BURO HAPPOLD

Hogsmill Heat Network Feasibility

Kingston Hospital Extension

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Glossary

Term	Definition
ASHP	Air Source Heat Pump
BAU	Business As Usual
Capex	Capital costs
CHP	Combined Heat and Power
CRE	Cambridge Road Estate
DFS	Detailed Feasibility Study
DHN	District Heat Network
DN	District Network
EC	Energy Centre
ESCo	Energy Services Company
HP	Heat Pump
KH	Kingston Hospital
LTHW	Low Temperature Hot Water
Opex	Operational costs
RBK	Royal Borough of Kingston Upon Thames
Repex	Replacement costs
TEM	Techno-Economic Model
TW	Thames Water
WSHP	Waters Source Heat Pump
WWTP	Waste Water Treatment Plant

1 Executive Summary

1.1 Potential Hospital benefits

This study into the potential benefits to the Hospital from connecting into the Hogsmill Heat Network finds that connection could offer significant value in comparison to onsite only solutions considered in the Carbon Architecture Report and can give the site a long-term future-proofed energy solution as well as commercial value whilst supporting a viable overall Heat Network project.

Put the Hospital on a trajectory for **long-term decarbonisation** of the campus, towards NHS net-zero target.

Between 50-85% carbon savings over existing Hospital system over 30 years.

The DHN project could contribute to the **costs of de-steaming the hospital** system to provide and operate the new network up to plant room transfer stations.

Modelling suggests that the network can provide this at **no extra annual cost** compared to what the hospital pay now (achieved through continued CHP power generation).

Meet **Hospital energy objectives** e.g sharing long term benefits with neighbours, resilience, CO2/waste

Provide a **GLA compliant** scheme.

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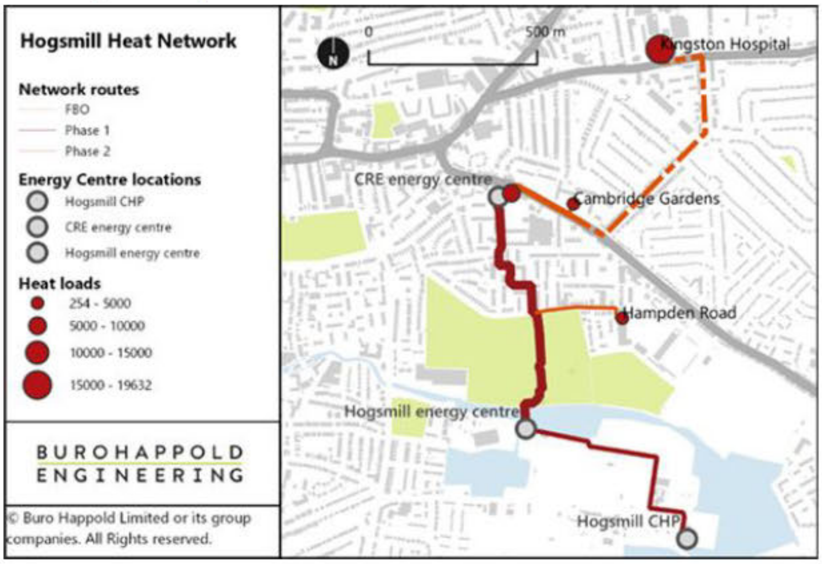
Improved local **air quality.**

Up to 83% of local gas boiler / CHP heat (fuel combustion) displaced with waste heat from Hogsmill DHN.

1.2 Hogsmill heat network overview

The Hogsmill DHN proposes to export low carbon resilient heat through a District Heating Network (DHN) 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 study explores the extension of the network from Cambridge Road Estate (CRE) to Kingston Hospital (KH).



Kingston Hospital is the largest consumer of heat in the borough, as well as one of the highest CO2 emitters. It currently operates a CHP engine that is reaching end of life. The proposed Hogsmill DHN provides a timely opportunity for KH to decarbonise its heat supply; providing a credible route towards the NHS-wide target of net-zero *"as soon as possible"*[1] and by 2050.

To connect to the network the Hospital site would need to be desteamed – currently being considered due to the

[1] https://www.england.nhs.uk/greenernhs/a-net-zero-nhs/

life expiry of the existing network in the coming years. By desteaming their existing onsite network and connecting into the Hogsmill DHN, KH could saving an average of at least 60% of their operational carbon emissions each year. This totals 125,000 tonnes of carbon over 30 years.

1.3 Connection options

Three energy strategies were modelled and tested for techno-economic performance:

- **Option 1 – no connection to Hogsmill DHN:** KH operate separately to the Hogsmill DHN, retaining CHP as their main source of heat and electricity generation (as per the Carbon Architecture recommendation). This is taken as the basecase in our analysis for comparison.
- **Option 2 – KH connection to Hogsmill DHN:** investigates the scenario where the Hogsmill DHN is extended to KH. It is assumed the Hogsmill DHN owner/operators takes on operation of KH energy centre and network up to plate heat exchangers. As per Option 1, it is assumed the hospital network is converted to all LTHW system. Two sub options are considered:
    - **Option 2A:** Connection to Hogsmill DHN with local 1.2MWe CHP and peak gas boilers at hospital
        - **Option 2Ai:** CHP size reduced to 0.6MWe to allow for increase heat import from Hogsmill
    - **Option 2B:** Connection to Hogsmill DHN with local peak gas boilers serving as heat network peaking plant serving the wider network

The results of the detailed feasibility study are summarised in Table 1—1 below.

Table 1—1 Summary of results

	Unit	Option 1	Option 2A	Option 2Ai	Option 2B
Annual heat demand connected to Hogsmill DHN (excl. losses)	*GWh/a*	8.24	24.47	24.47	24.47
Peak heat load connected to Hogsmill DNH	*MW*	6.1	12.7	12.7	12.7
Main plant at KH		1.2MWe CHP 7.5MW gas boilers	1.2MWe CHP 7.5MW gas boilers	0.6MWe CHP 7.5MW gas boilers	15MW gas boilers
Main plant at Hogsmill WWTP		1.5MWth HP	1.5MWth HP	1.5MWth HP	2.5MWth HP
Capital costs	*£m*	[redacted]	[redacted]	[redacted]	[redacted]
30-year IRR to Hogsmill DHN (no funding)	*%*	[redacted]	[redacted]	[redacted]	[redacted]
Level of funding required to reach 7% 30 year IRR	*£m*	[redacted]	[redacted]	[redacted]	[redacted]
% carbon saving at year 30 compared to BAU	*%*	27%	60%	70%	86%
Carbon savings over 30 years compared to BAU	*tCO2e*	58,200	124,060	145,070	178,130

1.4 Proposed strategy for Kingston Hospital

Of the scenarios tested, Option 2A provides the highest carbon savings for capital investment and is recommended as the highest value solution for Kingston Hospital.

Short term

By desteaming alone, the Hospital can make significant carbon savings (~27%) through reduced heat losses / dumping. As a minimum, KH should look to desteam their existing onsite network. However much larger carbon savings (up to ~86%) can be realised through Hogsmill DHN connection due to the delivery of electrified heat.

The modelling suggests an onsite CHP is needed to keep KH's annual energy expenditure at a similar rate to current operation, due to the reduced electricity import costs from the existing operational CHP. It is therefore proposed that the Hospital retain a smaller 1.2MWe CHP onsite to continue their low electricity import costs. Along with this, connection to Hogsmill DHN will provide low carbon heat equating to approximately 50% of the hospital's annual demand; significantly reducing the reliance on gas boilers (Option 2A).

- This option has an estimated capital cost of [redacted], of which ~[redacted] is towards the desteaming of KH's onsite network and peaking plant / CHP
- The DHN project could partially cover the costs of de-steaming the hospital system
- A positive IRR of [redacted] is achieved before funding
- For the Hogsmill DHN to achieve a [redacted] IRR over 30 years, [redacted] of funding is required (approx. 50% of total costs). Funding could be through a number of sources including HNIP, future RHI replacement and capital contributions from Kingston Hospital and Thames Water
- This would see carbon savings of up to 60% over 30 years, compared to BAU.

Long term

If the future energy centre is referable to the GLA, they have indicated that:

> *"if a CHP were to be implemented, it would need to be coupled with other local secondary heat sources and thought would also need to be given to how emissions (CO2 and NOx) are mitigated (both from a carbon and air quality perspective). Our preference would be for such a network to be expanded as part of a larger local energy system."*

Connection to Hogsmill now (even with CHP in the short term) locks the hospital into a long-term decarbonisation pathway at potentially no extra cost to KH. Taking this opportunity avoids the major changes required to the Hospital site in the future to meet decarbonisation targets. If CHPs become superseded as a heat generating technology, the long-term capacity of the Hogsmill DHN scheme is adequate to provide the majority of the Hospital heat load.

1.5 Next steps

The key next step is to confirm with Kingston Hospital interest in connection to include KH into the Detailed Project Development (DPD) study. The DPD will include technical, commercial, financial scheme development and culminates with an Outline Business Case for RBK sign off. This will include KH signing a Heads of Terms for Hogsmill connection. The outcome of this will be an Outline Business Case which will support an application for HNIP funding in January.

In order to achieve this, KH need to express further interest in network connection. A decision from the Director of Estates and Director of Finance is required to progress.

2 Key drivers for Kingston Hospital

2.1 Aims and focus of study

This study has been commissioned to assess the viability of Kingston Hospital desteaming their existing onsite network and connecting into the proposed Hogsmill District Heat Network (DHN). This report acts as an addendum to the Hogsmill DHN Detailed Feasibility Study (DFS) carried out by Buro Happold in January 2020.

KH has double the annual heat load of CRE and operates on an old, inefficient CHP system. As CRE is a new build, planning regulations require a low carbon solution for the site, therefore targeting KH will bring much larger carbon savings than connecting to CRE alone.

Kingston Hospital is the largest consumer of heat in the borough. It currently operates of a CHP engine that is reaching end of life. The proposed Hogsmill DHN provides an excellently timed opportunity for KH to decarbonise its heat supply; providing a simple route to meet the NHS target of net-zero.

Kingston Hospital have an aging onsite steam network providing heating and hot water. Steam networks were typically built to cater for higher temperature heat loads of a hospital campus such as the laundry services. Kingston Hospital (KH) have long since contracted out their laundry have no need for the high temperature steam produced by the Combined Heat and Power (CHP) engine. Reducing the temperatures of the system alone could lead to a reduction in heat losses, along with allowing connection to Hogsmill DHN or compatibility with other low carbon plant.

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. This report explores the benefits to both KH and RBK through extending the proposed Hogsmill DHN to KH.

2.2 Key drivers – Kingston Hospital

KH’s Sustainable Development Management Plan includes Energy key objective for 2018 through to 2023 (Figure 2—1). KH’s key drivers and targets are summarised below:

- Put the Hospital on a trajectory for **long-term decarbonisation** of the campus, towards NHS net-zero target
- Provide a **cost-effective solution** that will not significantly increase annual costs compared to current operations
- Provide a **GLA compliant** scheme
- Meet **Hospital energy objectives,** for example sharing long term benefits with neighbours, resilience, carbon emissions and waste heat reductions
- Improved local **air quality** through reductions in fossil fuel combustion
- **Future proof energy supply** against fluctuating energy prices and future policy requirements

Energy		Benefits		
When	Key Objectives	Natural	Social	Economic
2018 - 2019	• Understand how much energy we use and where using an Energy Management System. • Plan long term site energy strategy including proposal for new Energy Generation Centre. • Implement smart LED lighting across Esher. Wing, as part of the Fire Code Compliance work • Raise awareness of energy consumption to all Trust staff.	✓ Improved monitoring of energy usage and identification of improvement opportunities ✓ More accurate measurement of CO_2 emissions from fossil fuel consumption.	✓ Key staff informed. ✓ Improved reporting.	✓ Better billing validation. ✓ Controlled / reduced costs.
2019 -2022	• Develop a short term energy efficiency strategy based on information from the Energy Management System. • Procure new Energy Centre development partner.(Subject to business case - OBC Q2 19/20 & FBC Q4 19/20) • Implement smart LED lighting across main Trust buildings, as part of the Fire Code Compliance work • Raise awareness of energy saving measures staff can take.	✓ Reduction in wasted energy.	✓ Informed staff empowered to act. ✓ Supporting 'green' initiatives. ✓ Improved comfort in patient spaces.	✓ Controlled / reduced costs. ✓ Good value for money Energy Centre
From 2023	• Develop renewed energy saving strategy based on lessons learned from 2019-22. • Implement new Energy Centre including district heating to local housing. • Implement new energy saving technologies in main Trust buildings.	✓ Reduced CO_2 (compared to grid mix) ✓ Reduced dependence on fossil fuels.	✓ Sharing long-term benefits with neighbours. ✓ Increased resilience.	✓ Income opportunities from heating provided to tenants / nearby properties.

Figure 2—1 Kingston Hospital Sustainable development management plan

2.3 Hogsmill Heat Network Strategic vision

The borough wide opportunities presented in the Pre-Feasibility study have been consolidated to focus on connecting the Cambridge Road Estate (CRE) cluster and extending to Kingston Hospital.

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

Figure 2—2 illustrates the strategic vision in three phases:

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

If there is appetite from the hospital to connect, there is potential to bring forward its connection into Phase 1. It is the intention that the scheme can be extended into Kingston Town Centre in the medium/long term.

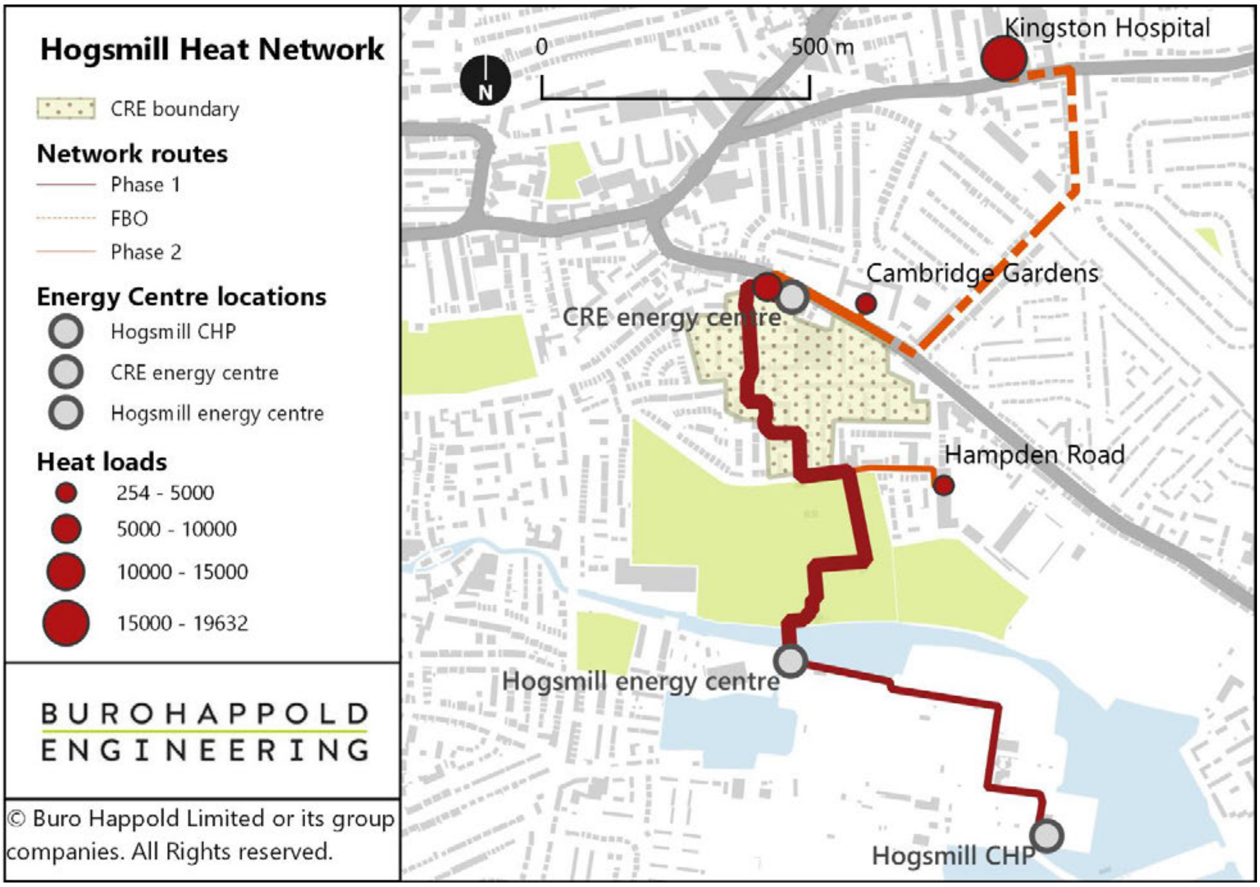


Figure 2—2 Strategic vision

3 Understanding the existing Hospital site

3.1 Current infrastructure

The Kingston Hospital (KH) Estates Strategy is currently in a state of flux. It is therefore assumed in this study on the basis of the existing site. It is understood however that any future estates strategy would likely consolidate the site and free up additional land for denser development which may have a comparable overall heat load.

The exception is the Regent Wing site which has been sold – currently an Advanced Living planning application is in with The Royal Borough of Kingston upon Thames (RBK). It is assumed that this would connect into any upgrade of the Hospital heat network.

The existing PFI contract with Veolia This includes operation of the CHP and gas boilers. The energy centre may be moved towards the centre of the site in the future; however, Hospital advise to assume that existing structure remains in place for next 7 years.

4 Energy supply strategy options

A long list of options was produced and presented to RBK, along with a qualitative RAG assessment of each (see Appendix B). Both onsite only networks and connection to Hogsmill DHN have been assessed.

From the initial assessment, three supply options were taken forward to detailed techno-economic modelling, as outlined in the following section.

General assumptions

- Gas boilers always retained at KH for resilience
- Kingston Hospital steam network is replaced by LTHW network that extends to all buildings on the estate (existing and planned i.e. Advanced Living)
- The network adopts the on-site Hospital network up to building PHE connections for Options 2A and 2B
- In options where KH retain an on-site CHP (1 and 2A), the generated electricity is provided to KH for free and any grid export revenue goes to KH (assumed 2% of annual generation)
- Upgrades to secondary building systems not included

4.1.1 Option 1: No connection to Hogsmill Heat Network

Option 1 is summarised in Figure 4—1 below. KH operate separately to the Hogsmill DHN, retaining CHP as their main source of heat and electricity generation (as per the Carbon Architecture recommendation). This is taken as the basecase in our analysis for comparison (based on LTHW ring with existing loads). Key assumptions:

- Move to fully LTHW system (De-steam)
- Connect up individually heated buildings on the KH site
- Connect up new buildings (i.e. Advanced Living site)
- 1.2 MWe CHP and peak gas boilers to replace existing

SAP10 carbon factors now mean that CHP is unlikely to meet planning requirements if referable to GLA. The GLA have indicated that *"if a CHP were to be implemented, it would need to be coupled with other local secondary heat sources and thought would also need to be given to how emissions (CO2 and NOx) are mitigated (both from a carbon and air quality perspective). Our preference would be for such a network to be expanded as part of a larger local energy system."*

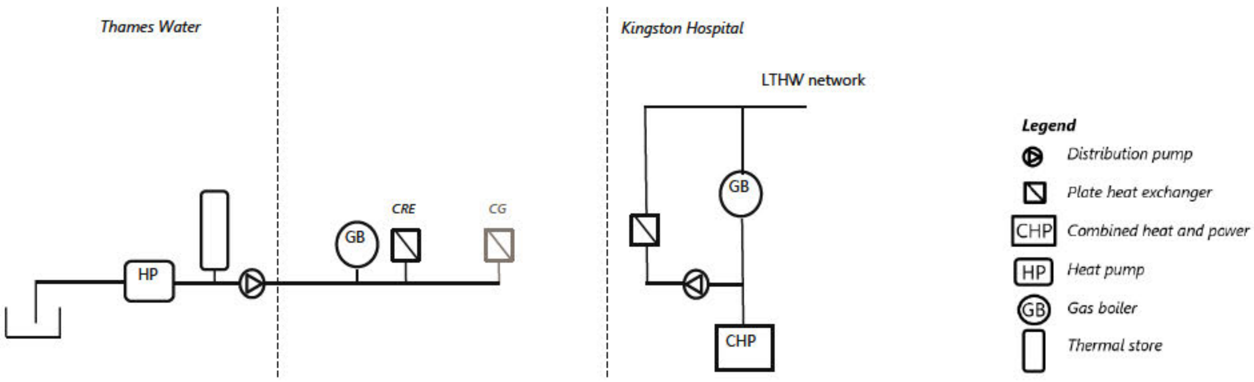


Figure 4—1 Option 1: No connection to Hogsmill Heat Network schematic

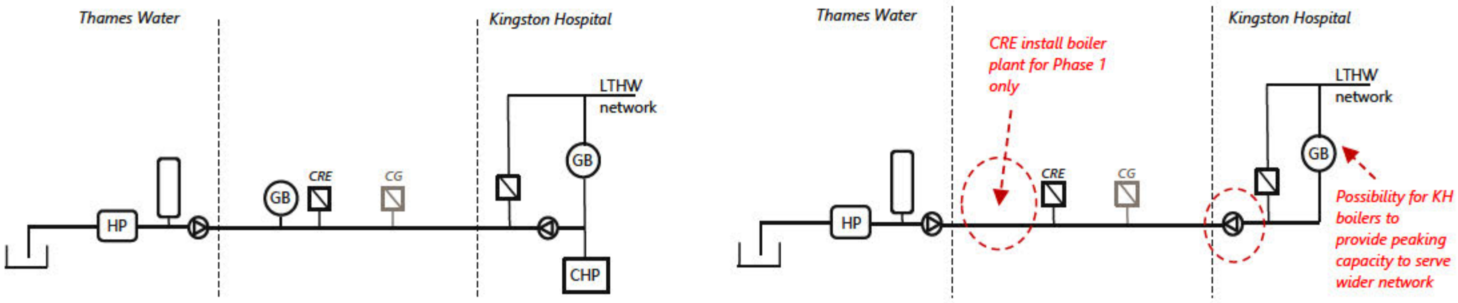
4.1.2 Option 2: Connection to Hogsmill Heat Network

Option 2 investigates the scenario where the Hogsmill DHN is extended to KH. As per Option 1, it is assumed the hospital network converted to all LTHW. Outline schematics are provided in Figure 4—2.

Option 2A: Connection to Hogsmill DHN with local 1.2MWe CHP and peak gas boilers at hospital

Option 2B: Connection to Hogsmill DHN with local peak gas boilers capacity to serve the wider network

Figure 4—2 Option 2: Connection to Hogsmill Heat Network, 2A and 2B schematics



Option 2A **Option 2B**

Commercial structure

It is assumed the Hogsmill DHN owner/operators takes on operation of KH energy centre and network up to plate heat exchangers (see Figure 4—3). This is the simplest commercial structure, with one ESCo taking on operation of all heat network connections as per the existing site is run under Veolia.

An alternative option is to sell heat at bulk to KH and KH operate their own onsite network (potentially via a third party). However, this would add additional operational expenditure to KH as adds complexity to commercial negotiations between two separate ESCos. It is not expected this would deliver added value to KH, thus the simplest arrangement is considered for the purposes of this report. Future Detailed Project Development will investigate the structure further.

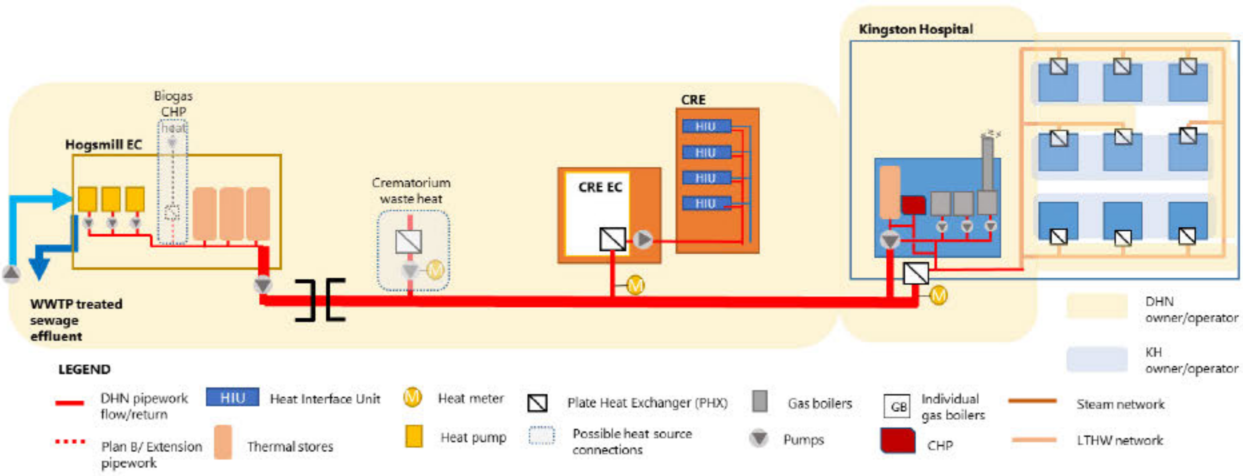


Figure 4—3 Option 2: ownership boundaries (show with CHP for Option 2A)

5 Update of Hogsmill Heat Network detailed feasibility scheme to include hospital

5.1 Scheme update

The energy centre modelling in the DFS report has been updated to reflect the new energy data gathered from the hospital (see Section 3). All assumptions around the Hogsmill WWTP and CRE connection remain as detailed in the DFS.

As, the basecase of 'CRE only' outperformed the option with an extension to Cambridge Gardens in the DFS modelling, this has been excluded from the modelling herein. However, the network has been sized to accommodation the additional load should it connect in the future (and if retrofit costs were to come from an alternative budget then it would potentially have a positive impact on the scheme).

The following section therefore focuses on the updates made to the modelling to incorporate Kingston Hospital. A full breakdown of plant is available in the bill of quantities (Appendix C).

5.2 Load schedule

The load schedule for each connection is shown in Table 5—1. CRE consisted of 5 phases, built in 2-year intervals as per the phasing plan in the DFS study.

Table 5—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	1,900	1.75	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	1,580	1.45	417	2025	Basecase	
CRE phase 3	1,600	1.47	421	2027	Basecase	
CRE phase 4	1,560	1.43	410	2029	Basecase	
CRE phase 5	1,600	1.47	421	2031	Basecase	
Kingston Hospital	[redacted]	[redacted]	n/a	2024	Basecase	Annual and peak loads provided by Kingston Hospital. Heat load includes the new residential development
TOTAL	**24,470**	**14.12**				

5.3 Energy modelling

The energy modelling software EnergyPro has been used to assess the annual heat flows of the network. The modelling process described in the DFS report has been followed. Hourly profiles from KH's online BMS have been used (see Section 3).

5.3.1 Network heat losses

Annual heat losses of 1,730MWh for the network have been estimated using the Logstor calculator with an additional 15% contingency added. The results are shown in Table 5—2.

Assumptions include:

- Series 2 steel Logstor pipework with constant distance of 150mm between each pipe (flow/return)
- Pipe sizing and length as per Section 1.1
- Flow/return temperatures 80/50degC
- Ambient air temperature in summer 15.7degC, reducing to 7.5degC in winter
- Soil cover of 1m
- Soil thermal conductivity of 1.6W/m
- Assumed 5% additional losses on CRE secondary network (route not currently known)

Table 5—2 Estimated heat losses

Network section	Length	DN	Annual heat loss + 15% contingency
	m	*mm*	*MWh/yr*
1. Kingston Hospital run	934	250	303
2. CHP connection	755	125	193
3. Hogsmill to CRE	1132	300	419
4. Cambridge Road	244	250	79
5. Cambridge gardens	34	65	7
6. Hampden Road	210	80	45
7. Mains ring around Kingston Hospital – increased DN from 125 (spec in CA report) to 250	1660	250	539
8. Individual runs to Kingston Hospital loads – allowed DN80 as per CA report	680	80	147
TOTAL	**5,650**		**1,732**

5.3.2 Kingston Hospital CHP modelling

The CHP at Kingston Hospital has been modelled to allow a varying heat and electrical capacity at partial load. A minimum operational period of 3 hours has been assumed. One day per month non-availability period is also assumed, along with two weeks in the summer for maintenance.

All other plant including the heat pump and biogas CHPs are modelled as described in the DFS report.

5.3.3 Results

Table 5—3 EnergyPro modelling results

Option		Option 1	Option 2A	Option 2B	Option 2Ai
Description		CRE and KH separate	CRE + KH (with CHP)	CRE + KH (no CHP, boiler export)	CRE + CG + KH (with CHP)
Annual heat demand (at energy centre including all losses)	*MWh/a*	28,352	28,352	28,352	28,352
Peak heat demand	*MWth*	9.4	9.4	9.4	9.4
Heat pump capacity	*MWth*	1.52	1.52	2.52	1.52
CHP capacity (KH)	*MWe*	1.20	1.20	-	0.60
Thermal store size	*m3*	-	150	150	150
Percentage of annual heat demand met by heat pump	*%*	15%	30%	60%	38%
Percentage of annual heat demand met by Hogsmill biogas CHPs	*%*	22%	23%	23%	23%
Percentage of annual heat demand met by KH CHP	*%*	31%	31%	0%	14%
Percentage of annual heat demand met by boiler top up	*%*	**32%**	**15%**	**17%**	**24%**

Table 5—3 details the results from the EnergyPro modelling for the three scenarios tested. The heat pump capacity remains 1.5MWth (as per the DFS) in all but Option 2B. In order to maintain reliance on gas boilers to below 20%, a larger heat pump at Hogsmill is required in Option 2B, where KH do not have an onsite CHP, Modelling suggests installing an additional 1.0MWth heat pump alongside the 1.5MWth unit can meet 60% of the network's annual heat demand.

A sensitivity of Option 2Ai is presented to show the trade-off between CHP size and amount of electricity import required by KH (Figure 5—1). The results from modelling a 0.6MWe CHP at KH are shown in as this reduces reliance on the CHP and increases low carbon heat supply from Hogsmill WWTP by almost 10%. But still gives KH a saving from CHP generated electricity compared to expensive grid import.

The combined waste heat from the three biogas CHP engines at Hogsmill have the potential to provide over 20% of the whole networks annual heat demand.

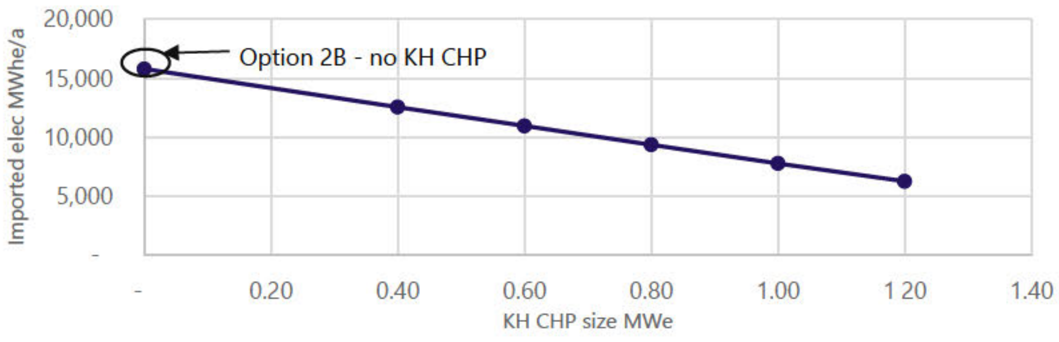


Figure 5—1 Option 2Ai KH CHP sizing – 1.5MWth heat pump at Hogsmill

5.4 Network routing

Multiple routing options to Kingston Hospital were investigated (shown in Figure 5—2).

- **Option 1** is the most direct route, however it requires going through Norbiton Train Station via a subway tunnel. It is thought that this would be too disruptive to local transportation and access to the hospital
- **Option 2:** is through Cambridge Gardens and avoids Gloucester Road, where there is a bus route, by going via Norbiton Avenue. The route then avoids the railway bridge on Gloucester Road by joining Coombe Road. There is a narrow pedestrian tunnel under the railway which is likely to constrain access. Coombe Road is also a major route connecting to the Hospital: one lane would likely have to remain open at all times for blue light traffic.
- **Option 3:** is a more direct route along Gloucester Road. The main barrier here in the railway bridge, which may not be have adequate deck depth for the pipework. The ownership of the bridge is currently unknown and construction may require permission from Network Rail. Gloucester Road is also part of a bus route which may need to be diverted. There is an UKPN LV network running over the bridge, but not SGN gas network.

Option 2 was selected as it is the shortest route that does not require pipework to be routed through Norbiton Station or require crossing the narrow railway bridge. This is subject to review at the next stage as a result of ownership discussions.

An initial review of UKPN, SGN and Thames Water utilities shows all route options cross over low and medium pressure gas mains, as well as 11kV UKPN power lines. Coombe Road has both a medium pressure gas main and Thames Water trunk sewer which pose a risk to working in the area and to potential space to accommodate a DH network. Along with trunk sewers, Thames Water distribution mains run along the majority of roads.. A full desktop survey of all utilities for route provision is required at the DPD stage.

Figure 5—2 Network routing options to Kingston Hospital

5.5 Network sizing

The network has been sized to allow for future expansion of the network to accommodation Kingston Hospital and Cambridge Gardens. A certain amount of oversizing is required to avoid having to replace pipework when the interconnection happens. Key inputs are shown in Table 5—4.

Table 5—4 Hydraulic modelling inputs

Input	Unit	Value
Delta T	ºC	30
Max allowable flow velocity	m/s	3
Water density	kg/m³	1000
Max allowable pressure gradient	Pa/m	100
Kinematic viscosity	m²/s	0.4091 x10⁻⁶
Specific heat capacity of water	kJ/kgK	4.181
Pipe roughness factor	mm	0.05

Total network length including Kingston Hospital is estimated at 2,825m. The Phase 1 network to CRE is approximately 940m. There is an assumed 550m of soft-dig trenching through Kingston Crematorium. The LTHW ring around KH is modelled as 830m trench length at DN250mm. Individual runs to buildings all modelled as DN80mm (340m total). Network sizing results are shown in Figure 5—3.

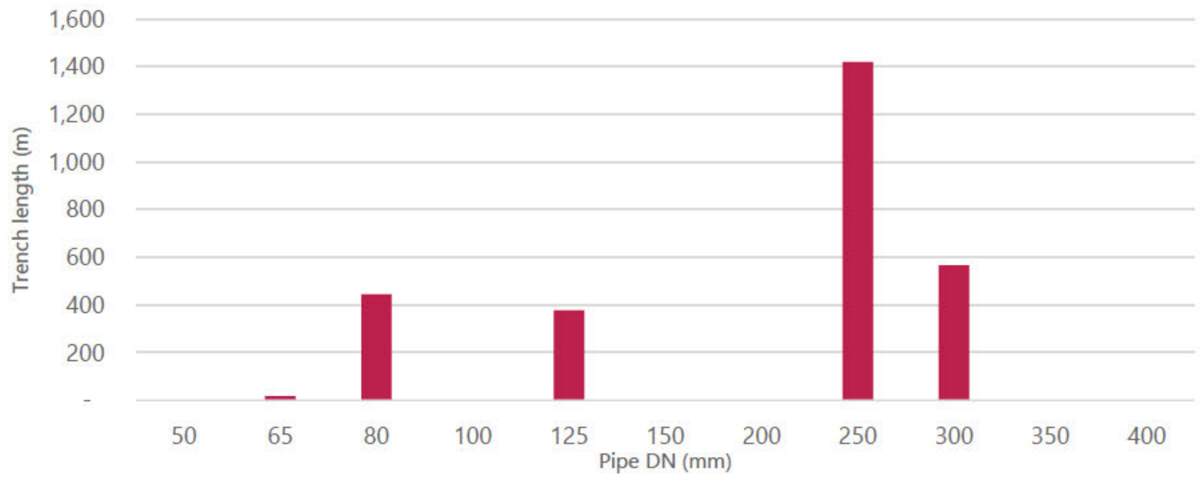


Figure 5—3 Network length by pipe DN

6 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 or KH to the network. Two sets of results are shown:

- **KH emissions only:** indicating the carbon savings from heat only the hospital would see in each option. The counterfactual being the current onsite system (steam and LTHW networks). A blended carbon factor for the heat network is used (gas CHP / biogas CHPs / Hogsmill heat pump / gas boilers – depending on option)
- **Hogsmill total network:** showing the carbon savings across the whole network (CRE plus KH). The counterfactual in this case is the current KH system (as above), with an ASHP led network at CRE

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

The biogas used in the CHP is being produced through onsite anaerobic digestion (AD). The Standard Assessment Procedure version 10.1[2] (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[3]. The electricity grid carbon factor varies over time as predicted by BEIS.

6.1 Kingston Hospital carbon emissions over 30 years – heat only

Figure 6—1 shows the carbon emissions from heat over 30 years for the KH site. Through desteaming alone (Option 1) KH could save 29% over 30 years. This increases up to a possible 88% saving if KH remove their onsite CHP and connect to the Hogsmill DHN.

As KH currently rely on their onsite CHP for 70% of their electricity supply, it is likely a CHP will be required onsite to maintain affordability of electricity supply. This is explored in the TEM section (Section 7.3.1). With KH retaining an onsite alongside connection to the DHN, carbon savings of 61% to 72% are possible, depending on the size of the CHP (Option 2A and 2Ai).

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

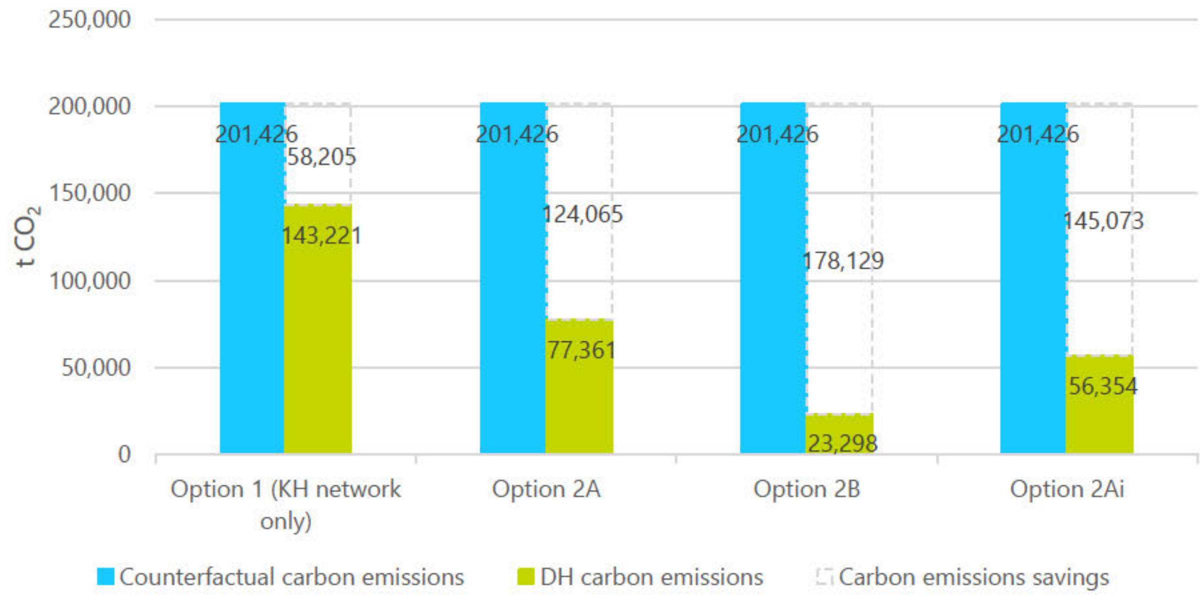


Figure 6—1 KH only carbon emissions over 30 years – heat only

6.2 Hogsmill network total carbon emissions over 30 years

Figure 6—2 shows the total emissions of the network over 30 years, including CRE. This follows a very similar trend to Figure 6—1 above. It illustrates that as the carbon factor of the network is so low, the majority of emissions arise from the KH onsite CHP.

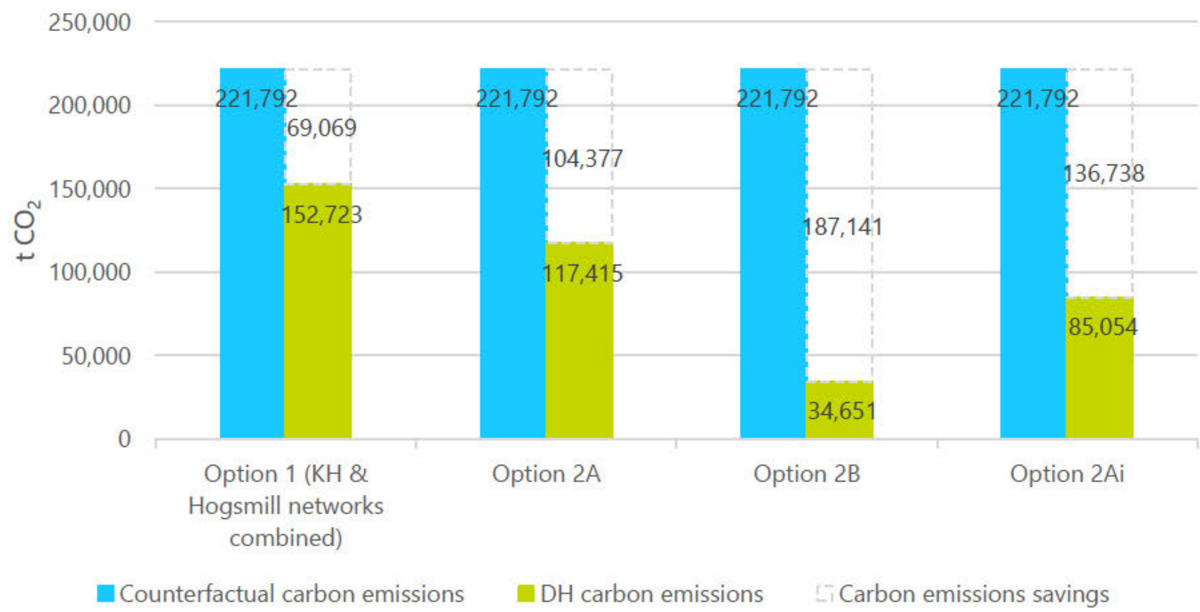


Figure 6—2 Hogsmill network total carbon emissions of 30 years

7 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. The three options have been assessed against possible funding streams.

7.1 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.

The key assumptions detailed in the DFS remain for the Hogsmill network options. Future assumptions include:

- Kingston Hospital de-steam existing on site network. It is assumed KH will have to contribute to the capital cost of these works
- The network owner/operator own and operate the heat network up to and including the PHEs at each building connection on the hospital LTHW network
- The hospital is connected to the heat network in Phase 1 (2024)
- No payments to Thames Water as basecase
- IRR is set as constant, with the amount of capital funding required to meet IRR the key output
- Cambridge Garden's excluded from basecase (however, network is sized to meet load should it connect)
- The biogas CHP heat is available from the Hogsmill WWTP

7.2 Modelling inputs

7.2.1 Capital costs

The capital costs for the hospital extension have been estimated based on the CA report and Buro Happold's previous experience. An estimated [redacted] is required to de-steam the onsite network, with a further [redacted] uplift for the connecting to the DHN. The capital costs for each option are summarised in Figure 7—1 and Table 7—1 and include 20% contingency, 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.

- **Connection charges:** a connection charge is applied to CRE to take into account avoided cost of installing counterfactual ASHP (see DFS for more detail). No connection charge applied to KH, assumed a capital contribution to desteaming is made

[redacted]

Table 7—1 Capital cost breakdown

Cost category	Option 1	Option 2A	Option 2B
	£m	*£m*	*£m*
LZC technology	[redacted]	[redacted]	[redacted]
Top-up technology	[redacted]	[redacted]	[redacted]
Ancillary equipment EC	[redacted]	[redacted]	[redacted]
EC building	[redacted]	[redacted]	[redacted]
Electrical EC	[redacted]	[redacted]	[redacted]
District network	[redacted]	[redacted]	[redacted]
Thermal substation at connections	[redacted]	[redacted]	[redacted]
Heat offtake at HSTW	[redacted]	[redacted]	[redacted]
Secondary system retrofit	[redacted]	[redacted]	[redacted]
TOTAL	[redacted]	[redacted]	[redacted]

7.2.2 Operational costs

- **Operational costs:** Table 7—2 presents the 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
- **Discount rate:** A discount rate of 3.5% has been applied to pre-debt cash flows
- **Replacement costs:** An annual sinking fund is built up across the equipment lifetime to account for the Repex costs for 75% of the total capex in the TEM model. This includes pumps, heat pumps, CHP, thermal stores, boilers, PHXs, water treatment, HIUs, heat meters and associated components. The lifetime of each component is detailed in Appendix C. Pipework replacement is excluded from the model as these typically last longer than the lifetime of the project
- All other assumptions are detailed in Appendix C

Table 7—2 Opex assumptions

	Value	Unit	Reference and notes
Heat pumps and Taprogge ball cleaning	[redacted]	p/kWh	Heat pump O&M based on information GEA – applied to annual heat load of heat pumps
Top-up gas boilers	[redacted]	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)	[redacted]	p/kWh	Based on manufacture quotes and Buro Happold experience – applied to total annual heat load[4]
Pumps	[redacted]	p/kWh	Distribution and abstraction (sump) pumps – applied to total annual heat load. Grundfos
CRE HIUs and PHEs	[redacted]	£ / yr	Operational cost of all HIUs, water treatment and block level PHEs at CRE
Metering and billing – non-bulk	[redacted]	£ / unit	
Staff costs	[redacted]	£ / yr	EC manned 4 days per week at £40k FTE
Business costs	[redacted]	p/kWh	Applied to total annual heat load[5]
Fuel charges			
Gas price at energy centre	[redacted]	p/kWh	Av. Blended gas cost at KH (incl. CCL)
Electricity price at energy centre	[redacted]	p/kWh	Av. Elec variable import price at KH
Fuel charges			
CHP generated electricity private wire	[redacted]	p/kWh	Assumption based on KH paying a reduced rate for CHP elec compared to grid import
Grid spill from CHP	[redacted]	p/kWh	
% electricity sold via private wire to hospital	98%	%	Where applicable (i.e. Options 1 and 2A). % based on current KH operation

7.2.3 Heat pricing

The assumed heat prices for residential and commercial connections are shown in Table 7—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 Buro Happold.

- The standing charge is a flat rate paid to the DHN operator for connection to the network. For heat network pricings, this is 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

[4] Department of Energy & Climate Change (DECC), 2015. *Assessment of the Costs, Performance, and Characteristics of UK Heat Networks*

[5] 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

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[6]. All schemes Buro Happold have based the heat price are based on are Heat Trust compliant[7] - 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.

Table 7—3 Heat price – variable and standing charge

	Variable rate (p/kWh)	Standing charge
Residential	[redacted]	[redacted]
Commercial	[redacted]	[redacted]

7.2.4 Modelling assumptions

Heat network operators:

Capital contribution to the upgrade of the Hospital network

Operate KH network up to building level PHEs (including fuel costs)

Charge KH for: heat – variable rate and standing charge, private wire electricity

7.2.5 Modelling boundaries

The modelling boundaries and ownership assumptions are detailed in Figure 7—2, Figure 7—3 and Figure 7—4.

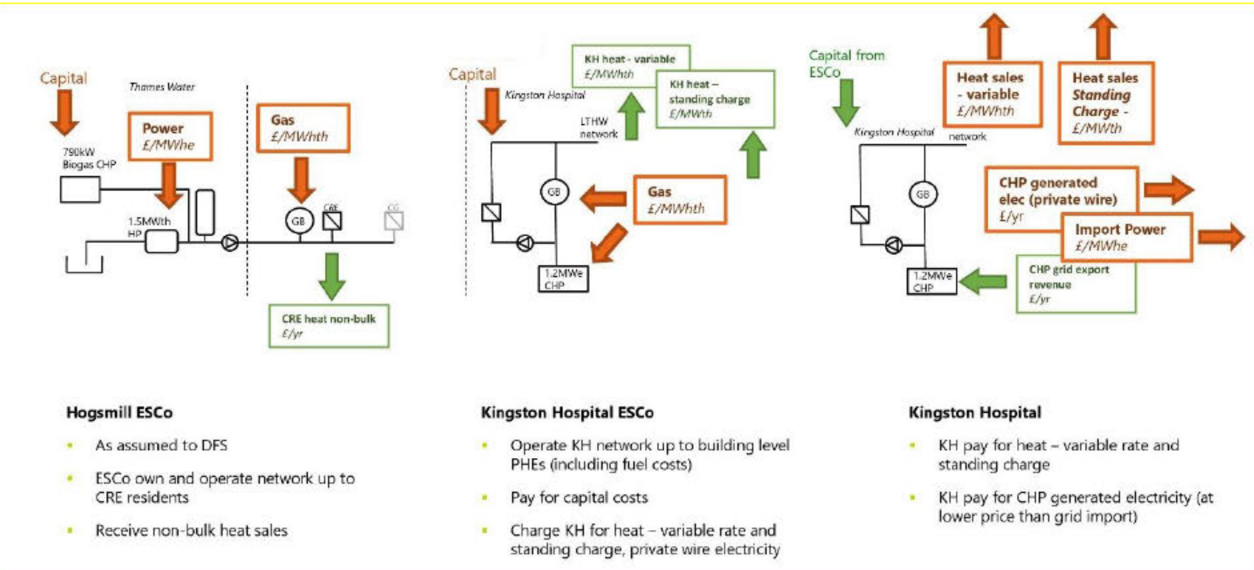
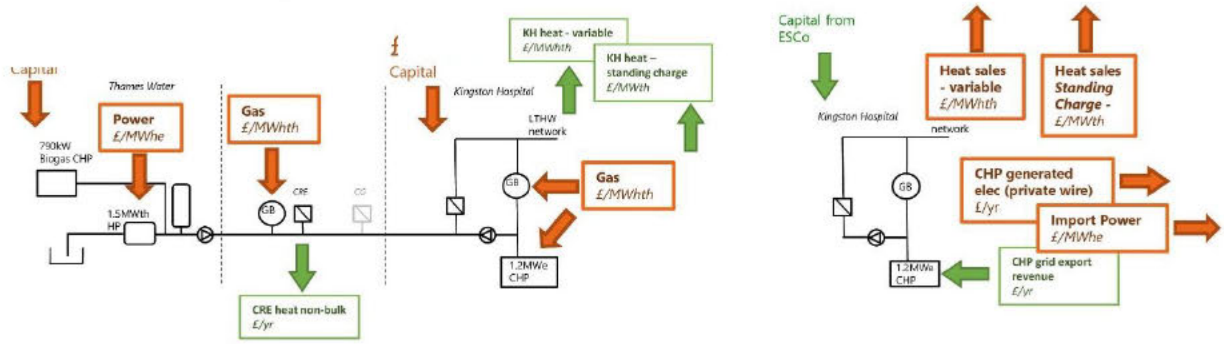


Figure 7—2 Modelling boundaries – Option 1

[6] http://www.legislation.gov.uk/uksi/2014/3120/pdfs/uksi_20143120_en.pdf

[7] 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>



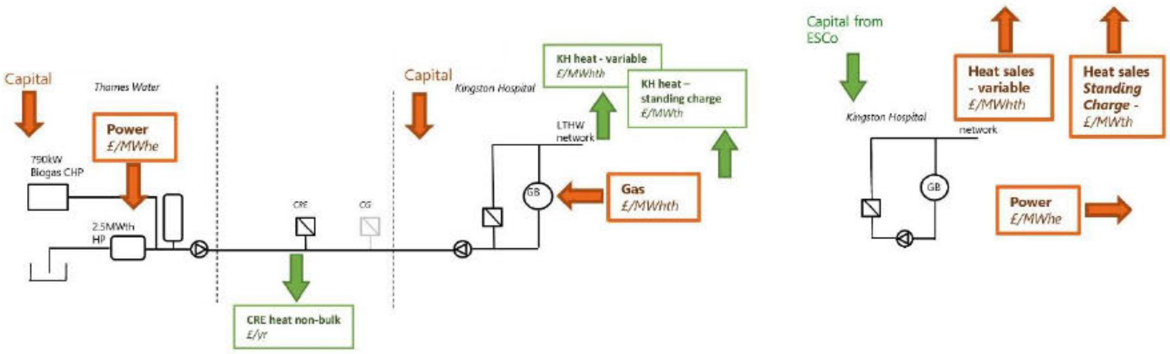
Whole network ESCo

- ESCo own and operate EC at Hogsmill and KH (up to building level PHEs)
- ESCo pays capital costs of whole network and ongoing fuel costs
- ESCo sells heat to KH at commercial rate, plus private wire electricity (at lower price than grid import)

Kingston Hospital

- KH pay for heat – variable rate and standing charge
- KH pay for CHP generated electricity (at lower price than grid import)

Figure 7—3 Modelling boundaries – Option 2A



Whole network ESCo

- ESCo own and operate EC at Hogsmill and KH (up to building level PHEs)
- ESCo pays capital costs of whole network and ongoing fuel costs
- ESCo sells heat to KH non-bulk rate
- No KH CHP – KH gas boilers export heat to network

Kingston Hospital

- KH pay for heat – variable rate and standing charge

Figure 7—4 Modelling boundaries – Option 2B

7.3 Results

Results for each option are presented alongside Kingston Hospital's current operation, used as the Business As Usual (BAU) comparison. The results are presented from both the perspective of the hospital and from the heat network owner/operator.

Disclaimer: Prospective information for revenue, capital expenditure and operating costs have been derived from information provided by different sources. Buro Happold does not accept responsibility for such information. Buro Happold emphasises that the realisation of the prospective financial information is dependent upon the continued validity of the assumptions on which it is based. Buro Happold 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.

7.3.1 Kingston Hospital annual expenditure

The annual expenditure of KH has been calculated for each option, presented as the year 10 annual undiscounted cashflow in Figure 7—5.

The current operation of Kingston Hospital's annual expenditure based on the Veolia contract is [redacted]. In Figure 7—5 this is used as the Business As Usual (BAU) on which to compare the energy options.

Option 1 (no connection to Hogsmill DHN) could deliver the largest annual saving of [redacted] a [redacted] saving compared to BAU. This is mainly due to the lower standing charge charged to the hospital compared to Veolia's rates, however, this is offset by the addition of private wire sales from the CHP to KH buildings.

With connection to Hogsmill DHN, KH could see an [redacted] ([redacted] annual saving) compared to BAU if a 1.2MWe CHP is installed onsite alongside the DHN connection (Option 2A). While the sensitivity testing with a smaller onsite 0.6MWe CHP (Option 2Ai) increases the utilisation of low carbon heat from Hogsmill WWTP, Figure 7—5 shows this increases KH's annual expenditure by [redacted] compare to BAU. This increase arises from the increase in grid imported electricity. If KH are happy to accept this increase in operating costs, option 2Ai would significantly improve carbon savings on the site by 46% (see Section 6).

Option 2B, connection to KH with no onsite CHP, leads to the largest increase in KH's annual operating costs, a [redacted] increase. Figure 7—5 shows that while the standing charge for heat reduces significantly, the electricity import costs make up the largest proportion of the annual expenditure. If KH can afford the additional expense, then carbon savings compared to BAU could be up to 85% (see Section 6).

[redacted]

7.3.2 Hogsmill heat network results

The results of the TEM are shown in Table 7—4 and Figure 7—6. The result for the unfunded options are compared to the required capital funding to reach a [redacted] IRR. This is the typical absolute minimum IRR for an ESCo. Hogsmill DHN may accept lower depending on final commercial structure.

Note: modelling excludes RHI and payments to Thames Water. Assumes that biogas CHP waste heat is available.

to achieve a [redacted] IRR, [redacted] capital funding is required. This could be reduced if RHI or a similar incentive is extended post 2022

The results suggest positive cash flows without funding if KH follow the CA recommendation (Option 1), achieving a [redacted] IRR over 30 years. However, carbon emissions savings are significantly lower due to CHP and unlikely to meet future requirements.

A possible solution to this trade-off between carbon emissions and KH annual expenditure is a smaller CHP at KH, allowing reduced carbon emissions while still generating cheaper electricity for KH (Option 2A and 2Ai). In this scenario a minimum of 50% capital grant funding is required to reach a [redacted] IRR. This may be sourced through HNIP and Kingston Hospital contributions for their onsite network desteaming.

The results for Option 2B suggest up to 70% capital funding is required to for the network to reach the [redacted] IRR hurdle rate. This, alongside the additional annual expenditure at KH, make this option unviable under the current assumptions. However, as the energy policy in London adapts this may become a viable option in the long term.

Table 7—4 Hogsmill heat network results summary table

Scenario	Total capital cost	Unfunded (over 30 years)			Gap funding required to reach 7% IRR over 30 years			
	£m	NPV @3.5% £m	IRR %	Funding £m	NPV @3.5% £m	IRR %	Funding £m	Funding % of capex
Option 1 (No DNH connection)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 2A (DHN connection, 1.2MWe)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 2Ai (DHN connection, 0.6MWe CHP)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 2B (DHN connection, no CHP)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

7.3.3 Sensitivity testing

[redacted] IRR

Sensitivity testing around the level of return required from the heat network owner/operator has been carried out to assess its impact of the level of capital funding required for the project.

If the RBK become the DHN owner/operator, the hurdle rate for could decrease to [redacted] IRR over 30 years. The impact of this on the capital funding required is compared to a [redacted] IRR in Table 7—5.

The modelling suggests Option 1 could achieve a [redacted] IRR over 30 years without any capital funding. However, as this option models the hospital's network operating separately to Hogsmill DHN, it is likely that a private ESCo will require higher returns than [redacted].

By reducing the return threshold from [redacted] to [redacted], capital funding for Option 2A reduces from [redacted] to [redacted]. As the level of achievable funding through HNIP typically lies around the 40% mark, this makes Option 2A viable.

Table 7—5 Hogsmill heat network results summary table – [redacted]% IRR sensitivity

Scenario	Total capital cost	Gap funding required to reach 7% IRR over 30 years				Gap funding required to reach [redacted]% IRR over 30 years			
	£m	NPV @3.5% £m	IRR %	Funding £m	Funding % of capex	NPV @3.5% £m	IRR %	Funding £m	Funding % of capex
Option 1 (No DNH connection)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
Option 2A (DHN connection, 1.2MWe)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 2Ai (DHN connection, 0.6MWe CHP)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 2B (DHN connection, no CHP)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Standing charges to match KH current expenditure

A sensitivity on heat standing charge rate to KH was carried out to explore the effect on the overall heat network's financial performance. The [redacted] standing charge was adjusted until its proportion matched the annual expenditure of the current KH system.

The results (Table 7—6 and Figure 7—7) suggest the standing charge in Option 2A can be increased to [redacted]/kW. This would provide additional revenue to Hogsmill DHN, leading to a reduction in capital funding required to meet [redacted]% IRR from 50% in the basecase (Table 7—4) to 37% ([redacted]m of capital funding). At this standing charge, unfunded Option 2A could see a positive IRR of [redacted].

Table 7—6 Hogsmill heat network results summary table – standing charge sensitivity

Scenario	Total capital cost	Standing charge	Unfunded (over 30 years)			Gap funding required to reach [redacted]% IRR over 30 years			
Core network	£m	*([redacted]/kW used in basecase)* £/kWth	NPV @3.5% £m	IRR %	Funding £m	NPV @3.5% £m	IRR %	Funding £m	Funding % of capex
Option 1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
Option 2A	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 2Ai	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 2B	[redacted]	[redacted]							

[redacted]

7.4 Funding options

Capital funding is required if the Hogsmill DHN is to be extended to KH. Alongside those funding streams detailed in the DFS, such as HNIP (gap funding to cover capital costs and commercialisation) and RHI (confirmed to be replaced by another incentive scheme in 2022) are those specific to Kingston Hospital:

- Commercial agreements with KH could leave to a capital contribution for the DHN owner/operator to upgrade and desteam their onsite system
- It is thought KH contribute approximately £200/yr to the EU Emissions Trading System (EU-ETS). Connection to the Hogsmill DHN may be able to reduce these payments. This additional benefit to the hospital could be quantified and play a part in commercial agreements, however details have not been made available at this stage
- Within the UK Government's 'Plan for Jobs' announcement that aims to help the UK's green recovery is an announcement of a £1 billion programme to make public buildings (including hospitals) greener and help in meeting the UK's net-zero by 2050 target[8]. At time of writing, little more is known about this funding stream, but it is thought likely grants will be awarded on a £ per tonne of carbon saved basis
    - Alongside this is an additional £1.5 billion for shovel-ready construction hospital maintenance and upgrade projects

[8] https://www.gov.uk/government/news/rishis-plan-for-jobs-will-help-britain-bounce-back

8 Summary

8.1 Proposed strategy

The NHS are targeting net-zero by "as soon as possible" and 2050 at the latest. Therefore, KH will need to decarbonise their heat supply in the next 15 years if they do not do something now.

By desteaming alone, the hospital can make significant carbon savings due to reduced heat losses / dumping; as a minimum KH should look to desteam their existing onsite network. However much larger carbon savings (up to ~85%) can be realised through Hogsmill DHN connection.

With the latest SAP carbon factors (used for planning) and projected decarbonisation of the grid gas-CHP can no longer deliver long-term carbon savings. If the future energy centre is referable to the GLA, they have indicated that *"if a CHP were to be implemented, it would need to be coupled with other local secondary heat sources and thought would also need to be given to how emissions (CO2 and NOx) are mitigated (both from a carbon and air quality perspective). Our preference would be for such a network to be expanded as part of a larger local energy system."*

Initial modelling suggests that an onsite CHP is needed to keep KH's annual energy expenditure at a similar rate to current operation, due to the reduced electricity import costs from the existing operational CHP. Connection to Hogsmill now (even with CHP in the short term) locks the hospital into a long-term decarbonisation pathway at potentially no extra cost. Taking this opportunity avoids major changes required to the Hospital site in the future for decarbonisation.

For Option 2A - Connection to Hogsmill DHN with local 1.2MWe CHP and peak gas boilers at hospital This option has an estimated capital cost of [redacted], of which ~[redacted]m is towards the desteaming of KH's onsite network and peaking plant / CHP.

- A positive IRR of [redacted] is achieved before funding.
- For the Hogsmill DHN to achieve a [redacted] IRR over 30 years, [redacted] of funding is required (approx. 50% of total costs). Funding could be through a number of sources including HNIP, future RHI replacement and capital contributions from Kingston Hospital and Thames Water.
- This would see carbon savings of up to 50% over 30 years, compared to BAU.

A possible solution to the trade-off between carbon emissions and KH annual expenditure is a smaller CHP at KH, allowing reduced carbon emissions while still generating cheaper electricity for KH (option 2Ai)

- The DHN project could partially cover the costs of de-steaming the hospital system
- Likely no increase (or potentially a saving) in annual expenditure for the hospital
- Additional ~[redacted]m of capital funding required to achieve required IRRs

8.2 Meeting Kingston Hospital's key drivers

Connecting to the Hogsmill DHN can contribute to KH's drivers and targets:

- Put the Hospital on a trajectory for **long-term decarbonisation** of the campus, towards NHS net-zero target, with up to 85% carbon savings over existing over 30 years
- The DHN project could partially **cover the costs of de-steaming the hospital** system (~[redacted])
- Modelling suggests that the network can provide this at **no extra annual cost** compared to what the hospital pay now
- Provide a **GLA compliant** scheme
- Meet **Hospital energy objectives,** for example sharing long term benefits with neighbours, resilience, carbon emissions and waste heat reductions
- Improved local **air quality** with up to 83% of local gas boiler / CHP heat (fuel combustion) displaced with waste heat from Hogsmill DHN

8.3 Next steps

The key next step is to confirm with Kingston Hospital interest in connection to include KH into the Detailed Project Development (DPD) study. The technical scheme be developed further and a full financial model prepared. This will lead to agreement of Heads of Terms for Hogsmill connection. The outcome of this will be an Outline Business Case which will support an application for HNIP funding in January.

In order to achieve this, KH need to express further interest in network connection. A decision from the Director of Estates and Director of Finance is required to progress.

Appendix A Network route crossing:

Coombe Road:

Manhole covers:

Collapsed retaining wall:

Appendix B Options long list

1. **On-site network only** – Hospital goes it alone
    a) Business as Usual (BAU). Steam and LTHW, with CHP
    b) De-steamed. CHP w gas boiler top-up (Carbon Architecture recommended scheme)
    c) De-steamed. Onsite heat pump w gas boiler top-up
    d) De-steamed. New lower capacity CHP with heat pump w gas boiler top-up
2. **Hogsmill DHN connection** – can be either a bulk load connection or the DHN takes on the O&M of KH's secondary network
    a) Hogsmill DHN connection. 100% load
    b) Hogsmill DHN connection. with new lower capacity onsite CHP. Both CHP and gas boilers provide peaking capacity for network and KH (prioritised to KH)
    c) Hogsmill DHN connection. with gas boilers providing peaking capacity for network and KH
    d) Hogsmill DHN connection. No de-steaming. with new lower capacity onsite CHP. Both CHP and gas boilers provide peaking capacity for network and KH (prioritised to KH)

	Driver Priority:	**1**	**2**	**3**	**4**	**5**	**6**		
Row	**Technology**	**Resilience**	**Carbon dioxide emission reduction**	**Alignment with site masterplan**	**Commercial simplicity and technology maturity**	**Appropriate cost**	**Future proof**	**Weighted Score (Out of 5)**	**Recommendation**
	Driver Weighting:	**30%**	**25%**	**10%**	**10%**	**15%**	**10%**		
1	Business as usual: CHP LTHW and steam boiler networks	5	1	2	3	4	1	**3.0**	**N**
2	Option 1: de-steam network and extend to whole site Heat pump replaces CHP	5	4	3	4	2	3	**3.8**	**N**
3	Option 2: de-steam network and extend to whole site Heat pump alongside new smaller CHP	5	3	3	4	4	3	**3.9**	**Y**
4	Option 3a: Connection to the Hogsmill heat network Heat supplied from Hogsmill with gas boilers	4	5	4	4	3	5	**4.2**	**Y**

	Driver Priority:	1	2	3	4	5	6		
Row	Technology	Resilience	Carbon dioxide emission reduction	Alignment with site masterplan	Commercial simplicity and technology maturity	Appropriate cost	Future proof	Weighted Score (Out of 5)	Recommendation
	Driver Weighting:	30%	25%	10%	10%	15%	10%		
	retained for peaking. Heat sold at bulk point, KH retain operation of their energy centre and secondary network								
5	Option 3b: Connection to the Hogsmill heat network Heat supplied from Hogsmill with gas boilers retained for peaking and supply peak capacity to CRE. Heat sold at bulk point. The Hogsmill DHN owner/operators takes on operation of KH energy centre	4	5	5	3	3	5	4.2	Y
6	Option 4: Connection to the Hogsmill heat network & retained CHP Heat supplied from Hogsmill with gas boilers and CHP retained and supply peak capacity to CRE. Heat sold at bulk point. The Hogsmill DHN owner/operators takes on operation of KH energy centre	5	4	5	3	4	5	4.4	Y
7	Option 5: Connection to Hogsmill heat network, no de-steaming As Option 4 but KH do not de-steam existing network. Hogsmill heat network only connected to the existing LTHW network. CHP and boilers retained onsite	3	2	3	2	4	2	2.7	N

Appendix C Capex & TEM inputs

C.1 Bill of quantities

The following section details the main plant and Bill of Quantities (BoQ) at Hogsmill and CRE as well as Kingston Hospital.

Hogsmill Energy Centre	Option 1	Option 2A	Option 2B
Effluent Abstraction	Grundfos submersible pumps (66% duty, assist, standby) SP 60-6 14A00006	As per option 1	Grundfos submersible pumps (66% 2x duty, 2x assist, standby) SP 60-6 14A00006
	2no. 150m of DN225mm MDPE pipework and trenching to EC (uninsulated)	As per option 1	As per option 1
Energy Centre building	250m2 concrete slab. 80m2 office, new substation and storage facilities	As per option 1	As per option 1
Heat generation	1.5MWth GEA high temperature ammonia heat pump (externally housed)	As per option 1	Cumulative capacity of 2.5MWth GEA high temperature ammonia heat pumps (externally housed)
	Taprogge ball heat exchanger cleaning system	As per option 1	As per option 1, but with additional cost incurred due to greater heat pump size.
Electrical substation	2MVA transformer (N+1 redundancy) 11/0.415kV, Dyn 11, 50Hz. Circuit breakers and batteries	As per option 1	As per option 1 – no increase in substation size needed.
	6.35/110kV 3 core 120mm and trenching 500m, looped cable (future proofed for FBO)	As per option 1	As per option 1
	HV Point of Connection (POC) for new 770kVA at LV (as per UKPN correspondence)	As per option 1	As per option 1
Distribution pumps	Grundfos CR 45-6 A-F-A-V-HQQV - 96122832 (66% duty, assist standby)	As per option 1	Grundfos CR 45-6 A-F-A-V-HQQV - 96122832 (1x 66% duty, 2x assist, 1x standby)
Water treatment	ENWA Water Treatment. EnwaMatic BS 300 with associated break tank, dedicated circulation pump (Grundfos CRI 20-1).	ENWA Water Treatment. EnwaMatic BS 300 and 1665 combined capacities, including associated break tank, dedicated circulation pump.	As per option 2A
Thermal stores	2no. Hartwell 50m3 (externally housed)	As per option 1	4no. 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.	As per option 1	As per option 1

Hogsmill Energy Centre	**Option 1**	**Option 2A**	**Option 2B**
Pipe bridge	Pipe bridge over the Hogsmill River (quote from Beaver Bridges)	As per option 1	As per option 1

Cambridge Road Estate	**Option 1**	**Option 2A**	**Option 2B**
CRE Energy Centre			
Boilers	3no. 500kW Hoval condensing boilers (steel heat exchangers). Sized to Cam Gardens and Hampden Rd peak with N+1 redundancy for future proofing. Remaining CRE capacity provided by Countryside. Incl. heat meter and control valve	As per option 1	As per option 1. The remaining CRE capacity is covered by the gas boiler capacity at the Kingston Hospital's EC. Gas boiler capacity only needed for CRE phase 1.
Gas upgrade	To allow for additional grid capacity to serve Cambridge Gardens and Hampden Rd	As per option 1	Not needed anymore as Kingston's Hospital is hosting this additional capacity.
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	As per option 1	As per option 1
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.	As per option 1	As per option 1
Block level distribution pumps	Grundfos 66% duty/assist (13 in total)	As per option 1	As per option 1
Water treatment	EnwaMatic 1672	As per option 1	As per option 1
Heat Interface Units (HIUs)	Evinox ModuSAT XR Twin Plate 100A-10A (2,170 units)	As per option 1	As per option 1

Kingston Hospital	**Option 1**	**Option 2A**	**Option 2B**
Heat generation	1.2MWth and MWe CHP engine, Edina model TCG2020V12. Includes a selective catalytic reduction (SCR) system to reduce NOx emissions from 250 to 50 mg/Nm3 and flues.	As per option 1	No CHP allowed.
	7no. 1,000kW and 1no. 500kW Hoval condensing boilers (steel heat exchangers). Incl. flues, heat meter and control valve.	As per option 1	15no. 1,000kW Hoval condensing boilers (steel heat exchangers). Incl. flues, heat meter and control valve.
Energy Centre building	Energy centre area assumed at 400m^2 from "Carbon Architecture" report.	As per option 1	As per option 1

Kingston Hospital	Option 1	Option 2A	Option 2B
Electrical substation	New HV/LV 1.8MW transformer sized as per the "Carbon Architecture" report, as a result of relocation of EC. Includes substation enclosure.	As per option 1	As per option 1
	130m cabling extension and trenching as a result of EC relocation (length from "Carbon architecture" report). Specification: 400mm Dia 11KV Cable 1 Core AWA.	As per option 1	As per option 1
Distribution pumps	Grundfos NB TP 65-930/2 A-F-A-BQQE-RX1 (1 duty / 1 assist / 1 standby setup)	As per option 1	Grundfos NB TP 65-930/2 A-F-A-BQQE-RX1 (1 duty / 1 assist / 1 standby setup) to provide Kingston Hospital's peak load. Another set of CR 95-8-2 A-F-A-V-HQQV (1 duty / 1 assist / 1 standby setup) to provide CRE peak heat.
Water treatment	ENWA Water Treatment EM 1672 water treatment unit (suitable for 80 - 130 m2) with associated break tank, dedicated circulation pump (Grundfos CRI 5-5)	ENWA Water Treatment EM BS 300 water treatment unit (suitable for 200 - 300 m2) with associated break tank, dedicated circulation pump (Grundfos CRI 20-1)	As per option 2A
Thermal stores	None allowed	As per option 1	As per option 1
Other	CCTV, intruder alarm, fire protection, data, ventilation and ductwork, fibre connection, cold water pipework, sewer, BMS, expansion and pressurisation units.	As per option 1	As per option 1

C.2 Capital cost breakdown

Kingston Hospital						Capital cost (incl. prelims., design, commissioning & contingency)		
		Item	**Rate (£ per unit)**	**Unit**	**Description**	**Option 1**	**Option 2A**	**Option 2B**
KH Energy Centre								
	Heat generation equipment							
		CHP engine	[redacted]	£/kWe	1.2MWth and MWe capacities, Edina model TCG2020V12 as cost ref for Options 1 & 2A. None allowed for 2B.	[redacted]	[redacted]	[redacted]
		CHP selective catalytic reduction (SCR) system	[redacted]	£/kWth	Reduction of NOx emissions from 250 to 50 mg/Nm3, rate based on past project. None allowed for 2B.	[redacted]	[redacted]	[redacted]
		Gas boilers	[redacted]	£/kWth	7no. 1,000kW and 1no. 500kW Hoval condensing boilers (steel HE) (cost expressed per kW). Sized to meet 6.5MW peak load of Kingston Hospital for options 1 & 2A with	[redacted]	[redacted]	[redacted]

Kingston Hospital					Capital cost (incl. prelims., design, commissioning & contingency)		
				N+1 redundancy. Additional peak capacity of 7.5MW of CRE loads (excluding phase 1) allowed for option 2B with N+1 redundancy (15no. 1,000kW boilers).			
	CHP flues	[redacted]	£/kWth	Past project experience - inflation accounted for	[redacted]	[redacted]	-
	Gas boiler flues	[redacted]	£/kWth	Past project experience - inflation accounted for	[redacted]	[redacted]	[redacted]
Civils							
	Building	[redacted]	£/m2	Energy centre area assumed at 400m2 from CA report. Cost from past project experience.	[redacted]	[redacted]	[redacted]
	Land clearing			Assumed it is taken on by the Masterplan	[redacted]	[redacted]	[redacted]
Electrical							
	HV/LV transformer	[redacted]	£/kVA	New transformer sized (capacity 1,800kVA) as a result of relocation of EC. Cost from past project experience which included use of cost consultant.	[redacted]	[redacted]	[redacted]
	Cabling extension	[redacted]	£/m2	Cabling extension and trench as a result of EC relocation. Same length as in CA report is assumed. Specification: 400mm Dia 11KV Cable 1 Core AWA. Cost from past project experience which included use of cost consultant.	[redacted]	[redacted]	[redacted]
	LV Switchgears	[redacted]	£/switchgear	LV switchgear upgrade for 21 plantrooms according to connected buildings. Cost taken from CA report as total electrical capacity is unknown.	[redacted]	[redacted]	[redacted]
	Substation enclosure	[redacted]	£/unit	One-off cost of enclosure of substation by EC.	[redacted]	[redacted]	[redacted]
Distribution							
	Pumps	[redacted]	£/ pump unit	Grundfos NB TP 65-930/2 A-F-A-BQQE-RX1 (1 duty / 1 assist / 1 standby setup) allowed for all options to provide Kingston Hospital peak load. Another set of CR 95-8-2 A-F-A-V-HQQV (1 duty / 1 assist / 1 standby setup) is allowed for option 2B to provide the boiler export load for the CRE development peak heat.	[redacted]	[redacted]	[redacted]
	Water treatment	[redacted]	£/ unit	ENWA Water Treatment EM 1672 water treatment unit (suitable for 80 - 130 m2) with associated break tank, dedicated circulation pump (Grundfos CRI 5-5) for option 1. ENWA Water Treatment EM BS 300 water treatment unit (suitable for 200 - 300 m2) with associated break tank, dedicated circulation pump	[redacted]	[redacted]	[redacted]

Kingston Hospital				Capital cost (incl. prelims., design, commissioning & contingency)		
			(Grundfos CRI 20-1) for options 2A & 2B.			
Thermal stores	[redacted]	£/ m3	No thermal store sized for any option.	-	-	-
Other						
CCTV/ Intruder alarm	[redacted]	£/unit	Estimate from prior project experience.	[redacted]	[redacted]	[redacted]
Fire protection and alarm	[redacted]	£/unit	Estimate from prior project experience.	[redacted]	[redacted]	[redacted]
Voice/data	[redacted]	£/unit	Estimate from prior project experience.	[redacted]	[redacted]	[redacted]
Ventilation and ductwork in office space	[redacted]	£/unit	Estimate from prior project experience.	[redacted]	[redacted]	[redacted]
Fibre connection	[redacted]	£/unit	Estimate from prior project experience: £15,000 - plus 50% for remote site location	[redacted]	[redacted]	[redacted]
Cold water pipework	[redacted]	£/unit	Estimate from prior project experience.	[redacted]	[redacted]	[redacted]
Sewer	[redacted]	£/unit	Estimate from prior project experience.	[redacted]	[redacted]	[redacted]
BMS system	[redacted]	£/kWt h	Estimate from prior project experience.	[redacted]	[redacted]	[redacted]
Expansion and pressurisation units	[redacted]	£/m3	Cost estimate from prior project experience. Total system volume estimated at 76m3 (entire LTHW system at KH) for option 1 and at 167m3 (entire LTHW system at KH + connecting DN250 pipe to larger DHN) for option 2A and 2B.	[redacted]	[redacted]	[redacted]
Network and connection equipment						
LTHW - new						
Distribution main ring (DN200) & trenching	[redacted]	£/m	Logstor series 2 1,100m (length taken from CA report). Hard dig. Rates allow for supply, delivery, offloading, installation, hydraulic testing, 10% N.D.T. Sized to satisfy 60% of estimated peak load.	[redacted]	[redacted]	[redacted]
Distribution pipework to KH buildings (DN80) & trenching	[redacted]	£/m	Logstor series 2, 700m (length taken from CA report). Hard dig. Rates allow for supply, delivery, offloading, installation, hydraulic testing, 10% N.D.T. Average size DN for all connected loads.	[redacted]	[redacted]	[redacted]
Heat meter and control valve at KH EC	[redacted]	£/EC	£200/heat meter and £400/valve from prior project experience.	[redacted]	[redacted]	[redacted]
Block level PHEs per load	[redacted]	£/activ e kW	PHE at each non-resi block connection (17) - sized to peak load 66% duty-assist. 2017 Armstrong equipment quote with 6% inflation. 0.75 cost factor applied to account for duty/assist set up.	[redacted]	[redacted]	[redacted]

Kingston Hospital						Capital cost (incl. prelims., design, commissioning & contingency)		
		Pumps per load	-	-	Pumps at each non-resi block connection (17) @ KH- duty/assist - selection from Grundfos website	[redacted]	[redacted]	[redacted]
		Heat meters per load	[redacted]	£/plantroom	£200/heat meter.	[redacted]	[redacted]	[redacted]
	LTHW - existing							
		Removal of existing LTHW pipework	[redacted]	£/m	Cost from past project experience which included use of cost consultant. Network length estimated from CA report.	[redacted]	[redacted]	[redacted]
	Steam distribution - existing							
		Removal of existing steam distribution pipework	[redacted]	£/m	Cost from past project experience which included use of cost consultant. Network length estimated from CA report.	[redacted]	[redacted]	[redacted]
					TOTAL	[redacted]	[redacted]	[redacted]

Hogsmill WWTP and CRE						Capital cost (incl. prelims., design, commissioning & contingency)		
		Item	**Rate (£ per unit)**	**Unit**	**Description**	**Option 1**	**Option 2A**	**Option 2B**
Heat Offtake at HSTW								
	Civils							
		New chambers (x2)	[redacted]	£/chamber	In-house cost	[redacted]	[redacted]	[redacted]
		Overpumping during construction	-	-	Temporary generators, pumps etc. - £20k per week during construction. 7 week construction	[redacted]	[redacted]	[redacted]
		Surveys, design etc.	[redacted]		One-off cost	[redacted]	[redacted]	[redacted]
	Offtake equipment							
		Sump pumps	-	-	Grundfos submersible pumps (66% duty, assist, standby) SP 60-6 14A00006 for options 1 and 2A. Number of duty and assist pumps doubled for option 2B as a result of greater heat pump size.	[redacted]	[redacted]	[redacted]
		Pipework & trenching	[redacted]	£/m	2no. 150m of DN225mm MDPE pipework and trenching to EC (uninsulated). Pipe price from Spon's 2017 plus 6% inflation and trenching from Logstor.	[redacted]	[redacted]	[redacted]
HSTW Energy Centre								
	Civils							
		Concrete slab	[redacted]	£/m2	250m2 EC area at full build out	[redacted]	[redacted]	[redacted]
		Building	[redacted]	£/m2	Office, substation, storage (assumed 80m2) - price from Spon's	[redacted]	[redacted]	[redacted]

Hogsmill WWTP and CRE					Capital cost (incl. prelims., design, commissioning & contingency)		
	Land clearing	-	-	Vegetation clearing, excavation and disposal, site investigation (Spon's 2018 with inflation) - RISK: assumes no contaminated land	[redacted]	[redacted]	[redacted]
Heat generation equipment							
	Taprogge ball cleaning system	[redacted]	£/kW	Quote directly from Taprogge email expressed on a per kW basis	[redacted]	[redacted]	[redacted]
	Heat pumps	[redacted]	£/kW	1.5MWth GEA high temperature ammonia heat pump (externally housed) for option 1 and 2A. A cumulative capacity of 2.5MWth for option 2B.	[redacted]	[redacted]	[redacted]
Electrical							
	Substation			2MVA transformer (N+1 redundancy) 11/0.415kV, Dyn 11, 50Hz. Spon's price used. No additional capacity required for option 2B.	[redacted]	[redacted]	[redacted]
	Switchgear			Circuit breakers and tripping batteries/ battery chargers (Spon's)	[redacted]	[redacted]	[redacted]
	Cabling extension			6.35/110kV 3 core 120mm and trenching 500m, looped cable (future proofed for FBO) - Spon's	[redacted]	[redacted]	[redacted]
	UKPN upgrades			HV POC for new 770kVA at LV (as per UKPN quote - additional 20% VAT)	[redacted]	[redacted]	[redacted]
Distribution							
	Pumps			Grundfos CR 45-6 A-F-A-V-HQQV - 96122832 (66% duty, assist standby) for options 1 and 2A. An additional assist unit is costed for option 2B.	[redacted]	[redacted]	[redacted]
	Water treatment			EnwaMatic BS 300 with associated break tank, dedicated circulation pump (Grundfos CRI 20-1) for option 1. EnwaMatic BS 300 and 1665 combined capacities, including associated break tank, dedicated circulation pump, for options 2A and 2B.	[redacted]	[redacted]	[redacted]
	Thermal stores	[redacted]	£/unit	2no. Hartwell 50m3 (externally housed) for options 1 and 2A. 2no. additional 50m3 stores for option 2B.	[redacted]	[redacted]	[redacted]
Other							
	CCTV/ Intruder alarm	[redacted]	£/unit	Estimate from prior project experience.	[redacted]	[redacted]	[redacted]
	Fire protection and alarm	[redacted]	£/unit	Estimate from prior project experience.	[redacted]	[redacted]	[redacted]
	Voice/data	[redacted]	£/unit	Estimate from prior project experience.	[redacted]	[redacted]	[redacted]
	Ammonia dectection (incl. internal ductwork and ventilation system)	[redacted]	£/unit	Direct quote from GEA	[redacted]	[redacted]	[redacted]

Hogsmill WWTP and CRE				Capital cost (incl. prelims., design, commissioning & contingency)		
Ventilation and ductwork in office space	[redacted]	£/unit	Estimate from prior project experience.	[redacted]	[redacted]	[redacted]
Fibre connection	[redacted]	£/unit	Estimate from prior project experience: £15,000 - plus 50% for remote site location	[redacted]	[redacted]	[redacted]
Cold water pipework	[redacted]	£/unit	Estimate from prior project experience.	[redacted]	[redacted]	[redacted]
Sewer	[redacted]	£/unit	Estimate from prior project experience.	[redacted]	[redacted]	[redacted]
BMS system	[redacted]	£/unit	Estimate from prior project experience.	[redacted]	[redacted]	[redacted]
Expansion and pressurisation units	[redacted]	£/m3	Cost estimate from prior project experience. Total system volume estimated at 296m3 (from Hogsmill EC to CRE block level PHEs) for option 1 and at 385m3 for option 2A and 2B.	[redacted]	[redacted]	[redacted]
LTHW pipework	[redacted]	£/unit	Estimate from prior project experience - allowance for additional connecting pipework	[redacted]	[redacted]	[redacted]
CRE Energy Centre						
Heat generation equipment						
Boilers	[redacted]	£/kWth	3no. 500kW Hoval condensing boilers (steel HE). Sized to meet peak load of Cam Gardens and Hampden Rd (1.177MWth) with N+1 redundancy. Remaining 14 boilers (N+1) for CRE peak assumed paid for by Countryside. Network pay for repex	[redacted]	[redacted]	[redacted]
Flues			Assume paid by Countryside	[redacted]	[redacted]	[redacted]
Gas connection upgrade			Assumption to allow for additional capacity to serve Cambridge Gardens / others for option 1 and 2A. Not needed for option 2B as Kingston's Hospital is hosting additional boiler capacity.	[redacted]	[redacted]	[redacted]
Distribution						
Thermal substation			Not required	[redacted]	[redacted]	[redacted]
Pumps			Assumed paid for by Countryside. Grundfos NB 65-315/320 ASF2ABQQE (duty, 2x assist, standby)	[redacted]	[redacted]	[redacted]
Water treatment			Not required	[redacted]	[redacted]	[redacted]
Other			Assume CRE pay for all other costs (CCTV, alarms, ventilation, sewer etc.)	[redacted]	[redacted]	[redacted]
Network and connection equipment						
Connection costs						
PHE at CRE			Not required. 2no. 4994kW. 66% duty assist PHE for CRE connection. SWEP quote.	[redacted]	[redacted]	[redacted]
Heat meter and control valve at CRE	[redacted]	£/EC	£200/heat meter and £400/valve. 3 heat meters (CRE, CRE EC, HSTW EC)	[redacted]	[redacted]	[redacted]

Hogsmill WWTP and CRE				**Capital cost (incl. prelims., design, commissioning & contingency)**		
CRE tertiary plant (repex and opex only)						
Water treatment at CRE			ENWA 1672 - tertiary system at CRE (REPEX and OPEX only). Includes additional % costs for install, commissioning etc.	-	-	-
HIUs	[redacted]	£/flat	Evinox quote (ModuSAT XR Twin Plate 100A-10A)	-	-	-
Block level PHEs			PHE at each phasing block connection on CRE (13 in total) - sized to peak load 66% duty-assist. Armstrong 2017 quote with 6% inflation. 0.75 cost factor applied to account for duty/assist set up	-	-	-
Pumps			Pumps at each phasing block connection on CRE (13 in total) - duty/assist - Grundfos website	-	-	-
Network costs						
Pipework & trenching – Hogsmill EC to CRE loads			Logstor Series 2, 1,165m, soft dig through cemetery. Sized to Cam Gardens peak. Max DN250 for Option1 and DN300 for options 2A and 2B (to allow for Hospital connection). Rates allow for supply, delivery, offloading, installation, hydraulic testing, 10% N.D.T	[redacted]	[redacted]	[redacted]
Pipe bridge			Beaver Bridges quote	[redacted]	[redacted]	[redacted]
Pipework and trenching – Cambridge Road to Kingston Hospital			Logstor Series 2 prices inflated to 2019 values - DN250 (length from Kingston report - 934m). Rates allow for supply, delivery, offloading, installation, hydraulic testing, 10% N.D.T	[redacted]	[redacted]	[redacted]
CHP heat offtake						
PHE			duty assist 66% sized to thermal peak of 3 CHPs at HSTW (1,547kW). Costs quote from Armstrong - skid	[redacted]	[redacted]	[redacted]
Pumps and valve to EC connection			duty assist jockey 66% 10% pumps, Grundfos. 2no. Isolating valves, Logstor.	[redacted]	[redacted]	[redacted]
Pipework and trenching to EC			Logstor series 2 795m DN125mm. Hard dig. Rates allow for supply, delivery, offloading, installation, hydraulic testing, 10% N.D.T	[redacted]	[redacted]	[redacted]
			TOTAL	[redacted]	[redacted]	[redacted]

C.3 TEM inputs

	Input / assumption	Option 1	Option 2A	Option 2B	Unit	Reference
Plant: Low-carbon technologies						
	Heat pump capacity	1,500	1,500	2,500	kWth	Energy modelling
	Heat pump thermal efficiency	350%	350%	350%	%	GEA
	Heat pump fraction as a % of total generation	38%	30%	60%	%	Energy modelling
	Biogas CHP peak thermal output to network (Hogsmill)	789	789	789	kWth	Energy modelling
	Biogas CHP heat fraction as a % of total generation (Hogsmill)	23%	23%	23%	%	Energy modelling
	KH CHP capacity	1,200	1,200	-	kWe	Energy modelling
	KH CHP heat fraction as a % of total generation	14%	32%	-	%	Energy modelling – depending of if CHP heat incl.
Plant: Back-up boilers						
	Natural gas boiler capacity	14,000	14,000	14,000	MWth	Energy modelling
	Natural gas boiler efficiency	89%	89%	89%	%	Assumed
	Boiler heat fraction as a % of total generation	25%	15%	17%	kW	Energy modelling – depending of if CHP heat incl.
Equipment life expectancy						
	Heat pump	20	20	20	yrs	[9]
	CHP	15	15	15		
	Top-up technology	15	15	15	yrs	[10]
	DHN connections	20	20	20	yrs	[11]
	Cambridge Road Estate HIUs	20	20	20	yrs	[12]
	Abstraction and distribution pumps	20	20	20	yrs	[13]
	DHN network	longer than scheme life			yrs	Assumed
Network losses						
	Parasitic pumping power	5.4%	5.4%	5.4%	%	2% network losses (CP1) and calculated 3.4% abstraction pumping at HSTW
	District heating standing losses	4.2%	6.5%	6.5%	%	Calculated
REPEX sinking fund						
	% of replacement expenditure incurred	75%	75%	75%	%	Assumed
Other						
	Discount rate	3.5%	3.5%	3.5%	%	Green Book
	Start year	2024	2024	2024		Assumed
	Modelling lifetime	30	30	30	yrs	Assumed

[9] Department of Energy & Climate Change (DECC), 2015. *Assessment of the Costs, Performance, and Characteristics of UK Heat Networks*
[10] Department of Energy & Climate Change (DECC), 2015. *Assessment of the Costs, Performance, and Characteristics of UK Heat Networks*
[11] Department of Energy & Climate Change (DECC), 2015. *Assessment of the Costs, Performance, and Characteristics of UK Heat Networks*
[12] Department of Energy & Climate Change (DECC), 2015. *Assessment of the Costs, Performance, and Characteristics of UK Heat Networks*
[13] Department of Energy & Climate Change (DECC), 2015. *Assessment of the Costs, Performance, and Characteristics of UK Heat Networks*

	Input / assumption	Option 1	Option 2A	Option 2B	Unit	Reference
	Discount rate	3.5%	3.5%	3.5%	%	[14]

[14] HM Treasury, 2018. *The Green Book, Central Government Guidance on Appraisal and Evaluation*

Appendix D Carbon assessment

D.1 Carbon assessment – KH network (heat only)

Scenario	Unit	Option 1	Option 2A	Option 2Ai	Option 2B
DH emissions saving @ year 15	*%*	27%	60%	70%	86%
DH emissions saving @ year 30	*%*	29%	62%	72%	88%
DH emissions saving (15yr total)	*tCO2e*	25,093	56,008	65,027	80,523
DH emissions saving (30yr total)	*tCO2e*	58,205	124,065	145,073	178,129
Energy centre emissions (30yr total)	*tCO2e*	143,221	77,361	56,354	23,298

D.2 Carbon assessment – Total network

Scenario	Unit	Option 1	Option 2A	Option 2Ai	Option 2B
DH emissions saving @ year 15	*%*	30%	46%	62%	85%
DH emissions saving @ year 30	*%*	29%	46%	62%	86%
DH emissions saving (15yr total)	*tCO2e*	29,849	49,888	62,867	84,889
DH emissions saving (30yr total)	*tCO2e*	63,087	104,377	136,738	187,141
Energy centre emissions (30yr total)	*tCO2e*	152,723	117,415	85,054	34,651

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