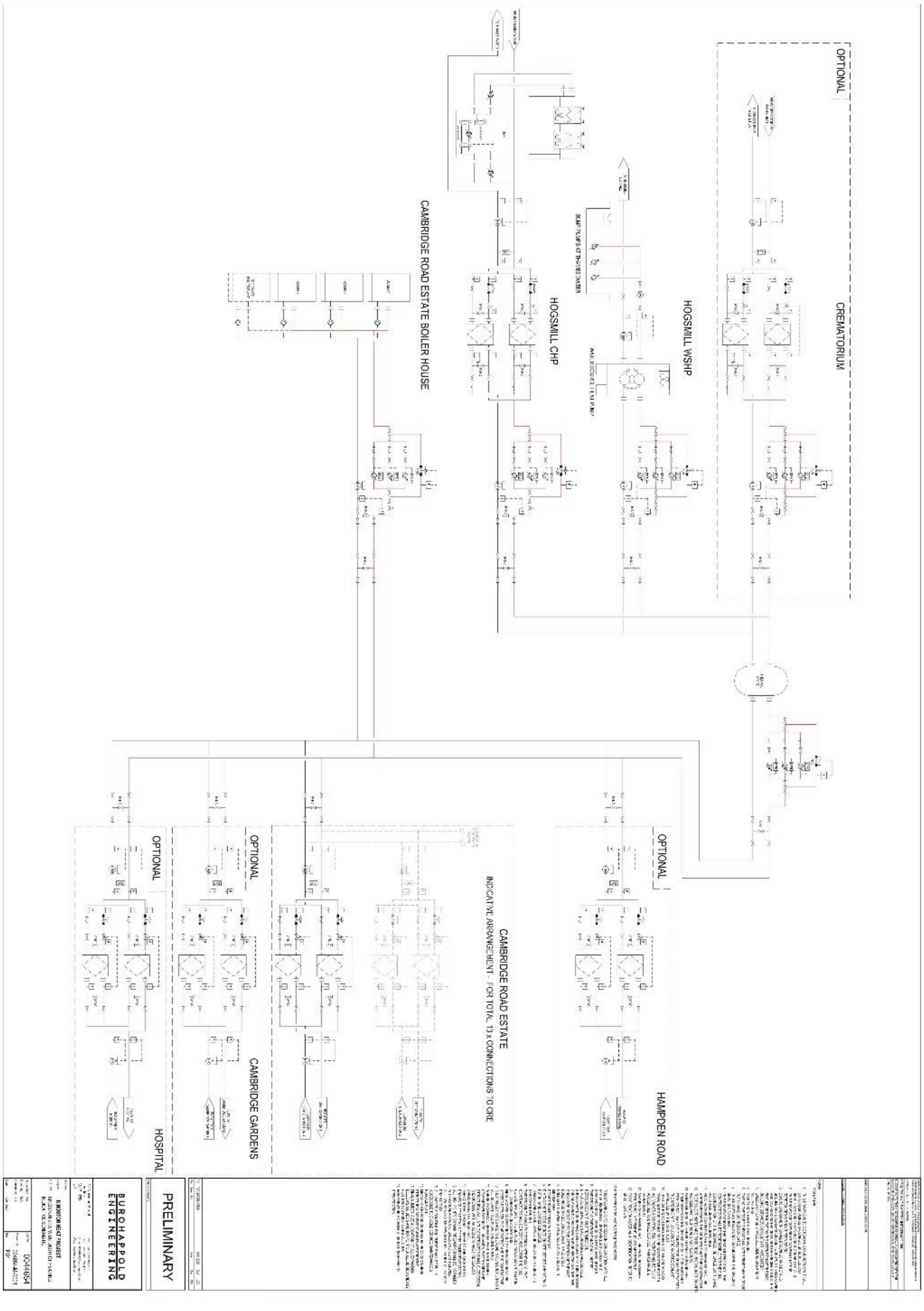
Provided separately

Appendix D Drawings

D.1 Energy Centre layout



D.2 Network schematic



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