Heat Mapping and Energy Masterplanning

(GLA 80814 - Task 3)

London Borough of Sutton

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Prepared by	Checked by	Approved by
Rachael Collins	Cornelius Kelleher	Matthew Turner

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Prepared for:

London Borough of Sutton

Prepared by:

AECOM Limited
Aldgate Tower
2 Leman Street
London E1 8FA
United Kingdom
aecom.com

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Abbreviations	Meaning
AQMAs	Air Quality Management Area
ASHP	Air Source Heat Pump
BEIS	Department of Business, Energy and Industrial Strategy (formerly DECC – see below)
BMS	Building Management System
CAPEX	Capital Expenditure
CHP	Combined Heat and Power
CIBSE	Chartered Institute of Building Services Engineers
CO_2	Carbon Dioxide
CSE	Centre for Sustainable Energy
D	Diversity factor
DC	District cooling
DE	District Energy
DEC	Display Energy Certificates
DHN	District Heating network
DHW	Domestic Hot Water
DIIP	Infrastructure Investment Plan
DoT	Department of Transport
DSM	Dynamic Simulation Modelling
EC	Energy Centre
EfW	Energy from Waste
EPC	Energy Performance Certificate
ERF	Energy Recovery Facility
FEE	Fabric Energy Efficiency
GSHP	Ground Source Heat Pump
HIU	Heat interface unit
HNCoP	Heat networks Code of Practice
HNDU	Heat Networks Delivery Unit
HP	Heat Pump
IAG	Inter Analysts Group
ICR	Institute of Cancer Research
IRR	Internal Rates of Return
kWe	Kilowatt electric
kWth	Kilowatt thermal
LBS	The London Borough of Sutton
LCH	London Cancer Hub
MID	Measuring Instruments Directive
MWe	Megawatt electric
MWth	Megawatt thermal
NOx	Nitrogen Dioxide
NPPF	National Planning Policy Framework
NPV	Net Present Values
OPEX	Operational Expenditure
PHEX	Plate Heat Exchange
PV	Photovoltaics
SAP	Standard Assessment Procedure
SCR	Selective Catalytic Reduction
SH	Space Heating
SPF	Seasonal Performance Factor
STC	Sutton Town Centre
UKPN	UK Power Networks
WSHP	Water Source Heat Pump

1. Executive Summary

AECOM was commissioned to carry out a Heat Mapping and Energy Masterplanning study for Sutton Town Centre (STC) and the London Cancer Hub (LCH) by the London Borough of Sutton (LBS). This involved the identification of heat loads, both existing and future, as well as the identification of possible heat sources and modelling of optimum networks for each site.

Various technologies to generate heat for the network were reviewed and compared against key criteria such as cost, deliverability, carbon emissions and air quality. Following this, several options were taken forward for more detailed technical and economic modelling. STC Considered combined heat and power (CHP), energy from waste (EfW) – (specifically heat from the Viridor energy recovery facility in Beddington) and ammonia-based air source heat pumps (ASHP). LCH considered CHP and ground source heat pump (GSHP)

For the LCH two scenarios, which are outlined in The London Cancer Hub Delivery Strategy, were modelled for each heat generation technology selected. Scenario 'a' comprises of a collocated hospital, with scenario 'b' entailing the incremental estate development of the existing Royal Marsden hospital.

A summary of the results for each potential heat network is provided below in Table 1-1.

Table 1-1 Summary of techno-economical results

	Network Option		
Sutton Town Centre	1 (CHP)	2 (EfW)	3 (ASHP)
Total thermal demand (MWh p.a.)	15,100	14,400	11,500
Option technology heat generation (as % of total)*	75.9%	90.0%	61.9%
Option technology capacity (kW)	3,070	15,000	1,600
25 year cumulative carbon emission savings (tonnes CO_2e)	-55,700	24,400	4,270
Total CAPEX (£)	18,000,000	19,200,000	15,000,000
25 year IRR (%)	5.46	4.76	0.39
25 year NPV (£)	3,850,000	3,310,000	-3,160,000

London Cancer Hub	4a (CHP)	4b (CHP)	5a (GSHP)	5b (GSHP)
Total thermal demand (MWh p.a.)	29,100	23,600	29,100	23,600
Option technology heat generation (as % of total)*	75.7%	75.3%	59.9%	69.9%
Option technology capacity (kW)	4,230	3,470	2,460	2,460
25 year cumulative carbon emission savings (tonnes CO2e)	-90,600	-74,100	7,910	20,000
Total CAPEX (£)	14,700,000	13,100,000	14,500,000	13,800,000
25 year IRR (%)	5.48	5.52	5.44	6.01
25 year NPV (£)	3,000,000	2,760,000	3,090,000	3,810,000

*Gas boilers were included for each network to meet peak thermal load

Economically, for Sutton Town Centre, a CHP solution (Option 1) or an EfW solution (Option 2) would be viable, although securing a source of government funding would be advisable in either case. Sensitivity analysis showed that with grant funding, for example from the Heat Network Investment Project (HNIP) scheme, the IRRs could increase by up to 6% (i.e. from 7% to 13%). For context, the IRR for these types of project tend to vary between 0 and 15%, with the majority sitting between 5 and 9%[1].

For LCH, sensitivity analysis showed that GSHP (Option 5a/b) would generate a negative IRR without the Renewable Heat Incentive (RHI) scheme. Given the uncertainty regarding an extension of the RHI scheme beyond its current end-date (2021), it is possible that RHI support will not exist in its current form during the key development phase of the LCH scheme. This presents an important project risk.

A review of the carbon factors associated with each network option shows that over time the carbon savings associated with a CHP led scheme rapidly diminish as the electricity grid decarbonises, however heat pump technology shows rapid improvement in terms of the carbon content of the delivered heat. For STC, the EfW option has the lowest carbon factor from 2016 onwards, using SAP 2016 consultation figures. Connecting to an EfW led network in STC would present a significant benefit to a developer and contribute to compliance with planning targets.

Moreover, a review of the potential air quality impacts of each of the technology solutions demonstrated that EfW was anticipated to have the least impact, with CHP the highest. It is likely that a CHP led scheme would struggle to positively contribute to local air quality compared to the counterfactual base case (ASHP and gas boiler). When considered with the focus that is being placed on air quality in London, including the shift away from gas-CHP in the draft new London Plan, a CHP led scheme would present a significant risk going forward.

For STC, as the EfW option demonstrates significant carbon savings, local air quality benefits and acceptable IRRs, further analysis was performed to outline a route-map to deliver this solution. This route-map indicated a phased build-out, with two smaller localised networks acting as a catalyst to connection the EfW facility. The Heat Network Investment Project (HNIP) offers funding (loans and or grants) to qualifying heat networks to encourage the development of heat networks. It is likely that the STC EfW option shown in the route map would be a suitable project and the availability of funding would improve the project IRR. However, to access this funding the development of the heat network would need occur during the HNIP investment window.

For LCH, due to air quality concerns and the decarbonisation of the grid, a GSHP solution would be a suitable solution. Feasibility of a GSHP driven heat network should be explored further, alongside clarification of the redevelopment timeline and building loads, whilst considering the risk to financial viability in the case that RHI support is discontinued.

[1] Investing in the UK's heat infrastructure: Heat Networks November 2015

2. Introduction

AECOM was commissioned to undertake a heat mapping and energy masterplanning study to identify key opportunities for decentralised energy schemes within the London Borough of Sutton (LBS) as part of the Greater London Authority's (GLA) Decentralised Energy Enabling Project (DEEP). As part of this work, network opportunities were technically and commercially assessed with a view to identifying the most viable solution.

2.1 Background to Study

Heat mapping, carried out in 2011 by URS as part of the GLA's DeMAP programme, identified areas in Sutton which had the greatest potential for district heating schemes. This included Sutton Town Centre (STC), Hackbridge, for which the council is already developing plans for a district energy network, and St Helier. LBS also recently entered a joint project with the Institute of Cancer Research (ICR), with the support of The Royal Marsden NHS Foundation Trust and the Greater London Authority, to develop a world-class centre for cancer innovation – the London Cancer Hub (LCH).

In view of the above, an energy masterplanning study was undertaken for two sites in Sutton, namely STC and the LCH. The nature of these sites is outlined in more detail below. This study builds upon the 2011 URS study and the existing Sutton Town Centre Masterplan adopted by the council in September 2016. Along with developing a strategy for decentralised heat and power schemes for STC and the LCH, the study will investigate the potential application of solar PV, and include a high level assessment of the potential to power the STC tram extension by renewable sources.

The development of district heat networks and reducing carbon emissions (e.g. through delivering 'zero carbon' standards for major residential developments) are also key policy drivers in both the London Plan and the Sutton Local Plan.

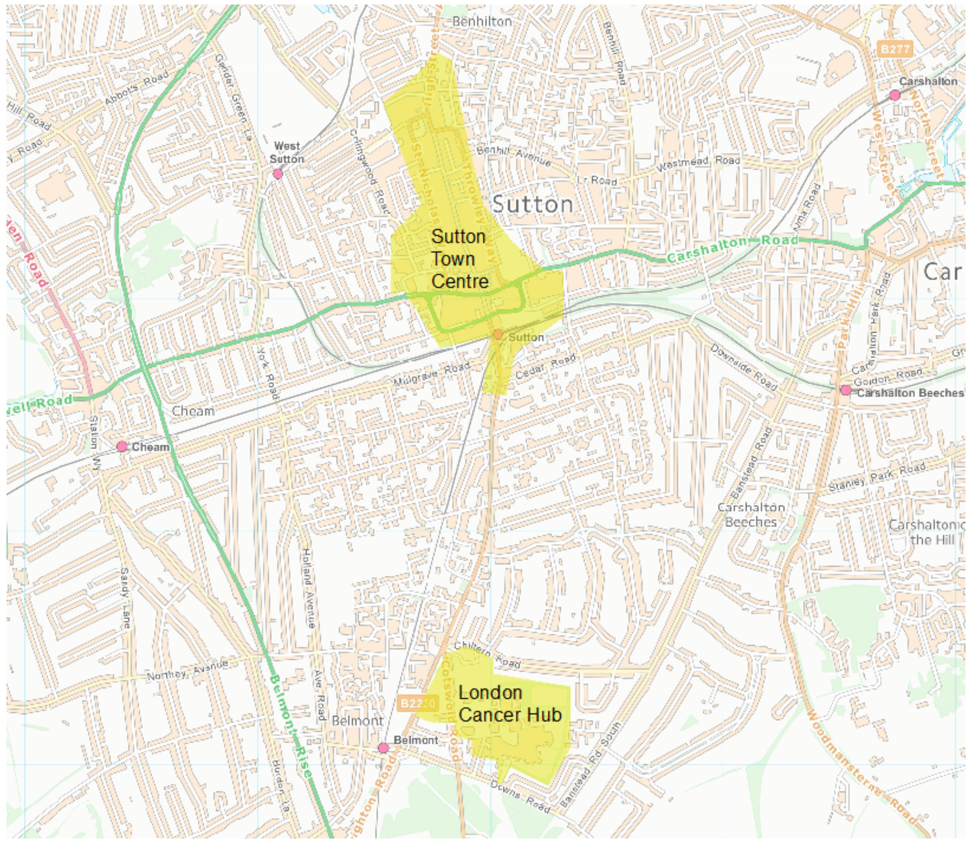


Figure 2-1 Map showing the two areas of study, Sutton Town Centre and London Cancer Hub

2.1.1 Sutton Town Centre (STC)

The Sutton Town Centre Masterplan 2016 outlines a sustainable vision of growth for the town centre, and sets the direction for investment and development up to 2031. The redline boundary of the area covered by the STC Masterplan is shown in Figure 2-2.

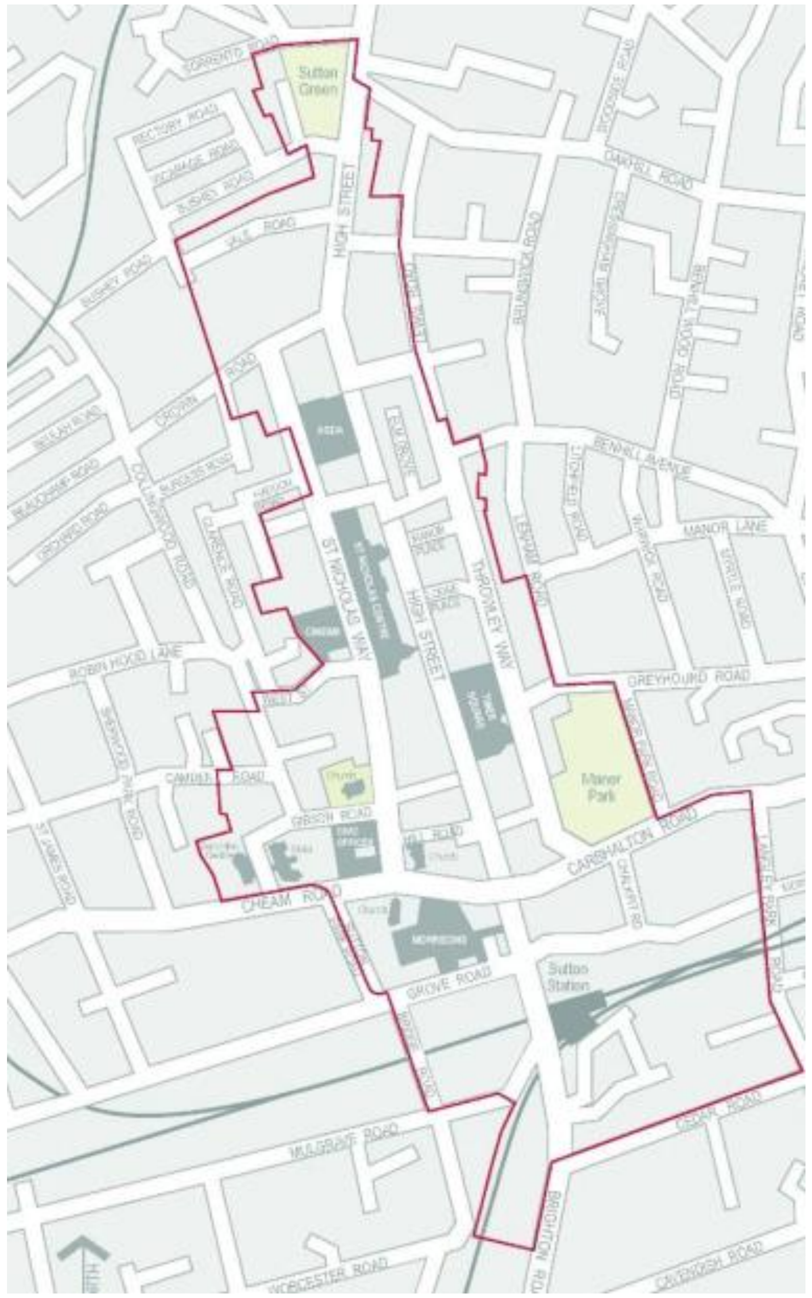


Figure 2-2 Sutton Town Centre Masterplan area[2]

The STC Masterplan identifies 45 sites that are planned to be redeveloped over the lifetime of the Masterplan and the majority of these have been allocated in Sutton's newly adopted Local Plan (February 2018). A number of these sites within the STC Masterplan redline boundary have been granted planning permission since 2011. All major developments granted planning permission since 2011, including those already completed, were required to be future-proofed for potential connection to a future district heating network as part of the planning process.

[2] Sutton Town Centre and London Cancer Hub Energy Masterplan Outline Specification

2.1.2 London Cancer Hub (LCH)

The London Cancer Hub is located approximately 2km south of STC. This site is intend to be a world-class centre for cancer innovation with the aim of creating 265,000 m² of state of the art facilities that will support 10,000 researchers, clinical staff and support staff. Figure 2-3 depicts the LCH Masterplan, as presented in the London Cancer Hub Development Framework.

Figure 2-3 London Cancer Hub Masterplan[3]

The current indicative delivery strategy sets out a plan to deliver the London Cancer Hub over 3 waves, up to 2035, as depicted in Figure 2-4. This includes the two scenarios for wave 2 of the development. Wave 2A comprises of the colocation of a new hospital alongside The Royal Marsden. Wave 2B entails the incremental estate development of The Royal Marsden hospital itself.

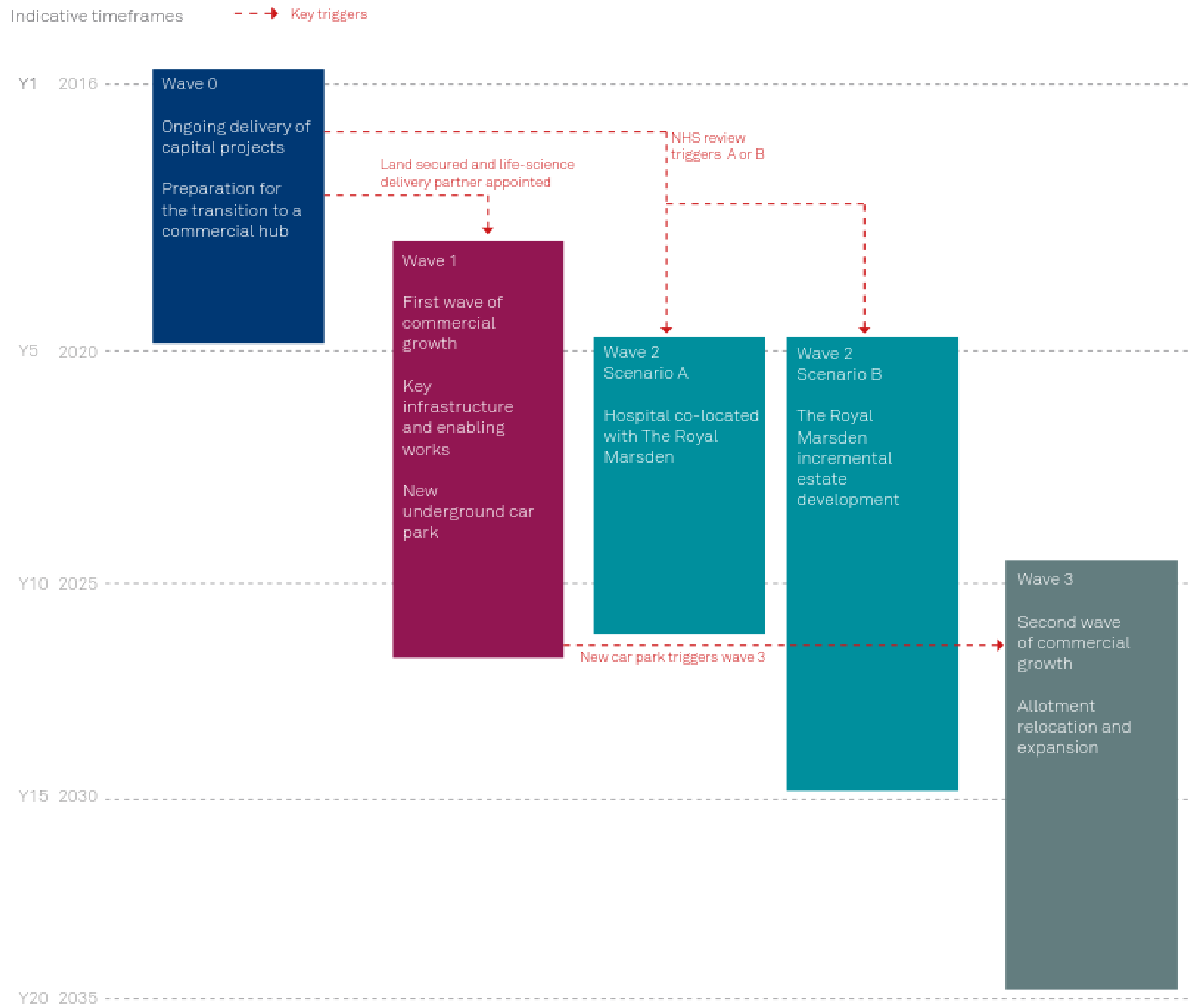


Figure 2-4 Indicative delivery strategy for The London Cancer Hub[4]

[3] The London Cancer Hub Development Framework, Page 6

[4] The London Cancer Hub Delivery Strategy

2.2 Aims and Objectives

In an effort to reduce its environmental impact the London Borough of Sutton (LBS) has committed to becoming a 'one planet' borough by 2025 through its One Planet Action Plan. This study was commissioned to support this initiative as well as to support the growth agenda for the STC and LCH sites and comply with the carbon emissions reduction targets in the London Plan. Although the Council's existing One Planet Action Plan is due to be superseded by a new Sustainability Strategy for the Borough in 2019, this is expected to carry forward the council's ambition to develop district heat networks to serve all identified decentralised energy (DE) opportunity areas within the Borough including STC.

The study addresses the Borough's key aims, supporting the transition to affordable low-carbon decentralised energy and providing an evidence base for future development planning.

The London Borough of Sutton has specified the following outcomes for the study:

- The study will help Sutton achieve their 'One Planet Vision' by providing a roadmap to efficient and low carbon energy supply which will help both business and community to thrive.
- The study will provide high level development advice for district heating networks on the STC and LCH sites.
- This study will support the Council's emerging Local Plan policies by providing a sound evidence base for promoting district heating and renewable energy sources.
- The study will provide planning policy advice and set out technical guidance for prospective developers to ensure future developments are compatible with the Council's vision.
- The study will help Sutton in working towards the Mayor's 'zero carbon' target for major residential developments.
- The study will outline impacts to air quality arising from any proposed energy centres.
- The study will provide clear strategy and guidance for the Council and its ESCo moving forwards with regard to its decentralised energy plans.

2.3 Methodology

The methodology developed to undertake this study is summarised below. This is in line with CIBSE/ADE CP1 Heat Networks: Code of Practice for the UK. A more detailed methodology will be presented in the relevant sections of this report.

1. **Data Collection:** Data collection was undertaken to identify the heating, cooling and power requirements of the existing and planned buildings within the red-line boundary. This used a number of sources to establish load quanta, including collecting energy consumption data, industry recognised benchmarks and AECOM modelled benchmarks. A heat consumption threshold was applied in order to omit smaller buildings, leaving only the most suitable for connection to a district energy network for further analysis.

2. **Energy Mapping:** Using the annual load analysis, energy maps were produced, illustrating the size and location of the key heating, cooling and power loads with STC and LCH.

3. **Energy supply Opportunities:** A high level review of potential low carbon technologies to supply heat to the Sutton sites was carried out. This review assessed each technology's suitability for use against deliverability, environmental, financial and technical criteria.

4. **Energy Masterplanning and Network Opportunities:** Optioneering of potential network opportunities was carried out, taking into account the main barriers and load priorities as well as possible energy centre locations. In addition, key network considerations are discussed, such as coordination with existing energy utilities.

5. **Techno-economic assessment:** A high-level technical evaluation was undertaken for the network options identified, in order to make initial technical recommendations based on cost, energy and carbon performance metrics. A high-level financial analysis was further undertaken providing a discounted cash flow analysis, Net Present Values (NPV) and Internal Rates of Return (IRR) for each network option over 25 and 40 year project lifetimes.

6. **Planning and Air quality review:** A review of the impact of implementing the proposed heat network on air quality and compliance with planning requirements was carried out.

7. **Solar PV:** A review of the potential to install solar PV in STC was carried out using GIS mapping.

8. **Consideration of Tram and Gyratory works:** A high level review of opportunities and risks to the development of a heat network in Sutton Town Centre from other infrastructure projects was undertaken. This includes the potential extension of the South London tram and changes to the gyratory circulating Sutton High Street.

9. **Project Plan, risks and next steps:** Recommendations for the most technically and commercially viable network options were made and the potential funding routes that could be pursued to realise these. A route-map was created detailing a possible path to full build-out of the network in Sutton Town Centre.

3. District Energy Overview

The standard approach to providing energy to buildings in the UK is relatively inefficient. Heat and cooling is usually generated at a building scale typically with gas boilers for heating and chillers or air conditioners for cooling, limiting the use of low and zero carbon technologies. Electricity is usually generated at power stations that are remote from the point of use, leading to inefficiencies from wasted heat produced in the generation process and the losses associated with transmission.

District Energy (DE) offers an alternative to this arrangement, generating and distributing heat and /or cooling to a number of buildings in an area and, depending on the generation equipment, may also generate and distribute electricity locally. Generation plant, which is located in a centralised location, generates hot water and /or chilled water which is then distributed via underground pipework to the connected buildings.

DE schemes can range in size from simply linking two buildings together, to spanning entire cities. Benefits include:

- **Emissions reductions in hard-to-treat buildings –** where retrofitting fabric improvements to existing stock is challenging (e.g. for listed or critical buildings), DE provides an alternative method by which to reduce CO_2 emissions.
- **Reduced environmental taxes –** certain policies place a financial value on CO_2 emissions, meaning a reduction in emissions also provides financial benefit. It is expected that the effect of such policies may increase in future as the pressure to reduce emissions increases.
- **Reduction in energy prices –** increased efficiencies and economies of scale can lead to reduced energy costs for customers. This can mean improved competitiveness for local businesses, and reduced energy bills and the alleviation of fuel poverty in households.
- **Energy security –** the higher plant efficiencies and in-built resilience, combined with alternative forms of energy generation increases energy security and reduces reliance on fossil fuels.
- **Opportunity to deliver CO_2 reductions in partnership with the private sector –** revenue opportunities from the sale of energy attract investment from the private sector, transferring some or all of the financial risk of energy projects from the public sector.
- **Local dividends –** profits from the sale of energy from DE networks can accrue to local authorities, communities, and/or businesses, rather than to national or international businesses.
- **Local economy –** the construction and operation of a network can create employment and opportunities for local businesses to be involved in the supply chain.
- **Use of waste or secondary heat sources –**use of alternative sources of heat, in place of fossil fuels, can facilitate the transition towards near zero-carbon heat. This could be, for example, waste heat arising as a by-product from an industrial process.
- **Efficiency and diversity of demand –** a DE scheme can support the efficient distribution of heat due to diverse energy demands seen across the buildings connected to the network, which can lead to a reduction in the equipment capacity needed to be installed.

3.1 District Heating

District heating (DH) is the distribution of thermal energy (Low Temperature Hot Water (LTHW)) from a central source to a number of different buildings where it is used to provide space heating and hot water.

Where buildings have conventional wet heating systems, connection to district heating can be straightforward. Potentially only minor changes to the building's secondary side distribution systems are necessary; the existing boiler could be removed or decommissioned and replaced with a plate heat exchanger which transfers heat from the DH network (DHN) to the local building distribution system. Compatible temperatures however do need to be established at an early stage.

The following heat generation technologies can be applicable to district heating, depending on the location in question:

- Energy from waste
- Anaerobic digestion
- Biomass and biofuel boilers
- Deep geothermal
- Air, water and ground source heat pumps
- Solar thermal
- Gas fired combined heat and power (CHP)
- Biomass or biofuel fired CHP

The choice of heat generating technology that is employed in a network depends on a number of technical, financial, environmental and deliverability factors, as described in Section 4.

Areas with large concentrated heat loads present significant opportunities for the installation of a DHN. High heat density areas are made up by groups of buildings and/or a single, or collection of anchor load(s). 'Anchor' heat loads are deemed to be buildings (or a group of buildings in an estate, e.g. hospital) that comply with one or more of the following criteria:

- Buildings with a high level of heat consumption (e.g. hospitals and care homes);
- Buildings with a stable, constant and predictable level of year-round heat consumption (e.g. swimming pools); and
- Buildings over which the Council has a high degree of control or influence to support their connection to a DHN (e.g. public sector Council buildings in STC), since it is often easier to secure customers for a DHN if there is consent from related institutions.

Initial heat mapping exercises and feasibility studies can reveal particularly dense areas of heat demand which may be considered for further analysis to determine heat network strategic development areas.

3.2 District Cooling

Like DH, District cooling (DC) operates by distributing chilled water through a network of insulated Chilled water is generated centrally (typically at around 6°C flow/12°C return) : through conventional electrically-driven vapour compression chillers; or via absorption (i.e. heat-driven) chillers.

Sutton has not been deemed a favourable site for district cooling due to the absence of significant cooling demands or available metered data. Therefore DC is not considered going forwards in this report.

4. Energy Mapping

A high level analysis was undertaken to determine the key existing and future buildings in Sutton that could be considered suitable for a DE scheme. In order to incorporate the most appropriate energy data for the study, a number of sources were considered. These sources, and the assumptions made, have been briefly described in the sections that follow.

4.1 Existing Developments

Data on the quantum and type of existing developments was acquired from the following sources:

- A list of public buildings provided by LBS
- A list of social housing addresses provided by LBS
- National Heat Map data provided by the Centre for Sustainable Energy (CSE)
- The Energy Performance Certificate (EPC) register

An extensive list of sites was compiled including all developments identified from the above sources. The list was narrowed down to only include buildings with an annual thermal demand higher than a 100MWh (the equivalent of c.20-30 new build residential apartments),From AECOMs experience of similar inner city DH projects, it is at this threshold that the demand density is sufficient to justify the capital to lay the infrastructure to connect to the network. . These buildings typically fall in the following categories:

- Large residential schemes
- Large office buildings
- Hospitals
- Hotels
- Schools, colleges and universities
- Large industrial sites
- Community centres
- Leisure centre/Health clubs
- Libraries
- Museums

Heating, cooling and electrical energy consumption figures were analysed for these building types using the following source hierarchy (listed in order of data quality):

- Energy meter readings/data
- Display Energy Certificates (DEC) (annual data)
- Energy Performance Certificates
- Benchmarks:
    - CIBSE Guide F 'Energy Efficiency in Buildings' (Third Edition, May 2012);
    - CIBSE Technical Memorandum 46; and
    - Building Regulations approved software modelling experience from AECOM projects.

Depending on the nature, class and condition of the building, a combination of the above methodologies may be suitable. CIBSE Guide F[5] is a widely recognised industry standard document on energy efficiency in buildings which includes energy consumption benchmarks for fossil fuel and electricity uses. Although the benchmarks are considered outdated and tend to overestimate energy consumption in new buildings, they still form accepted benchmarks in the industry and are more applicable to existing buildings. Fossil fuel uses were converted to heating consumption using an assumed boiler efficiency of 90% and removing any gas uses attributed to cooking (which is not an appropriate end use for district heating).

Cooling and electricity consumption was also estimated from CIBSE Guide F. Following the review of a wide range of industry standards including Energy Consumption Guides, CIBSE TM22[6] and BSRIA Rules of Thumb[7], it was found that cooling benchmarks only exist for Offices and Retail building types. It is assumed that other building types do not have a significant demand for cooling in Sutton.

A detailed technical note on the Benchmarking and threshold methodology is included in Appendix A.

4.2 Future Developments

AECOM engaged with the council to determine a list of proposed developments for Sutton Town Centre. This included 45 STC sites to be developed in phases between the years 2016 and 2031. For The London Cancer Hub site, all buildings included in the energy mapping were new builds, as part of the new multi-purpose development.

For new developments in Planning, current Building Regulations standards are likely to be more appropriate for estimating energy requirements than CIBSE Guide F due to the significant improvements to energy efficiency in buildings made in recent years. Energy calculations are derived from government-approved Dynamic Simulation Modelling (DSM) software and Standard Assessment Procedure (SAP) calculations.

Data from previous AECOM projects was used for this purpose. Building Regulations compliant calculations identify those energy uses which are 'regulated' (including for heating, cooling, ventilation, lighting and hot water) and 'unregulated' (including for appliances, cooking, external lighting, etc.). It is important to note that for the baseline calculation exercise, the unregulated energy demand will also be taken into consideration in order to fully account for the electricity requirements in buildings.

For future build hospitals, which dominate the LCH energy demand, a benchmark heat demand value of 250 kWh/m² was derived from a database of real hospital data, specifically hospitals whose age profile fell predominantly in the category of 2015-present day.

For residential schemes, the Building Regulations Fabric Energy Efficiency (FEE) standard from SAP models informed the space heating demand. For the Domestic Hot Water (DHW) demand, a similar principle was followed and the average DHW demand per unit floor area from various previous projects was applied

In the absence of specific modelling data and other suitable sources, it is considered appropriate to assume that the 'Good practice' standards included in CIBSE Guide F most accurately estimates fuel consumption for future developments.

[5] http://www.cibse.org/Knowledge/knowledge-items/detail?id=a0q20000008I7oTAAS
[6] http://www.cibse.org/Knowledge/knowledge-items/detail?id=a0q20000008I7eWAAS
[7] https://www.bsria.co.uk/download/product/?file=zxrulZgWBrY%3D

4.3 Energy Demand Mapping

The energy consumption analysis described above is used to produce maps illustrating the annual heat demand for the buildings deemed most appropriate for connection to a district heating network in the STC and LCH sites (see Figure 4-1 and Figure 4-2 respectively). These maps include both proposed and existing building demands for the STC sit.

In both cases, buildings are represented by coloured circles, where the colour represents the expected date for development, and the size of the circle is scaled to the amount of energy consumed by the building.

4.3.1 Sutton Town Centre

When considering the energy mapping for Sutton Town Centre the future STC sites, as identified in the STC Masterplan, were included as an important part of the local energy demand. These proposed future development sites were deemed in general likely to connect to a DHN as opposed to existing builds that already have heating systems in place. Furthermore, their connection can be conditioned in the planning process. Using benchmarks and modelled results from other projects, the future energy demand was estimated for the majority of these sites by considering the planning use type and proposed floor area, with most of the sites being mixed-purpose developments. For Gibson Road car park (STC 31), future heat demand could not be estimated due to a lack of data provided about this development, and so this site has been omitted from the study.

Figure 4-1 presents the findings of the heat mapping study for STC. The potential future heat customers (illustrated by the yellow, orange and red circles) are superposed upon their respective STC site allocation. These proposed developments are of mixed use type, and include office, retail, residential, hotel and leisure space. The existing heat demands (blue circles) include both commercial and residential demands close to or within the redline boundary area of the STC Masterplan.

Table 4-1lists the individual building details for the STC sites and the existing commercial buildings mapped. Information for STC sites, specifically name, type, ownership, number of residential units and non-residential floor area, has been taken from Local Plan Site Allocations, Dec 2017. Note, no information was provided to AECOM for STC sites 27, 42, 43 and 44.

It is not immediately clear whether loads are eligible for connection to a DHN or whether such a connection would be commercially viable. Each load must undergo scrutiny to inform this decision, focussing on a range of feasibility parameters, including:

- Distance from energy centre or heat source
- Physical barriers to potential pipework routes
- The building heat distribution system

The last parameter is particularly relevant for the existing demands identified. A finalised list of buildings included in network analysis for this study can be found in section 6.5.

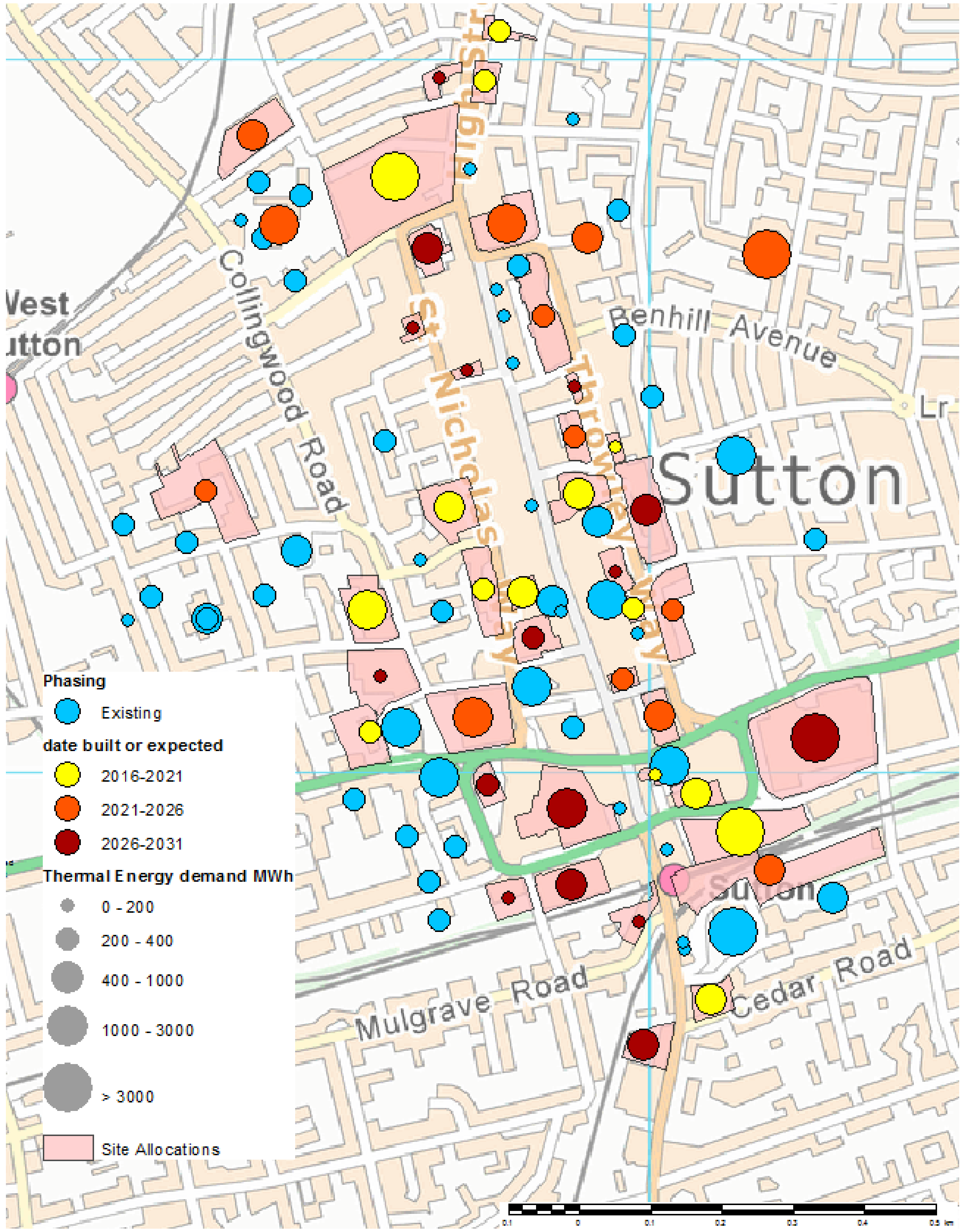


Figure 4-1 Sutton Town Centre Heat Demand Map

Table 4-1 STC sites and existing commercial buildings

Site	Expected date of build	Building name	Building type	Ownership	Postcode	Number of residential units	Non-residential floor area m^2	Heat demand MWh	Source
Existing	n.a.	Chancery House	B1 Offices and Workshop businesses	Private	SM1 1JB	-	8,155	1,248	EPC
Existing	n.a.	Times Square Centre	A1/A2 Retail and Professional services	Private	SM1 1LF	-	27,062	2,514	EPC
Existing	n.a.	Marks & Spencer Plc	A1/A2 Retail and Professional services	Private	SM1 1NQ	-	7,521	699	EPC
Existing	n.a.	Sutton Grammar School	Schools And Seasonal Public Buildings	Council	SM1 4AS	-	10,460	1,174	DEC
Existing	n.a.	Marshalls Court	B1 Offices and Workshop businesses	Private	SM1 4DU	-	2,137	327	EPC
Existing	n.a.	Holiday Inn	C1 Hotels	Private	SM1 2RF	-	7,628	2,362	EPC
Existing	n.a.	Metropolitan Police	Emergency Services	Council	SM1 4RF	-	10,675	2,038	DEC
Existing	n.a.-	Quadrant House	B1 Offices and Workshop businesses	Private	SM2 5AS	-	25,126	3,846	EPC
STC 1	2017	The Old Gas Works	Residential, Retail	Private	SM1 1LG	186	12,221	1,180	Benchmark
STC 2	2026-2031	Morrisons Local and Car Park	Residential and Retail	Private	SM1 1LW	14	521	157	Benchmark
STC 3	2017	Former Burger King Site	Residential and Retail	Private	SM1 1PR	40	662	283	Benchmark
STC 4	2021-2026	Sutton West Centre	School or Residential	Council	<Null>	56	-	212	Benchmark
STC 5	2021-2026	North of Lodge Place	Residential and Retail	Private	SM1 4AF	63	489	225	Benchmark
STC 6	2016-2021	South of Lodge Place	Residential and Retail	Private	SM1 4DB	31	2,525	200	Benchmark
STC 7	2016-2021	Kwikfit Site	Residential and Retail	Council, private lease	SM1 4AF	15	456	67	Benchmark
STC 8	2026-2031	North of Greenford Road	Residential and Retail	Private	SM1 1JY	18	428	153	Benchmark
STC 9	2021-2026	Civic Centre Site	Civic, Community, Retail	Council	SM1 1EA	165	14,607	872	Benchmark
STC 10	2016-2021	Secombe Theatre Site	Community or Primary School or Residential	Council/ Private	SM1 2SS	65	-	212	Benchmark
STC 11	2016-2021	Beech Tree Place	Residential and Retail	Council/ Private	SM1 1SF	64	312	304	Benchmark
STC 12	2016-2021	North of Sutton Court Road	Residential	Private	<Null>	178	-	673	Benchmark
STC 13	2016-2021	South of Sutton Court Road	Residential, Hotel, Health & Fitness	Private	SM1 4SZ	452	9,665	2,720	Benchmark
STC 14	2021-2026	Sutton Station	Offices, Residential, Retail, Car Parking	Private	SM1 1DE	85	9,252	541	Benchmark
STC 15	2026-2031	Shops opposite Station	Residential and Town Centre uses	Private	SM2 6LE	10	363	110	Benchmark
STC 16	2016-2021	Sutherland House	Residential	Private	SM2 5AJ	128	-	484	Benchmark
STC 17	2026-2031	Petrol Station north of Subsea 7	Residential, Retail and Town Centre uses	Private	SM2 5BQ	108	1,438	464	Benchmark
STC 18	2016-2021	Sutton Superbowl Site	Hotel and Restaurant or Residential	Private	SM1 1AT	-	4,714	867	Benchmark
STC 19	2016-2021	Helena House	Residential and Town Centre uses	Private	SM1 1PX	38	340	211	Benchmark
STC 20	2026-2031	Herald House	Residential and Town Centre uses	Private	SMI 4AY	16	-	60	Benchmark
STC 21	2021-2026	Sutton Park House	Residential and Town Centre uses	Private	SM1 4FD	94	1,559	368	Benchmark
STC 22	2016-2017	Old Inn House	Residential and Town Centre uses	Private	SM1 4RA	28	443	109	Benchmark
STC 23	2021-2026	Bus Garage	Residential	Council/ Private	SM1 1QJ	203	-	173	Benchmark
STC 24	2026-2031	Halfords Site	Residential and Retail	Private	SM1 1SE	80	1,256	310	Benchmark
STC 25	2021-2026	Matalan Block	Residential and Retail	Private	SM1 1PG	164	3,660	679	Benchmark
STC 26	2026-2031	St Nicholas Way	Residential and Retail	Private	SM! 1JN	15	-	57	Benchmark
STC 28	2016-2021	St Nicholas Centre Car Park	Unknown	Unknown	<Null>	-	2,294	454	Benchmark
STC 29	2026-2031	St Nicholas House	Town Centre uses and Residential	Private	SM1 1EH	67	-	219	Benchmark
STC 30	2016-2021	Robin Hood Lane Site	Health and residential	Public/Private	SM1 2RJ	48	4,707	1,094	Benchmark
STC 31	2026-2031	Gibson Road Car Park	Residential, Public car park, Community	Council	<Null>	n/a	n/a	-	No data
STC 32	2026-2031	City House	Residential and Town Centre uses	Private and Council	SM1 4LD	22	680	218	Benchmark
STC 33	2026-2031	Land North of Grove Road	Residential and Town Centre uses	Private	SM1 1DD	178	3,036	700	Benchmark
STC 34	2026-2031	Greensleeves Manor	Residential	Private	SM1 2AF	22	-	83	Benchmark
STC 35	2026-2031	Land South of Grove Road	Residential and Town Centre uses	Private	SMA11DA	122	2,493	496	Benchmark
STC 36	2026-2031	B&Q Site	Retail, Residential and Town Centre uses	Private	SM1 4RQ	482	13,519	2,102	Benchmark
STC 37	2021-2026	Wilko Site	Residential and Retail	Council, private lease	SM1 1EZ	26	636	110	Benchmark
STC 38	2021-2026	Houses adjacent to Manor Park	Residential and Town Centre uses	Council/Private	SM1 4AF	101	-	330	Benchmark
STC 39	Built	Land to the rear of Times Square	Unknown	Private	<Null>	34	445	128	Benchmark
STC 40	Built	STC 40	Residential	Unknown	<Null>	28	-	91	Benchmark
STC 41	2026-2031	Times Square Car Park	Residential, car parking and other	Council	SM1 4AG	135	441	458	Benchmark
STC 45	2021-2026	Elm Grove Estate	Residential and Town Centre uses	Council/Private	SM1 4EU	47	281	165	Benchmark
Housing redevelopments	Unknown	Benhill Estate	Residential	Council	SM1 4DD	1,076	-	3,515	Benchmark
	Unknown	Roseberry Gardens	Residential	Council	SM1 4DD	184	-	696	Benchmark
	Unknown	Collingwood Estate	Residential, retail	Council	SM1 1RX	535	333	1,761	Benchmark

Benchmark demands were applied to the floor area data provided by LBS

4.3.2 London Cancer Hub

The LCH site will see newly developed research and hospital facilities developed alongside office, retail, restaurant and leisure space. The plan also includes hotel accommodation for visitors and patients, as well as a secondary school to the north of the site. Future heat demands were calculated from the floor area and usage class schedule provided in The London Cancer Hub Delivery Strategy, applying the relevant benchmark for each building class.

Figure 4-2 presents the findings of the heat mapping study for the LCH. The site layout, development waves and indicative building locations have been derived from the information in The London Cancer Hub Delivery Strategy and London Cancer Hub Roadmap. Development waves are indicated by coloured areas.

Heat demands, scaled by circle size, have been superposed within their respective wave area, and labelled by the building use. Where possible, the position of these heat demands indicates the anticipated location of the demand. However, it should be noted that the heat demand may cover several buildings within its development wave.

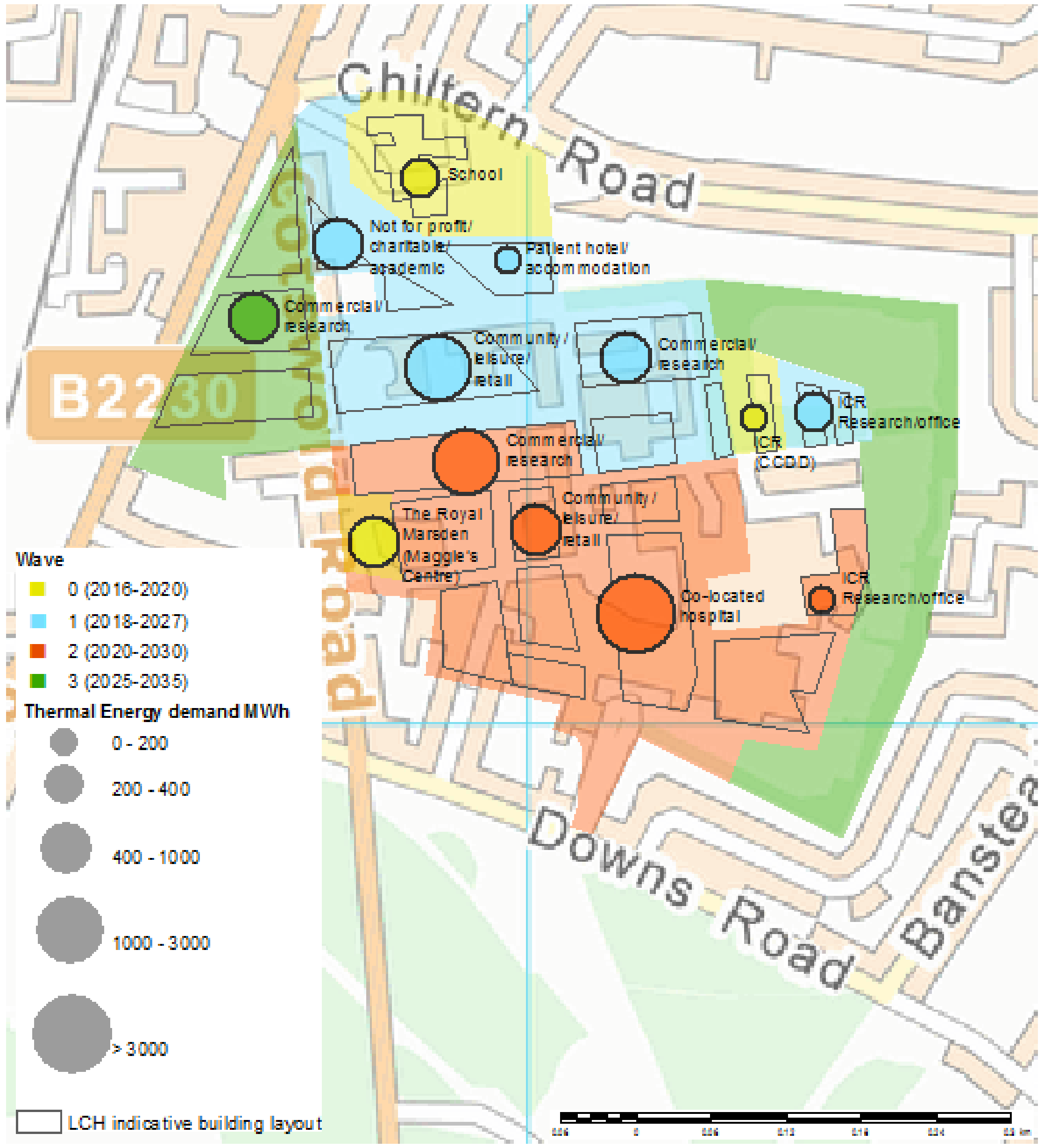


Figure 4-2 London Cancer Hub Heat Demand Map

Two existing prisons, HMP Downview and HMP Down lie approximately 1km south of the LCH site. These represent a high and consistent energy demand and are included in the modelling.

Table 4-2 The London Cancer Hub building list

Wave	Building name	Building type	Ownership	Date built	Area m^2	Heat demand MWh	Source
0	Secondary School	School	Public	2016-2018	12,390	260	Benchmark
0	ICR (CCDD)	Office	Public	2016-2019	8,000	176	Benchmark
0	The Royal Marsden (Maggie's Centre)	Hospital	Public	2016-2020	1,150	288	Benchmark
1	Commercial / research 1	Office	Public	2019-2026	22,805	502	Benchmark
1	Not for profit/ charitable/academic 1	Office	Public	2019-2026	18,310	403	Benchmark
1	ICR 1	Office	Public	2019-2026	12,400	273	Benchmark
1	Patient hotel/accommodation 1	Residential	Public	2019-2026	2,200	119436	Benchmark
1	Community/leisure/retail 1	Retail	Public	2019-2026	5,965	233	Benchmark
2A	Commercial / research 2A	Office	Public	2020-2026	38,890	856	Benchmark
2A	ICR 2A	Office	Public	2020-2026	5,155	113	Benchmark
2A	Co-located hospital 2A	Hospital	Public	2020-2026	102,630	25,658	Benchmark
2A	Community/leisure/retail 2A	Retail	Public	2020-2026	4,915	192	Benchmark
2B	Commercial / research 2B	Office	Public	2020-2030	63,110	1,388	Benchmark
2B	ICR 2B	Office	Public	2020-2030	5,155	113	Benchmark
2B	The Royal Marsden 2B	Hospital	Public	2020-2030	78,410	19,603	Benchmark
2B	Community/leisure/retail 2B	Retail	Public	2020-2030	4,915	192	Benchmark
3	Commercial / research 3	Office	Public	2016-2018	27,065	595	Benchmark
Existing	HM Downview Prison	Prison	Public	n/a	16,287	3,025	DEC
Existing	Highdown Prison	Prison	Public	n/a	39,346	10,151	DEC

4.4 Energy Supply Mapping

In order to identify good opportunities for district energy schemes in the STC and LCH areas, available sources of low grade or waste heat were also reviewed. AECOM carried out a high level review of the area to identify sources of energy (both heat and electricity). Through use of various tools such as the national heat map, the following sources of energy were investigated:

- Energy from Waste plants
- Industrial waste heat
- Water source heat potential from rivers, mines and lakes (LB Sutton is landlocked, so the sea was omitted)
- Other reasonable renewable low to zero carbon sources (i.e. recovered heat from the London Underground or large electrical substation transformers)
- Existing decentralised energy schemes; and
- Existing gas CHP, biomass, geothermal and solar thermal installations.

Following the review, the existing Energy from Waste plant at Beddington, the Viridor ERF, was identified as representing an opportunity for providing heat to customers in Sutton. This facility it is already being connected to a heat network operated by the Sutton Decentralised Energy Network (SDEN), which will supply heat to the Felnex site in Hackbridge. Based on a report supplied by the council (Heat Demand Assessment: Extension of a heat network beyond the Felnex development, May 2014) it was estimated that there is 15MW of capacity, with annual supply of 111GWh/yr, available for further connections beyond the Felnex development. It is approximately 3km of pipework from the Felnex site to Throwley Way.

Pyl Brook, which is north of STC, was identified as a water body on the national map, but was not deemed suitable as a source of heat due to its modest size and distance from the STC area. No other potential sources of heat or renewable energy were identified.

The capacity and location of each supply opportunity was ascertained or estimated through the following hierarchical approach:

- From information provided by the council
- National Heat Map[8] (now closed)
- Estimation from AECOM experience

Investigation as to the technical viability of utilising energy sources was carried out only if sources were found to be in close proximity to high density areas of energy demand. A full list of the energy supply opportunities considered is provided in Table 4-3.

Table 4-3 Available sources of energy in Sutton

Source	Identified	Description	Potential
Energy from Waste plant	Yes	Viridor ERF located in Beddington.	15MW of capacity with annual supply of 111GWh/yr available for further connections beyond the Felnex development. It is approximately 3.2km of pipework from the Felnix site to Throwley Way.
Industrial waste heat	No	N/A	N/A
Water source heat potential from rivers, mines and lakes (LB Sutton is landlocked, so the sea was omitted)	Yes	Ply Brooke, approximately 1km north of STC	Due to small size of potential heat and issues associated with extracting this heat (e.g. crossing of train tracks) this was not deemed a suitable source of heat.
Other reasonable renewable low to zero carbon sources	No	N/A	N/A
Existing decentralised energy schemes	Yes	SDEN (supplied by the Viridor ERF located in Beddington.)	As above, 15MW of capacity with annual supply of 111GWh/yr available for further connections beyond the Felnex development. It is approximately 3.2km of pipework from the Felnix site to Throwley Way.
Existing gas CHP, biomass, geothermal and solar thermal installations;	No	N/A	N/A

[8] http://nationalheatmap.cse.org.uk/

5. Heat Generation Technologies

This section appraises the technical feasibility of various heat generation technologies available to the STC and LCH network opportunities, taking into account the energy supply mapping discussed in section 0. The appraisal's findings form the justification for the chosen heat generation technologies that are taken forward into the commercial evaluation phases of this study. **Error! Reference source not found.** gives a broad overview of each of the technologies discussed in this section.

5.1 Methodology for the Technology Appraisal

In order to assess each technology fairly, they are scored against a range of criteria which are of key concern. These criteria fall into four categories:

- **Technical –** Different technologies have been assessed against their suitability to deliver the scale and the profile of the required heat supply and to operate under required supply temperatures. Examples have been called on to provide evidence of technology maturity and the reliability of the technology's integration with a DHN, while security on fuel delivery has been further considered.
- **Environmental -** A range of environmental implications have been considered for each technology. Direct impacts such as pollution and changes to the local air quality have been discussed for the various technologies. The scale of carbon savings have been estimated on the basis of both current and predicted carbon emission factors. The carbon saving for each technology has been discussed in the context of the fuel used, efficiencies attainable and the relevant emission factors.
- **Financial -** The financial benefit of each technology has been assessed in relation to current and projected fuel prices, efficiency and the expected maintenance level required over the technology's lifetime. Long term financial risks were also taken into account.
- **Deliverability -** Consideration has been given to the criteria that may affect deliverability of the technology, such as reliance on third parties, and implications on space requirement and energy centre size/design. Technologies were further evaluated based on their suitability on a local level.

Table 5-1 details each criterion and their given 'Importance', a score between one and five, to reflect its impact on the overall assessment. Please note that one represents low importance and five represents high importance. Each criterion is then given a proportional weighting, which is calculated based on the score, such that all weightings sum to 100.

Table 5-1 Criteria for the feasibility assessment

Category	Criterion	Relative Importance 1 - 5	Weighting %
Technical	Technology maturity and availability	5	9.4
	Suitability for scale and profile of heat demand	3	5.7
	Security of supply	3	5.7
	Suitability for required supply temperatures	4	7.5
	Proximity to heat demands	4	7.5
Environmental	Level of CO_2 emission savings	5	9.4
	Air quality implications	5	9.4
	Wider environmental impacts	2	3.8
Financial	Technology cost	3	5.7
	Impact on scheme financial viability	4	7.5
	Long term financial risks	3	5.7
Deliverability	Suitability to London Borough of Sutton	5	9.4
	Implications for energy centre size/design	3	5.7
	Implications for additional space requirements	2	3.8
	Reliance on third parties	2	3.8
Total		53	**100.0**

Each technology was scored between 1 and 5 against each criterion. The weighted total score (out of 100%) was calculated for each technology, allowing them to be ranked. The methodology was conducted for two scenarios; a short-term assessment of 0-15 years of DHN operation (to reflect the likely first date for plant replacement) and a longer term assessment at 15+ years of DHN operation.

5.2 Technology Appraisal Results

The results of the technology appraisal for both sites and operational timescale scenarios are detailed in full in Appendix C. A summary of the total score and ranking of each technology is shown in Table 5-2 and Table 5-3, with rank 1 representing the most viable technology. This is followed by a brief explanation for each technology. From these results the selected heat generation technologies to be modelled for each site are outlined in section 5.3 and section 5.4.

Table 5-2 Technology appraisal results summary - STC

STC	0-15 year assessment		15+ year assessment	
Technology	**Score, %**	**Rank**	**Score, %**	**Rank**
Gas-fired CHP	77.4	**2**	71.7	**5**
Biomass-fired CHP	65.7	**9**	69.8	**7**
Biofuel-fired CHP	65.7	**9**	69.8	**7**
Energy from Waste	77.7	**1**	77.7	**1**
Biomass Boiler	66.0	**7**	63.4	**11**
Biofuel Boiler	66.0	**7**	63.4	**11**
Geothermal	55.8	**13**	58.9	**13**
Anaerobic Digestion	65.7	**9**	67.5	**9**
Air Source Heat Pump	73.6	**3**	77.0	**2**
Water Source Heat Pump	62.6	**12**	66.0	**10**
Ground Source Heat Pump	68.3	**5**	74.0	**3**
Heat Recovery from Industry	72.1	**4**	72.8	**4**
Solar Thermal	67.2	**6**	70.9	**6**

Table 5-3 Technology appraisal results summary - LCH

LCH	0-15 year assessment		15+ year assessment	
Technology	**Score, %**	**Rank**	**Score, %**	**Rank**
Gas-fired CHP	75.5	**1**	71.7	**5**
Biomass-fired CHP	65.7	**8**	69.8	**6**
Biofuel-fired CHP	65.7	**8**	69.8	**6**
Energy from Waste	72.5	**4**	72.5	**4**
Biomass Boiler	66.0	**6**	63.4	**11**
Biofuel Boiler	66.0	**6**	63.4	**11**
Geothermal	55.8	**13**	58.9	**13**
Anaerobic Digestion	65.7	**8**	67.5	**8**
Air Source Heat Pump	73.6	**3**	77.0	**2**
Water Source Heat Pump	62.6	**12**	66.0	**10**
Ground Source Heat Pump	74.0	**2**	79.6	**1**
Heat Recovery from Industry	72.1	**5**	72.8	**3**
Solar Thermal	65.7	**8**	67.5	**9**

5.2.1 Short-term assessment

The analysis shows the technologies most viable for serving a DH network in the two Sutton sites to be **energy from waste, gas-fired CHP and air or ground source heat pumps.**

Gas-fired CHP
The expected size and profiles of the heat demands that have been identified for DH networks in Sutton will be well suited for the use of a gas-CHP system, enabling the delivery of economic[9] run hours of gas-CHP engines at a scale that will enable the generation of electricity. This may provide both carbon savings (in the short term) along with financial returns. However, air quality implications and diminishing carbon savings in the medium term are likely to be considerable barriers to implementing this technology.

Energy from Waste
Energy from waste is a mature technology that is particularly suitable to Sutton Town Centre thanks to the proximity of the Viridor energy recovery facility and the already established Sutton Decentralised Energy Network (SDEN). SDEN, an ESCo owned by LBS have an agreement to purchase the heat recovered from the Viridor facility and is looking for opportunities to deliver this heat via networks across the borough. EfW scores well with regards to carbon savings both now and in the future, as well as enabling significant savings on associated space requirements. However the reliance on a third party does present a risk.

Air Source Heat Pumps
Heat pumps are considerably favourable with regard to their environmental impacts. Air source heat pumps generally result in smaller capital costs than ground source, for which boring costs can be quite significant and can also delay development schedules. Networks served by heat pumps ideally run at lower supply temperatures or suffer inefficiencies in order to supply higher temperature heat. This means existing building stock cannot be connected without significant refurbishment works. There is potential to consider ammonia refrigerant air source heat pumps, which can achieve higher supply temperatures.

[9] In excess of 5,000 hours of operation per year

Ground Source Heat Pumps
Ground source heat pump technology has been identified as a viable choice for the LCH site. This is because the compact nature of the redevelopment provides a larger potential ground area to meet the additional space requirement for this technology. As extensive regeneration works will transform the current site, there is potential to incorporate a low temperature heat network at the LCH.

The remaining technology choices were seen as less viable for the two sites considered, as explained below.

Water Source Heat Pump
The large size and profile of demand in STC is not an ideal match for water source heat pump technology. No significant source of surface water has been identified for a water source heat pump solution. Moreover, the STC site sits within a Source Protection Zone with an aquifer of 'high' vulnerability, meaning an open source groundwater solution is unlikely to be viable.

Biomass and Biofuel
Although biomass or biofuel CHP and boilers are generally considered a good substitute technology for gas-fired CHP, they entail significant disadvantages which render them undesirable for Sutton. These include there reliance on third parties, the need to import fuel and the higher cost of these fuels relative to gas, and their air quality implications which include high levels of NOx and particulate emissions.

Geothermal
Geothermal energy plants are more suited to regions where there is volcanic activity. In the UK heat from shallow depths is generally exploited via ground or water source heat pumps.

Anaerobic Digestion
No anaerobic digestion plants were identified within the vicinity of STC or the LCH meaning this technology is not considered as a viable solution for heat generation in Sutton.

Heat Recovery from Industry
Heat recovery from industry is a particularly desirable means of serving a district heating network. This is thanks to its extremely low environmental impact and ability to capture and reuse waste heat which would otherwise be a local pollutant. The main risk of heat recovery is its reliance on a third party, which causes an inherent risk to security of supply. For Sutton no significant heat recovery source was identified, rendering this solution unviable.

Solar Thermal
Solar thermal systems score low due to the additional space requirements of the thermal collectors. It was not considered likely that enough land (or roof space) would be secured near to a central energy centre to support the system. However, the incorporation of solar PV for new developments in Sutton is evaluated further in section 12.

5.2.2 Long-term assessment

Due to the decarbonisation of the grid, as indicated in the IAG Green Book[10], gas-led technologies should continue to lose favour in the future. Hence, for both the STC and LCH sites, gas-fired CHP is no longer a high ranking option for the 15+ year's appraisal. Indeed, gas-fired CHPs suitability for a London based scheme, where air quality requirements are particularly stringent, only worsens looking forward.

Consequently technologies that are currently less feasible from an economic perspective such as heat pumps and heat recovery facilities will become more suitable options in the future.

The most likely outcome is that future district energy networks will incorporate a number of different technologies, and be controlled in a way that ensures heat or cooling is delivered with delivering focus on optimising both the carbon savings and financial benefits for the network operators. A review of the optimum technology mix for the network should be carried out in advance of cyclical plant replacement.

It is critical that all proposed Heat Networks are robustly assessed and demonstrate a clear strategy towards flexibility and adaptation. AECOM have captured this in the risk register and documented future mitigation strategies.

[10] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

5.3 Heat Generation – STC

The chosen heat generation technologies to be modelled for the Sutton Town Centre network opportunity are energy from waste, gas-fired CHP and air source heat pumps.

As discussed above, the recent development of the Sutton Decentralised Energy Network (SDEN) poses an opportunity to source heat from the local Viridor Energy Recovery Facility in Beddington. The Viridor Energy Recovery Facility is c.3.5 km from the town centre and has significant heat generating capacity. This facility is currently undergoing exploratory analyses looking at exporting heat to a number of neighbouring customers, including the Felnex heat network in Hackbridge which is currently under progress. This process is being led by SDEN who have an exclusive agreement to purchase all the available heat.

The SDEN programme plans to expand to a wider network which could include significant loads located to the west of the Felnex development, such as St Helier Hospital and Carshalton High School for Girls. There is an estimated 111 GWh/yr available for additional connections beyond the Felnex development. It is assumed that the Viridor ERF plant will have a capacity to meet 15MW of heat load11.

An alternative to an EfW heat source for STC would be gas-fired CHP. This is a mature technology which scores high both financially and technically. However, due to the on-going decarbonisation of the electricity grid the carbon saving performance of gas-fired CHP will decline in the near future. It is also a poor scorer in terms of its impact on local air quality which is key consideration for Sutton Town Centre due to it being identified by the Mayor as an Air Quality Focus Area within a wider Air quality management area Indeed, the whole Borough is identified as an Air Quality Management Area (AQMA).

Air source heat pumps will also be examined as a third option as they have no local effect on air quality and with the expected future decarbonisation of the grid are expected to produce carbon savings compared to CHP. In order to meet the mixed demand profile for STC, which would include supplying DHW to future residential buildings, the ASHP solution will need to be based on an ammonia heat pump system. Early investigation has identified that this type of system could deliver supply temperatures of 70°C whilst having a Global Warming Potential of less than 10.

In all cases, provision for top-up boilers will be made. These boilers will enable the network to meet peak demands above the base load, which would be served by heat from the EfW, CHP or air source heat pump. The boilers will be sized to meet 100% of peak demand, to ensure full resiliency in case of plant failure.

Network scenarios with EfW, gas CHP and air source heat pumps as the heat source will be modelled and compared.

5.4 Heat Generation - LCH

The chosen heat generation technologies to be modelled for the London Cancer Hub network opportunity are **gas-fired CHP and ground source heat pumps.**

A ground source heat pump system would be a potential low-carbon solution to heat generation at the LCH site. The considerations for ground source heat pump systems are discussed in detail in Appendix M. This study will consider a vertical closed loop system due to the lower associated risk and relatively high efficiencies compared to a horizontal system. The GSHP boreholes can either be incorporated into the building substructure, usually within the foundation piles, or located in open land. A potential land area has been identified along the east edge of the LCH site, as labelled 'green amenity area' in Figure 5-1. If the option of GSHP is to be taken forward, the suitability of using this green space will need to be assessed, as installation of GSHP boreholes will limit the future use of the area. Another option would be to embed piping into the piles of new build on site. This would require close collaboration with the building design team.

As an alternative a gas-fired CHP solution will also be modelled. CHP is now seen as a transition technology for heat networks, as due to the decarbonisation of the grid it no longer entails the same level of carbon savings. It is however a more financially attractive option do to the ability to generate revenue from both heat and electricity sales.

Figure 5-1 London Cancer Hub Roadmap - complete redevelopment site with green amenity space

6. Network Design

Following the energy mapping and technology appraisal for STC and the LCH, masterplanning of the two sites was undertaken to develop the network design of district heating networks. A detailed methodology providing the background to the masterplanning phases of this study is provided in Appendix E. In short, this exercise includes the following:

- Determining the pipework routing for the network, considering any major constraints
- Assessing the optimum Energy Centre location
- Prioritising the buildings considered for connection and undertaking stakeholder engagement
- Carrying out site surveys of the area and buildings
- Developing the phasing of loads and plant over the installation of the network

This section will start by discussing the major constraints to pipework routing, the potential energy centre locations and the prioritisation of buildings for connection to the network. Stakeholder engagement was undertaken for existing buildings identified as having potential to connect to the STC network. This engagement received limited response and is detailed in Appendix D. Using the above considerations, network scenarios were developed to give an indication of their feasibility, in terms of both financial and carbon saving performance. Initial techno-economic modelling highlights the optimum network layout for each site, effectively finalising the building list and network route.

After assessing the optimum network layout, a site survey of Sutton Town Centre was carried out to check viability of the route and the buildings to be connected. No major problem to the proposed route and network was identified. The results of this site survey are detailed in Appendix O. As the London Cancer Hub is to be extensively redeveloped, no site survey was untaken for this site. Finally, phasing of the loads and plant is taken into consideration during the detailed techno-economic modelling stage of the study.

6.1 Local Constraints to Network

The development of a DHN requires that suitable routes are found to install pipework. The installation of pipes and associated equipment is expensive and potentially disruptive, so careful consideration should be given to the routes selected. It is preferable to avoid major infrastructure obstacles, listed below, which can add additional costs and time delays to a DHN scheme.

- Major roads
- Railways
- Bridges
- Tram Line
- Topology

Table 6-1 outlines the main physical barriers encountered in the STC and LCH sites and discusses the impact of these and any possible route alterations.

Table 6-1 Key network constraints

Site	Identified Constraint	Description
STC – all networks	A232 main road	Although the majority of the redline boundary area is north of the A232, several key heat loads lie south of this main road, which would require two separate crossings. This would add expense to the pipework installation as well as causing disruption to local traffic during works. Competition for space from other utilities can also form a constraint when crossing major roads.
STC – all networks	Tram line extension route	The proposed tram line extension route, as shown in Figure 6-1, encircles the high street, incorporating Throwley Way and St Nicholas Way. This will conflict with parts of the DHN network route. The two infrastructure projects will need to be coordinated. This is discussed further in Section 13.
STC – all networks	Railway line and bridge by Sutton Station	Two railway lines separate the southern most heat loads from the rest of the STC site. Passing beneath the lines would be very expensive. There is a possibility for the network to cross at the High Street bridge; given it has sufficient room and depth. The road bridge over the train tracks was found to be particularly shallow with limited scope for DH network pipes. An atypical district heating trench can be as much as 1.8m in order to provide a 1.2m cover depth (pipe crown to wearing course) but shallow lays are possible up to 0.6m with specialist pipe protection
STC and LCH	Topology	The change in land elevation from STC, specifically the Civic Centre Site, to the London Cancer Hub is approximately 150ft. This is a reasonable gradient and would incur additional pumping costs if pipework was run between the two sites.

Figure 6-1 Possible tram line extension route

In addition, investigation of local protected areas (i.e. conservation areas; AQMAs) and flood risk areas is important. These may place constraints on network routing as well as plant location and appropriate technologies. Indeed, both Sutton sites are situated within area quality management areas, meaning the DHN solution should help towards the improvement of local air quality. Air quality considerations are discussed further in section 10. Sutton is not an area of particular flood risk, falling in a flood zone 1 area, as shown in Figure 6-2, and hence this does not present a constraint on plant location.

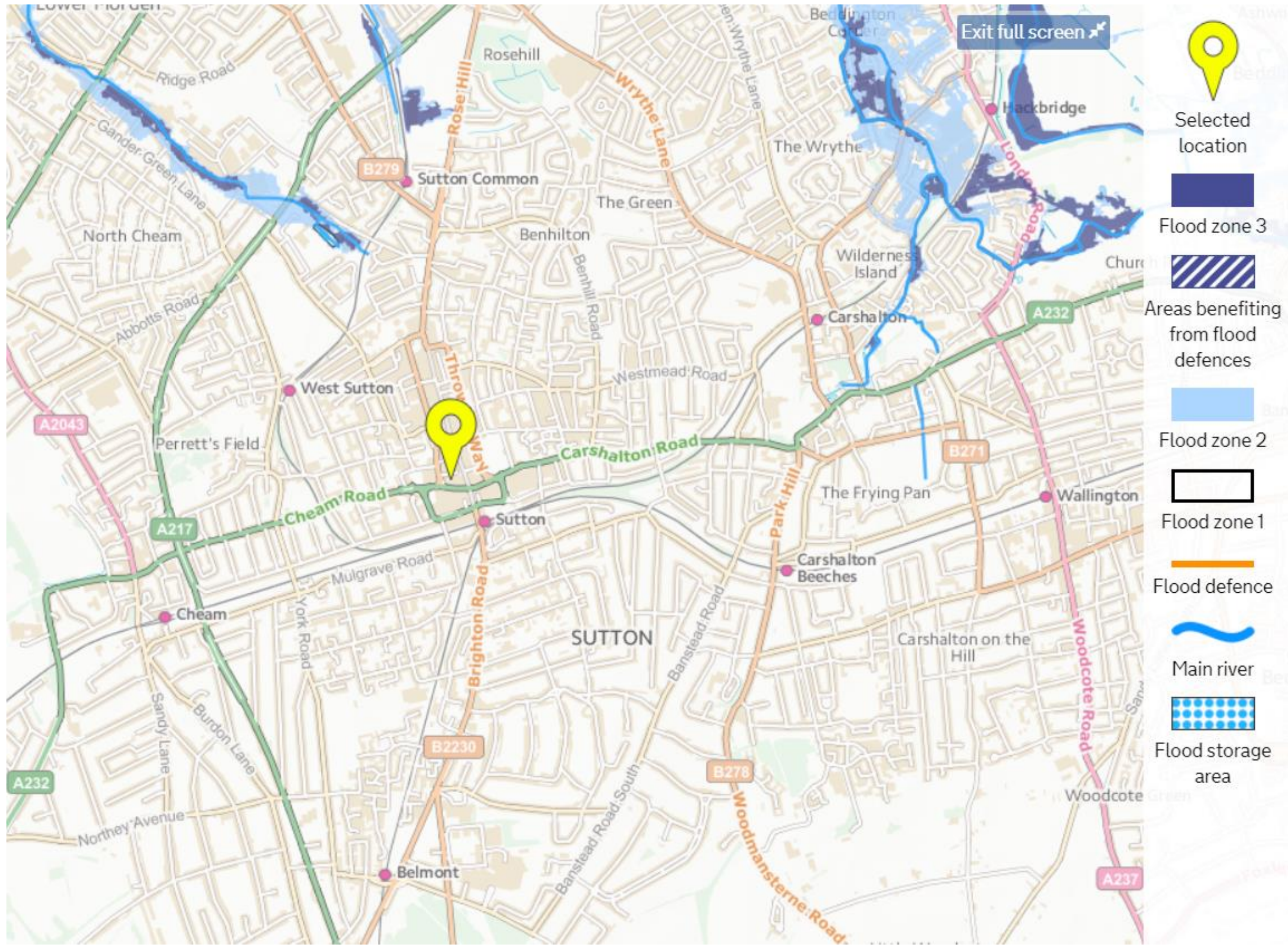


Figure 6-2 Flood map for planning[11]

At Masterplanning stage the following potential constraints have not been investigated and should be considered at the appropriate stage of project development.

- Archaeological surveys
- Unexploded Bomb Survey
- Land Contamination

6.2 Energy Centre Considerations- STC

The delivery of the district heating to the STC network would be through centralised generation of heat. This generation will either take place at the existing Viridor ERF facility, via air source heat pumps, or in a gas-fired combustion plant. All options require a new energy centre. For the EfW this energy centre will house only the back-up boilers and related equipment, and thus can be relatively small. For the gas-fired CHP option, the energy centre will also house the CHP engines. The ASHP option will require roof space as part of the energy centre to locate the ASHPs.

A detailed review of energy centre considerations can be found in Appendix D. At this stage of the study, energy centre sizing depends on the maximum possible peak load of the network, in the case where all buildings are connected. Indicative sizes for optimum network scenarios, found using iterative modelling, will be presented in section 9.

Site ownership is a key consideration for location of an energy centre. Through discussion with LBS, it is assumed that STC 9 (the Civic Centre Site) is a probable choice for the STC energy centre location, as shown in Figure 6-3. This site has a relatively large footprint of approximately 8900 m² and is easily accessible via the A232 for delivery of plant equipment. It is likely that the EC will be at basement or ground level.

In the case of using ammonia ASHP as the generation technology, significant roof space would need to be dedicated to housing the ASHP units. The height of the roofs will also be crucial in determining the safety of using an ammonia refrigerant, which is a toxic substance. It is possible that the ASHP could be places across different sites such as STC 31 (Gibson Road Car Park) and STC 41 (Times Square Car Park); this has not been considered in this report but should be considered during a feasibility study.

The Energy Centre, and it proposed fit-out, may be phased to suit the development of the network. This reduces the debt the scheme has to carry in advance of revenue. Whilst the Energy Centre shell will be developed in the initial phase, only the first phase of plant will be installed in order to meet the anticipated diversified peak demands and thermal energy requirements. The LZC technology installed may also be phased in order to maximise utilisation of the installed assets. The current model predicts when the additional phases of development will be complete and reflect in a fixed, deferred date, of addition generation capacity being installed within the EC

6.3 Energy Centre Considerations - LCH

It is beneficial for the EC to be located in close proximity to the major thermal loads to reduce heat losses from pipework, as well as reduce CAPEX costs and OPEX pumping costs. The London Cancer Hub Roadmap suggests an ‘energy plant’ location on the north east corner of the co-located hospital development, as depicted in Figure 5-1. This is a suitable choice for the LCH energy centre, and has been used within our modelling.

For the GSHP solution the EC will house the networks top-up boilers, thermal stores and heat pumps. There are further space requirements outside of the energy centre for the GSHP boreholes.

6.4 Building Prioritisation and Network Routing

All buildings included in the energy mapping had individual or benchmarked annual heating demands of at least 100 MWh. For the London Cancer Hub, due to the compact nature of the site, all buildings will be included in the detailed modelling stage.

For Sutton Town Centre, as an initial test of viability, the mapped buildings, represented in Figure 4-1, were grouped into clusters. For each cluster preliminary network routing was undertaken to connect it to the heat source. A high level threshold of 3,500 kWh of heating demand per meter of necessary pipework was used to ascertain whether a building or cluster would be economically viable for connection. This threshold was determined from previous AECOM experience on similar projects. Two clusters to the West of STC, incorporating STC 4 (Sutton West Centre) and STC 23 (Bus Garage) along with existing buildings were deemed financially unattractive.

Existing residential buildings were also excluded as these tended to lie on the outskirts of STC and, from undertaking a site survey, it was determined that they predominantly had individual boilers. Due to the expense associated with converting these buildings to an internal network system, they were not considered for further assessment.

Connection of buildings towards the south of STC would involve both the crossing of major roads (A232) and a railway line. Although these buildings have been included in the study, the respective physical constraints will be evaluated further as part of the techno-economic modelling.

Following this building clustering and network routing exercise detailed technical and financial modelling will determine the optimum selection of buildings to connect.

[11] https://flood-map-for-planning.service.gov.uk/

6.5 Designing an Optimum Network

For the buildings identified for connection an iterative process was run to compare a large number of building combinations. This process enabled comparison of key technical and financial aspects of each possible network, including heat load, percentage of heat from low-carbon generation, internal rate of return and net present value. Based on analysis of the iteration results, the optimum network route and number of building connections was identified for each site, as shown in Figure 6-3 and Figure 6-4.

The buildings that form the optimised networks are referenced in Table 6-2 and Table 6-3 respectively.

6.5.1 STC Optimum Network

Existing building connections place technical constraints on the proposed heat network which could lead to a lower operating efficiency. Additionally, existing loads are likely to delay connections in order to operate their current heating asset to end of their operating life time. This leads to a higher risk profile for existing buildings resulting in them being removed from the initial development of the proposed future network. This does not rule out their future inclusion. Rather, these buildings will need to be assessed on a case by case basis. In a similar vein, phase 1 buildings that were identified as already built or under construction during the site visit to Sutton Town Centre were also excluded. This includes the Old Gas Works, Sutton Superbowl Site, North of Lodge Place, North of Sutton Court Road and South of Sutton Court Road.

A similar network layout for each technology option in STC is presented, as shown in Figure 6-3, with only a slight difference in the number of connections as detailed below:

Option 1: Gas-fired CHP - 24 development connections, being all sites shown in Figure 6-3

Option 2: Energy from Waste – 23 development connections, as in Option 1, but with the exclusion of Roseberry Gardens. The STC network will be connected to the Viridor ERF facility in Beddington via a 3.5 km pipe route, as shown in Appendix J. This will enable opportunity to connect to further sites along the route, which should be considered if this option is taken forward.

Option 3: Air Source Heat Pump – 23 development connections, as in Option 1, but with the exclusion of Benhill estate. The use of this renewable technology alone poses a constraint on the size of the network, potentially limiting future expansion. This is discussed further in Appendix L.

In all cases, the cost of crossing the railway lines did not justify the additional heat sales achieved from the connections south of the rail line. Connection to St Nicolas Centre car park, a site towards the exterior of the network, was also deemed undesirable.

6.5.2 LCH Optimum Network

The optimum LCH network was mapped using the indicative building locations presented in section 4.3.2 along with the results of the model iteration process. Two technology options were modelled, with both networks containing the same 11 building connections:

Option 4: Gas-fired CHP

Option 5: Ground Source Heat Pump

These networks exclude the school, which has been constructed to Passive House standards and therefore is expected to have a negligible SH demand, as well as the Wave 3 commercial development for which the thermal demand did not justify the length of pipework needed for connection. Additionally, connection to the existing prisons south of the LCH was not financially desirable due to the excess CAPEX required for pipework and plant.

For each heat generation technology option two scenarios will be modelled, which mirror Wave 2A and Wave 2B, as outlined in the London Cancer Hub Delivery Strategy.

In both cases, these routes should be subject to further scrutiny and detailed planning, should a network option be chosen for further development. Future network design and development will require detailed surveys of the proposed routes, and further granularity added to the cost estimates, such that more appropriate cost metrics are applied to each pipework length. Metrics would be adjusted to allow for prevailing conditions such as dig type – soft, medium, hard etc., traffic considerations, relocation of/coordination with existing subsurface services (such as mains water, mains gas, telecommunications networks in road surfaces, etc.) and other factors that affect the installation of pipework.

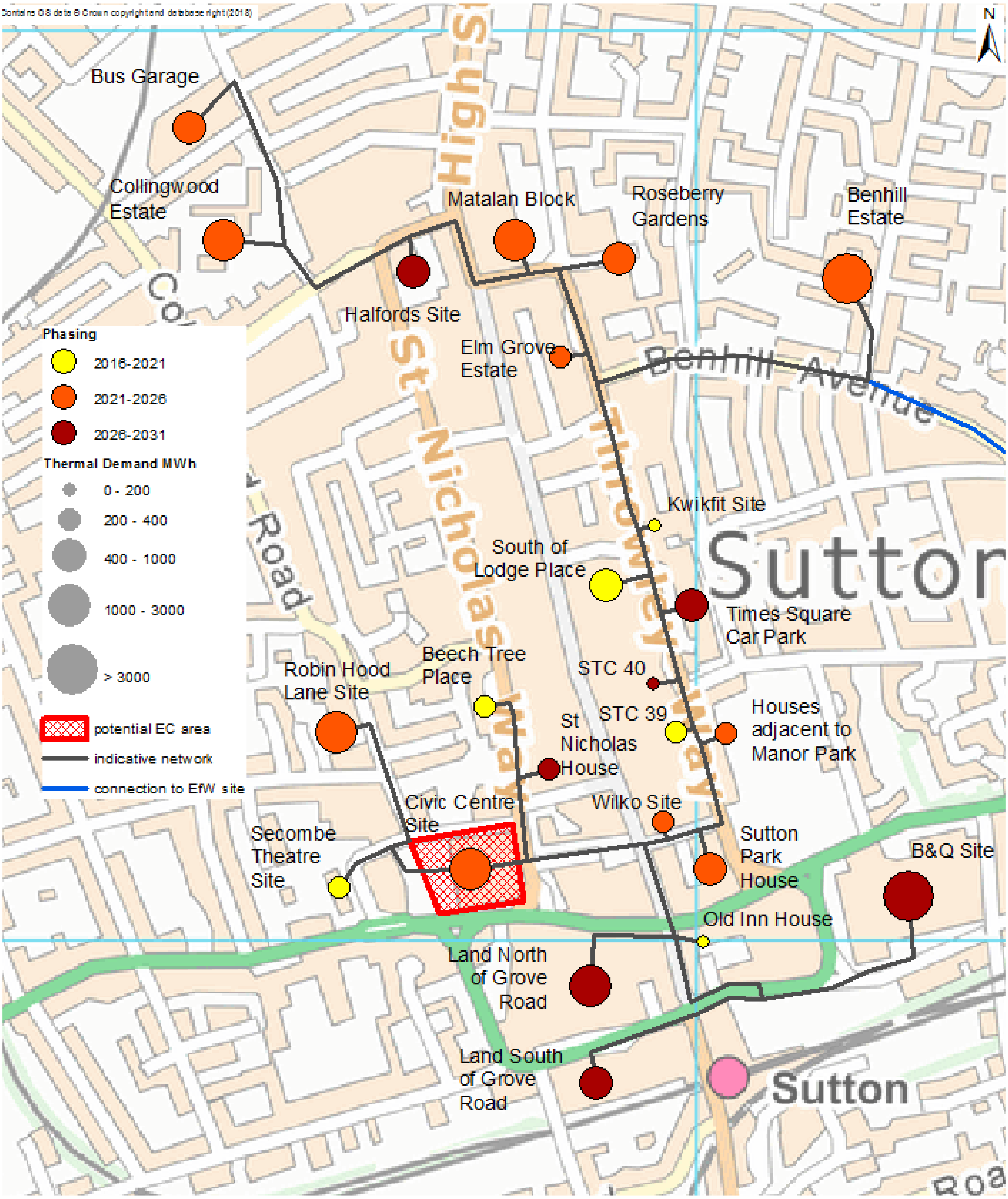


Figure 6-3 Sutton Town Centre indicative network routing

Table 6-2 Sutton Town Centre optimum network building list

Site	Expected date of build	Building name	Building type	Ownership	Postcode	Network	Number of residential units	Non-residential floor area m^2	Peak heat demand kW*	Heat demand MWh	Source
STC 6	2016-2021	South of Lodge Place	Residential and Retail	Private	SM1 4DB	ALL	31	2,525	159	200	Benchmark**
STC 7	2016-2021	Kwikfit Site	Residential and Retail	Council (with Private lease)	SM1 4AF	ALL	15	456	61	67	Benchmark
STC 9	2021-2026	Civic Centre Site	Civic, Community, Retail	Council	SM1 1EA	ALL	165	14,607	799	872	Benchmark
STC 10	2016-2021	Secombe Theatre Site	Community or Primary School or Residential	Council/ Private	SM1 2SS	ALL	65	-	223	212	Benchmark
STC 11	2016-2021	Beech Tree Place	Residential and Retail	Council/ Private	SM1 1SF	ALL	64	312	319	304	Benchmark
STC 21	2021-2026	Sutton Park House	Residential and Town Centre uses	Private	SM1 4FD	ALL	94	1,559	355	368	Benchmark
STC 22	2016-2017	Old Inn House	Residential and Town Centre uses	Private	SM1 4RA	ALL	28	443	105	109	Benchmark
STC 23	2021-2026	Bus Garage	Residential	Council/ Private	SM1 1QJ	ALL	203	-	182	173	Benchmark
STC 24	2026-2031	Halfords Site	Residential and Retail	Private	SM1 1SE	ALL	80	1,256	301	310	Benchmark
STC 25	2021-2026	Matalan Block	Residential and Retail	Private	SM1 1PG	ALL	164	3,660	639	679	Benchmark
STC 29	2026-2031	St Nicholas House	Town Centre uses and Residential	Private	SM1 1EH	ALL	67	-	230	219	Benchmark
STC 30	2016-2021	Robin Hood Lane Site	Health and residential	Public/Private	SM1 2RJ	ALL	48	4,707	1,023	1,094	Benchmark
STC 33	2026-2031	Land North of Grove Road	Residential and Town Centre uses	Private	SM1 1DD	ALL	178	3,036	674	700	Benchmark
STC 35	2026-2031	Land South of Grove Road	Residential and Town Centre uses	Private	SMA1 1dA	ALL	122	2,493	470	496	Benchmark
STC 36	2026-2031	B&Q Site	Retail, Residential and Town Centre uses	Private	SM1 4RQ	ALL	482	13,519	1,935	2,102	Benchmark
STC 37	2021-2026	Wilko Site	Residential and Retail	Council (with Private lease)	SM1 1EZ	ALL	26	636	102	110	Benchmark
STC 38	2021-2026	Houses adjacent to Manor Park	Residential and Town Centre uses	Council/ Private	SM1 4AF	ALL	101	-	346	330	Benchmark
STC 39	Built	Land to the rear of Times Square	Unknown	Private	<Null>	ALL	34	445	126	128	Benchmark
STC 40	Built	STC 40	Residential	Unknown	<Null>	ALL	28	-	96	91	Benchmark
STC 41	2026-2031	Times Square Car Park	Residential, car parking and other	Council	SM1 4AG	ALL	135	441	472	458	Benchmark
STC 45	2021-2026	Elm Grove Estate	Residential and Town Centre uses	Council/ Private	SMA1 4EU	ALL	47	281	167	165	Benchmark
Housing redevelop ments	Unknown	Benhill Estate	Residential	Council	SM1 4DD	EfW, CHP	1,076	-	3,689	3,515	Benchmark
	Unknown	Roseberry Gardens	Residential	Council	SM1 4DD	CHP, ASHP	184	-	730	696	Benchmark
	Unknown	Collingwood Estate	Residential, retail	Council	SM1 1RX	ALL	535	333	1,841	1,761	Benchmark

*See Appendix D for peak heat demand calculation methodology
**See Appendix A, benchmark demands were applied to the floor area data provided by LBS

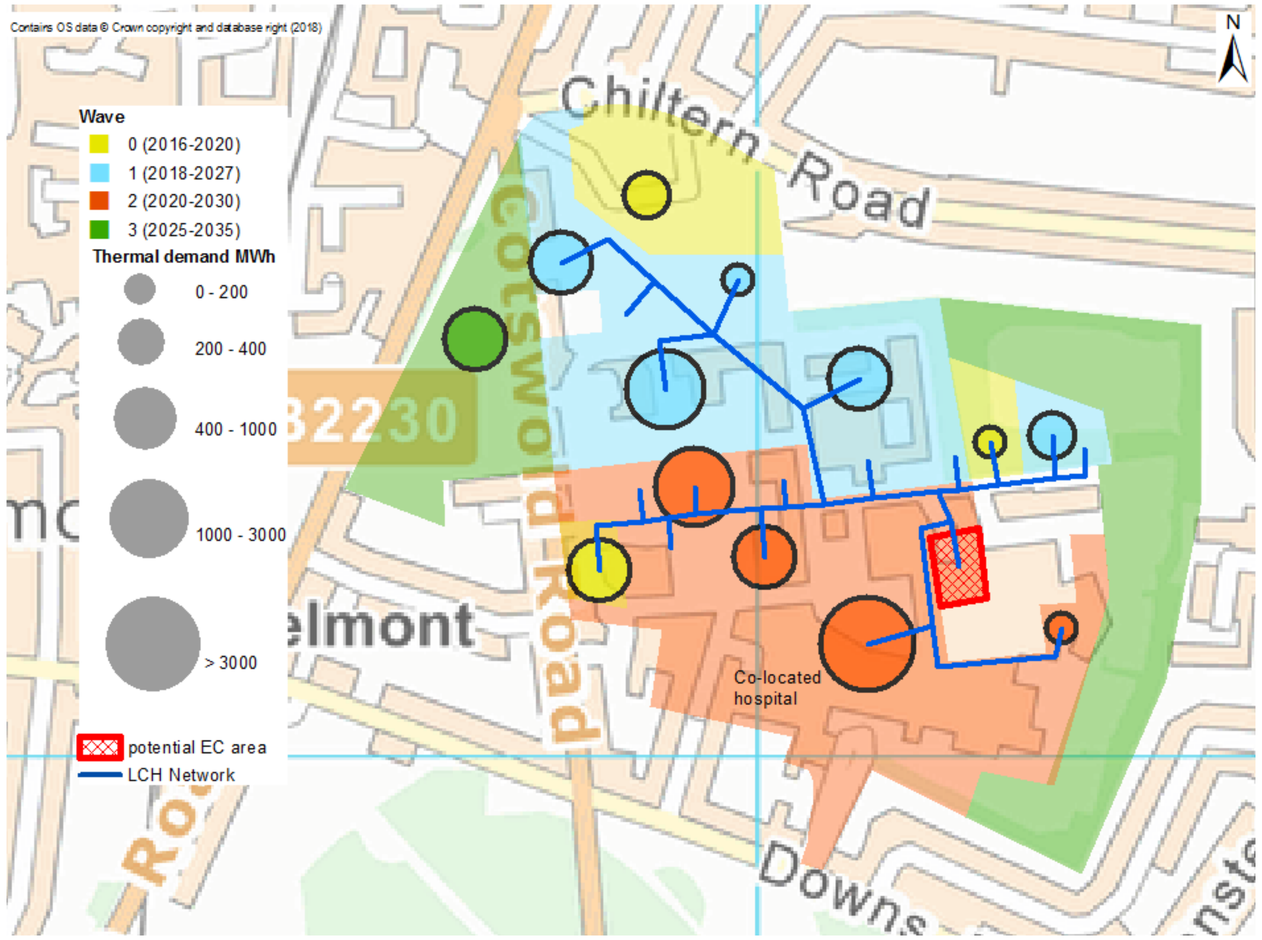


Figure 6-4 London Cancer Hub indicative network routing

Table 6-3 London Cancer Hub optimum network building list

Wave	Building name	Building type	Ownership	Date built	Network	Peak heat demand kW*	Heat demand MWh
0	ICR (CCDD)	Office	Public	2016-2019	ALL	246	176
0	The Royal Marsden (Maggie's Centre)	Hospital	Public	2016-2020	ALL	84	288
1	Commercial / research 1	Office	Public	2019-2026	ALL	701	502
1	Not for profit/charitable/academic 1	Office	Public	2019-2026	ALL	563	403
1	ICR 1	Office	Public	2019-2026	ALL	381	273
1	Patient hotel/accommodation 1	Residential	Public	2019-2026	ALL	223	436
1	Community/leisure/retail 1	Retail	Public	2019-2026	ALL	141	233
2A	Commercial / research 2A	Office	Public	2020-2026	Scenario A	1,196	856
2A	ICR 2A	Office	Public	2020-2026	Scenario A	159	113
2A	Co-located hospital 2A	Hospital	Public	2020-2026	Scenario A	7,510	25,658
2A	Community/leisure/retail 2A	Retail	Public	2020-2026	Scenario A	116	192
2B	Commercial / research 2B	Office	Public	2020-2030	Scenario B	1,941	1,388
2B	ICR 2B	Office	Public	2020-2030	Scenario B	159	113
2B	The Royal Marsden 2B	Hospital	Public	2020-2030	Scenario B	5738	19,603
2B	Community/leisure/retail 2B	Retail	Public	2020-2030	Scenario B	116	192

*See Appendix D for peak heat demand calculation methodology

7. Network Considerations

7.1 Coordination with Existing Utilities

Coordination of pipework routing with existing utilities will need to be undertaken, particularly when directing pipework under roads and footpaths. Detailed utility searches will need to be undertaken including the location, depth and required exclusion zones for:

- Power (HV and LV)
- Gas
- Potable water mains
- Drainage/foul sewers
- Telecommunications

For Sutton Town Centre, there is a possible opportunity to synchronise pipework routing with any other major infrastructure works to help minimise cost and disruption during works. For the London Cancer Hub, implementation district heating network should coordinate with the site regeneration, leading to a potential for reduced costs.

7.2 Operating Temperatures

The operating temperature of any district heating network will depend on the buildings that are connected to it. Existing building often present temperatures of 82/71°C flow/return[12], used to serve radiators and other water based-heat emitters for space heating. However, in recent years there has been a drive to reduce network and service temperatures in an effort to reduce distribution losses and to increase the efficiency of heat generating plant. Low temperature (<70°C) flow is preferable for networks using heat pumps, since the efficiency of heat pumps reduces as operating temperatures increase.

At this stage the following temperatures are proposed:

- **70/40°C flow/return for the STC network**
- **65/35°C flow/return for the LCH network**

The implementation of a low temperature district heating network is particularly suited to the London Cancer Hub site as this network will only serve new build. In this case it would be recommended that Sutton Council engage with stakeholders and impose requirements for them to design to lower heating supply temperatures, such that the developments would be compatible. Although the STC network will serve predominantly new build, it will provide heat for a large number of residential developments that have significant DHW demands.

For both cases, the temperature strategy is based on a 5°C temperature approach to the basement heat exchangers. For STC, this would result in building level systems operating no higher than 65°C on flow and 35°C on return.

The proposed network for STC does not include any existing buildings at this stage. However, whilst it requires detailed consideration, there are many examples of existing buildings being reduced from 82/71 to lower temperature flow/return, with limited capital investment. Older radiators are normally oversized and are therefore capable of meeting heating demands with lower temperatures. Where this is not possible, building heating systems can be designed to operate at lower temperatures but their implementation often necessitates a full replacement of the heating system, with high associated capital cost. It should be noted that the hot water from the EfW facility could be supplied at 90ºC, which would facility the connection of existing buildings without retrofitting.

[12] More recent design practices have led to the common adoption of 80/60°C.

7.3 Network Distribution Losses

Energy losses from the distribution network result from the temperature difference between the distribution pipework and the medium in which the pipework is sited (usually in the ground). As ground temperatures are typically ~10°C, pipework that is located in the ground experience losses due to a temperature difference between the fluid in the pipework and the ground of up to ~80°C. Despite these challenges, distribution losses can be reduced significantly through appropriate network design (reducing unnecessary network lengths and appropriate sizing of pipework), the specification of good quality and well-manufactured pipework, the use of appropriately sized and specified insulation at all points across the network and careful installation on site. Good quality heat networks should result in heat losses no higher than 10% of annual demand for the entire network, although this figure is affected by a number of factors such as the heat density and the proportion of buried pipework and pipework within buildings.

Operating the STC network at 70/40°C flow/return and the LCH network at 65/35°C flow/return will reduce heat losses to the ground. For this particular study, primary network heat losses have been assumed to be 10%. For residential connections, a further 20% heat loss[13] has been added to the residential consumption load. This takes into consideration the expected internal heat loss that would be experience between the plant room and the individual dwellings.

7.4 Pipework

Detailed pipework sizing and specification should be undertaken at a later design stage. The pipework assumptions used for the techno-economic analysis for each model are detailed in Appendix K.

For high temperature heat networks, steel pipework is predominantly used. Low temperature networks may realise cost savings through use of plastic pipework. However, at this stage all costs have been based on the use of steel pipework.

7.5 Potential for Expansion

The heat footprint and future development plans in Sutton support a phased approach for the DHN, with potential to expand in the future. Buildings that are far from the proposed networks or that would require crossing significant physical barriers such as railway lines or waterways present challenges for network expansion (for example, by needing to cross these barriers, their routing through already ‘crowded’ conduits for utility services is likely to make designing these routing pinch-points challenging). These must be considered on a case-by-case basis.

7.6 Building Connections

The connection of customer buildings and loads to the DH network will require a choice regarding how heat is drawn from the network and put to use in the customer buildings. A fundamental design choice is whether the buildings are directly connected to the heat network (where the water in the network flows directly through the heating circuits of the buildings) or indirectly (where a heat exchanger is used to provide a physical barrier to the water). The choice has an impact on cost and operating temperatures and pressures.

Hydraulically separated systems (indirect connection through the installation of heat interface units or heat substations) are usually considered to be a better commercial option, since they offer better control of network operating conditions and ensure contaminants from customer services do not compromise the DH network and Energy Centre plant (a problem that is often encountered when using direct connections).

There may be some requirement to undertake changes to the heating services in customer buildings, depending on the nature of the building. If the existing heating system is a wet LTHW system, then works will be minimal and plant room based only. The formation of a heat sub-station will often be placed in the location of the existing boiler plant and normally occupy a smaller footprint. Surveys should be undertaken, as the project design develops to ensure any such connection requirement is viable.

[13] This value exceeds the recommend loss identified within CP1. AECOMs current experience of new build has been that this value is very hard to practically achieve within commercially developed residential projects.

8. Electrical Distribution Network

For co-generation technologies, such as CHP, revenue can be generated through the sale of electricity as well as heat. Utilising the electrical output from the CHP is of a high priority; it is pragmatic to identify a solution that maximises revenue from electricity sales whilst ensuring the effective operation of the CHP plant.

The electricity generated by the CHP engine can be sold as a private wire service to large electricity consumers in the area which involves entering into a private power purchase agreements with a third parties, or via a sleeving arrangement, or by exporting directly to the grid. These approaches are explained further in Appendix E.3. Either way, suppliers of electricity require a connection to the UK grid network. The supplier must ensure it can meet its customers demand at all times, and if demand exceeds the CHP plant capacity, the difference can be passed on from the national grid.

Due to the higher risk involved with selling electricity privately, this has been modelled as a sensitivity for the STC and LCH networks, rather than incorporated in to the base case. The base case scenario assumes electricity can be sold wholesale via the Licence Lite scheme, which is explained in Appendix F.5.

Revenue generated through the sale of electricity via private wire or a sleeving arrangement is dependent on the agreement with the customer. Finding relevant and willing private wire customers can be an essential part of district heating network development in the case of CHP. Prices will usually be linked to the prevailing retail price, such that the customer benefits from a reduction in its energy bills what they would pay otherwise. The rate that electricity is sold at via private wire is adjustable in AECOM's techno-economical model, and is based on energy price tariffs published by BEIS, as outlined in Appendix F.3. A discount rate of 10% is applied to these price tariffs.

Although private wire electricity distribution demands certain up front capital expenditure, due to the instalment of an electrical distribution network, the revenues generated are much higher than exporting to the grid. As such, the ratio of electricity generated which is sold via a private wire or sleeving arrangement to that which is exported at whole sale rates affects the commercial viability of the network. This is highlighted as a key risk item in the case that a CHP solution is pursued, and should be subject to further investigation in subsequent studies. Whilst it is generally preferable to sell all generated electricity privately, AECOM recognises that this may not be technically feasible. Instead, a conservative assumption is made, that only a set proportion of the generated electricity is sold privately, with the remainder exported to the grid.

In order to undertake a high-level assessment of the benefit of private wire for the STC and LCH sites, is has been assumed that electricity can be sold to the buildings included in the network. This is a likely scenario for LCH, as the developments are generally large commercial customers. For the STC network, which is based predominantly on residential developments, this solution would face much greater risk and barriers. Residential demand is relatively inconsistent in nature and entails a high number of end consumers. If a CHP solution in STC is taken forward, it would be important to carry out a detailed assessment of potential customers in the area. Alternatively, it may be preferable to sell wholesale via a scheme such as Licence Lite.

The annual electricity consumption for each of the buildings in the STC and LCH CHP networks has been benchmarked, according to data from industry guides and AECOM models, as detailed in Appendix A. From this, the total electricity private demand has been calculated. For STC, this demand is 50% of the net electricity available from the CHP engines, after onsite use in the energy centre, taken as 5%, and transmission losses. At this stage transmission losses are assumed to be 20%. In practice, the loss seen will depend on the current and length of the distribution network and can be minimised by transmission at a high voltage. For LCH, total electricity demand would meet 60%of the CHP plant capacity. The remainder of electricity in each case would be sold wholesale at a lower price.

At this stage, it is assumed that the electrical distribution network would follow the route of heat network, as it is serving the same end customers. Therefore the cost of electrical cabling installation has been based on the length and path of the heat network. This is a much higher upfront cost for the STC site, as its customers are dispersed more widely compared to the LCH site. These costs, along with a summary of the private wire scenario for both STC and LCH, are detailed in section 9.4.1.

9. Techno-Economic Modelling

This section details the techno-economic modelling results for the network scenarios identified in section 0. Each model contains a high number of user-variable inputs and thus not all results can be presented in this report. Appropriate parameters for each variable have been selected, as detailed in Appendix F. Sensitivity analysis on key parameters has been carried out to predict how variations of these parameters would affect the system feasibility.

Heat revenue is based on a counterfactual price of heat, as detailed in section 9.3. For STC, a 10% discount on the price of heat has been applied relative to the counterfactual. This is an optional discount and could be used to incentivise connection to the heat network and provide savings to its customers. Note however that SDEN's policy is to achieve price parity. For the LCH, no heat discount has been applied. This is an entirely new development and the aim is to be competitive with the counterfactual heating system, rather than provide savings on top of this.

9.1 Sutton Town Centre analysis

For the Sutton Town Centre site, the following network scenarios have been modelled:

- **OPTION 1: Gas-fired CHP**
- **OPTION 2: Energy from Waste**
- **OPTION 3: Air Source Heat Pump**

All options include top-up boilers capable of meeting 100% of the peak demand as well as thermal storage.

The first year of operation of the network is taken to be 2026, as by this date STC Phase 2 sites should be complete. Phase 3 buildings will then connect to the existing network as they come online. There is additional uncertainty over the Phase 1 sites, many of which are already either in existence or under construction. For those to be complete before the heat network is operational, temporary plant may need to be considered.

It has been assumed that capital costs will be accrued across a 2 year period prior to the networks first year of operation. If developments fall behind schedule and come online later than expected this would delay revenue streams and have a negative impact on project financials.

9.1.1 Technical evaluation

The key technical parameters at full build out for each network considered for Sutton Town Centre are summarised in Table 9-1 Technical evaluation: STC. In all cases it is assumed that low NO_x condensing boilers are used in the EC, sized to cover 110% capacity inclusive of network losses. This enables an additional 10% resilience above peak network demand. Total thermal generation also is inclusive of network losses, and thus exceeds the respective total thermal demand seen by each option.

Table 9-1 Technical evaluation: STC

	OPTION 1 (CHP)	OPTION 2 (EfW)	OPTION 3 (ASHP)
Total thermal demand (MWh p.a.)	15,064	14,447	11,548
Total thermal generation (MWh p.a.)	19,338	18,547	14,698
Option technology heat generation (as % of total)	75.9%	90%	61.9%
Option technology capacity (kW)	3,074	15,000	1,600
Peak thermal load (kW)	13,973	13,383	10,524
No. of developments connected	24	23	23
Network pipework run length (m)	4,072	7,596	3,631
Energy centre footprint (m2)	1,187	802	894
Total gas consumption (MWh/yr)	43,351	2,061	6,227
EC boiler capacity (kW)	14,461	13,849	10,883
25 year cumulative carbon emission savings (tonnes CO_2e)	-55,719	24,379	4,267
40 year cumulative carbon emission savings (tonnes CO_2e)	-92,798	37,505	7,512

In order to qualify for HNIP funding, heat networks must be served by a CHP engine generating at least 75% of the total heat, or renewable technology generating at least 50%. This consideration was taken into account when selecting the appropriate plant size, along with the model optimisation process. Hence in all options presented above this criteria has been met.

The 40 year cumulative carbon emission savings indicates the net difference in carbon emissions between the counterfactual case and the respective technology option. For CHP this takes a large negative value, highlighting the fact that gas-fired CHP is likely to become more and more carbon intensive compared to the alternative options. The carbon outlook is explained further in Appendix F.6, with Appendix N providing detail on the chosen counterfactual.

Further technical discussion surrounding the use of ASHPs for Sutton district heating can be found in Appendix L.

9.1.2 Economic Evaluation

Table 9-2 lists, to the nearest £1000, the respective capital expenditure (CAPEX), operational expenditure (OPEX) and revenue streams for the three STC network options, including the payback period. The payback period disregards the time value of money and can be used as a simple indication of the length of time necessary to reimburse the investment cost of a DHN project.

For DH networks, CAPEX is often relatively high due to the provision of network infrastructure, as well as any heat generation plant and fit-out required. All secondary and tertiary systems are not included in this cost; it is assumed these costs are covered by developers. OPEX costs occur annually and include fuel consumption, maintenance and plant replacement. Fuel costs have been indexed against IAG projections of energy prices, see Appendix F.4 for details. Revenue can come from a range of sources, as discussed in Appendix F.5, mainly due to the networks provision of heat. In the case of CHP, electricity sales also provide an important revenue stream. In the calculations below, RHI benefit and carbon savings are listed under revenue where applicable.

Table 9-3 presents the internal rate of return (IRR) and net present value (NPV) at both 25 and 40 years for the STC options. The NPV gives an indication of project profitability, as it shows the difference between the present value of cash inflows and outflows over the length of time considered. To calculate the present value of cash flows a discount rate of 3.5% has been applied. The IRR is the discount rate that would make the NPV equal to zero. Generally the higher the IRR, the more financially viable the project is.

Table 9-2 Financial evaluation: STC

	OPTION 1 (CHP)	OPTION 2 (EfW)	OPTION 3 (ASHP)
CAPEX	**£18,021,000**	**£19,242,000**	**£14,969,000**
EC building	£2,969,000	£2,007,000	£2,236,000
EC plant (ASHP/CHP/GSHP)	£3,167,000	-	£2,784,000
EC boiler and ancillaries	£3,818,000	£3,656,000	£2,873,000
Thermal Store	£290,000	£278,000	£220,000
Network pipework	£3,691,000	£9,603,000	£3,352,000
Network substations HIUs	£523,000	£501,000	£394,000
Network additional costs (crossings)	£80,000	£230,000	£80,000
Gas connection	£100,000	£100,000	£100,000
Electricity connection	£700,000	-	£700,000
Contingency	£1,534,000	£1,638,000	£1,274,000
Professional fees	£767,000	£819,000	£637,000
Legal fees	£383,000	£409,000	£318,000
OPEX	**£1,091,000**	**£457,000**	**£619,000**
Maintenance cost p.a.	£250,000	£155,000	£96,000
Gas p.a.*	£841,000	£52,000	£157,000
Electricity p.a.*	-	£18,000	£365,000
Imported heat p.a.*	-	£250,000	-
Revenues *	**£2,801,000**	**£1,982,000**	**£1,531,000**
RHI benefit (20 years)	-	-	-
Heat sales p.a.*	£1,976,000	£1,885,000	£1,513,000
Electricity sales p.a.*	£1,016,000	-	-
Carbon savings p.a * (associated with Climate Change Levy)	-£191,000	£97,000	£17,000
Payback period	**10.5 years**	**12.6 years**	**16.4 years**

* averaged over payback period

The carbon savings in Table 9-2 relate to the difference between the option's net emissions (in tonnes of CO_2) and those of the counterfactual. This difference has been multiplied by IAG's projected carbon price for the respective year of operation.

Table 9-3 Economic evaluation: STC

	OPTION 1 (CHP)	OPTION 2 (EfW)	OPTION 3 (ASHP)
25 year assessment			
IRR (%)	5.46	4.76	0.39
NPV (£)	3,854,275	3,315,614	-3,163,818
40 year assessment			
IRR (%)	6.85	6.54	3.53
NPV (£)	7,183,426	9,394,198	-£185,243

For Option 2 it is possible to omit the additional cost of crossing the railway in Hackbridge given the network becomes an extension of the current pipework supplying the Felnex development. In this case the network additional costs (crossings) will reduce by £150,000. The resulting 25 and 40 years IRRs would increase slightly to 4.85% and 6.62% respectively.

9.2 London Cancer Hub analysis

For the London Cancer Hub site, the following network scenarios have been modelled:

- **OPTION 4A: Gas-fired CHP** for the co-located hospital
- **OPTION 4B: Gas-fired CHP** for the Royal Marsden estate development
- **OPTION 5A: Ground source heat pump** for the co-located hospital
- **OPTION 5B: Ground source heat pump** for the Royal Marsden estate development

All options include back-up boilers capable of meeting 100% of the peak demand as well as thermal storage.

For the London Cancer Hub, the first year of operation of the network is taken to be 2026. This is an approximation of when developments in both Wave 1 and 2 will be largely complete. As a detailed timeline of individual building schedules was not made available for the LCH, it has been assumed that from 2026 full network build out can be achieve, with all relevant buildings online, In reality, revenue streams are likely to be delayed for a year or two as building completions are staggered. The two Wave 0 developments considered for connection may need temporary plant installed until the operational start date. Note, Wave 3 was excluded from the optimum network and so does not need considering.

It has been assumed that capital costs will be accrued across a 2 year period prior to the networks first year of operation. If developments fall behind schedule and come online later than expected this would delay revenue streams and have a negative impact on project financials.

9.2.1 Technical evaluation

The key technical parameters at full build out for each network considered for the London Cancer Hub are summarised in Table 9-4. In all cases it is assumed that low NO_x condensing boilers are used in the EC, and that they are sized to cover 110% capacity, inclusive of network losses. This enables an additional 10% resilience above peak network demand. Total thermal generation also is inclusive of network losses, and thus exceeds the respective total thermal demand seen by each option.

Table 9-4 Technical evaluation: LCH

	OPTION 4A (CHP)	OPTION 4B (CHP)	OPTION 5A (GSHP)	OPTION 5B (GSHP)
Total thermal demand (MWh p.a.)	29,127	23,605	29,107	23,605
Total thermal load (MWh p.a.)	32,403	26,334	32,403	26.334
Option technology heat generation (as % of total)	75.7%	75.3%	59.9%	69.9%
Option technology capacity (kW)	4,234	3,465	2,460	2,460
Peak thermal load (kW)	10,586	9,626	10,586	9,626
No. of developments connected	11	11	11	11
Network pipework length (m)	1,543	1,543	1,543	1,543
Energy centre footprint (m2)	899	818	799	737
Total gas consumption (MWh/yr)	72,810	58,979	9,580	6,117
EC boiler capacity (kW)	10,960	9,937	10,960	9,937
25 year cumulative carbon emission savings (tonnes CO_2e)	-90,594	-74,070	7,913	20,029
40 year cumulative carbon emission savings (tonnes CO2e)	-141,926	-116,048	22,723	40,733

All options presented for LCH meet the heat generation criteria for HNIP funding. Further technical details and the key assumptions used for the GSHP options are given in Appendix M.

The 40 year cumulative carbon emission savings indicates the net difference in carbon emissions between the counterfactual case and the respective technology option. The carbon outlook is explained further in Appendix F.6.

9.2.2 Economic Evaluation

Table 9-5 lists the respective capital expenditure (CAPEX), operational expenditure (OPEX) and revenue streams for the four LCH network options, including the payback period. The payback period disregards the time value of money and can be used as a simple indication of the length of time necessary to reimburse the investment cost of a DHN.

For DH networks, CAPEX is often relatively high due to the provision of network infrastructure, as well as any heat generation plant and fit-out required. All secondary and tertiary systems are not included in this cost; it is assumed these costs are covered by developers. OPEX costs occur annually and include fuel consumption, maintenance and plant replacement. Fuel costs have been indexed against IAG projections of energy prices, see Appendix F.4 for details. Revenue can come from a range of sources, as discussed in Appendix F.5, mainly due to the networks provision of heat. In the case of CHP, electricity sales also provide an important revenue stream. In the calculations below, RHI benefit and carbon savings are listed under revenue where applicable.

Table 9-6 presents the internal rate of return (IRR) and net present value (NPV) at both 25 and 40 years for the LCH options. The NPV gives an indication of project profitability, as it shows the difference between the present value of cash inflows and outflows over the length of time considered. To calculate the present value of cash flows a discount rate of 3.5% has been applied. The IRR is the discount rate that would make the NPV equal to zero. Generally the higher the IRR, the more desirable the project is.

Table 9-5 Financial evaluation: LCH

	OPTION 4A (CHP)	OPTION 4B (CHP)	OPTION 5A (GSHP)	OPTION 5B (GSHP)
CAPEX	**£14,721,000**	**£13,098,000**	**£14,455,000**	**£13,844,000**
EC building	£2,250,000	£2,045,000	£2,000,000	£1,844,000
EC plant (ASHP/CHP/GSHP)	£4,404,000	£3,591,000	£4,428,000	£4,428,000
EC boiler and ancillaries	£2,893,000	£2,623,000	£2,893,000	£2,623,000
Thermal Store	£486,000	£198,000	£486,000	£395,000
Network pipework	£1,299,000	£1,332,000	£1,299,000	£1,332,000
Network substations HIUs	£396,000	£360,000	£396,000	£360,000
Network additional costs (crossings)	-	-	-	-
Gas connection	£100,000	£100,000	£100,000	£100,000
Electricity connection	£700,000	£700,000	£700,000	£700,000
Contingency	£1,253,000	£1,115,000	£1,230,000	£1,178,000
Professional fees	£626,000	£557,000	£615,000	£589,000
Legal fees	£313,000	£279,000	£308,000	£295,000
OPEX	**£1,714,000**	**£1,397,000**	**£1,199,000**	**£1,011,000**
Maintenance cost p.a.	£305,000	£255,000	£104,000	£99,000
Gas p.a.*	£1,409,000	£1,142,000	£363,000	£221,000
Electricity p.a.*	-	-	£732,000	£691,000
Imported heat p.a.*	**-**	-	-	-
Revenues	**£3,199,000**	**£2,726,000**	**£2,561,000**	**£2,360,000**
RHI benefit (20 years)	-	-	£753,000	£726,000
Heat sales p.a.*	£1,796,000	£1,599,000	£1,797,000	£1,580,000
Electricity sales p.a.*	£1,712,000	£1,381,000	-	-
Carbon savings p.a *	-£310,000	-£253,000	£11,000	£54,000
Payback period	**9.9 years**	**10.0 years**	**10.6 years**	**10.3 years**

* averaged over payback period

The carbon savings in Table 9-5 relate to the difference between the option's net emissions (in tonnes of CO_2) and those of the counterfactual. This difference has been multiplied by IAG's projected carbon price for the respective year of operation.

Table 9-6 Economic evaluation: LCH

	OPTION 4A (CHP)	OPTION 4B (CHP)	OPTION 5A (GSHP)	OPTION 5B (GSHP)
25 year assessment				
IRR (%)	5.48	5.52	5.44	6.01
NPV (£)	3,009,438	2,764,733	3,085,375	3,811,690
40 year assessment				
IRR (%)	7.09	7.09	6.95	7.44
NPV (£)	6,028,770	5,445,299	6,889,490	7,826,138

9.3 Project Counterfactual

In order to assess the economic and technical performance of a district heating scheme, it is necessary to establish what developers and customers would do in the event that the district heating scheme is not brought forward. This is defined as a Counterfactual case, and provides a base case for assessing the performance of the district heating scheme. It enables an indication of the amount of revenue a fair DH network should be accruing, as well as a carbon savings benchmark to enable comparison with the DHN options.

Historically, the counterfactual has been modelled on a conventional gas boiler system. However, due to recent policy changes in London this is no longer a reasonable alternative for new build developments. It is difficult to predict the solution that developers would implement in the near future, given the industry is continuously adapting to meet the changing priorities proposed in Government policies and the draft New London Plan, which are being driven by the reduction in grid electricity carbon emissions and air quality concerns.

As the STC and LCH optimised networks have been modelled entirely on new build, the counterfactual heating system adopted for this study is a hybrid air source heat pump and gas boiler system, with each technology being responsible for 50% of the annual heat provision. This system is explained further in Appendix N.

For modelling purposes, the counterfactual price of heat has been applied as a yearly cost. For example, as the replacement lifetime of the boiler plant is assumed to be 20 years, each year a 5% CAPEX charge is included in the counterfactual for the boiler plant, along with typical annual maintenance costs. In practice, is it often advisable to reduce the gap between capital outlay and project revenue streams by introducing an upfront connection charge to developers looking to connect to the heat network. Connection charges are discussed further in Appendix F.5.

The breakdown of the counterfactual cost of heat provision for each network option is outlined in Table 9-7. Here the annual costs are split into those costs associated with heat generation via boilers, and those for heat generated by ASHP. The total counterfactual cost of heat in p/kWh is then calculated using the assumption that 50% of this heat is generated by each technology.

The suggested heat network tariff includes a 10% reduction on the counterfactual cost of heat. This reduction provides a financial incentive for customers to join the network and can be assigned a different value depending on the viability and priority of the scheme.

Table 9-7 Counterfactual heat price breakdown

	OPTION 1	OPTION 2	OPTION 3	OPTION 4A/5A	OPTION 4B/5B
Boiler – associated costs					
CAPEX and replacement costs, £/MWh	24.0	24.1	24.5	18.5	20.7
Maintenance costs, £/MWh	4.0	4.1	4.1	3.1	3.5
Replacement cycle, years	20	20	20	20	20
Blended gas price, p/kWh	4.7	4.7	4.6	2.5	2.5
Boiler efficiency	90%	90%	90%	90%	90%
Price of fuel, p/kWh	5.2	5.2	5.1	2.8	2.8
Boiler price of heat, p/kWh	**8.0**	**8.0**	**8.0**	**5.0**	**5.2**
Air Source Heat Pump – associated costs					
CAPEX and replacement costs, £/MWh	143.7	144.4	147.0	60.9	68.3
Maintenance costs, £/MWh	4.6	4.6	4.7	1.9	2.2
Replacement cycle, years	20	20	20	20	20
Blended electricity price, p/kWh	14.2	14.2	13.9	11.3	11.2
ASHP COP	2.9	2.9	2.9	2.9	2.9
Price of fuel, p/kWh	4.9	4.9	4.8	3.9	3.9
RHI	2.69	2.69	2.69	2.69	2.69
ASHP price of heat, p/kWh	**17.0**	**17.1**	**17.3**	**7.5**	**8.3**
Total counterfactual cost of heat, p/kWh	**12.5**	**12.6**	**12.6**	**6.2**	**6.7**
Discount on heat price	10%	10%	10%	0%	0%
Heat Network Tariff, p/kWh	**11.3**	**11.3**	**11.4**	**6.2**	**6.7**

The difference in heat revenue price for the two sites stems from the contrasting heat profiles. For STC, close to 80% of the modelled demand would come from residential developments. Residential demand tends to be split fairly equally between space heating and domestic hot water, with reasonable peaks in demand. The price of gas and electricity for residential customers, as outlined in Appendix F, are a lot higher than for a commercial customer, which drives up the counterfactual total. For the London Cancer Hub, the majority of the demand is expected to come from the large hospital. Hospitals tend to have large consistent loads and as large commercial customers experience lower tariff rates.

Industry best practice in the district heating sector is managed by the Heat Trust. This voluntary scheme is supported by the government and aims to standardise the quality and level of customer's service provided by heat suppliers. The Trust hosts an online calculator that calculates the expected annual heat costs for residential customers depending on their postcode. The calculator was run for a 2 bed 4 person flat in Sutton town centre; the resulting heat price was 15.2p/kWh. The counterfactual price calculated for STC is lower, at 12.5 p/kWh. Although this is a blended price, as 20% of the network demand is commercial, it indicates that the proposed heat networks could supply heat to residential customers at a competitive price level.

9.4 Sensitivity Analysis

The financial viability of the DH schemes is dependent on a variety of factors which can be difficult to predict, including heat sales revenue, capital cost, fuel costs, plant efficiency, annual heat volume and electricity revenue (where relevant). The effect of changing heat sales, capital cost and fuel cost assumptions on the Internal Rate of Return (IRR) and the Net Present Value (NPV) of the project, with reference to the Base Case, is depicted in Table 9-8. With regards to fuel cost, sensitivity was carried out on the main fuel implied in each case. For options incorporating a gas-fired CHP solution, this would be gas. Although gas would provide fuel for the top-up boilers in other options, sensitivity was run on the price of imported heat (EfW) or electricity (heat pumps). Sensitivity results for the variables mentioned above are also depicted graphically in Appendix I.

Bespoke sensitivities have been run for the individual technologies. This includes private wire consideration for options that include CHP and RHI consideration for heat pump technologies. The results of this analysis are presented in the remainder of this chapter.

Table 9-8 Sensitivity analysis results

	IRR (40 years)	NPV (40 years)
Option 1 – STC gas-fired CHP		
Base Case	**6.85%**	**£7,183,426**
Heat sales revenue -10%	5.34%	£4,081,289
Heat sales revenue -5%	6.11%	£6,016,840
Heat sales revenue +5%	7.55%	£9,887,942
Heat sales revenue +10%	8.22%	£11,823,492
Capital costs -10%	7.98%	£9,733,743
Capital costs -5%	7.39%	£8,843,067
Capital costs +5%	6.36%	£7,061,715
Capital costs +10%	5.90%	£6,171,038
Gas price -10%	7.46%	£8,915,829
Gas price -5%	7.16%	£8,049,627
Gas price +5%	6.54%	£6,317,224
Gas price +10%	6.21%	£5,451,022
Option 2 – STC EfW		
Base Case	**6.54%**	**£9,394,198**
Heat sales revenue -10%	5.42%	£329,621
Heat sales revenue -5%	5.99%	£1,822,618
Heat sales revenue +5%	7.08%	£4,808,610
Heat sales revenue +10%	7.61%	£6,301,607
Capital costs -10%	7.46%	£5,217,525
Capital costs -5%	6.98%	£4,266,570
Capital costs +5%	6.14%	£2,364,658
Capital costs +10%	5.76%	£1,413,702
Imported heat price -10%	6.69%	£9,904,715
Imported heat price -5%	6.61%	£9,649,456
Imported heat price +5%	6.47%	£9,138,939
Imported heat price +10%	6.40%	£8,883,680
Option 3 – STC ASHP		
Base Case	**3.53%**	**-£185,243**
Heat sales revenue -10%	1.98%	-£2,900,809
Heat sales revenue -5%	2.78%	-£1,421,062
Heat sales revenue +5%	4.24%	£1,538,432
Heat sales revenue +10%	4.92%	£3,018,178
Capital costs -10%	4.32%	£1,533,263
Capital costs -5%	3.91%	£795,974
Capital costs +5%	3.18%	-£678,604
Capital costs +10%	2.85%	-£1,415,893
Electricity price -10%	3.89%	£559,869
Electricity price -5%	3.71%	£187,313
Electricity price +5%	3.35%	-£557,800
Electricity price +10%	3.16%	-£930,356
Option 4A* – LCH gas-fired CHP		
Base Case	**7.09%**	**£6,028,770**
Heat sales revenue -10%	5.28%	£3,104,691
Heat sales revenue -5%	6.22%	£4,963,984
Heat sales revenue +5%	7.91%	£8,682,571
Heat sales revenue +10%	8.68%	£10,541,864
Capital costs -10%	8.28%	£8,277,991
Capital costs -5%	7.66%	£7,550,634
Capital costs +5%	6.57%	£6,095,921
Capital costs +10%	6.10%	£5,368,564
Gas price -10%	8.34%	£8,939,269
Gas price -5%	7.73%	£7,484,019
Gas price +5%	6.42%	4,573,520

	IRR (40 years)	NPV (40 years)
Gas price +10%	5.72%	£3,118,271
Option 5A* – LCH GSHP		
Base Case	**6.95%**	**£6,889,490**
Heat sales revenue -10%	5.27%	£3,343,746
Heat sales revenue -5%	6.14%	£5,203,040
Heat sales revenue +5%	7.72%	£8,921,626
Heat sales revenue +10%	8.45%	£10,780,919
Capital costs -10%	8.03%	£8,497,915
Capital costs -5%	7.47%	£7,780,124
Capital costs +5%	6.48%	£6,344,542
Capital costs +10%	6.05%	£5,626,751
Electricity price -10%	7.57%	£8,382,361
Electricity price -5%	7.26%	£7,635,925
Electricity price +5%	6.64%	£6,143,054
Electricity price +10%	6.31%	£5,396,618

*similar trends are seen for options 4B and 5B

It can be seen that even a 5% change in an input variable can have a significant financial impact. Therefore as the project moves onto the detailed project development stage, assumptions should be continuingly refined, including a thorough assessment of optimism bias.

Options 1 and 4 are inherently very sensitive to gas prices due to the fact that both the CHP engine and top-up boilers require this fuel. The impact of a change in the cost of imported heat from EfW (Option 2) is a lot smaller. This is due to the particularly low prices associated with this heat, with the base case at 1.5p/kWh. Option 5 is more sensitive to electricity price changes than Option 3 as this scheme as a larger associated thermal load.

9.4.1 Private wire sensitivity

DH projects tend to be particularly sensitive to the cost of heat sold to the network customers and the capital cost. Increasing the price at which the schemes heat is sold it not recommended as this would not align with the councils aim to promote district heating, and could have fuel poverty implications. However, for CHP led schemes an alternative approach would to be maximise revenue from electricity sales. This can be done by selling electricity privately to individual customers, as opposed to wholesale. This approach entails increased capital costs due to electrical cabling and also significant risk in securing customers privately. Moreover, in providing electricity privately the seller would be under legal obligation to meet there customers' electricity demand at all times.

Ideally private wire agreements are made with large commercial buyers who have greater demands and can enter into long term contracts. For modelling purposes, it has been assumed that electricity can be sold to the developments connected to the heating network. This is to give an indication of typical revenues. If private wire was pursued a detailed study of potential buyers in the area would be necessary.

For the STC option 1, the electricity demand of the connected buildings is estimated to meet 50% of the CHP electrical capacity. For the LCH option 4A, this figure is estimated to be 60%. The additional cost and revenue streams related to private wire inclusion are presented in Table 9-9. The effect on the IRR and NPV of each option is indicated in Table 9-10. It is assumed that transmission losses for the electrical networks would be 20%.

Table 9-9 Additional costs associated with Private Wire

	OPTION 1	OPTION 4A
% of electricity sold via private wire	50%	60%
% transmission loss	20%	20%
Effective electricity export price, p/kWh	11.9	10.2
Electricity sales p.a.	£1,367,231	£2,096,261
CAPEX cost of electrical cabling	£1,969,830	£622,103

Table 9-10 IRR and NPV sensitivity analysis: private wire

	IRR (25 years)	IRR (40 years)	NPV (25 years)	NPV (40 years)
Option 1 – STC CHP				
Selling electricity wholesale to GLA at 5.5 p/kWh (base case)	5.46%	6.85%	£3,854,275	£7,183,426
Selling 50% of electricity via private wire agreement	6.61%	7.87%	£7,014,374	£12,080,151
Option 4A – LCH CHP				
Selling electricity wholesale to GLA at 5.5 p/kWh (base case)	5.48%	7.09%	£3,009,438	£6,028,770
Selling 60% of electricity via private wire agreement	8.56%	9.67%	£8,295,898	£13,233,964

Selling electricity via private wire should be a key consideration for the LCH as it has an appreciable impact on project IRR- in the 25 year timeline project IRR increases over 3% above the base case with its inclusion. This site inherently can offer large commercial customers that are suitable for private sales of electricity. Further study should be undertaken into feasibility of an electrical network and transmission losses of such a scheme if this option is pursued.

For Option 1 in STC, the impact is a lot more modest, with only just over 1% increase in IRR for the 25 year assessment. This is due to the larger spatial extent of the network despite the higher export price of electricity. Selling to residential customers is also not advisable. An appropriate large commercial buyer in STC was not identified, and hence in this case the risks associated with private wire possibly outweigh the financial gain.

9.4.2 Renewable Heat Incentive sensitivity

The Renewable Heat Incentive is a government programme that provides financial incentive to pursue renewable heat solutions. Eligible installations receive quarterly payments over a 20 year period based on the amount of heat generated[14]. RHI support should be considered for the options using heat pump technology. Importantly, schemes receiving RHI payments would not be eligible for HNIP funding.

[14] https://www.ofgem.gov.uk/environmental-programmes/non-domestic-rhi/about-non-domestic-rhi

No RHI support has been included for Option 2. This is due to the assessed plant Coefficient of Performance (CoP) being modelled at 2.7 based on the current performance seen for large ASHPs in the UK. To attract RHI systems must currently have a CoP of at least 2.9 and a design Seasonal of at least 2.5. As heat pump technology advances, it is possible that this condition could be met by the time a STC DH network comes online (assumed mid-2020s). Table 9-11 presents the affect RHI support would have on the economic case for Option 2.

In this case RHI would be beneficial unless HNIP funding of over £3million can be secured.

Table 9-11 IRR and NPV sensitivity: inclusion of RHI (option 2)

	IRR (25 years)	IRR (40 years)	NPV (25 years)	NPV (40 years)
Option 2				
Without RHI (base case)	0.39%	3.53%	-£3,163,818	-£185,243
With RHI, 20 years	3.60%	5.46%	£602,345	£3,708,215

For Option 5A and 5B it has been assumed that RHI will be rewarded for the first 20 years of the ground source heat pump operation. However, it is uncertain whether RHI will continue to be available up to the network operation date. Sensitivity analysis has therefore been run to model option 5A and 5B without RHI support, with results shown in Table 9-12.

Evidently on current cost assumptions the inclusion of GSHP at the LCH site is dependent on RHI savings. However, the instance of RHI removal for GSHP would perhaps suggest that significant reductions in the capital cost of this technology, so much so that government support is no longer required.

Table 9-12 IRR and NPV sensitivity: exclusion of RHI (option 5A and 5B)

	IRR (25 years)	IRR (40 years)	NPV (25 years)	NPV (40 years)
Option 5A				
With RHI, 20 years (base case)	5.44%	6.95%	£3,085,375	£6,889,490
Without RHI	-6.54%	2.02%	-£7,261,279	-£3,457,164
Option 5B				
With RHI, 20 years (base case)	6.01%	7.44%	£3,811,690	£7,826,138
Without RHI	-4.28%	2.58%	-£6,158,053	-£2,143,605

9.4.3 HNIP funding sensitivity

Scenarios where the CAPEX is reduced are equivalent to securing capital grant funding for the project. UK Government schemes, such as the HNIP funding stream, are available for LBS to apply to in order to fund a portion of the DH networks. One of the pre-requisites of this scheme is that over 50% of the heat in the network is met through renewable means, or 75% of heat is met via CHP. This requirement would be met for each network proposed in this report if the assumptions detailed are achieved. See section 16 for further information in relation HNIP.

The effect of securing government funding has been analysed explicitly in Figure 9-1. For all options apart from Option 5A, funding levels in increments of £1million are compared to the base case. However, as HNIP funding cannot be awarded to a scheme receiving RHI support, the values for Option 5A exclude RHI. For the London Cancer Hub, only Scenario A is shown, however a similar trend is seen for Scenario B.

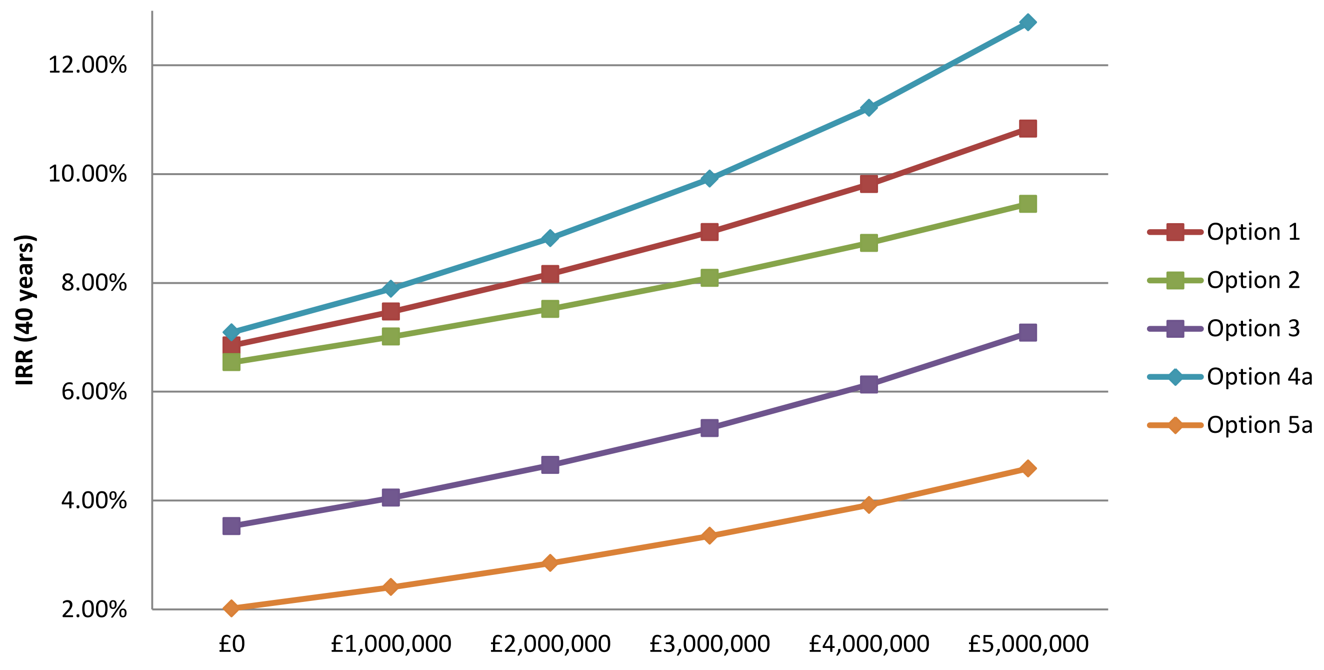


Figure 9-1 IRR sensitivity: funding level

It is clear that as the funding becomes an increasing proportion of the capital costs the rate of return increase accelerates. At this stage however, the probability of securing funding for each DH option is unknown and therefore cannot be relied upon.

Interestingly, for Options 5A/B receiving RHI support is more significant on the scheme's financial viability than HNIP funding.

9.5 TEM discussion

Seven network options have been analysed to assess their respective financial and economic outlook. This section will first compare the three options for Sutton Town Centre, followed by the four options modelled for the London Cancer Hub.

9.5.1 TEM result discussion for STC

The optimal thermal load for Option 1 (gas-fired CHP) is larger than the EfW and ASHP alternatives, at 19,338 MWh per annum. Due to the significant revenue streams associated with both heat and electricity sales for CHP a larger network is desirable. In the EfW case, the size of the network is constrained by the peak capacity that will be available from the Viridor ERF, currently identified at 15 MW. Hence the proposed network size, with a peak thermal load of 13.4 MW is nearing this limit. Option 3 has the smallest thermal load; heat pump technology is relatively expensive and is limited by the nature and temperature of the heat source. Lower efficiencies in the winter months are likely to drive down the performance of this solution.

Option 2 consumes considerably less gas than the other options. This is due to the fact that 90% of the heat is imported from the Viridor ERF. As a result, the lifetime carbon savings associated with this solution are significantly higher than the other options. Option 3, a central high temperature ASHP, also delivers carbon savings above the counterfactual. By having HPs in parallel with top-up boilers, rather than in series, the thermal load delivered from the HPs is less constrained. A central solution also sees a more diversified load and can be sized accordingly. High temperature ASHP's are less appropriate for an individual building solution due to the heightened safety measures associated with the use of ammonia refrigerant.

Option 2 has the highest CAPEX, mainly due to the expensive pipework involved with pumping heat from the Beddington to STC. On the other hand, savings are made in the energy centre as less heat generation plant needs to be installed. Additionally, the OPEX expected for this option is the lowest. Waste heat is relatively cheap to purchase, especially compared to electricity. Per kW, the ASHPs in Option 3 are particularly expensive. However, as the thermal demand addressed in Option 3 is significantly smaller, this option requires the lowest CAPEX outlay.

Due to its high associated revenue streams, Option 1 has the shortest payback period, at 10.5 years. Despite its high CAPEX, Option 2 has a significantly shorter payback than Option 3, at 12.6 years compared to 16.4 years for the latter.

Unsurprisingly, option 1 is the most attractive scenario from an economic perspective. CHP is a mature technology with a strong financial case. For STC, at 40 year assessment, gas CHP can offer an IRR close to 7%, with a NPV of over £7 million. However, the carbon and air quality case for gas-fired CHP is less favourable than the other options.

Option 2 is a good alternative to gas-fired CHP. The 40 year assessment shows an IRR of 6.5%, and an NPV of £9 million, helped by the considerable carbon savings associated with the use of waste heat. This option is also a good candidate for government funding. With HNIP support, the IRR of Option 2 could reach up to 9.5%, as shown in Figure 9-1.

The financial case for Option 3 is weak; the 40 year assessment shoes an IRR of only 3.5%, with a negative NPV. The revenue streams for this solution are not important enough to recuperate the capital outlay. Strong government support, through either upfront funding or RHI incentive would be necessary if this option is to be considered.

Sensitivity analysis showed that even a 5% change in capital cost for each STC option could have a significant financial impact, again highlighting the importance of securing funding. Option 1 is particularly sensitive to a change in fuel price, with a 5% rise in gas price resulting in a 0.31% decrease in IRR.

9.5.2 TEM result discussion for LCH

Two scenarios have been considered for the London Cancer Hub, with an option of gas-fired CHP and GSHP in each case. Due to the condensed nature of the site it would be advisable to connect all future developments to the DH network, with the exclusion of the Wave 3 commercial buildings. Therefore the thermal load for all options is relatively high, and depends on the chosen hospital scenario: a co-location or an estate development of the Royal Marsden.

As the plan of the LCH progresses, exact locations of buildings will help with updating the measured pipework route, currently estimated at just over 1.5 km.

For options 4A and 4B, CHP engines have been sized to ensure 75% of the thermal load is met via this technology. This entails CHP thermal capacities of 4.2MW and 3.4 MW respectively. GSHP sizing for options 5A and 5B is explained in detail in Appendix M.

Options 5A/B show that the GSHP solution enables considerable carbon savings over the 40 year assessment period. This is in stark contrast to options 4A/B, for which carbon emissions are well in excess of the counterfactual case, thanks to the large gas consumption associated with combustion technologies.

When comparing the CAPEX involved with CHP to the GSHP solution there is little aggregate difference. Although GSHP technology has a higher upfront cost per kW than CHP, the advised capacity installed for GSHP is significantly smaller. As the network length required for the LCH site is a lot smaller than for STC, total capital costs for the LCH options are generally lower, around £14 million.

Options 4A/B, with CHPs ability to sell both heat and power enables higher revenue streams than their GSHP counterpart. This results in slightly shorter payback periods around the 10 year mark. Importantly, GSHP revenue streams are boosted by the RHI benefit for the first 20 years of operation. Without this support the financial viability of GSHP disintegrates.

Economically, all LCH options show a similar performance, with 40 year IRRs around 7%. Option 5B has a slightly higher IRR that 5A. This is due to scenario B have a smaller thermal load, causing a lower capital outlay, as well as having a higher percentage of heat demand met by GSHP output, which means greater carbon savings.

Sensitivity analysis shows that for options 4A/B selling electricity via private wire could have an appreciable positive impact on the project finances. Indeed, for option 4A, selling power directly to the buildings connected to the LCH network, rather than selling wholesale, could increase the 40 year IRR by over 2.5%. As the LCH site is dominated by large commercial customers this is more suitable for private wire than STC, and hence in this case private wire should be further explored if a CHP option is taken forward.

9.6 TEM Conclusion

For the STC network, the techno-economical modelling revealed that Option 1 gas-fired CHP and Option 2 EfW are the most viable. Albeit there is a trade-off between these two options with gas-fired CHP showing the better financial return and EfW the much greater carbon savings. In both cases, securing a form of funding, such as HNIP, would be advisable.

Both Option 4a/b gas-fired CHP and Option 5a/b GSHP for the LCH showed similar economic performance, with 40 year IRRs around 7%. GSHPs enable considerable carbon savings to be made, which is not the case for gas-fired CHP. However, when examining the impact of government funding, Option 2 becomes less viable as it would have to forego RHI support in order to receive this. Importantly, RHI support is only confirmed for installations completed and commissioned before 2021, and after March 2021 this subsidy may cease to exist. This would have significant financial implications for Option 5a/b, unless another form of support is established.

10. Planning Review

The Sutton Local Plan[15] will continue to require new developments to meet a 35% on-site CO2 emission reduction from Part L 2013, in line with the GLA's London Plan. Major new domestic developments will also be required to meet the 'zero carbon homes' target (for regulated emissions only) which can be met through payment into an offset fund. The draft new London Plan[16] proposes this payment to be set at £95 per tonne of CO_2 emissions for a period of 30 years, This is an increase from £60 per tonne for 30 years, as currently required by the current London Plan (2016 version). For Sutton, Local Plan Policy 31 and part 1 of the council's Technical Note for Developers, adopted in June 2018, requires payment of carbon offset contributions prior to commencement.

The London Plan Policy 5.6 is also relevant to the Energy Masterplan as it promotes connection of new developments to district heating networks. The draft new London Plan policy SI3 also retains connection to district heating as the top priority under the Mayor's Heating Hierarchy. However, policy position has shifted away from the use of CHPs which are at the bottom of the heat hierarchy, above ultra-low NO_x gas boilers. Policy SI3 states that CHP systems should be designed to ensure that there is no significant impact on local air quality. In addition, the Local Plan currently requires, through Schedule 10.A, that major developments within 500m of a proposed network should commit to connecting. It also requires developments within close proximity to existing or proposed district heat networks to investigate connection. Therefore, the ability of new development connection opportunities, as identified within the Sutton Town Centre and London Cancer Hub Energy Masterplan, to meet local CO_2 emission reduction targets will largely depend on the performance of local District Heating Networks.

This section of the report investigates whether the CO_2 emission targets, as defined in the LB of Sutton's emerging Local Plan and in the GLA's draft new London Plan, could be deliverable through connection to each of the heat network options assessed in this report. Appendix G summarises the key national and local policies relating to reductions in CO_2 emissions and the development of district heat networks to provide further contextual background.

10.1 Network Performance

The following table outlines the assumptions for each of the heat network options identified as part of this study. The performance of the networks will be compared against the counterfactual case identified in Section 11.3.

Table 10-1 Technology split and heat loss assumption for each of the network options

Option	Technology	Proportion of heat from each technology	Primary Losses	Secondary Losses
Option 1 – CHP	Gas Boilers	24.1%	10.0%	18.4%
	CHP	75.9%		
Option 2 – EfW	Gas Boilers	10.0%	10.0%	18.2%
	EfW	90.0%		
Option 3 - ASHP	Gas Boilers	38.1%	10.0%	17.3%
	ASHP	61.9%		
Option 4A - CHP	Gas Boilers	24.3%	1.2%	10.0%
	CHP	75.7%		
Option 4B - CHP	Gas Boilers	24.7%	1.6%	10.0%
	CHP	75.3%		
Option 5A - GSHP	Gas Boilers	40.1%	1.2%	10.0%
	GSHP	59.9%		
Option 5B - GSHP	Gas Boilers	30.1%	1.6%	10.0%
	GSHP	69.9%		
Counterfactual option - communal ASHP	Gas Boilers	50.0%	0.0%	10.0%
	ASHP	50.0%		

Please note the losses shown in the above table for STC options are higher than what would be expected with CP1. This is due to AECOMs experience with losses in large residential developments.

Table 15-1 outlines the anticipated heat splits and network losses at full build out. The analysis of CO_2 performance is based on the anticipated full build out and building connections for each of the network options identified. In reality each of the network options may take time to reach these heat splits as the networks build out and development comes forward for occupation.

The performance of the above network options will depend on the CO_2 intensity of fuels to generate heat or electricity. In 2016, the BRE consulted on proposed changes to the current SAP calculation method, including setting out a projection of the expected average grid electricity carbon emissions factors for electricity. This showed a rapid decline in expected grid emissions for electricity which, if adopted into future updates to SAP and Part L calculations, would have a substantial impact on the calculated emissions associated with the different heat generating technology options.

The heat demand map identifies new development in the STC and LCH that will come forward up to 2035. It is, therefore, important to consider the impact of grid decarbonisation on the ability of developments to meet planning CO_2 emission targets. In order to estimate the impact of the expected grid decarbonisation, the analysis presented here assumed that national calculation methods would be updated to reflect projected reductions in grid electricity emission factors as set out in the BRE's SAP 2016 consultation document[17]. The following table outlines the projected CO_2 emission factors for grid electricity and gas as proposed in the SAP consultation, and which have been used in this analysis.

Table 10-2 Projected CO2 SAP emission factors

	2012-2015 SAP Emissions (currently in use)	2016-2018 SAP Emissions	2019-2021 SAP Emissions	2022-2024 SAP Emissions	2025-2027 SAP Emissions
Grid Electricity (kgCO2/kWh)	0.519	0.399	0.302	0.229	0.183
Gas[18] (kgCO2/kWh)	0.216	0.208	0.208	0.208	0.208

Within SAP there is a specific CO_2 emission factor for waste heat from power stations, which under SAP 2012 is currently 0.058 $kgCO_2/kWh$. The CO_2 emission factor is estimated based on the decrease in electricity generation when waste heat from a power station is recovered for use in district heating networks; this relationship of power loss as a function of recovered heat is known as the Z ratio. The current 2012-2015 SAP emission factor is based on the assumption that there will be a 1kW reduction in electricity output for each 9kW of heat generated, which is equivalent to a Z ratio of 9. Therefore the emission factor for waste heat is 1/9th of the emission factor for grid generated electricity.

The Energy from Waste facility at Beddington is understood to have a Z ratio of 7. For the purposes of this analysis we have assumed a Z factor of 7 for estimating the CO_2 emission performance of the EfW facility at Beddington.

[15] Sutton Plan, February 2018
[16] Drat London Plan, December 2017

[17] The Government's Standard Assessment Procedure for Energy Rating of Dwellings. DRAFT 2016 edition for consultation. BRE
[18] The SAP consultation provides an estimate for the gas grid up until the period of 2016-2018. For subsequent period the same figure has been used.

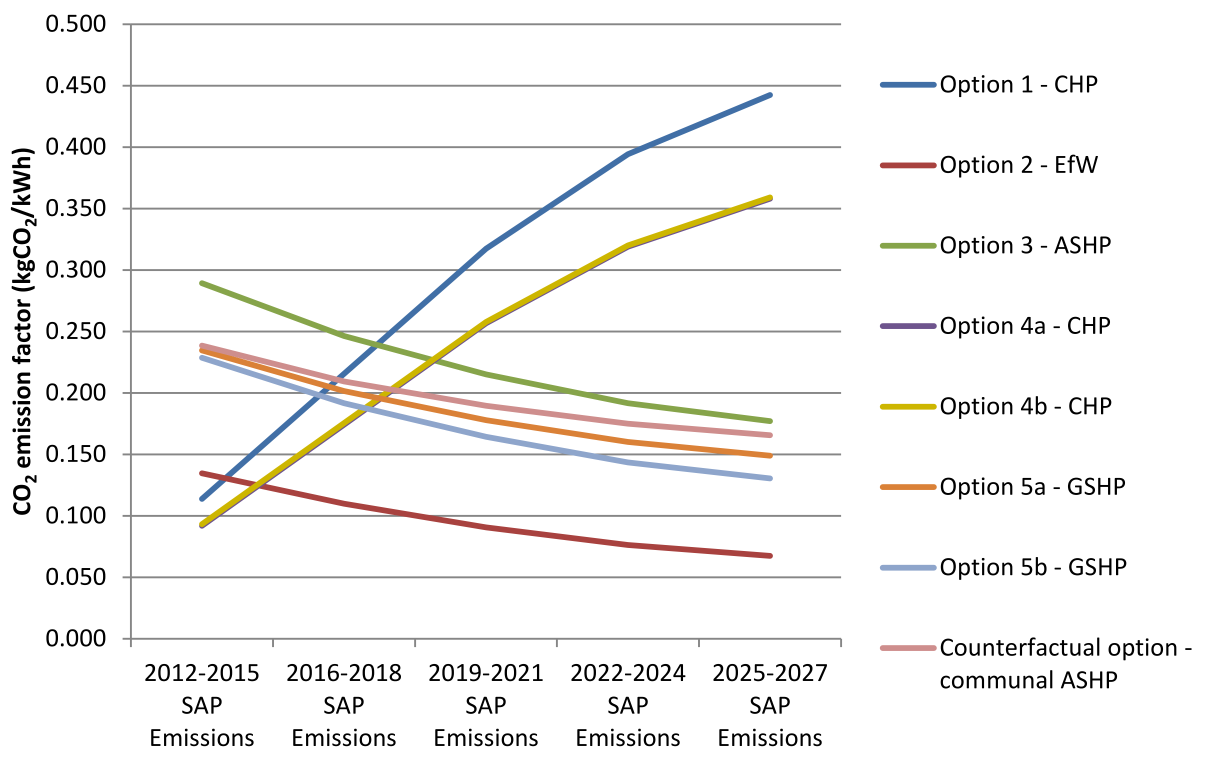


Figure 10-1 Estimate carbon intensity of each network option

EfW (Option 2) has the lowest carbon intensity of the options assessed. The figure also shows that over time the CO_2 intensity of the CHP options (1, 4a & 4b) increases significantly over time. This is primarily due to the decarbonisation of grid electricity which CHP offsets through generation. Conversely the CO_2 intensity of heat pump options (3, 5a, 5b & counterfactual) improves, due to the reduction in CO_2 intensity of the electricity used to power the heat pumps. However, under current Part L (which uses SAP 2012-2015 emission factors) the performance of the heat pump options would be worse than a gas boiler. Therefore, unless the Government updates Part L in line with the SAP 2016 consultation emission factors, there is a risk that developments that utilise heat pumps will not be able to meet Part L compliance.

Figure 10-1, Figure 10-2 and Figure 10-3 appear in Appendix T for clarity.

10.2 Development performance

This section of the report assesses the potential Part L CO_2 emission savings that are achievable through the connection of new developments to the heat network options identified in this study.

The analysis utilised SAP-compliant software to calculate the performance of residential development. In order to estimate the CO_2 emission performance of non-domestic development, Part L 2013 benchmarks from AECOM's portfolio of relevant projects have been used. Performance was measured against the carbon emissions targets required by Building Regulations and London Plan carbon policy targets and assumed that carbon factors are updated in line with the projections in the SAP 2016 consultation.

In line with the Local Plan and GLA Energy Hierarchy new developments should also include measures to reduce CO_2 through energy efficiency and building integrated low carbon or renewable technology. Therefore, in order to understand the potential for meeting the on-site 35% CO_2 emission improvement over Part L 2013, an estimate of savings for energy efficiency measures and building integrated renewable technology has been made. Assumptions on energy efficiency improvements have also been made in line with the new draft London Plan targets of Policy SI2, which requires that developments aim for the following savings over Part L 2013:

- 10% improvement for domestic development
- 15% improvement for non-domestic development

It has also been assumed that an element of PV will be incorporated in to the design in line with the assumptions in Appendix G.

Improvements in CO_2 emission performance is measured against the Part L Target Emission Rate (TER). In line with current GLA Guidance on Preparing Energy Statements for Planning Applications[19], the carbon savings for the network options have been compared against a case where buildings are assumed to be supplied by communal gas boilers.

At this stage it is not known how or if the TER will be updated in future. Government has announced in its Green Growth strategy that it will be consulting on updating Part L of the Building Regulations in summer 2018, which implies the potential for Building Regulations to be updated in 2019. In order to fully account for the changes in CO_2 emission factors, the TER has also been adapted to reflect the SAP 2016 consultation; this approach is in line with the GLA's evidence base for assessing the impact of changes in CO_2 emission factors.

10.2.1 Sutton Town Centre

To illustrate the potential performance of the Sutton Town Centre network options a 'standard' development representing a 155 domestic unit block has been used. The Figure 10-2 outlines the estimated comparative CO_2 emission improvement through each of the network options identified.

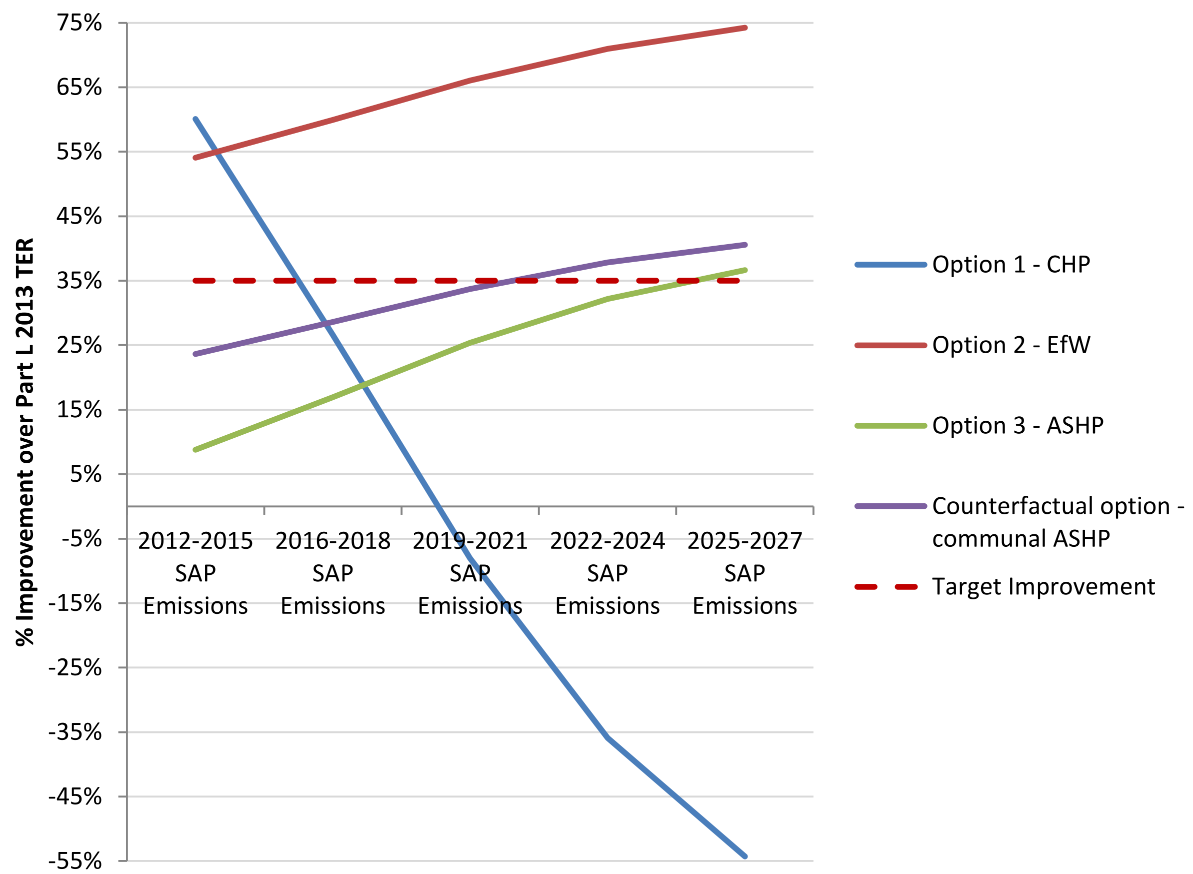


Figure 10-2 Estimate of CO_2 emission improvements for STC

EfW (Option 2) consistently exceeds the 35% on-site improvement target. The improvement against the Part L target TER over the years assessed ranges from approximately 55% to 71%. This would significantly reduce the carbon reductions required to be met via financial contributions when compared with the counterfactual option. The counterfactual option is not anticipated to be able to meet the 35% target until 2022. However, the counterfactual option does perform better in carbon terms than both ASHP (Option 3) and CHP (Option 1) over the course of the years assessed.

[19] Energy Planning: Greater London Authority guidance on preparing energy assessments (March 2016)

The above figure shows that the effectiveness of CHP to save CO_2 diminishes over time and that from 2016 onwards the London Plan 35% improvement target may not be met. Furthermore, the analysis suggests that, by the early 2020s, the CHP option would not meet the minimum carbon performance required to meet Building Regulations Part L targets.

10.2.2 London Cancer Hub

Development in the London Cancer Hub area is predominately non-domestic, such as hospital/research facilities and office space. Offices development has been used to estimate the potential savings of the LCH network options. Offices tend to have high electrical demand and will have lower space heating/hot water demand than hospitals, which will limit the effectiveness of low carbon heat on overall savings. It is therefore considered a conservative building to assess for the LCH masterplan area.

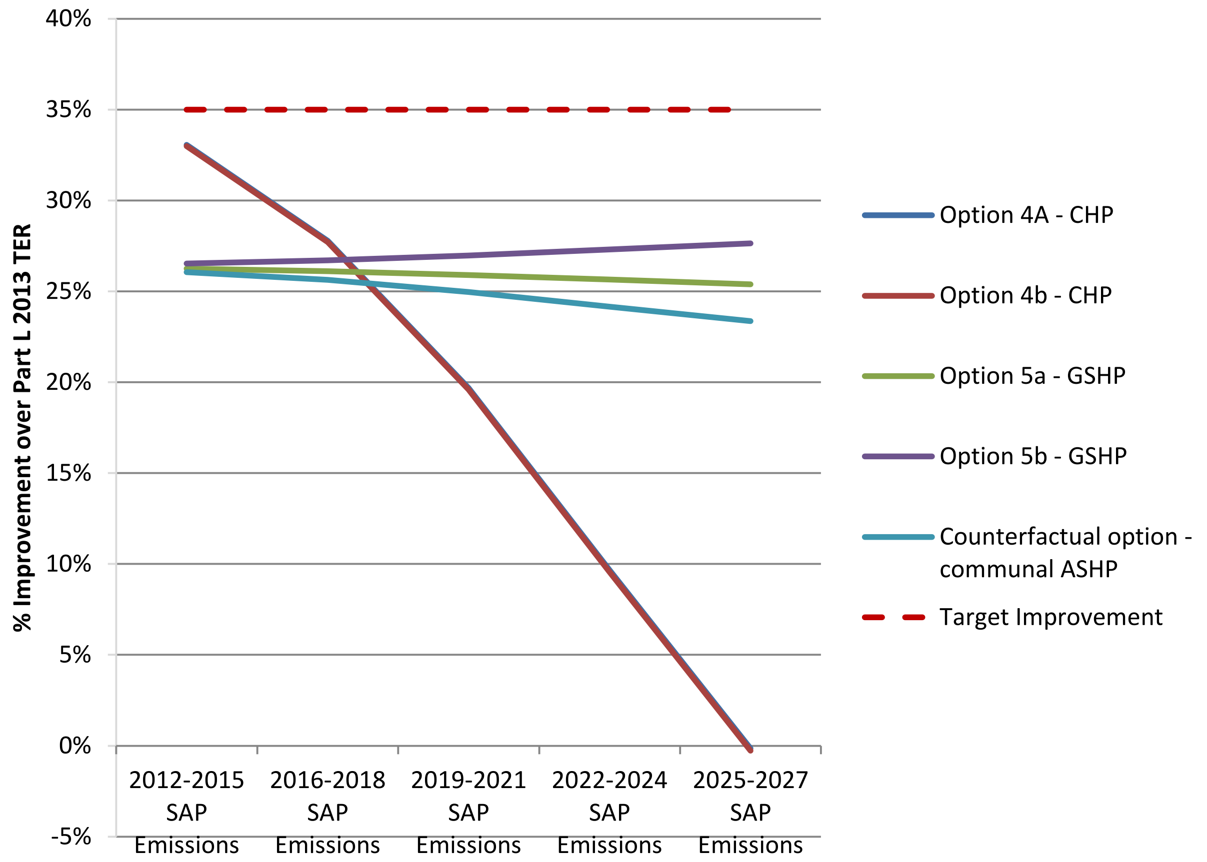


Figure 10-3 Estimate of CO_2 emission improvements for LCH

The analysis indicates that none of the Options identified would enable development to meet the 35% improvement target for any of the years tested. This is not all together unexpected as offices generally have a low proportion of heating/hot water demand in comparison to electrical demand, such as lighting and cooling. Therefore, the effectiveness of low carbon heat is reduced in comparison to the savings that are expected for a heat led development, such as domestic development.

With the exception of CHP the results do, however, indicate that each of the network options assessed perform better in carbon terms than the counterfactual communal ASHP. Option 5b performs strongest over the course of the years tested. Option 5a and the counterfactual slightly decrease in performance as the grid decarbonises. This is due to the decarbonisation of the TER high electricity demand eclipsing the improvement in the network.

The CHP options (4a and 4b) are almost identical in performance but begin to perform poorly after 2019. By the late 2020s, it is expected that CHP-led solutions will fail UK Building Regulations targets.

10.2.3 Discussion

The results show that CHP led networks perform poorly in terms of carbon savings and over their lifetime any future developments required to use the proposed future SAP carbon factors would struggle to comply with London Plan carbon reduction targets.

For heat pump led schemes either ASHP or GSHP show an improved carbon performance over time. This is due to the expected decarbonisation of the grid. As heat pumps are powered by electricity as the grid decarbonises so does the heat output. For STC, the ammonia based ASHP does not perform better than the counterfactual, however the heat network would offer lower cost heat compared to a plot by plot solution. The EfW waste option shows the best carbon performance and would offer compelling argument for connecting to the network.

For LCH, the GSHP offers carbon savings compared to the CHP led solution and the ASHP counterfactual option.

10.2.4 Next steps

This section of the report sets out recommendations for London Borough of Sutton which are aimed at ensuring that connection opportunities are maximised through the planning application process for new development, including recommendations on developing LBS's corporate strategy and preparing guidance for new development planning applications.

Guidance for developers

A key factor when developing heat networks is to ensure that sufficient information is provided to developers at an early stage in order to make the most of all potential connection opportunities. It is therefore recommended that a document is developed by the London Borough of Sutton to promote the network and also to set out the requirements for connection for developments in the area. This could, for example, be in the form of a Supplementary Planning Document or Supplementary Planning Guidance. Examples in London include Islington's Guidelines for connecting to heat networks[20] and Enfield's Decentralised Energy Network Technical Specification Supplementary Planning Document[21]. These documents should refer to and build upon the London Heat Network Manual[22].

It is recommended that the planning document includes:

- A map of the proposed pipe route so that developers can gain an understanding of how their plot fits into the wider network proposals
- Connection requirements for new development applications based on their location to the proposed network, for instance based on development distance from the proposed pipe route
- Technical requirements for applicants connecting to the network, for instance temperature regimes, location of connection points to the site boundary, spatial requirements for substations etc.
- Arrangements for temporary measures if connection is not immediately possible due to timescales of both proposed developments and the network build out in order to maximise the connections through new development. For example, if connection is likely within a reasonable time period from completion of a new development site a planning obligation could be developed that would require connection at a later date.
- The carbon intensity of the DH network and guidance on how applicants should be calculated for the purposes of estimating CO_2 emission improvements against planning policy targets. The carbon intensity of the network would need to be regularly reviewed to account for potential changes in Government or GLA methodologies.

[20] https://www.islington.gov.uk///~/media/sharepoint-lists/public-records/energyservices/information/guidance/20152016/20160310connectionsguidepart1
[21] https://new.enfield.gov.uk/services/planning/planning-policy/supplementary-planning-documents/planning-policy-information-den-technical-specification-spd.pdf
[22] https://www.london.gov.uk/sites/default/files/london_heat_map_manual_2014.pdf

Corporate Strategy

To support the development of heat networks it is recommended that LBS take the following steps:

- Promote the DH network as a priority project within LBS and seek organisational buy in from LBS as the success of a DH network will require highest levels of the LBS management. (Not sure this one really fits in the planning section)
- Ensure a joined-up approach to implementing the DH network across departments within LBS, particularly between the network delivery team and planning team:
    - The LBS energy officer (or equivalent) should be well-informed on the development of the network so that the latest information is available when reviewing energy strategies of new planning applications, for instance identifying whether connection of a new development site is considered significant importance.
    - Planning case officer route map for developments – A step by step guide of what they need to do to support connection to the DH network especially during pre-application stage
- Develop lessons learned from other councils and Hackbridge site to support implementation of network
- Any council owned development sites that are being brought forward in partnership with private sector should be required to connect to the network e.g. civic centre, car parks, housing redevelopments. This needs to be built into the development agreement.

The following three chapters outline complimentary analysis undertaken in parallel with the Energy Mapping and Masterplanning study, specifically a review of local air quality, the opportunity for solar PV and the opportunity and risks presented by local infrastructure works.

11. Air Quality Review

A high level air quality review was carried out on the various options for both the STC and LCH sites. The full report is shown in Appendix P. This review considered the base case for Sutton through consultation with the LBS air quality officer. Air quality within Sutton is influenced by emissions from significant numbers of vehicles utilising the local road network. Parts of the Borough are characterised by relatively high levels of car ownership, and consequently high dependency on private car transport. Other contributors to local air pollution include point sources of combustion-related emissions such as domestic and commercial boilers and CHPs, as well as various industrial sources in the northeast of the Borough. On the basis of excessive ambient concentrations (above national Air Quality Objectives) of NO_2 and PM_{10}, portions of the Borough were declared an Air Quality Management Area (AQMA) in March 2001, and were subsequently updated in 2004 and 2009. In June 2013, LBS declared the entire Borough an AQMA in an effort to tackle actual/likely exceedances of both the NO_2 and PM_{10} objectives. Sutton Town Centre itself has been designated an 'Air Quality Focus Area' by the Mayor.

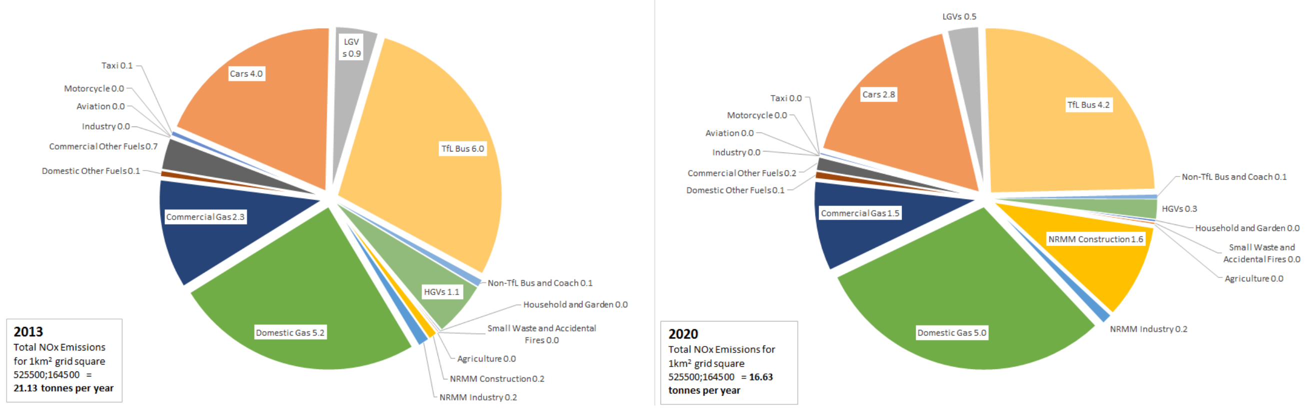


Figure 11-1. STC Site - Local Sources of NOx (tonnes per annum) – LAEI Data for 2013 and 2020 (Greater London Authority, 2017)

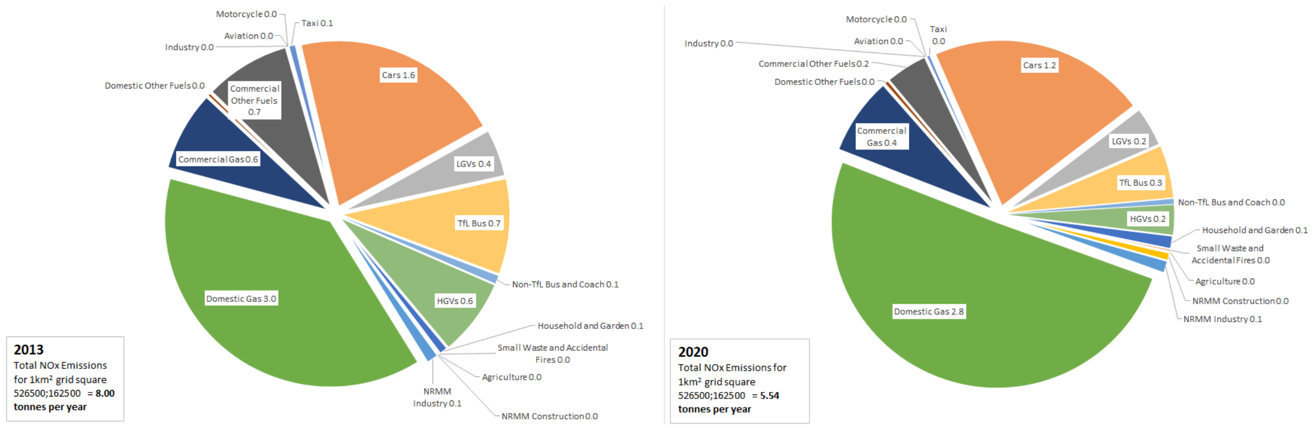


Figure 11-2. LCH Site - Local Sources of NOx (tonnes per annum) – LAEI Data for 2013 and 2020 (Greater London Authority, 2017)

The air quality review found that in the current policy context, gas-fired CHP led proposals would appear to require two-stages of regulatory authorisations in order to proceed; namely local planning permission and a nationally-administered environmental permit. Based on the review of information undertaken as part of this study, no fundamental constraints in terms of air quality were identified which would prevent the proposals being brought forward to planning.

Further study shall be required to determine the suitability and ultimate acceptability of the proposals and subsequently secure the required legal permissions. However, it should be noted that the draft London plan which is expected to come into force this year or early next year states in S13 Energy Infrastructure "CHP and ultra-low NOx gas boiler communal or district heating systems should be designed to ensure that there is no significant impact on local air quality." It is possible that in the time frames envisaged for the build out of the network that the development of CHP will no longer be possible due to air quality concerns.

In the event that either energy centre relies on ASHP, GSHP or the connection to the Beddington ERF as the primary source of heat (and consequently the need for on-site CHP is avoided), it is considered unlikely that an environmental permit would be required for this site (as the MCPD focuses on combustion plant which generate electricity). The envisaged scope for future air quality study and key technical considerations for project designs are outlined in Appendix P.

12. Solar PV Review

The current plans for the STC and LCH sites present an opportunity to include roof mounted Solar PV. The inclusion of PV in new developments in London is increasingly common as it contributes to meeting GLA carbon reduction targets and compliance with UK Building Regulations Part L.

Roof space is expected to be limited in relation to the floor area due to the anticipated density of buildings and building height. Furthermore, there are many demands for the available roof space in modern commercial and residential developments. These demands include roof mounted plant, telecommunications equipment, flue vents and other ventilation shafts, building maintenance units and the associated rail tracks, green roofs, brown roofs and sedum roofs. In addition, roof areas are increasing been seen as new amenity areas for building users through the provision of roof terraces as a communal space or as private spaces for penthouse apartments. This consideration has meant that have we made several assumptions on the available roof space.

A detailed description of the assumptions is provided in Appendix G along with the building list and the PV details for each site.

Key assumptions:

- **30% of roof area can be utilised for PV**
- **PV output of 0.166Wp/m^2 of panel area**

12.1 Solar PV for STC

For STC, if the 45 identified STC sites were to have 30% of their roof area covered in PV they would be expected to have a total installed capacity of around 4MW and an annual output of around 3,441MWh. Based on the current grid carbon intensity of 0.519kgCO_2/kWh this represents a saving of around 1,785 tonnes of CO_2 per year. The national electricity grid is expected to decarbonise over the coming years. It is expected that in the next version of building regulations the carbon factor could be reduced to 0.398kgCO_2/kWh[23]. At this lower carbon factor, the carbon savings would be around 1,369 tonnes of CO_2 per year.

12.2 Solar PV for LCH

In the LCH site, it has been assumed that the average building will be 5 stores in height with 30% of the roof area covered in PV. Based on these assumptions it is estimated that that there could be space for the installation of around 2.5MW PV with an annual output of around 2,111MWh. The expected carbon savings with the current Part L carbon factor of 0.519kgCO_2/kWh would be around 1,096 tonnes of CO_2 per year and with the reduced carbon factor of 0.398kgCO_2/kWh this would be around 840 tonnes of CO_2 per year.

As per current and anticipated draft new London Plan policies, it could be expected that at least some of the PV opportunities identified above would be brought forward as part of the build out of the STC and LCH sites.

[23] Draft SAP 2016 for consultation

13. Sutton Tram Extension and Gyratory Works

The STC masterplan envisages the Extension of the South London Tram into Sutton High Street; this is included as a transport priority in the upcoming London Plan. In addition LBS are in the early stages of examining option for changes to the gyratory around Sutton High Street. Both of these infrastructure projects present opportunities and risks to the development of a heat network and so are discussed here in the context of a proposed heat network in Sutton Town Centre.

13.1 Tramlink extension

Figure 13-1 shows an option for the proposed Tramlink extension overlaid on the proposed DH network route for Sutton Town Centre. As can be seen the proposed tram route overlays the DH network in several places, including much of the pipework route down Throwley Way, a portion of St Nicholas Way, as well as on the A232. This would present a risk to the development of the heat network pipework route as it would be desirable to maintain a distance of several meters between the buried pipework and the tracks for the tram. The maintenance requirements for network pipe work is low, however they would require replacement at the end of their operational life time. Also, they may require reactive maintenance if a fault were to occur during normal operation. This would require access to the network and may require excavation, similar, to a water main. This can be quite invasive and by maintaining a distance between the network and a tram line would reduce the risk of the tram service being rusticated or shut down during the repair period.

The dashed line shown in Figure 13-1 is an alternative pipework route that follows the high street, allowing buildings on Throwley Way to be served. This would require the high street to undergo significant works to allow the laying of the DH network pipe work. In addition, the pipe work would need to cross under the track in a few locations and this would need to be considered as part of any tram works. The site tour identified several access points and manholes e.g. BT and Thames water. These services would require detailed coordination if this alterative option was selected as these would represent a significant barrier to the development of the network.

The development of the tram network would present an opportunity for the sale of renewable electricity generated by the STC scheme (via CHP) to Transport for London (TFL) to power the network. To do this would require the DH scheme that is brought forward to be capable of generating and exporting electricity. Of the options considered for STC only the CHP led scheme would be capable of doing this. During the techno-economic analysis an option for the export and sale of electricity to the GLA via its Licence Lite scheme was considered, the details of which are described in Appendix F.5. This Licence Lite option would involve the GLA purchasing electricity from the CHP system via the grid and TFL using the purchased electricity to meet some of its electricity requirements. This would allow the tram to be powered by energy generated in Sutton.

13.2 Gyratory works

The current STC masterplan vison for the gyratory is for it to be transformed into an urban boulevard that is a high quality pedestrian realm. Depending on the scope of the works to be undertaken during this transformation it is possible that there will be an opportunity to lay the pipework at the same time and/or allow for other services work to be done during this work such as the installation of broadband. This could present an opportunity for synergies across multiple infrastructure works but would require both the careful consideration of programme impacts and the detailed coordination of services and works. Any benefits or savings that could be achieved have not been included in any of the technical or financial works to date. This could be explored in further detail during any further work.

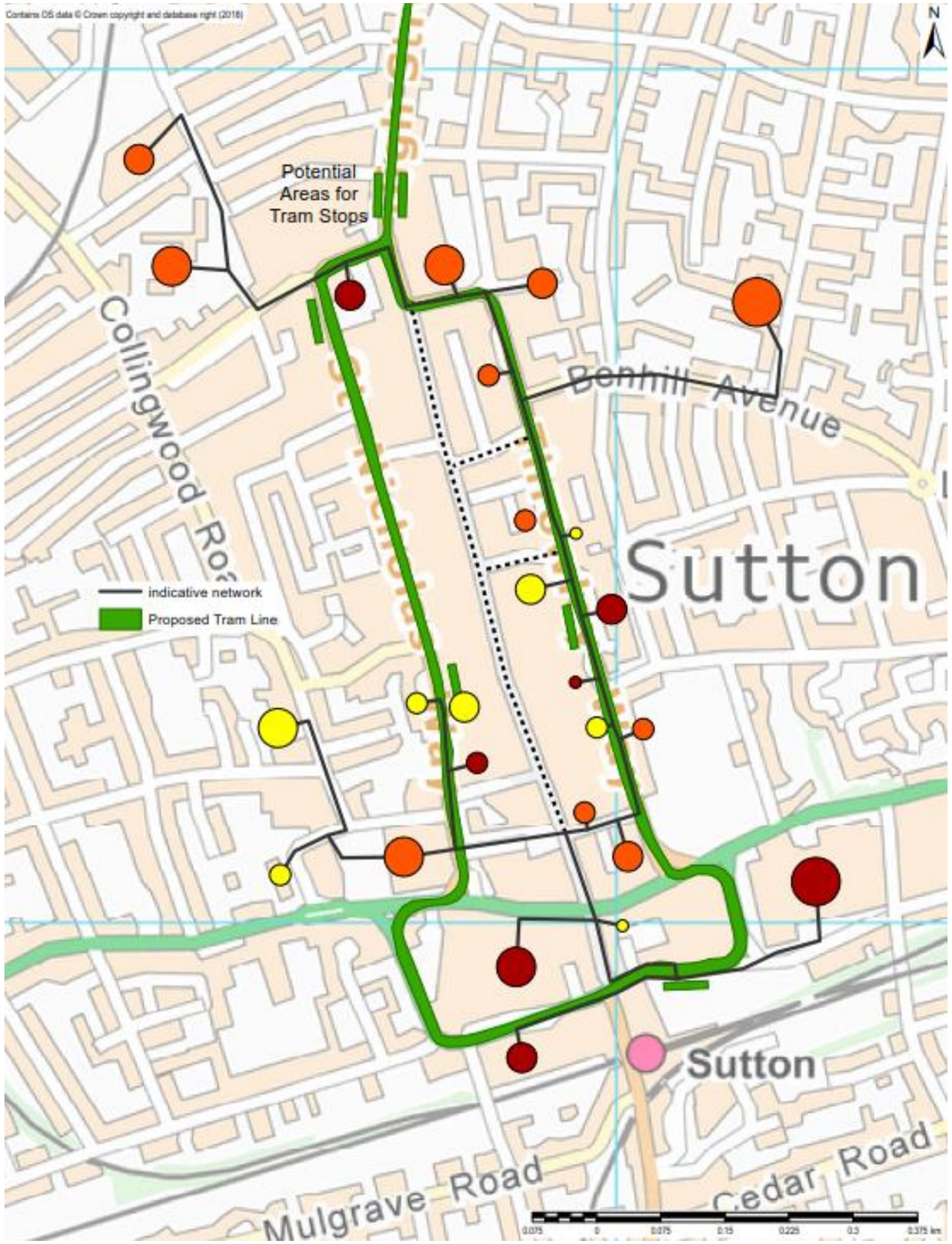


Figure 13-1 Sutton Tram Extension proposed route and overlaid proposed district heating network

14. Project Plan, risks and next steps

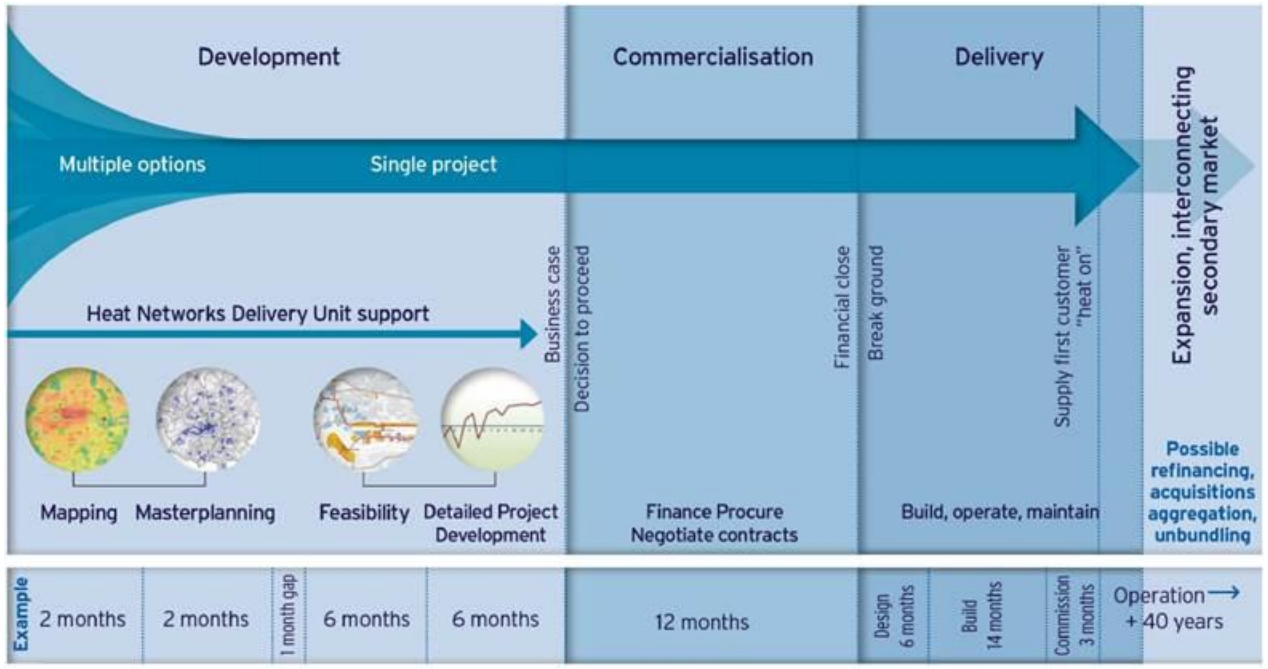
14.1 Project Plan

An outline project plan has been developed. This shows estimated start dates and stages for the various phases of the project, from the present Heat Mapping and Energy Masterplanning study, through to building connections. Table 14-1 and Table 14-2 present the outline project programmes for the STC and LCH sites respectively. Should Sutton decide to move forward with a feasibility study, it is important to start the process as soon as possible as there are many barriers and risks to overcome to ensure the success of the district heat network.

It has been assumed that next steps in terms of feasibility study, detailed design and commercialisation would be partially funded through the central government HNDU programme and the programmes are based on the HNDU development lifecycle. Other sources of funding such as the DEEP programme would also be suitable. Further information is provided in Section 14.2 about HNDU and HNIP funding options.

In addition to the project plans shown below, a route for the development of STC EFW supplied heat network has been prepared and is shown in section 14.5. The purpose of this route map is to demonstrate a route to deliver the beginning of a heat network for STC based on the EFW option.

Figure 14-1 below shows the typical expected heat network development lifecycle which the project plans are based on.



Typical heat network development project lifecycle (Source: DBEIS Heat Networks Delivery Unit)

Figure 14-1 Typical heat network development project lifecycle HNDU

Sutton Town Centre Project Plan

Table 14-1 STC project plan

	Start Date	End Date	Key output	Cost
LBS to review Report and select network option for further work	Q4 2018	Q1 2019	Option selection	-
Feasibility of selected option - secure HNDU funding and appoint consultant to carry out feasibility study and complete feasibility study.	Q2 2019	Q3 2019	Secure funding from the HNDU or other funding sources for feasibility study. Appoint consultant to carry out works. Carry out feasibility study Note time estimate is based on HNDU estimates.	£50k – £80k (HNDU suggested cost of stage). Possibility that funding will not be made available until start of next financial year.
Detailed Project Development	Q4 2019	Q1 2020	Detailed Project Development Timescale estimate is based on HNDU estimates.	£150k (HNDU suggested cost of stage). Could be significantly more subject to the scope of the selected project.
Commercialisation	Q1 2020	Q4 2020	Secure funding from HNDU or other funding sources for commercialisation study to explore potential commercial routes to delivery (e.g. ESCo procurement). Appoint consultant to carry out works. Project capital funding sources could include HNIP grants and loans, Public Works Loan Board or other sources of funding. Timescale estimate is based on HNDU estimates.	£200-400k (HNDU suggested cost of stage).
Pre-construction works design works	Q1 2021	Q1 2022	Detailed design of heat network including tender specification LBS to obtain capital funding	TBC subject to option selection.
Civic Centre Site construction including energy centre	Q1 2022	Q4 2025	Construction of Civic centre, the site identified for the energy centre.	-
Energy Centre	Q1 2022	Q4 2025	Construction of energy centre as part of the overall Civic	£15m-18m

	Start Date	End Date	Key output	Cost
			Centre site development. To include construction, fitting out and commissioning of energy centre plant and equipment.	
Lay pipe work	Q1 2023	Q4 2025	Construction of heat network.	
Heat on	Q1 2023	Q1 2026	Initial heat sales (see route map)	-
Remaining connections	Q1 2026	Q4 2030	Final build out of network (see route map)	Costs included above.

The costs outlined above are based on HNDU budget estimates and the results of techno economic modelling as discussed earlier in the report.
Construction times have been assumed based on the wider masterplan, to be confirmed during feasibility stage of the project.
Project programme assumes decisions are made in timely manner.

London Cancer Hub Project Plan **Table 14-2 LCH project plan**

	Start Date	End Date	Key output	Cost
LBS to Review Report and select option for further work	Q1 2019	Q1 2019	Option selection	-
Feasibility of selected option - secure HNDU funding and appoint consultant to carry out feasibility study and complete feasibility study.	Q2 2019	Q3 2019	Secure funding from the HNDU or other funding sources for feasibility study. Appoint consultant to carry out works. Carry out feasibility study Timescale estimate is based on HNDU estimates.	£50k – £80k (HNDU suggested cost of stage). Possibility that funding will not be made available until start of next financial year.
Detailed Project Development	Q4 2019	Q1 2020	Detailed Project Development Timescale estimate is based on HNDU estimates.	£150 (HNDU suggested cost of stage. Could be significantly more subject to project).
Commercialisation	Q2 2020	Q1 2021	Secure funding from HNDU or other funding sources for commercialisation study to explore potential commercial routes to delivery (e.g. ESCo procurement). Appoint consultant to carry out works.	£200-400k (HNDU suggested cost of stage).
			Project capital funding sources could include HNIP grants and loans, Public Works Loan Board or other sources of funding. Timescale estimate is based on HNDU estimates.	
Pre-construction works including obtaining project finance	Q2 2021	Q1 2022	Detailed design of heat network including tender specification LBS to obtain capital funding	TBC subject to option selection. £150k-£200k Likely sources of capital funding including HNIP and combination of loans from Public Works Loan Board.
LCH construction Inc. energy centre	Q2 2022	Q1 2026	Construction of LCH	-
Energy Centre	Q1 2022	Q4 2025	Construction of energy centre as part of the overall LCH build out. To include construction, fitting out and commissioning of energy centre.	£13.8m-£14.7m
Lay pipe work	Q1 2022	Q4 2025	Construction of heat network.	
Heat on	Q1 2026	Q1 2026	Initial heat sales	-
Remaining connections	Q1 2026	Q4 2035	Final build out of network	-

The costs outlined above are based on HNDU budget estimates and the results of techno-economic modelling as discussed earlier in the report.
Construction times have been assumed based on the wider masterplan, to be confirmed during feasibility stage of the project.
Project programme assumes decisions are made in timely manner.

14.2 Funding

This section describes the possible funding pathways LBS can explore to support the implementation of a district heating network in Sutton.

14.2.1 Heat Network Delivery Unit (HNDU)

The Heat Networks Delivery Unit provides grant funding and guidance to local authorities in England and Wales for heat network project development. Since its inception, HNDU has run 7 funding rounds – awarding £17 million in total – and is currently running Round 8. Over 200 unique projects have so far been supported across 140 local authorities. Further information is available at https://www.gov.uk/guidance/heat-networks-delivery-unit#overview.

If LBS were to consider moving to the feasibility stage for a selected DH network HNDU could be a possible source of funding. It can provide up to 67% of external costs, with the remaining to be borne by the council or other 3rd party sources of funding. Further details are available at https://www.gov.uk/guidance/heat-networks-delivery-unit#round-8. Sutton have been successful in HNDU applications in the past, receiving funding during rounds 1, 4 and 6 for a total of £158,962.

Round 8 funding will close on 31st December 2018. If the scheme is continued it is anticipated that Round 9 would open in early 2019.

Table 14-3 Project development stages supported by HNDU [24]

Phase	Detail
Heat mapping	Area-wide exploration, identification and prioritisation of heat network project opportunities
Energy masterplanning	Area-wide exploration, identification and prioritisation of heat network project opportunities
Feasibility study	Project specific - An increasingly detailed investigation of the technical feasibility, design, financial modelling, business modelling, customer contractual arrangements and delivery approach, up to business case
Detailed project development	Development of business/commercial model and financing options; development of outline business case (typically green book compliant depending on scheme size); development of detailed financial model; development of procurement strategy; further scheme design including development of proposed network route, network sizes, and customer connections, development of proposed energy centre solution and location; costing reviews to improve cost certainty; initial scoping and development of commercial agreements; soft market testing
Commercialisation	Reasonable legal costs such as in relation to developing customer commercial agreements, heat supply contracts, necessary land purchase, land access arrangements, etc.; further development of tariff structure for customer contracts; further development of financial model and business case and associated commercial advice costs where necessary. Potential for preparatory works depending on scheme needs, assessed on a case-by-case basis

14.2.2 GLA DEEP

This report has been funded by the Greater London Authority (GLA) Decentralised Energy Enabling Project (DEEP). DEEP was established through joint GLA and EU funding to provide public sector intervention and support to larger-scale decentralised energy (DE) projects in London. It is likely that the GLA deep programme would be a suitable source of funding to take the development of heat networks in Sutton to the next stage. Please see https://www.london.gov.uk/what-we-do/environment/energy/energy-supply for further information.

14.2.3 Heat Networks Investment Project (HNIP)

HNIP is a capital investment scheme designed to support development of good quality heat networks. It will seek to provide £320m of gap funding by 2021 with the aim of creating the conditions for a self-sustaining heat networks market that contributes to the decarbonisation of the UK energy system at lowest cost to the economy by 2050. The pilot scheme supported 9 projects with £24m of funding.

HNIP will now progress to the general scheme, which is anticipated to be launched in Autumn/Winter 2018. The scheme and its criteria are still being developed by the Department for Business, Energy & Industrial Strategy BEIS and their delivery partner, however minimum eligibility criteria have been released, which require the project:

- To be a heat network serving 2 or more buildings
- To be located in England and/or Wales
- To be connected to an eligible heat generation source (75% gas CHP or 50% renewable, recovered heat; or a combination of CHP plus renewable/recovered heat)
- To meet technical and customer requirements including Heat Trust (or equivalent) standards and Heat Network Metering and Billing Regulations.[25]

The final eligibility criteria are yet to be released by HNIP and are expected in early 2019. However, it is expected that the support on offer will take the form of grants between £0 and £5m, or loans between £25,000 and £10m. The loans will take the form of 25 year corporate loans or up to 3 year project loans.

The Corporate Loan would be provided to the credit worthy project sponsor and be:

- For up to 25 years
- Below market rates
- Fixed annuity repayment
- Principal repayment starts at operation
- Equal ranking with other lenders

The Project Loan would be lent to the project company and be nonrecourse. It would include a connection delay feature to help cash flow if offtake fails to materialise:

- Beyond operator's control
- Up to 3 years
- Subject to meeting a Debt Service Cover Ratio
- Within the first 10 years

Please see heatnetworks@beis.gov.uk for further information.

14.2.4 Private funding

Private funding is also an option for heat networks in cases where a project with an attract IRR is proposed. To attract private funding IRRs above 10% would typically need to be available. The heat network at Olympic Park in Stratford is an example of a private Energy Services Company (ESCO) funded heat network.

14.3 Risk

A risk register has been prepared and is provided in Appendix R. This identifies the risk, risk category, action champion, commentary, probability of the risk, the severity of the risk, impact of the risk, suggested risk mitigation and resultant probability, severity and impact.

At this stage in the project life cycle the majority of the actions sit with the Promotor. The promoter is defined as "…a party with the motivation to establish a successful heat network and which takes responsibility for driving delivery"[26]. In this case the Promotor is LBS.

The Responsibilities of the Promoter are:

- Defining physical nature of the project;
- Commissioning studies to establish the viability of the network;
- Identifying funding options;
- Defining the scale and timing of demand for services;
- Publicising the opportunity and communicating the benefits to key stakeholders; and

[24] https://www.gov.uk/guidance/heat-networks-delivery-unit#project-development-stages-supported-by-hndu

[25] HNIP Regional Workshop slides 10 May 2018

[26] Heat Network Detailed Project Development Resource: Guidance on Strategic and Commercial Case

- Attracting developers, investors, operators and customers.

Some of the key risks found for each network are further explored below.

14.3.1 Network Design timelines

The STC and LCH masterplans are currently being built out, with developments coming forward in STC in particular. To supply heat to these developments via a DH network by 2026, the design and construction of the DEN needs to be planned in conjunction with all future developments.

14.3.2 Energy Centre

For the STC, the proposed energy centre is the Civic Centre site. The proposed energy centre represents a significant proportion of the site. It is important that the development plans for the site include a space allowance for the energy centre even at this early stage of the development programme. Failure to confirm the spaces identified in this report may necessitate alternative energy centre locations to be sought, which may:

- affect the technical and economic performance indicated in this report, and
- cause project delivery delays resulting in heat not being available in time for the completion of the construction phases of any new developments.

If the civic centre site becomes unavailable or is not able to provide the required space to host an energy centre, alternative locations will need to be considered.
It has been assumed that energy centre for LCH will be incorporated within the podium car park and a space allows for this will be maintained through the design process.

14.3.3 Pipework routing

Some network opportunities investigated in this study will require the installation of buried insulated pipework in busy roads. Some network scenarios also require this pipework to cross railway lines. Should LBS choose to pursue any of the networks detailed herein, the barriers identified for that network in question shall require detailed surveys from an experienced contractor in order to assess both the viability and the costs associated with installing pipework along the specified routes. The development of the tramline would present a specific risk.

Existing utilities will also likely be present along the routes specified. This study has not assessed the presence or location of existing utilities in roads etc.; a PAS256 certified scan of buried assets in the routes specified will be necessary to mitigate risks around pipework installation. It is expected that this would be investigated in a Feasibility Stage study.

14.3.4 Existing Building Connections

There is a risk that some of the buildings identified for connection to the networks will either be owned by parties that are not interested in connection, or technically unviable. Operators of the identified existing private buildings must be engaged with as early on in the network development as possible. Full building audits must be carried out to assess technical viability. Examples of what technical viability would cover are listed below:

- Centralised wet heating system
- Centralised plant in building plant room
- Temperatures
- Control strategy

Developers of future buildings must be consulted on connection and made aware of any planning conditions that will affect them, and which are necessary for the development of the network.

14.3.5 Network temperature and Future Proofing

The ability to install a future proofed network with lower operating temperatures is dependent on the design of the buildings on the network and their eligibility for accepting lower supply temperatures than would be conventionally designed for, in addition to ensuring a high temperature differential across all Heat Interface Units (HIUs) and thermal substations. For instance lower temperatures would reduce heat loses in the network but would also allow different technologies to be used such as ASHPs.

Through engagement with the developers/owners/occupiers of eligible buildings, LDC shall need to ascertain the temperature requirements of the buildings proposed for connection. This assessment will inform the lowest available operating temperature of the networks, thus influencing the feasibility of the various heat generation systems discussed within this report and potential pipework materials.

14.3.6 Financial Incentives and Funding Schemes

The potential inclusion of financial incentives (i.e. RHI) and funding schemes (i.e. HNIP) have a significant impact on the financial modelling results for all applicable network options. Any changes to these potential revenue and funding streams can therefore have a significant influence on anticipated cash flow models, potentially affecting the viability of the network. In order to assess the importance of financial incentives and funding schemes to project viability, an analysis was conducted.

Furthermore, state aid rules restrict the applicability of multiple funding routes for any proposed scheme. At the time of writing, it is understood that HNIP cannot be used to finance the capital costs associated with generation equipment that is supported by the RHI. However, HNIP can be used to finance the capital costs of the heat network infrastructure that is connected to that generation plant. Through early engagement with the scheme operational bodies (i.e. OFGEM or BEIS) a clearer insight into the amount of state aid available to any proposed scheme can be established and incorporated into the developed business model.

14.4 Next steps

In order to move the opportunity of delivering a district heating network for STC and/or LCH forward, LBS will need to:

1. Review the information presented in this report and select an option to take forward to feasibility stage;
2. Secure additional funding sources to support the feasibility study; and
3. Carry out feasibility study and implement recommendations.

In addition to the above, further work should be carried out to address the risk items identified in the risk assessment. Furthermore, additional stakeholder engagement is required to encourage engagement and to help secure the connection of additional existing loads that could present additional heat sales opportunities to increase the viability of the scheme should be carried out.

It is important that the next steps are undertaken quickly in order to maximise the opportunities presented by the planned new development in Sutton. The STC and LCH sites are currently being built out with both sites progressing to their individual programmes. For instance, the Old Gas Works site has been fully developed in the STC area and any future connection to a network will be based on commercial considerations. This presents LBS with less leverage to encourage developments to connect to a network.

Similarly for LCH the school is now operational and will be therefore be very difficult to connect to a heat network, particularly due to the significantly reduced heat loads associated with the Passivhaus design which reduces the heat sales revenue and therefore the viability of connection.

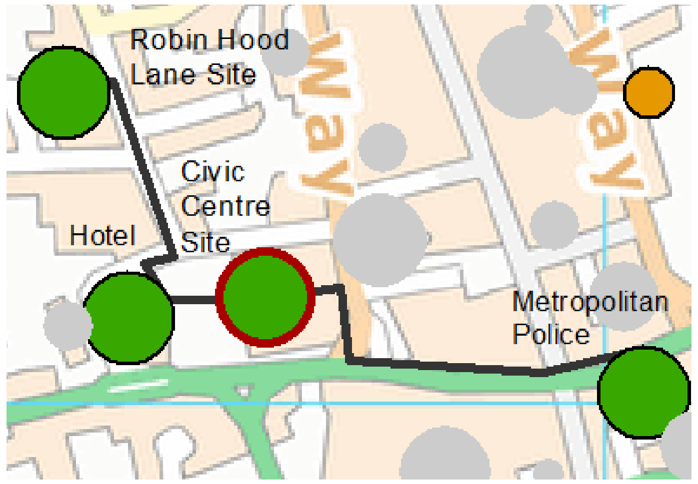
It will be important to gain greater certainty regarding the future availability of a number of funding and financial incentive programmes (e.g. HNDU, HNIP and RHI). Some of these schemes are expected to come to an end in their current format, and it is possible that they may not be available in their current format for the project to utilise in the future. For example, RHI support is currently scheduled to end in 2021, and although the Government is currently consulting on the issue, it is possible that the scheme will not be extended. Even if the scheme is extended beyond 2021, it is possible that payments could be reduced in value. Similarly for HNIP funding, the scheme funding is only secured for up to 2 years, with the initial HNIP funding grants being awarded to applicants in 2019. For these reasons it is important that LBS considers if it wishes to move to a feasibility stage and utilise external funding opportunities.

14.5 STC route-map

Phase 1a

Civic Centre Site and Sutton Town Centre existing buildings

Technology: Low NOx Gas Boilers
Network Operational: 2023
Energy Centre Location: O Civic Centre Site



Building List

Ref.	Building Name	Size*	Ownership	Motivation
STC 9	Civic Centre Site including hotel	1,397 MWh	Council	Planning policy
STC 30	Robin Hood Lane Site	435 MWh	Public / Private	Planning policy
Existing	Metropolitan Police	2,038 MWh	Council	Stakeholder engagement

*Sizes have been updated due to new information provided by LBS on 16/10/2018

Financial Modelling Results*

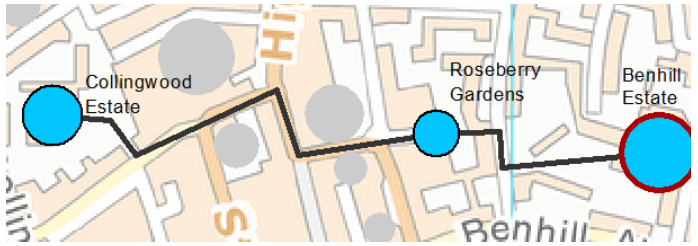
CAPEX	**£2,800,000**
Heat generation	**4,300 MWh**
Annual heat sales	**£350,000**
Payback period	**Requires funding** (£1million funding – 14 years payback)

*results provided to 2sf

Phase 1b

Residential redevelopments to the north of STC

Technology: Low NOx Gas Boilers
Network Operational: 2023
Energy Centre Location: O Benhill Estate



Building List

Ref.	Building Name	No. of units	Ownership	Motivation
Redevelopment	Collingwood Estate	535	Affinity Sutton	Align with Affinity
Redevelopment	Roseberry Gardens	184	Affinity Sutton	Align with Affinity
Redevelopment	Benhill Estate	1,076	Affinity Sutton	Align with Affinity

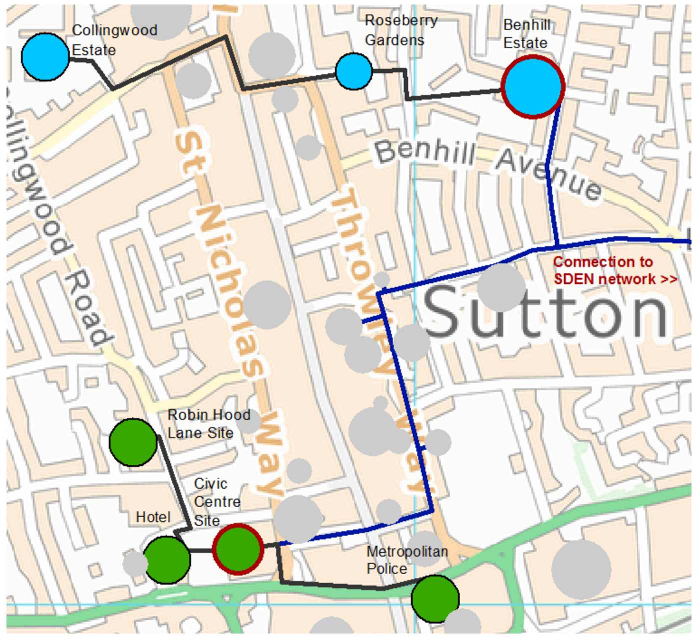
Financial Modelling Results

CAPEX	**£5,400,000**
Heat generation	**7,700 MWh**
Annual heat sales	**£870,000**
Payback period	**13 years**

Phase 2

Connection to SDEN heat network via ~3km of pipework

Technology: Energy from Waste
Network Operational: 2024
O Energy Centre Locations



Building List

Combination of buildings from Phase 1a and Phase 1b

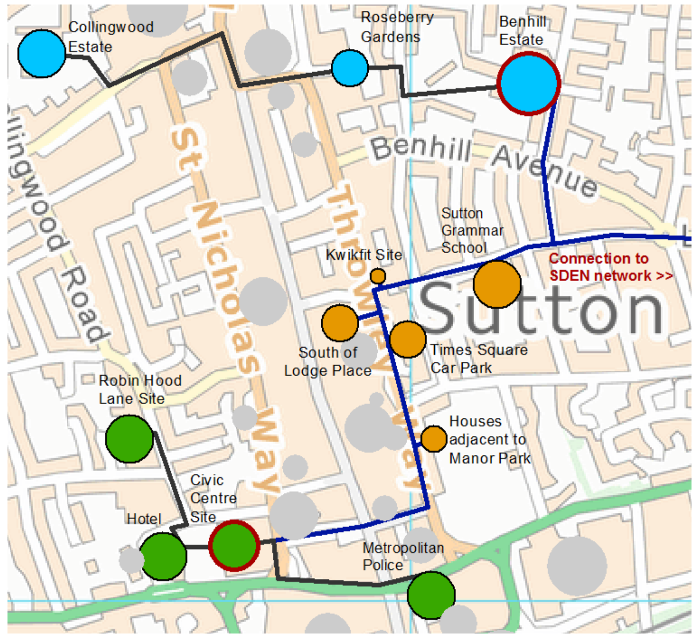
Financial Modelling Results

Cumulative CAPEX	**£13,000,000**
Heat generation	**12,000 MWh**
Annual heat sales	**£1,200,000**
IRR, 25 years	**2.8%**
NPV, 25 years	**£300,000**

Phase 3

Connection of other new developments within STC

Technology: Energy from Waste
Network Operational: 2024 +
O Energy Centre Locations



Building List (plus buildings from Phase 1a and Phase 1b)

Ref.	Building Name	Size*	Ownership	Motivation
Existing	Sutton Grammar School	1,174 MWh	Council	Stakeholder engagement
STC 7	Kwikfit Site	91 MWh	Council (Private Lease)	Planning policy
STC 6	South of Lodge Place	200 MWh	Private	Planning policy
STC 41	Times Square Car Park	576 MWh	Council	Planning policy
STC 38	House Adjacent to Manor Park	680 MWh	Council / Private	Planning policy

Financial Modelling Results

Cumulative CAPEX	**£15,000,000**
Heat demand	**15,000 MWh**
Annual heat sales	**£1,500,000**
IRR, 25 years	**4.6%**
NPV, 25 years	**£2,200,000**

14.5.1 Route map description

Consideration of the techno-economic modelling results alongside the planning and air quality review suggested that the preferred solution for a Sutton Town Centre heat network would use the SDEN connection for supply of waste heat. Therefore further study of this solution was undertaken to produce a route-map, shown on the previous page, which outlines the potential steps necessary to realise the heat network.

The route-map depicts three phases that are explained in detail below. Phase 1 incorporates two separate smaller-scale networks that form the catalyst for the phase 2 connection to the SDEN supply via a 3km pipe. Once the connection of the energy from waste heat supply is made, phase 3 outlines the additional buildings in Sutton Town Centre that can then connect to the network.

The modelling of the route-map used the same technical and cost assumptions outlined in section 9 of this study. However, updated building information (building type, GIA, date of development, etc.) for some of the STC sites was provided on the 16/10/2018 by LBS. It was agreed that this new data would be used in the development of the route-map so that it reflects the most up-to-date knowledge. This updated information is presented in Table 14-4. Stakeholder motivation for the connections, in support of the route-map, is outlined in section 14.5.6.

Table 14-4 Updated building information received for STC sites

Site	Information received
STC 9 - Civic Centre Site	Redeveloped 2021-2022, to include: 13,300 sqm office 1,300 sqm retail 68 homes 140 bed hotel – to replace the existing holiday inn
Holiday Inn (Existing)	140 bed, part of the Civic Centre redevelopment
STC 30 – Robin Hood Lane Site	Part of the Civic Centre Site – new build NHS of 2,500 sqm
STC 7 – Kwikfit Site	24 homes and 550 sqm workspace
STC 41 – Times Square Car Park	167 homes, 1,400 sqm office
STC 38 – House Adjacent to Manor Park	108 homes, 2,415 sqm office

14.5.2 Phase 1a

The Civic Centre site (STC 9) was recommended to host the energy centre for the STC heat network due to its ownership by the council, upcoming redevelopment and relatively large footprint. It is likely that the Holiday Inn will now be redeveloped alongside the original STC 9 site, providing a larger land footprint and a significant onsite heat demand. Hence it is suggested that this site host the energy centre for phase 1a that will include a small local network also encompassing Robin Hood Lane Site (STC 30) and the Metropolitan Police Station just south of the A232. If necessary, this network can be temporarily run on low NOx gas boilers, installed to meet peak demand with N+1 resilience, while pipework is installed for connection to the SDEN network.

14.5.3 Phase 1b

A second local network will connect three social housing redevelopments planned to the north end of Sutton Town Centre. These are to potentially be developed by Affinity Sutton and would provide over 1,700 homes between them. It is suggested that Benhill estate, the large of the three sites, would contain the energy centre for this network. Again, the network can temporarily be run on low NOx gas boilers (N+1 capacity) before connection to SDEN. Importantly, phase 1b is necessary to establish sufficient local demand to economically justify the pipework connection to the SDEN network at the Felnex development.

14.5.4 Phase 2

Phase 2 involves the connection to the EfW heat supply via approximately 3km of pipework. This pipework will cost an additional £5 million. Consequently, despite the significant carbon savings, this network has a very low IRR and financial return. Securing government funding would be prudent, indeed with £3 million of funding the 25 year IRR would increase from 2.8% to 5.6%. It is important to note that given the use of multiple energy centres a hydraulic control strategy will be required to manage the system flows and plant.

14.5.5 Phase 3

Once connection to the SDEN network has been made, additional buildings in the town centre can also connect to the network. To enable this, the energy centre at Benhill Estate has been sized with room for boilers of capacity to meet peak demand of the full EfW network (depicted in Figure 6-3). To model a potential phase 3, five additional buildings deemed most likely to connect are included. Connection of these buildings increases both the IRR and NPV fairly significantly. It would be prudent to secure as many additional connections as possible, within the heat capacity available from the EfW plant.

14.5.6 Consumer motivation for connection

Consumers would be motivated to connect to a heat network for STC for a variety of reasons.

New Build

1) **Planning policy on heat networks:** It is policy requirement of the London Plan for new developments to connect to a DH network where feasible. The development of a heat network in STC would facilitate compliance with this policy. Where a heat network is not available or not feasible at the time of planning application the development must allow for future connection.
2) **Planning policy on carbon emissions:** Some of the networks studied in this report would provide low carbon heat. For instance a network with heat from the EfW would have a low carbon factor compared to other heat generation technologies such as heat pumps or gas boilers. Connecting to a network with a comparable low carbon factor would contribute to meeting the GLA 35% on-site carbon reduction target.
3) **Space savings**: A new build block of flats would be expected to have gas boilers and ASHP (the counter factual used in the project) to generate heat. Connecting to a heat network would allow for omission of this equipment, thus reducing the space required for plant. Some of this space would be required for a plate heat exchanger to draw heat from the network. Pumps and other ancillaries would still be required. This reduced space requirement would increase the available space for other uses such as additional retail area, storage space or car parking spaces all of which have a value to a developer. By avoiding the use of combustion plant i.e. boilers on site, the need for a flue is avoided. Since boilers are typically located in basements or ground floors, a flue to the roof is required to discharge the combustion gases at high level. This space requirement is required on each floor of a building. Upper floors are typically the most valuable space and avoiding space take on these floors for a flue could be quite valuable.
4) **Reduced construction costs**: By not installing plant such as boilers development costs would be reduced through reduced equipment costs and commissioning time. It is this offset value that is used to assist in the development of a value-for-money connection charge. The connection charge will be used to offset a portion of the capital cost for the heat network capital costs.

Existing Buildings

The driver for connection of existing buildings to a heat network may be presented as follows:-

1) **Plant end of life:** Existing buildings will already have a means to meet and deliver their current thermal energy requirements. Conventional boiler plant has an estimated economic life of 20-25 years. This can result in a major plant refurbishment at each cycle end. Due to the changes in plant performance, these costs can be significant if not adequately planned for. A connection to a DH system can provide a cost effective alternative to a capital replacement of heating assets.
2) **Operational cost:** A DH connection is targeted to provide heat at a competitive level, when compared to the current operational counterfactual. In addition the heat connection may be seen as a service with contractual performance requirements, de-risking the use of the connected load.
3) **Environmental performance:** With ever more stringent targets and internal Corporate and Social Responsibility targets (Carbon reduction), a DH solution can provide a very cost effective method of delivering carbon reductions.

It is important to undertake stakeholder engagement with potential developers and occupiers at the next stage of the project to ensure the potential benefits of connection are conveyed to the appropriate stakeholders to ensure buy in.

Appendix A – Technical Note on Benchmarking

Technical Note

AECOM

Project:	**London Borough of Sutton – District Heating Masterplan**	Job No:	**60562200**
Subject:	**Benchmarking and threshold methodology**		
Prepared by:	**Cornelius Kelleher**	Date:	**26.02.2018**
Checked by:	**Alban Leiper**	Date:	**26.02.2018**

Summary

This note summarises the background processes used in the energy mapping phases of the London Borough of Sutton Town Centre and London Cancer Hub Energy Masterplan study. It describes the energy benchmarks used to derive the heat and electricity consumption data for buildings considered, as well as the threshold used to eliminate smaller, less eligible, buildings from the study.

Energy benchmarking

Where Display Energy Certificates (DEC) or Energy Performance Certificates are available for existing buildings through the Landmark register, this information will be favoured over the use of energy benchmarks as it is considered to give more accurate estimates.

Where this information is not available, benchmarks will be used to determine building energy usage from a given floor area. The benchmark chosen will depend on the building type, and whether it is an existing building or a future planned development.

CIBSE Guide F is a widely recognised industry standard document on energy efficiency in buildings, which includes energy consumption benchmarks for fossil fuel and electricity uses. Although benchmarks found in Guide F are considered outdated and to overestimate energy consumption in new buildings, they still form the most extensively accepted benchmarks in the industry and are considered the most reliable source for establishing energy use in *existing* buildings.

For new developments in planning, it is expected that the use of CIBSE Guide F may not accurately represent actual loads, due to the significant improvements that have been made in energy efficiency performance standards over recent years. Therefore, current Building Regulations standards are likely to be more appropriate. These are derived from government-approved Dynamic Simulation Modelling (DSM) software and Standard Assessment Procedure (SAP).

SAP/DSM results from previous AECOM projects will be used for the purposes of new developments. Additionally, for the baseline calculation exercise, the unregulated energy demand will also be taken into consideration in order to fully account for the electricity requirements in buildings. In the absence of specific modelling data, CIBSE Guide F 'Good practice' benchmarks are used, as per Existing buildings.

Table 1 gives the electricity and heat benchmarks used in this study for existing and future buildings, for each building type.

Table 1: Energy Benchmarks - existing and future

Type	Existing							Future development (Catering assumption as previous)					
	Electricity (kWh/m^2)	Fossil fuel (kWh/m^2)	Of which catering	Heat (kWh/m^2)	Source	Cooling (kWh/m^2)	Source	Electricity (kWh/m^2)	Fossil fuel (kWh/m^2)	Heat (kWh/m^2)	Source	Cooling (kWh/m^2)	Source
Residential	44	247	20%	158	Guide F	0	Assumption	13	72	54	Model	0	Assumption
School	25	108	0%	86	Guide F	0	0	40	23	21	Model	7	Model
Library	45	105	0%	84	Guide F	0	0	45	105	94	Guide F	0	
Community centre	22	125	0%	100	Guide F	0	0	40	23	21	Model	7	Model
Office	128	97	0%	78	Guide F	31	Guide F	89	25	22	Model	20	Model
Museum	45	105	0%	84	Guide F	0	0	45	105	94	Guide F	0	
Hospital	48	401	0%	321	Guide F	0	0	48	401	361	Guide F	0	
Emergency room	50	343	0%	275	Guide F	0	0	50	343	309	Guide F	0	
Nursing home	59	492	10%	354	Guide F	0	0	52	46	37	Model	21	Model
Leisure centre	96	264	0%	211	Guide F	0	0	75	221	199	Model	0	
Entertainment hall	180	420	0%	336	Guide F	0	0	95	18	16	Model	44	Model
Swimming pool	164	573	0%	458	Guide F	0	Assumption	75	221	199	Model	0	
Hotel	80	260	15%	177	Guide F	0	Guide F	64	258	198	Model	5	Model
University	150	161	15%	109	Guide F	0	0	150	161	123	Guide F	0	
Retail	237	194	0%	155	Guide F	0	0	80	43	199	Model	0	
Restaurant	650	1100	50%	440	Guide F	0	0	167	151	68	Model	12	Model
Storage	145	80	50%	64	Guide F	0	0	145	80	72	Model	0	

Assumed boiler efficiency	**Existing sites**	**80%**
	New sites	**90%**

Threshold building size

Buildings with lower heat consumption are less appropriate for connection to a district heating network than those with higher consumption as they will provide lower revenues and will take longer to payback the connection costs.

Sutton Town Centre and LCH contains a range of building sizes with varying levels of heat consumption. As part of the energy mapping phase of the study, it is important to define a threshold size of building below which buildings will be discounted for connection. This helps focus the study on to the larger, more appropriate buildings.

AECOM have used the following threshold for existing commercial and other non-domestic uses:

- 100MWh of heat demand per year

This threshold of 100MWh of heat demand would equate to around £5,000 revenue (c.£0.05/kWh heat sales), below which it is not significant enough to pay back the likely connection costs.

AECOM have used the following threshold for existing residential developments:

- developments of 20 units or more for residential properties.

For a residential development of 20 units (assumed at 70m^2 each), this would represent a higher heat load of around 500MWh. Whilst the revenue generated from this amount of heat is significantly higher than the commercial threshold building, costs associated with connection to the residential development are much higher due to the added pipework and heat interface units (HIUs) associated with the higher number of actual connections. Furthermore, the commercial and legal costs associated with establishing and managing 20 individual customers over a single commercial customer make the revenue threshold for economic deliverability higher.

Please note that below these threshold values, buildings will not be completely ignored: AECOM will back-validate buildings below the threshold by checking building types with high heat demand density, e.g. hospitals, care homes, leisure centres and entertainment facilities.

For the London Cancer Hub site we have assumed that the energy requirements of new build office space for space types identified as commercial / research, not for profit/charitable/academic and ICR. This is a conservative assumption as any heat requirements above this estimate would only serve to improve the financial returns on the network. When greater detail about the type and usage of buildings is available, the heat loads for the LCH can be updated and checked that the proposed engineering solution is viable.

Appendix B – Heat Generation Technologies

B.1 Gas Fired Combined Heat and Power (CHP)

CHP or cogeneration refers to the simultaneous generation of heat and electricity from the same process. Conventional electrical power generation is centralised in the UK and normally located away from other buildings or businesses. Electrical power generated at these stations generates a significant amount of heat that is wasted and significant losses also result from the transmission to consumers. By contrast, a CHP system tends to be located close to the end user. As such, the heat by-product of electrical generation can be captured and sold as a commodity to local customers.

CHP plants can reach overall energy efficiencies in excess of 80%, compared with 35% for traditional power stations. CHP systems use one of a number of prime movers, including a turbine based system, and reciprocating (piston) engine types. Each of these technologies has individual characteristics that best lend their use to certain applications and situations. Reciprocating engines (the technology type most commonly deployed in networks of the scale expected to be appropriate for Sutton) are essentially internal combustion engines that operate in a similar way to car engines. Instead of providing mechanical drive however, the pistons drive a shaft to generate electricity. Different grades of heat are recoverable, including from the exhaust gases (high-grade/temperature heat, ~450°C), from the jacket of the unit (low-grade/temperature, ~90°C) and intercoolers (low-grade/ temperature, ~40°C). Typically, intercooler heat is expelled to atmosphere.

CHP technology is best deployed in buildings/areas that have a high and consistent demand for heat, such as for space heating, water heating and process heating (e.g. sterilisation, chemical heating in industrial operations). Consideration should also be given to how electricity generated by the CHP will be utilised. Options include using the electricity onsite to offset grid consumption; to export directly to the grid; to agree a Power Purchase Agreement (PPA) with a 3rd party user to 'sleeve' electricity generation through the grid to the user; and the use of a private wire to distribute electrical generation directly to a 3rd party.

To optimise the payback period of gas-CHP it is necessary to run CHP plant in excess of 4,000 hours per annum. This level of operation allows for further financial saving through the bulk buying of fuel at lower prices. How the generated electricity is utilised (and therefore the price at which it realises a value) also plays a key role in the economic performance of the system.

Because the benefits of gas-CHP are derived from the production of electricity that is cleaner than that which is taken from the grid, the CO2 saving benefits of gas-CHP are likely to reduce over time if, as outlined by the Department of Energy and Climate Change (DECC – now BEIS) emission projections[27] , the CO2 emissions attributed to grid electricity fall. Grid decarbonisation is projected to occur over the next 40 years due to further integration of green generation technologies and the increase in efficiencies of fossil fuel generation processes. However, it is expected that gas-fired CHP will continue to be an effective technology in reducing carbon emissions until the 2030s.

Gas-fired CHP systems typically have higher NOx emissions than individual gas boilers and post combustion treatments (e.g. catalytic and non-catalytic abatement technologies) may be needed to ensure air quality is not significantly affected.

Gas-CHP is a proven technology and has numerous examples of working and reliable application throughout the world and within the UK. The technology offers levels of flexibility as it allows modular build-out. Plant can be installed in conjunction with network phasing, resulting in the optimisation of supply and demand.

B.2 Biomass Combined Heat and Power (CHP)

The use of biomass as fuel is considered renewable and low-carbon, since the CO2 that is released during combustion is offset by the CO2 that was absorbed previously by the source biological material through photosynthesis. The process is considered carbon neutral because, in contrast to fossil fuels, the carbon cycle (from growth to combustion) occurs across a short time period (in the order of years and decades, compared to millennia and millions of years for fossil fuels). However, the fuel is assigned a nominal carbon intensity to account for the energy consumed in its processing and transportation.

Biomass fuel can be sourced from various residual waste streams, sometimes making them a relatively cheap and reliable fuel, although this depends on the sector from which the waste streams originate. If a local source of biomass can be found, the costs of the fuel can be low, leading to significant financial returns. The ability to obtain other incentives, such as Renewable Heat Incentive (RHI)[28] can also help to deliver significant revenues. However, some sources of biomass, such as highly processed biomass pellets can be relatively expensive compared to conventional fuels. Additionally, biomass fired CHP systems also require greater levels of maintenance in comparison to other CHP systems; over the life time of a CHP this can have a detrimental impact on its payback period and commercial viability. Additionally, the delivery and safe storage of the fuel to and on site respectively will likely have significant safety and operational cost implications.

Currently, the fuel supply for biomass is a risk due to uncertainties around future availability and cost in what is still a maturing supply market. The security of the biomass fuel source must be considered for the commercial viability of biomass-fired CHP engines. Although the availability of biomass fuel is not likely to be an issue, due to the availability of fuel from agricultural residues and waste materials from other sectors, the cost of the fuel may not be stable and prices could potentially rise due to the emergence of competition for its use. This would have further impact on the commercial feasibility.

Biomass combustion typically has a more significant impact on local air quality (through elevated particulate and NOx emissions) than other fuels and also requires downstream management in the form of safe ash storage and removal. This is an additional cost factor and will weaken the commercial viability in comparison to other heating technologies.

B.3 Biofuel Combined Heat and Power (CHP)

Similarly to biomass, biofuel is considered a renewable fuel source which can be used in CHP engines to provide heat and electricity. Biofuel is classified as liquid fuels that are derived from biological products, and include products such as biodiesel, vegetable oils (e.g. rape seed oil) and bioethanol.

However, biofuels also suffer similar drawbacks to those experienced by biomass systems. These include the requirement to be transported to and stored safely on site, requiring additional storage space for fuel storage and frequent deliveries to site by suppliers. Concerns over the security of fuel supply and price stability should also be noted, although this is improving as the market matures and the number of sources and uses of these fuels increases.

Biofuels also suffer from high levels of NOx and particulate emissions that contribute to air quality problems.

B.4 Energy from Waste (EfW)

Energy from Waste (EfW) is the process of generating energy from the primary treatment of household and municipal waste. Where there is residual waste (i.e. remaining waste that cannot be economically or practically reused or recycled), the main aim is to get the most value from it via energy recovery.

There are a number of treatment processes and technologies that can be used to recover energy. Most EfW processes produce electricity and/or heat directly through combustion but are typically available in two main forms: mass burn and non-mass burn. In mass burn processes the residual waste burns at typically 850°C, with the energy recovered used to raise steam and generate electricity (through a steam turbine), or to provide heat. Non-mass burn processes include gasification and pyrolysis. Thereafter, the generated heat can be exported for use in local heat networks.

B.5 Anaerobic Digestion

Anaerobic Digestion (AD) is a form of waste disposal that uses microorganisms to convert organic waste to a methane-rich biogas. This in turn can be combusted to generate electricity and heat, or converted to biomethane. This technology is most suitable for wet organic wastes or food waste.

[27] DECC (2015) *Bespoke natural gas CHP analysis,* https://www.gov.uk/government/publications/bespoke-natural-gas-chp-analysis

[28] The Renewable Heat Incentive (RHI) is a government programme that provides financial incentives to domestic and non-domestic stakeholders to support renewable heat generation and use. Further information is provided by Ofgem (n.d.) *Environmental Programmes,* https://www.ofgem.gov.uk/environmental-programmes [Accessed July 2018].

AD is considered to offset Greenhouse Gas (GHG) emissions associated with waste landfill disposal since it avoids the natural generation (and subsequent leakage to atmosphere) of methane in landfill sites. CO2 savings can also be realised through the displacement of natural gas consumption by AD biomethane production.

AD is significantly wide spread, with over 200 AD[29] plants operating in the UK. AD plants are usually located a long distance from large urban areas, as they are generally sited close to their primary source of farm waste material. This can make them challenging to incorporate into DH network schemes, as they are unlikely to be close to areas of high heat demand.

B.6 Biomass & Biofuel Boilers

Due to their impact on local air quality, and the restrictions placed on particulate and gaseous emissions, we do not consider these options to be viable as the initial technology for the proposed scheme. Further issues around increased energy centre size, access and storage also make the use of biomass and biofuel boilers less favourable than other options.

Subject to development of the technology (in particular, the mitigation of emissions that compromise local air quality) and future changes in fuel price and security, this is a technology that might be worthwhile investigating in the future. However, practical issues such as energy centre size, access, fuel delivery, ash removal (for biomass systems) and air quality are likely to remain.

B.7 Geothermal

The temperature underground increases with depth and the term geothermal energy specifically refers to energy that is of sufficiently high temperature for the provision of heating (typically 50°C or higher).

Ground temperatures are stable below a depth of around 10m. In the UK the temperature at this depth is in the region of 5-15°C. Below this depth, the temperature increases linearly at a rate of 0.025°C/m, such that it is approximately 50°C at a depth of 1,600m. However, typical heating supply temperatures in the UK are around 80°C, which requires depths of up to 3,000m.

Drilling wells to these depths requires specialist equipment used in the oil and gas industry and is very expensive as a result. The revenues generated from the sale of heat via a DH network will not justify the high capital expenditure associated with this technology.

Geothermal heating systems typically only become commercially viable when an existing deep well that has been drilled for the extraction of oil or gas can be reused for the purposes of extracting heat.

The technology is not widely used in the UK, due to the required drilling depths. There are a few deep geothermal energy projects in the UK at various stages of development, designed to provide heat and electricity to local communities. Other countries where geothermal energy is present closer to the surface, like Iceland, have had greater success in the implementation of deep geothermal energy systems.

Carbon emissions from harnessing deep geothermal energy are very low since the energy required to extract the renewable heat is negligible when compared to the useful energy generated.

B.8 Heat Pumps

Heat pumps use vapour compression refrigeration cycles to transfer heat against the thermal gradient, from a cold medium to a warmer medium.

Heat pumps are considered renewable systems, since the heat extracted from the ‘source’ is renewed constantly through natural processes. However, there is an impact on the environment, as the compressor systems needed to operate the system requires the use of electricity.

Benefits of heat pump systems include the non-requirement for flue systems to exhaust combustion gases like in conventional heating systems. ASHPs also do not require fuel deliveries (such as is the case for biomass installations) or fuel pipework (such as in gas-fired systems).

[29] Please refer to WRAP (n.d.) *Operational AD Sites*, http://www.wrap.org.uk/content/operational-ad-sites [Accessed July 2018] for map showing operational anaerobic digestion plants in the UK.

Heat pump compressor systems still require the use of electricity, which involves fuel costs. Despite the operating Coefficient of Performance (CoP) of heat pumps being favourable over the efficiency levels of other heating technologies, due to the current carbon emissions of grid electricity, the carbon savings currently achieved are only marginally better than efficient gas fired systems.

Air Source Heat Pump (ASHP)

Air Source Heat Pumps (ASHPs) can extract heat from the ambient air, even when temperatures are as low as -5°C. Importantly, the lower the ‘source’ temperature, the lower the efficiency of the heat pump. Similarly, the higher the temperature being delivered to a heating network, the lower the efficiency of the heat pump.

With the use of a typical refrigerant, such as R407C, ASHPs are most suited to providing heat for LTHW heating circuits. However, if ammonia is used as the refrigerant, temperatures of 70ºC or more can be achieved. Ammonia is both toxic and explosive and thus requires additional safety measures, which limit its suitability in many applications. Having an ammonia system at roof level in an open space inherently provides a level of safety due to the fact that ammonia is lighter than air. If this is not practical an enclosed plant room containing an ammonia heat pump system would require specific ventilation/detection requirements.

While the low efficiencies achievable for high-temperature heat pump systems mean their operating costs and CO2 emissions performance are not as favourable as, for example CHP systems, the long term prospects for ASHP systems are good. This is due to expected increases in operating efficiencies achievable as the technology matures, and increasing carbon savings as the electricity grid decarbonises.

ASHPs with Heat Recovery from the London Underground or Electrical Substations

A simple way of increasing the performance of ASHPs within London is by utilising waste heat sources in order to raise the initial ‘source’ air temperature from which the pump extracts heat.

One such readily available source is the London Underground (LU) network, in which heat is generated through the trains’ motors and braking systems, lighting systems, operating equipment and the bodies of passengers. Heat exchangers placed within the ventilation shafts can capture this extracted heat as it is vented to the atmosphere.

Another possible waste heat source is from electrical substation transformers, where heat is generated naturally as a by-product of operation. Heat exchangers placed within the transformers’ cooling system can capture this extracted heat as it is removed from the equipment.

By extracting this waste heat and using it to pre-warm the ‘source’ air from ambient temperature, the overall ASHP CoP is increased. This results in less electricity being required to run the compressor to provide the required amount of heat to warm a space, and thus reduces the associated running costs and carbon emissions.

A number of heat recovery projects based around waste heat from both the LU and National Grid Transformers have already been implemented in London. For example, heat recovered from a LU ventilation shaft in Islington is being utilised as part of the Bunhill Heat & Power scheme to provide heat for 1200 homes. Meanwhile, the Tate Modern Gallery’s heating system extracts heat from the adjacent Bankside Transformer Substation to reduce carbon emissions by 1,400 tonnes a year[30]. It is worth noting that due to the high capital costs associated with these projects, some degree of funding was required to realise financial viability. However, as more of these projects are developed, it is expected that such capital costs will reduce.

Ground Source Heat Pump (GSHP)

Ground source heat pumps (GSHP) work in a similar principle to other heat pump systems but source low grade heat from the soil and ground and take advantage of the inherent temperature difference between cold flow water and the ambient soil temperature.

GSHP systems can be used almost anywhere, although their use in DH networks is limited, due to the mismatch between the low-grade heat (i.e. low temperatures) that the GSHP system operates best at and the higher temperatures that DH systems require. Although higher temperatures can be achieved, efficiencies are

[30] http://www.britishgas.co.uk/business/blog/how-is-londons-tate-modern-planning-to-reduce-1400-tonnes-of-carbon-emissions/

significantly reduced, albeit to a lesser extent than that experienced in air source systems (due to the ground being at a more consistent source temperature than air).

Water Source Heat Pump (WSHP)

The majority of heat pumps used in the UK are currently primarily based on ground source or air source systems. However, water is another source of energy which can be used for heat pumps with a number of advantages. Water Source Heat Pumps (WSHP) systems work on a similar principle to both air source and ground source heat pumps, but source heat from the relatively stable temperatures found in a body of water.

Their main operational principle is submerging a series of flexible pipes in a body of water, like a lake, river or stream. A heat pump pushes working fluid through the network of piping and this fluid absorbs the heat from the surrounding water, causing it to evaporate and turn into gas. This working gas is then compressed by an electric compressor, akin to the other types of heat pumps, which increases its temperature. A heat exchanger is used to remove heat from this working gas, producing hot water that can be used for space heating. For the purposes of hot water demand, a small amount of additional heat is usually required (often from a boiler system) in order to bring the temperature up to required levels.

Water source heat pump efficiencies are comparatively high compared to those of an ASHP system, as it is more efficient for a heat pump to exchange heat with water than air. In addition, the thermal capacity of water enables it to retain more of the solar heat gained in summer through to winter in relation to its volume. River water and ground water will be warmer than the air temperatures on cold winter days and therefore provide a more attractive input temperature to a heat pump.

B.9 Solar Thermal

Solar systems capture and collect solar energy using two technology types: Solar photovoltaics (PV) and solar thermal (ST) systems.

PV systems utilise semi-conductor technologies to convert solar radiation to electricity. An advantage of PV technology is that it delivers electricity at the point of use. Provided that there is a suitable place to mount the system, PVs are ideal for industrial or commercial applications and have numerous cost-effective applications to suit specific needs. PV technology can also be installed in remote locations where grid connection is not feasible.

PV panels present opportunities for zero carbon electricity production and revenue generation. However, to achieve economies of scale, significant areas of available roof areas will need to be found in order to accommodate them. Alternatively, panels can be sited at ground level, for example on land given over from agricultural production. PV panels however do not contribute to heat generation required for a DH network but could provide some energy to service the electricity loads required to operate the pumps and ancillary equipment required to service the systems.

ST systems are a simple and well-proven technology for producing low-carbon heat, which uses solar collectors, mounted on a roof or free-standing, to capture solar energy to heat water for domestic and/or industrial uses. ST installations offer both reductions in energy bills as well as carbon emissions.

As with PV technology, there are a number of solar thermal types; evacuated tubes and flat plate collectors. Flat plates consist of an absorber plate in an insulated metal box. The top of the box is glass or plastic, to let the sun's energy through, while insulation minimises heat loss. Thin tubes carry water through the absorber plate, heating it up as it passes through. Evacuated tube collectors have glass tubes containing metal absorber tubes through which water is pumped. Each tube is a vacuum which minimises heat losses.

Solar thermal panels should be sized in order to provide most of the hot water demand during summer months but their contribution during winter months can vary significantly, as it is heavily dependent on the solar irradiation levels.

Solar thermal systems can provide zero carbon thermal generation for use in a DH network. With potential increases in operating efficiencies, the thermal generating capacity per m2 of installation is likely to increase in the future. However, their use for DH application will face inherent constraints, in particular the scale required to achieve sufficient capacity to serve the network. Also due to the challenges associated with the seasonal storage of thermal energy, the required panel area to ensure effective operation during winter months would be significantly higher still.

B.10 Electrically-driven Vapor Compression Chillers

Conventional electrically-driven chillers can be arranged in a central energy centre, with chilled water distributed to customer buildings. While this approach can generate capital savings, through the scaling of chiller units, it is unlikely to generate significant energy or operational cost savings, due in part to any savings generated being partially or wholly offset by the losses experienced in distributing the chilled water over long distances in pipework.

B.11 Absorption Chillers

Absorption cooling is the process of using waste heat (typically from CHP plant) to drive an absorption chiller and produce chilled water. Despite absorption chillers being less efficient (with the measure of efficiency, the Coefficient of Performance (CoP), typically ~0.7) than typical conventional chillers (~4 or greater), the use of gas as fuel and the generation of electricity as a by-product in absorption cooling generates significant carbon and operational cost savings.

Appendix C – Technology Appraisal Results Tables

Technology Appraisal Matrix (0-15 Years) – Sutton Town Centre

		Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8	Option 9	Option 10	Option 11	Option 12	Option 13
Category	**Name Ref**	**Gas Fired CHP**	**Biomass Fired CHP**	**Biofuel Fired CHP**	**Energy From Waste**	**Biomass Boiler**	**Biofuel Boiler**	**Geothermal**	**Anaerobic digestion**	**Air Source Heat Pumps**	**Water Source Heat Pump**	**Ground Source Heat Pump**	**Heat recovery from industry**	**Solar Thermal**
Technical	Technology maturity and availability	5	4	4	4	4	4	1	4	4	4	4	4	3
	Suitability for scale and profile of heat demand	4	4	4	5	4	4	3	2	3	1	3	4	1
	Security of supply	4	2	2	4	2	2	3	4	5	4	5	3	3
	Suitability for required supply temperatures	5	5	5	5	5	5	3	5	2	2	2	4	3
	Proximity to heat demands	4	4	4	3	3	3	1	1	5	1	3	1	4
Environmental	Level of CO2 emission savings	2	4	4	5	4	4	5	5	4	4	4	5	5
	Air quality implications	2	1	1	3	1	1	5	4	5	5	5	5	5
	Wider environmental impacts	3	3	3	4	3	3	3	4	3	3	3	5	3
Financial	Technology cost	4	3	3	4	4	4	1	4	4	4	2	4	3
	Impact on scheme financial viability	4	3	3	3	3	3	1	3	3	3	3	4	3
	Long term financial risks	3	3	3	2	3	3	2	2	3	3	3	3	4
Deliverability	Suitability to Sutton Town Centre	5	4	4	5	4	4	1	1	3	1	3	1	2
	Implications for energy centre size/design	4	3	3	4	3	3	5	4	4	4	4	4	4
	Implications for additional space requirements	5	3	3	5	3	3	5	5	1	4	1	5	2
	Reliance on third parties	5	2	2	1	3	3	5	1	5	5	5	3	4
	Total score (%)	77.36	65.66	65.66	77.74	66.04	66.04	55.85	65.66	73.58	62.64	68.30	72.08	67.17
	Rank	2	9	9	1	7	7	13	9	3	12	5	4	6

Technology Appraisal Matrix (15+ Years) – Sutton Town Centre

		Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8	Option 9	Option 10	Option 11	Option 12	Option 13
Category	**Name Ref**	**Gas Fired CHP**	**Biomass Fired CHP**	**Biofuel Fired CHP**	**Energy From Waste**	**Biomass Boiler**	**Biofuel Boiler**	**Geothermal**	**Anaerobic digestion**	**Air Source Heat Pumps**	**Water Source Heat Pump**	**Ground Source Heat Pump**	**Heat recovery from industry**	**Solar Thermal**
Technical	Technology maturity and availability	5	5	5	4	4	4	2	4	4	4	4	4	4
	Suitability for scale and profile of heat demand	4	4	4	5	4	4	3	2	3	1	4	3	1
	Security of supply	4	3	3	4	2	2	3	4	5	4	5	3	3
	Suitability for required supply temperatures	5	5	5	5	5	5	3	5	3	3	3	4	3
	Proximity to heat demands	4	4	4	3	3	3	1	1	5	1	3	1	4
Environmental	Level of CO2 emission savings	2	4	4	5	3	3	5	5	5	5	5	5	5
	Air quality implications	1	1	1	3	1	1	5	4	5	5	5	5	5
	Wider environmental impacts	3	3	3	4	2	2	3	4	3	3	3	5	3
Financial	Technology cost	4	4	4	4	4	4	2	4	4	4	3	4	3
	Impact on scheme financial viability	4	3	3	3	3	3	1	3	3	3	3	4	3
	Long term financial risks	3	3	3	2	3	3	2	2	3	3	3	3	4
Deliverability	Suitability to Sutton Town Centre	3	4	4	5	4	4	1	2	3	1	3	2	3
	Implications for energy centre size/design	4	3	3	4	3	3	5	4	4	4	4	4	4
	Implications for additional space requirements	5	3	3	5	3	3	5	5	1	4	1	5	2
	Reliance on third parties	5	2	2	1	3	3	5	1	5	5	5	3	4
	Total score (%)	71.70	69.81	69.81	77.74	63.40	63.40	58.87	67.55	76.98	66.04	73.96	72.83	70.94
	Rank	5	7	7	1	11	11	13	9	2	10	3	4	6

Technology Appraisal Matrix (0-15 Years) – London Cancer Hub

		Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8	Option 9	Option 10	Option 11	Option 12	Option 13
Category	**Name Ref**	**Gas Fired CHP**	**Biomass Fired CHP**	**Biofuel Fired CHP**	**Energy From Waste**	**Biomass Boiler**	**Biofuel Boiler**	**Geothermal**	**Anaerobic digestion**	**Air Source Heat Pumps**	**Water Source Heat Pump**	**Ground Source Heat Pump**	**Heat recovery from industry**	**Solar Thermal**
Technical	Technology maturity and availability	5	4	4	4	4	4	1	4	4	4	4	4	3
	Suitability for scale and profile of heat demand	4	4	4	5	4	4	3	2	3	1	3	4	1
	Security of supply	4	2	2	4	2	2	3	4	5	4	5	3	3
	Suitability for required supply temperatures	5	5	5	5	5	5	3	5	2	2	2	4	3
	Proximity to heat demands	4	4	4	2	3	3	1	1	5	1	5	1	3
Environmental	Level of CO2 emission savings	2	4	4	5	4	4	5	5	4	4	4	5	5
	Air quality implications	2	1	1	3	1	1	5	4	5	5	5	5	5
	Wider environmental impacts	3	3	3	4	3	3	3	4	3	3	3	5	3
Financial	Technology cost	4	3	3	4	4	4	1	4	4	4	2	4	3
	Impact on scheme financial viability	4	3	3	3	3	3	1	3	3	3	3	4	3
	Long term financial risks	3	3	3	2	3	3	2	2	3	3	3	3	4
Deliverability	Suitability to Sutton LCH	4	4	4	3	4	4	1	1	3	1	4	1	2
	Implications for energy centre size/design	4	3	3	4	3	3	5	4	4	4	4	4	4
	Implications for additional space requirements	5	3	3	5	3	3	5	5	1	4	2	5	2
	Reliance on third parties	5	2	2	1	3	3	5	1	5	5	5	3	4
	Total score (%)	75.47	65.66	65.66	72.45	66.04	66.04	55.85	65.66	73.58	62.64	73.96	72.08	65.66
	Rank	1	8	8	4	6	6	13	8	3	12	2	5	8

Technology Appraisal Matrix (15+ Years) – London Cancer Hub

		Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8	Option 9	Option 10	Option 11	Option 12	Option 13
Category	**Name Ref**	**Gas Fired CHP**	**Biomass Fired CHP**	**Biofuel Fired CHP**	**Energy From Waste**	**Biomass Boiler**	**Biofuel Boiler**	**Geothermal**	**Anaerobic digestion**	**Air Source Heat Pumps**	**Water Source Heat Pump**	**Ground Source Heat Pump**	**Heat recovery from industry**	**Solar Thermal**
Technical	Technology maturity and availability	5	5	5	4	4	4	2	4	4	4	4	4	4
	Suitability for scale and profile of heat demand	4	4	4	5	4	4	3	2	3	1	4	3	1
	Security of supply	4	3	3	4	2	2	3	4	5	4	5	3	3
	Suitability for required supply temperatures	5	5	5	5	5	5	3	5	3	3	3	4	3
	Proximity to heat demands	4	4	4	2	3	3	1	1	5	1	5	1	3
Environmental	Level of CO2 emission savings	2	4	4	5	3	3	5	5	5	5	5	5	5
	Air quality implications	1	1	1	3	1	1	5	4	5	5	5	5	5
	Wider environmental impacts	3	3	3	4	2	2	3	4	3	3	3	5	3
Financial	Technology cost	4	4	4	4	4	4	2	4	4	4	3	4	3
	Impact on scheme financial viability	4	3	3	3	3	3	1	3	3	3	3	4	3
	Long term financial risks	3	3	3	2	3	3	2	2	3	3	3	3	4
Deliverability	Suitability to Sutton LCH	3	4	4	3	4	4	1	2	3	1	4	2	2
	Implications for energy centre size/design	4	3	3	4	3	3	5	4	4	4	4	4	4
	Implications for additional space requirements	5	3	3	5	3	3	5	5	1	4	2	5	2
	Reliance on third parties	5	2	2	1	3	3	5	1	5	5	5	3	4
	Total score (%)	71.70	69.81	69.81	72.45	63.40	63.40	58.87	67.55	76.98	66.04	79.62	72.83	67.55
	Rank	5	6	6	4	11	11	13	8	2	10	1	3	9

Appendix D – Stakeholder consultation

As part of the study several existing buildings were identified as having the potential to connect to the STC and LCH networks. These buildings have the potential to be key anchor points in the network due to their large heat demands such as the Old Gas Works residential development in the north of STC and Quadrant House in the south of STC. Following their identification, the relevant stakeholders were contacted regarding the potential to connect to the proposed networks. A letter was sent by the council to each of the identified stakeholders. This letter asked the following questions:

1. Would you be interested in connecting to a heat network?
2. What type of heating system do you have?
    - Wet system e.g. hot water radiators
    - Dry system e.g. air conditioning
3. How is the heating system fuelled (e.g. oil, gas or electric)?

Table 14-5 Identified Stakeholders

Zone	Name	Address	Property type
STC	The Old Gas Works	SM1 1LG	Residential, retail and town centre uses
STC	Holiday Inn	SM1 2RF	C1 Hotels
STC	Metropolitan Police	SM1 4RF	Emergency Services
STC	Quadrant House	SM2 5AS	B1 Offices and Workshop businesses
STC	Chancery House	SM1 1JB	B1 Offices and Workshop businesses
STC	St Nicholas House	SM1 1EH	TBC

The Purdah period associated with the May 2018 local elections meant the stakeholder engagement was delayed until after the election.

The result of the stakeholder engagement was that no responses have been received for the above sites and thus were not considered for the network. Additional attempts were made to directly contact the Metropolitan Police and the St Nichols Centre Shopping centre. No additional information was provided by the Met Police site however there was limited success with the St Nichols Centre. AECOM were able to speak to the centre's management and the following information was obtained:

- It uses gas powered burners to supply the roof mounted air handling units
- Hot water boilers for the WC areas
- No radiators and split AC units for the centre management suit
- Gas with over door heaters
- Annual energy consumption was not provided

If further heat network feasibility studies are carried out we would recommend that this stakeholder engagement exercise is repeated in a more proactive way to ensure that the relevant parties are informed of the plans and the relevant information about their buildings is collected to inform the analysis. For instance, existing buildings are likely to be operating at higher heating temperatures compared to new buildings and unless the network is designed to supply them with the appropriate temperatures they will be unable to obtain maximum benefit from a network. Existing loads also have high heat demand compared to new build which increases sales and revenue.

Template Stakeholder consultation letter provided by AECOM and sent by LBS to targeted stakeholders.

Dear Sir/Madam

London Borough of Sutton - District Heating Feasibility Study

The London Borough of Sutton is looking to engage stakeholders with regards to exploring opportunities for collaboration with new potential energy infrastructure in the borough which we believe can offer a number of benefits to our stakeholders.

In an effort to meet UK Government carbon emission reduction targets set out under the 2008 Climate Change Act, the London Borough of Sutton is undertaking a study to investigate the potential for a district energy network as part of the Sutton High Street Masterplan. District heating networks supply sustainable heat to buildings through a network of pipes carrying hot water from a central generation facility to customer buildings. This solution can offer three key potential advantages to customers or stakeholders:

1. Significantly reduced carbon emissions
2. Lower cost energy (heat and/or electricity) when compared to conventional systems
3. Removal of the need to maintain and replace heating plant in the individual buildings connected to the network

At this point in the study, the LB Sutton, alongside our engineering consultants AECOM, are assessing the feasibility of a network for the Sutton High street area. Part of this work now involves reaching out to potential future network stakeholders and customers – you – and engaging with them effectively such that all parties fully understand the benefits such a network could bring, and to explore the potential for further collaboration.

We would greatly appreciate if you could respond to the below high level questions.

1. Would you be interested in connecting to a heat network?
2. What type of heating system do you have?

- Wet system e.g. hot water radiators
- Dry system e.g. air conditioning

3. How is the heating system fuelled (e.g. oil, gas or electric)?

Please return your response to Olyver Cox at 24 Denmark Road, Carshalton SM5 2JG via letter or email to olyver.cox@sutton.gov.uk . We would be grateful if you could provide a response by the 13th of June.

Yours faithfully,

XXXXXX

Appendix E - Energy Masterplanning Methodology

E.1 Introduction

This section outlines the energy masterplanning methodology followed for the two Sutton sites considered for district heating networks. Specifically, the approach for building prioritisation, identifying peak demand and energy centre planning are explained in detail.

E.2 Building prioritisation

Within the areas studied, only a proportion of the buildings are suitable for connection to a wider district heating network. Each building has been assessed individually to ascertain whether it is viable for connection to a district heating network.

Priority was given to proposed buildings and new developments. Indeed for STC the focus was on the 45 STC sites earmarked in the Sutton Masterplan for development between 2016-2031. As the LCH site is a campus development, with a reasonably compact footprint, all new buildings will be modelled for this network.

Existing buildings deemed to have a particularly high and stable load, or those in close proximity to each other forming a 'cluster' of demand, are also prioritised.

Buildings were assessed against the following key criteria:

- **Heat load and distance from 'anchor load' area** – Buildings underwent high level assessment as to whether the CAPEX costs associated with installing the pipework necessary to serve them would be paid back through the revenues generated through additional heat and electricity sales. A high level threshold of 3,500 kWh of heating demand per meter of necessary pipework was used to ascertain whether a building would be commercially viable for connection.
- **Stable load –** Buildings such as residential developments, leisure centres and hospitals are deemed to present high and stable heat loads over the year, making them a good fit for DHNs.
- **Physical barriers** – Buildings that have significant physical barriers such as railways and waterways between them and the anchor load score lower in the prioritisation assessment. In addition, buildings located in the protected areas (i.e. conservation areas; AQMAs; areas of high grade agricultural land, etc.) and flood risk areas are less prioritised.
- **Ownership** – Council owned buildings and new developments that the council can influence (e.g. through the planning systems) are deemed to be a high priority for a district heating network connection and are therefore scored highly.
- **Future developments** – Undeveloped buildings or future redevelopments are typically high priority for connection to a DH scheme, as their design can be influenced throughout the early stages of planning and their design, such that they are compatible with the network.
- **Heating system type** – Customer buildings will be required to be compatible with a wet heating system. Buildings that use electric systems to provide heating and DHW are not typically compatible with DH services and are of lower priority. While converting existing electric or non-compatible systems is possible, the cost, complexity and extensive engagement required with the buildings' landlords/owners associated with their conversion, represents a significant obstacle for inclusion within a DH network.

E.3 Energy Centre Considerations

The delivery of district heating to buildings in Sutton would be through the following means:

- Sutton Town Centre: heat purchased from the neighbouring Viridor ERF facility or heat generated centrally via gas-fired CHP or high temperature air source heat pumps
- The London Cancer Hub: heat generation by on-site gas fired CHP or ground source heat pumps
- In both cases: backup boiler provision installed to meet the full network heat demand in the event that the alternative low carbon technology is not available (e.g. it is down for maintenance).

Heat generation plant, heat exchangers to enable the import of heat from third parties and all other associated equipment will reside in an Energy Centre (EC): a safe and secure enclosed environment protected from adverse weather and fire and suitably designed such that noise emitted from within the enclosure is attenuated and any exhaust emissions are appropriately dispersed.

The proposed ECs will require a significant amount of floor area in order to accommodate all the necessary plant and equipment, whilst also allowing for the appropriate spatial requirements for the installation, maintenance and removal of plant. The masterplanning phase of the study estimates the size requirements of the EC for each network, and provides suggestions/inputs on where to locate it.

Peak Heating Demands

The peak network demand for heat is a key factor in calculating thermal generation plant sizes as well as the overall energy centre size and component requirements. Network peak demand is an aggregate of all the peak heat demands of the buildings on the network, with a Diversity Factor (D) applied to account for the fact that the peak loads of each building are not experienced at exactly the same time.

$$\dot{Q}_{\text{Network}} = D \sum \dot{Q}_{\text{Buildings}}$$

The diversity factor chosen depends on the nature of the buildings on the network. On large scale networks with a hundred or more individual residential units whose peak heat demand is mostly governed by domestic hot water requirements that are short term and sporadic in nature, and are often not experienced simultaneously across all dwelling units. The Heat Networks Code of Practice recommends the use of a stated diversity calculation for domestic hot water, based on the Danish Standard DS439. Peak space heating has been currently been assessed to coincide with the DHW peak load, in order to produce a conservative estimate for residential capacities and provide a peak residential load.

Based on AECOMs experience of other networks, a further diversity factor of 0.7 has been applied to the STC network[31] to reflect the mixed nature of the properties. A factor of 0.85 has been applied to the LCH site, as this is comprised of solely commercial properties.

At this stage it is important not to undersize the plant and network, hence a resilience factor of 10% was applied to the total diversified peak demand.

Peak heat demands for each building were estimated from the annual heating consumption by applying a weighted load factor. This load factor was comprised of both a space heating and domestic hot water component, weighted by the benchmarked percentage of total demand. The SH/DHW split has been verified by previous AECOM modelling experience using an in-house tool. This uses degree day analysis and suitable occupancy patterns per building type to estimate the peak demand for both SH and DWH from an annual total consumption.

Building Type	Space Heating	DHW	Data Source	Weighted Load Factor	Load Factor Reference
Hospital	69%	31%	AECOM data	39%	From AECOM hospital data - SCCC
Hotel	70%	30%	CIBSE Guide F	22%	Assumption from AECOM template
Office	87%	13%	Modelling experience	8%	Assumption from AECOM template
Police Station	90%	10%	Assumption	12%	Assumption from AECOM template

[31] The diversified residential load and the undiversified non-residential load

Building Type	Space Heating	DHW	Data Source	Weighted Load Factor	Load Factor Reference
Prison	69%	31%	AECOM data	14%	From AECOM prison data - Maidstone
Residential	53%	47%	Modelling experience	10%	Assumption from AECOM template
Retail	90%	10%	Modelling experience	19%	Assumption from AECOM template
School	90%	10%	Modelling experience	7%	Assumption from AECOM template

Energy Centre Capacity

Analysis of the peak annual heating demands and diversity of loads required for each network option was undertaken, together with other key considerations such as required boiler resilience and heat generation provision. This helped identify an appropriate composition for each EC plant.

Based on the anticipated loads for the schemes identified, boiler plant capacity required to service the different heat networks can be sized. For this project, boilers are sized to meet 100% of the peak network demand, including network losses.

Where co-generation is proposed, high level CHP sizing is made from assumed CHP run hours of 6,200, with approximately 75% of all heat supplied via CHP. Appropriate numbers of engines will be selected based on the scale of the CHP requirement and in order to provide good turn down levels. The remaining 25% heat consumption would be met by boilers.

For option 2, a potential capacity of 15MW of heat output from the Viridor ERF was identified, with an estimated 111GWh/year available. These figures will need to be verified as other local heat networks may be prioritised. However, this capacity is sufficient to cover total demand modelled for STC. In reality, maintenance of the ERF would mean that supply would occasionally be interrupted, and in such instances heat demand would be met by the top-up EC boilers.

For options 3 and 5 the chosen heat generation technologies are air and ground source heat pumps. These are sized to meet the network's base load, with boilers meeting the rest of the demand. Sizing and capacities for these technologies are detailed in Appendix L and Appendix M respectively.

Required energy centre footprint for a given energy centre thermal output capacity is based on extensive AECOM experience in energy centre design and has been validated against actual installation details. However, as with any assumption of this nature, there are risks associated with its use and the actual required energy centre size can only be confirmed once the energy centre design has been developed further.

Energy Centre Location Appraisal

A key consideration for the EC location is land ownership and its proximity to the major thermal loads in the area; lower pipework lengths between an EC and the loads being serviced reduce both CAPEX costs associated with laying the pipes and the earth works, and the OPEX costs associated with additional pumping power, maintenance, and pipework distribution heat losses.

Locating the EC on council owned land is preferred as it will help the development of the DHN by avoiding the work involved with leasing/buying or re-appropriating other areas of land, or by depending on 3rd party developers to provide space for the EC.

Total required EC footprint is dependent on its thermal output capacity, the thermal generation technology chosen, and other considerations, including any requirement to boost gas pressures, pumping equipment, etc. Certain technologies also require additional outdoor space for the storage of other equipment such as biomass fuel storage, heat rejection or storage units.

The location of the EC is a key factor in the viability of DHNs in Sutton and will requires the following considerations:

- Detailed assessment of required EC capacity, footprint and utilities provision;
- Identification of access routes for plant installation;
- Detailed existing utilities infrastructure assessment

At this stage, the proposed EC for the STC DH network is the Civic Centre Site. For the London Cancer Hub it is assumed the EC can be located adjacent to the future co-located hospital.

Gas Connections

It is proposed that the Energy Centre would be connected to the mains gas network, if necessary by providing an extension of the mains pipework to the EC.

- A medium pressure gas mains was identified in the STC area that extended to the corner of Collingwood Road and Robin Hood Lane, approximately 350m from the Civic Centre site.
- A medium pressure gas main has been identified as entering the LCH site on the eastern side, adjacent to the proposed hospital site. In addition a high pressure main was identified further east of the site.

Further investigation into connection with the local gas mains will be undertaken at a later design stage to identify the location, and capacity of available gas mains in the vicinity of the potential energy centre locations.

Electricity Generation

In the case of any proposed co-generation schemes (e.g., implementation of gas CHP), utilising the electrical output is of a high priority. It is of particular importance to identify a robust solution in order to ensure the potential revenue that could result from electricity sales is maximised, while also ensuring the effective operation of the generating plant.

Options for the sale of generated electricity include providing private wire services to a large electricity consumer in the area; entering into a private power purchase agreement with a third party consumer, to take electricity via 'sleeving' of electrical output via the grid; and exporting directly to the grid.

In this case, there is potential to sell any electricity generated by a CHP to the GLA , at an agreed price in the range of 4.5-6.5 p/kWh.

Private Wire and Sleeving Arrangements

Private wire is considered the least technologically attractive solution, due to the dependence of electrical demand from the end customer, but is the most commercially attractive solution due to higher revenues associated with electricity sold privately (and which can therefore compete with retail prices for electricity). Should electrical demand at the end customer not be sufficient to absorb the electrical output from the Energy Centre, excess electricity will need to be exported to the grid, such that the co-generation plant continues to meet heat demands and operates in a 'thermally-led' mode.

The £/kWh price for electrical sales would need to be negotiated with the end customer, and would likely need to be offered at a discount (around 5-20%) to the retail price paid currently by the customer in order to incentivise its use. Additionally, a long term contract (~15 years) will need to be drawn up between the generating entity and the end customer, in addition to an agreement regarding the quantity of electricity the customer would be required to purchase per year and the indexation mechanism to allow for price rises over time.

The best customers for the sale of private-wire electricity are those that have constant demands, such as industrial and commercial users.

A more technologically secure solution is to 'sleeve' electrical output to an end customer via connection to the grid. This solution protects against the possibility of low electrical demand from the end customer, since surplus electrical generation can be exported to the grid on the wholesale market. Any direct sales to an end customer would need to be agreed in the form of a power purchase agreement (similar to that agreed for the private wire option), which would commit the end customer to purchase a minimum quantity of electricity per year, and determine the price levels and indexation of price rise in the future. As for the private wire option, the sale price achievable benefits are competing with the retail price currently paid by the end customer. However, a discount to the retail price would likely need to be offered in order to secure agreement.

Electricity Export

Alternatively, electrical sales can be made by exporting directly to the grid. This option does not require power purchase agreements to be in place with 3rd parties, and offers the greatest technical resilience and lowest risk option. However, a major drawback of this option is the low prices that can be achieved for electricity sales, since sales are made on the wholesale electricity market (typically ~£0.04-0.06/kWh at present rates).

For the Civic Centre site a Budget/Estimate application was submitted to the local DNO for the connection of 5MW of export capacity via a G59 application. The initial conversion with the DNO confirmed that the nearest suitable substation was south of the train track and that a directional drill would be the most suitable option at an approximate cost of £150k with an additional £300k of costs for cabling. The demolition of a bridge could also be an option. Costs were not obtained for the upgrading of the substation; however, it is expected to be significant.

If electricity export is required, then the network's capacity and associated required upgrades will need to be further investigated with UK Power Networks (UKPN) via a G59 application based on the selected option.

Flue sizing

The flue is an integral component of any energy centre. The purpose of the flue is to discharge combustion at high level to avoid build-up of combustion gases local. Typically they discharge at the roof level at 600mm above nearby by buildings as a minimum.

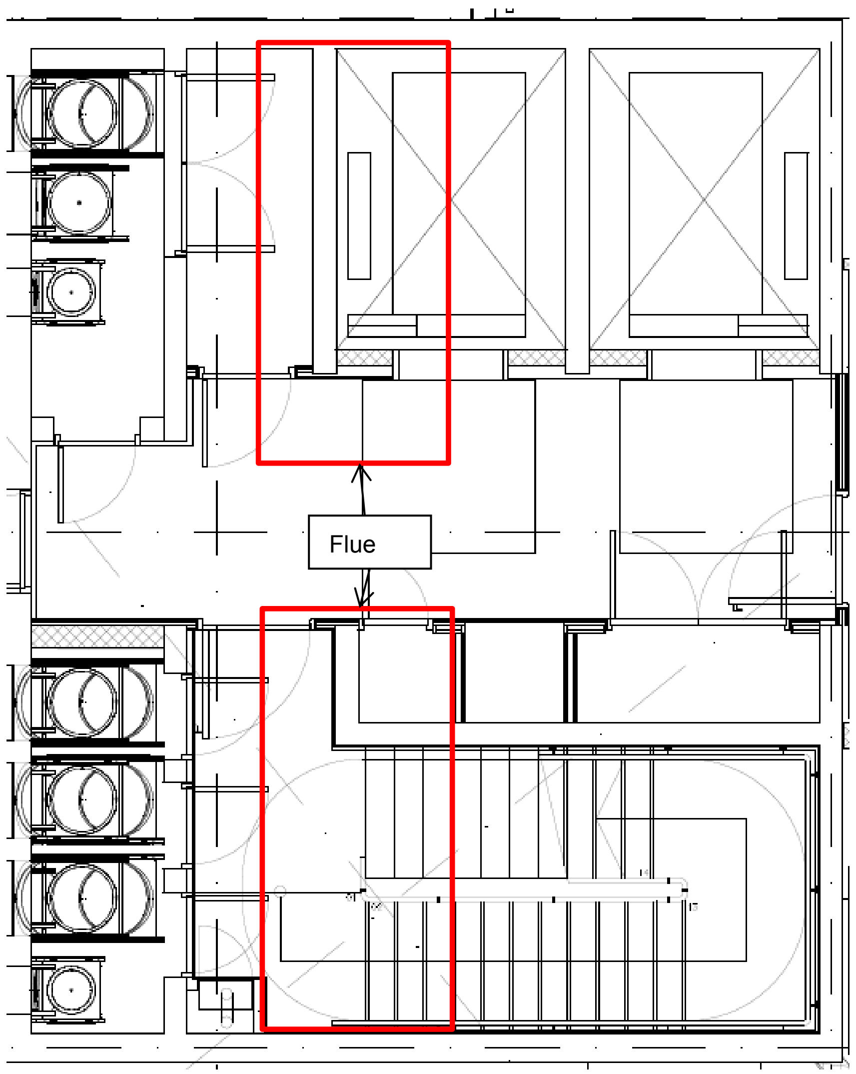
It is expected that for both STC and LCH, the energy centre plant rooms will be located in the basement and the flue will run through the building to roof level. Flues can be located in the building core or a stair core depending on the form and design of the building and the location of the energy centre within the building. From other projects AECOM work on, the flues are typically part of the central core. An extract of a building core with flue is shown below. Here, the flues have been split into two risers. Each flue riser is 4m x 2m for a total of 16m² floor space on each level. This is a 15MW gas boiler with 2.5MW of CHP scheme in a high rise building. Similar to what could be envisaged for Civic Centre site in STC.

Flue sizing is normally carried out in the feasibility assessment rather than at the masterplan stage due to the level of detail required to provide an accurate figure. However, it could be expected that for the options reviewed for STC flue size of 10 m² to 24 m² could be required. This would be subject to option selection, detailed design, plant selection, energy centre location and building form.

LCH is a slightly smaller scheme in terms of peak heating load requirements with a 10MW of gas boiler required and 3-4 MW of CHP capacity. It could be expected that for the options reviewed for LCH similar flue sizes could be required to STC, if not slightly smaller. This would be subject to option selection, detailed design, plant selection, energy centre location and building form.

In both cases, detailed work will be required to reduce air quality impacts. Some of the technical considerations provided in the air quality report are highland below. Please refer to the Air quality report in Appendix P for further details.

- The energy plant exhaust flues for both sites will need to be of an adequate height and be suitably sited to optimise dispersion and dilution, and to align with good engineering practice. This is particularly relevant to both of the proposed sites, as there are existing surrounding buildings of multiple storeys.
- Based on first principles, the flues will likely be required to discharge to atmosphere at an elevated point (typically above parapet height of the nearest tallest building, and no less than 3m higher than any adjacent area to which there is general access (e.g. roof terrace), nearby openable windows and/or ventilation plant intakes). Therefore, it is highly recommended that air quality factors are taken into account at an early stage of determining the location and design of the flues.



Example of flue in building core

Other Considerations

In addition to the key considerations (plant size, use of electrical output, connection to gas mains) analysed above, there are other important considerations that will have to be taken into account when designing an Energy Centre. These are outlined below, as follows:

- **Air Quality** – The UK's air quality is strictly regulated and attention must be paid to emissions levels. Of relevance to Energy Centres, Selective Catalytic Reduction (SCR) systems can reduce NOx emissions from combustion plant by up to 95%. SCR units utilise urea as a catalyst to reduce the NOx gases back into their constituent elements, nitrogen and oxygen.
- **Acoustics** - Acoustic protection (in the form of acoustic baffles and enclosures) might be necessary to reduce the external effects of noise resulting from plant operation.
- **Visual Impacts** - Visual impacts of the DH scheme will be limited to those relating to the Energy Centre, since the pipework will be located beneath roads and pathways, and connections to customer buildings would be located within customer building premises (and likely within their plantrooms). Additionally, it is recommended that the external design of the Energy Centre complements its surroundings and reduces potential negative visual impacts.

Appendix F – Techno-economic modelling assumptions

A detailed techno-economic model was developed for each of the network options. The purpose of this modelling is to give an indication of the financial viability of the project under the assumed capital and operational costs and associated energy sales revenues. Comparison of the model results should enable a ranking of preferred technology options for the two sites.

The majority of loads identified for both STC and LCH are new developments planned for construction by 2026. Hence the models assume network operation will begin in 2026, with capex expenditure starting from 2024. It is important to note that many of the technical and economic assumptions made are time sensitive, and may vary significantly over the eight year period to the proposed network operation.

F.1 Network options

The different network options modelled are summarised in the table below.

Site	Network	Technology	Description
STC	Option 1	Gas-fired CHP and top-up boilers	CHP engines and top-up boilers to be housed in a central energy centre
	Option 2	EfW and top-up boilers	Heat to be purchased from the Viridor ERF in Beddington and brought to STC via a 3.5 km pipe
	Option 3	ASHP and top-up boilers	Ammonia refrigerant ASHPs to provide a temperature lift to 70°C in parallel with a top-up boiler system
LCH	Option 4A	Gas-fired CHP and top-up boilers	CHP engines and top-up boilers to be housed in a central energy centre in the vicinity of the co-located hospital
	Option 4B	Gas-fired CHP and top-up boilers	CHP engines and top-up boilers to be housed in a central energy centre in the vicinity of the Royal Marsden estate development
	Option 5A	GSHP and top-up boilers	GSHP boreholes to be incorporated in the piles of the new development foundations. Heat pumps to be located alongside top-up gas boilers in the vicinity of the co-located hospital
	Option 5B	GSHP and top-up boilers	GSHP boreholes to be incorporated in the piles of the new development foundations. Heat pumps to be located alongside top-up gas boilers in the vicinity of the Royal Marsden estate development

For the STC network, temperatures of 70/40ºC flow/return have been assumed. This is to enable the use of renewable technologies at adequate efficiencies whilst ensuring a DHW supply above 60ºC. Existing buildings that wish to connect to the network may not be compatible at these temperatures. In this case additional costs may be involved in recommissioning the existing buildings' system.

For the London Cancer Hub, temperatures of 65/35ºC flow/return have been assumed. This site is entirely new build and lower temperatures enable the use of ground source heat pump at a COP entitling RHI assistance.

F.2 Capex and maintenance cost assumptions

Listed below are the cost assumptions, both CAPEX and OPEX, that have been used in the models.

All stated metrics have been developed by AECOM based upon our experience in specific District Energy projects in addition to our other projects and publication of the SPONS pricing guides. Costs are All-In rates and include overhead, profit, labour and materials. At Masterplanning stage, cost accuracy is limited as a number of factors require exploration and confirmation. This risk has been recorded within the Risk Register and a number of mitigation actions have been undertaken and recommended for future project development.

Item	Metric	Based on	Network relevance
Energy centre building	£2,500/m²	Value reflects a relatively expensive build, anticipating basement location	All
Boilers and associated equipment	£264/kW	Includes ancillary equipment (flues; ventilation; distribution pumps; energy centre electrical costs and pipework; water treatment; pressurisation and expansion; and BMS/Controls)	All
Thermal storage	£1000/m³	Based on previous tender returns	All
DH network pipework	Varying	See Appendix K	All
Heat Interface Units	£35/kW	DECC assessment of the costs performance and characteristics of UK heat networks 2015	All
Gas CHP engines	£1000/kWe	Engine and supporting ancillary plant, including flues	Option 1, 4A/B
Air source heat pump	£1740/kW	AECOM cost modelling, includes ancillaries	All (counterfactual)
Ground source heat pump	£1800/kW	Spon's Mchanical and Electrical Services Price Book 2018 (installed cost)	Option 5A/B
Electrical grid connection	£700,000	Indicative allowance	Options 1,3,4,5
Gas grid connection	£100,000	Indicative allowance	All
Private wire Cabling	£450/m	AECOM project experience	Option 1, 4A/B
Contingency	10% of CAPEX		All
Professional fees	5% of CAPEX		All
Legal fees	2.5% of CAPEX		All

Assumptions for the required replacement cycles of plant and equipment have been made on the basis that a like-for-like replacement will be sought throughout the network lifespan. All other plant and equipment is assumed to last beyond the project lifetime.

Maintenance costs are assumed to be constant over the lifespan of the project. The figures given below are based on AECOM experience.

Item	Maintenance cost p.a.	Replacement Cycle	Replacement cycle source
Boilers	£4/kW	20 years	CIBSE Guide M
Thermal storage	negligible	50 years	

Item	Maintenance cost p.a.	Replacement Cycle	Replacement cycle source
DH network pipework	1% of CAPEX	50 years	
Heat interface units	£1/kW	20 years	
Gas CHP engine	£9/MWhe	20 years	CIBSE Guide M
Air Source Heat pumps	£5/kW	20 years	
Ground source heat pumps	£14/kW	20 years	

F.3 Fuel costs

Fuel unit prices for gas and electricity are based on energy price analysis published by the Department for Business, Energy & Industrial Strategy (BEIS). Domestic values are specific to regions; those published for London (2017) have been used for the current study. Unless specified, the fuel cost metrics below include the Climate Change Levy.

For option 2, heat is purchased directly from the Viridor energy recovery facility. The cost metric from the 2014 ARUP report[32] supplied by LBS has been used.

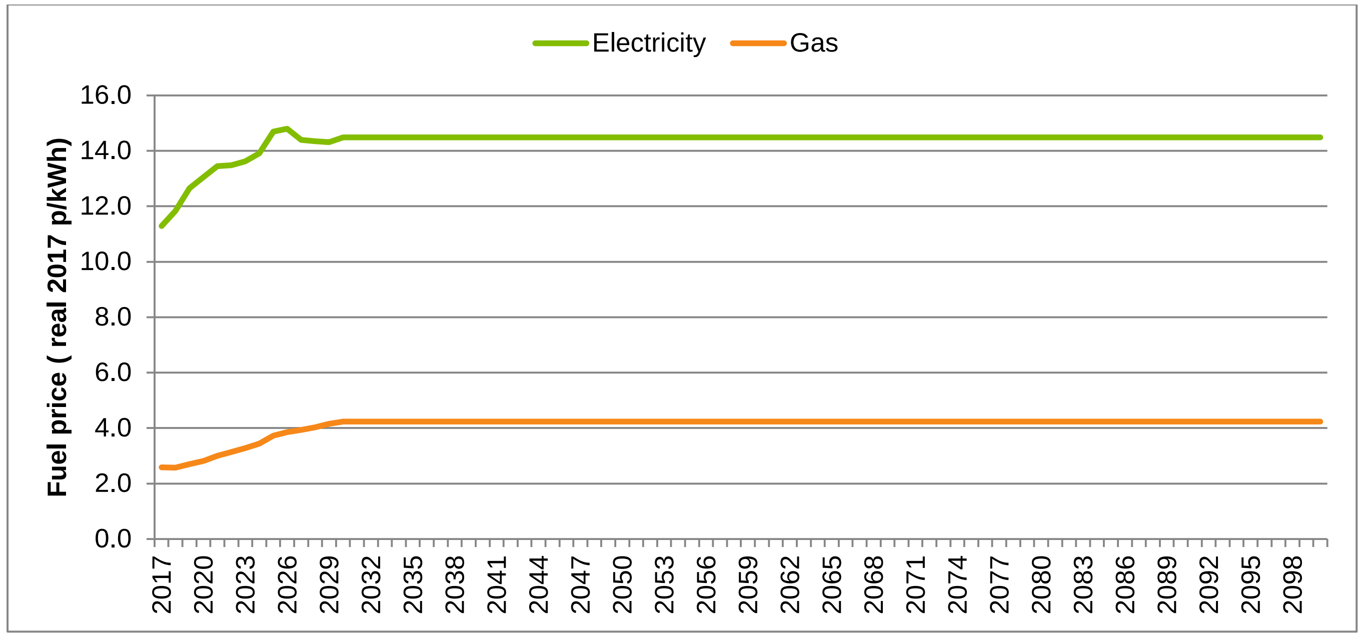
Item	Fuel cost (p/kWh)	Used for
Gas		
Gas tariff - medium	2.08	EC boiler gas price
Gas tariff (excluding CCL) - large	1.54	EC CHP gas price
Non-residential gas tariff - very small	3.96	Counterfactual heat price
Non-residential gas tariff - small	2.24	Counterfactual heat price
Residential gas tariff - London	4.37	Counterfactual heat price
Electricity		
Electricity tariff (excluding CCL) - medium	10.08	EC electricity price
Non-residential electricity tariff - small	12.60	Private wire sales
Non-residential electricity tariff - s/m	11.00	Private wire sales
Non-residential electricity tariff - medium	10.49	Private wire sales
Residential electricity tariff - London	16.49	Private wire sales
Heat		
Heat import tariff (from Viridor)	1.5	Heat price for Option 2 network

F.4 Future fuel price projections

Trend projections of future energy prices are taken from the BEIS Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal[33]. Year 1 costs are taken as described above, with future prices indexed to the Interdepartmental Analysts' Group (IAG) trends provided.

Within the IAG tables, three bands of prices are given: High, Central and Low. For the purposes of the model, it is assumed that customers are currently paying the Central price for gas and electricity.

The graph below shows the HM Treasury Green Book future fuel price projections, showing the Central scenario for electricity and gas. Whilst the trend of these projections have been used in the model, the IAG projections do not show any change to price beyond c. 2030, an unlikely scenario. This could pose a risk for the viability of the network.



F.5 Revenue

For modelling purposes, revenue streams have been based on the counterfactual annual price of heat, the methodology for which is detailed in Appendix N. For Sutton Town Centre, heat sales include a 10% discount on the counterfactual price to incentivise connection to the network.

In practice, revenue will come from a number of sources, including direct charges for heat and fixed charges for operation (comparable to standing charges on conventional utility services). For the options based on gas-fired CHP, revenue will also come from any electricity income which may be available through wholesale to the grid, or directly to electricity consumers. Other one-off sources of revenue are also often charged, for example to help cover the cost of connecting individual customers to the network.

The following paragraphs explain these different revenue streams that make up the counterfactual heat price. If a DH network option is pursued the rates of each of these respective charges will need to be determined.

One off charges

Connection Charge

A Connection Charge is a one off contribution towards the capital cost of initiating a customer's connection to the heat network. The connection charge could be designed to cover:

- The capital outlay required to contribute to the scheme
- An amount not more than the cost which would be incurred for connection to/installation of an alternative heat source
- An amount not more than the cost incurred of replacing existing plant for that building
- Planning Authority requirements

[32] Decentralised Energy for London, Hackbridge, Heat Demand Assessment: Extension of a heat network beyond the Felnex development, May 2014

[33] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

LBS may wish to consider if it has any funds available for injection into the scheme as a capital contribution or whether any of the potential customers to the schemes may be willing to pay a connection charge. For existing buildings, connection charges should be linked to the cost of replacing the current heating plant system, less a chosen discount rate. For developers of new residential housing or commercial buildings, connection costs can be higher due to planning conditions to connect to the network that can be imposed by the council.

Heat Sale

Heat networks typically charge for heat via a Fixed Charge plus a Variable Charge (based on consumption), similar to most electricity or gas supply contracts. Some schemes charge using a Flat Charge, but this method of charging is no longer allowed under the Heat Network (Metering and Billing) Regulations 2014 unless it is not technically possible and economically justified to implement metering and charging based on actual consumption.

Fixed/Standing Charge

Fixed charges are often set to cover the fixed costs or minimum running costs of the scheme. This gives comfort to the operator (and funder) of the financial viability of the scheme. A common complaint made by customers is that Fixed Charges are too high, and therefore a commercial decision should be taken as to whether the full extent of fixed costs should be included in the Fixed Charge. The higher the element of Fixed Charge relative to Variable Charge, the lower the risk to the operator, i.e. variability in income relative to demand.

Variable (unit) Charge

The variable charge is often set to cover the marginal costs of supplying heat to the customer, e.g. fuel costs and efficiency losses. It would also be expected that an element of profit would be included within the variable charge on a 'for-profit' project.

When setting heat charges, prices will need to be set low enough that they are competitive to attract customers to connect to the scheme (i.e. will need to be considered with respect to current heating costs). At the same time, prices will need to be set high enough such that a satisfactory return on investment is met.

Electricity Revenue

The proposed heat generation technology for options 1 and 4 is CHP. The electricity generated by the CHP can either be sold privately or exported to the grid. It has been assumed in the latter case that this can be done via a Licnece Lite agreement.

Licence Lite is a UK government scheme that helps reduce the barriers of entry to new suppliers in the electricity supply market. Through this the GLA are able to buy electricity from low carbon electricity generators and sell on to end customers such as Transport for London, passing through 100% of the benefits to the generator. The price at which this electricity is sold is up for negotiation. For modelling purposes a price of 5.5p/kWh was assumed for electricity sold via Licence Lite. The IAG Long Run Variable Cost trend was applied for price projection.

Revenue generated through the sale of electricity via private wire is dependent on the agreement with the customer. The prices will usually be linked to the prevailing retail price, such that the customer benefits from a reduction in its energy bills over what they would pay otherwise. The default values for the purposes of the results given in this report are that electricity is sold privately at a discount rate of 10% against the BEIS published statistical retail electricity price. The remaining electricity is assumed to be exported wholesale via a Licence Lite agreement.

Although private wire electricity distribution demands certain up front capital expenditure, the revenues generated are much higher than exporting to the grid. As such, the ratio of electricity generated which is sold via a private wire to that which is exported at whole sale rates affects the commercial viability of the network significantly. Whilst it is preferable to sell all generated electricity privately, AECOM recognises that this may not be technically feasible, and depends on identification of appropriate private customers.

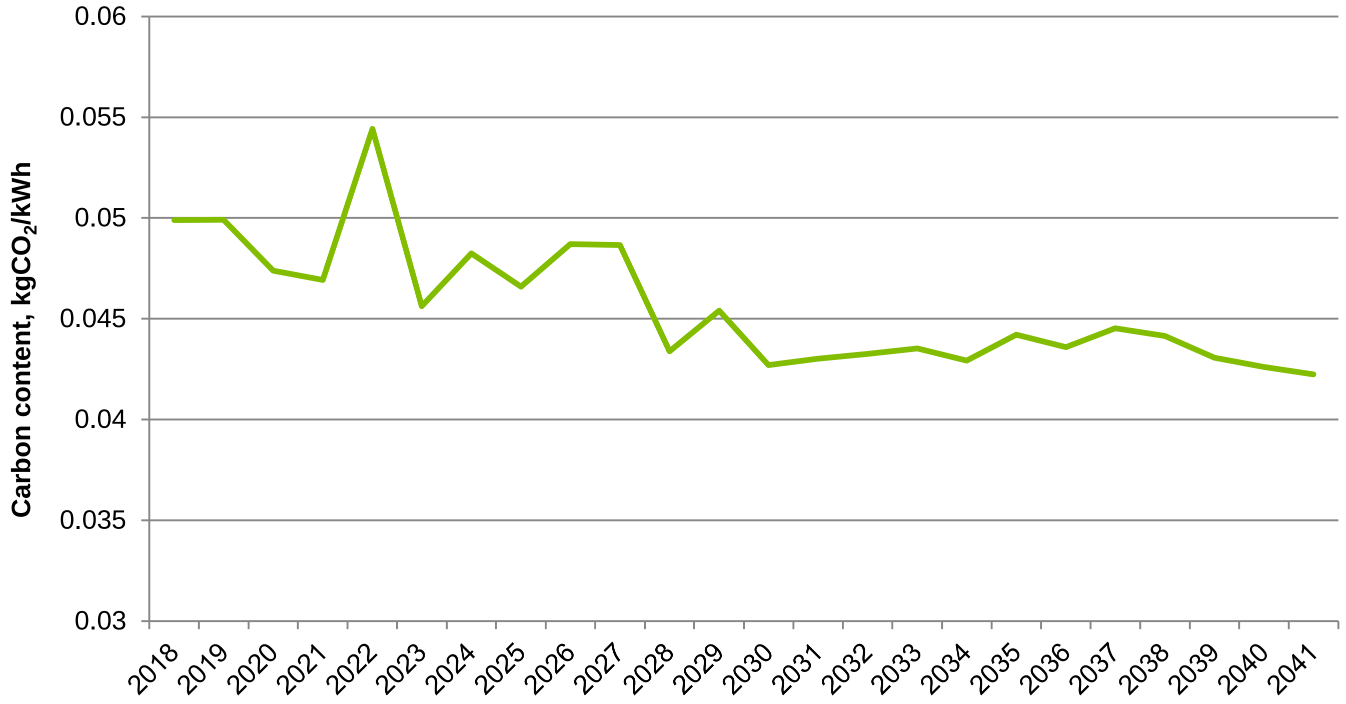
F.6 Carbon

Scheme carbon savings depend on the input fuel and the associated carbon factors of the fuel which is being offset by the heat generation technology. Emissions associated with the combustion of gas are assumed to be constant over the lifetime of the project, where the emission factor used is 0.208kgCO_2/kWh, based on UK Government SAP consultation 2016. In cases where grid electricity is displaced by CHP electricity, carbon factors are taken from the BEIS bespoke CHP emissions factors[34] spreadsheet for electricity exported and used on site.

Gas CHP currently delivers carbon savings compared to conventional gas boiler systems, as the electricity produced is cleaner than that which is taken from the grid. However, as outlined by the DECC emission projections, the CO_2 emissions attributed to grid electricity are expected to fall. As a result, the carbon savings associated with the use of gas CHP schemes is expected to decrease over time.

For modelling purposes, carbon emissions for each technology option are compared to the counterfactual alternative to check if any carbon savings are made. As this counterfactual reflects current policy changes, it is based on a hybrid ASHP/gas boiler solution. In effect, the emissions from the counterfactual are lower than a conventional gas boiler system and thus pose a tougher standard to beat.

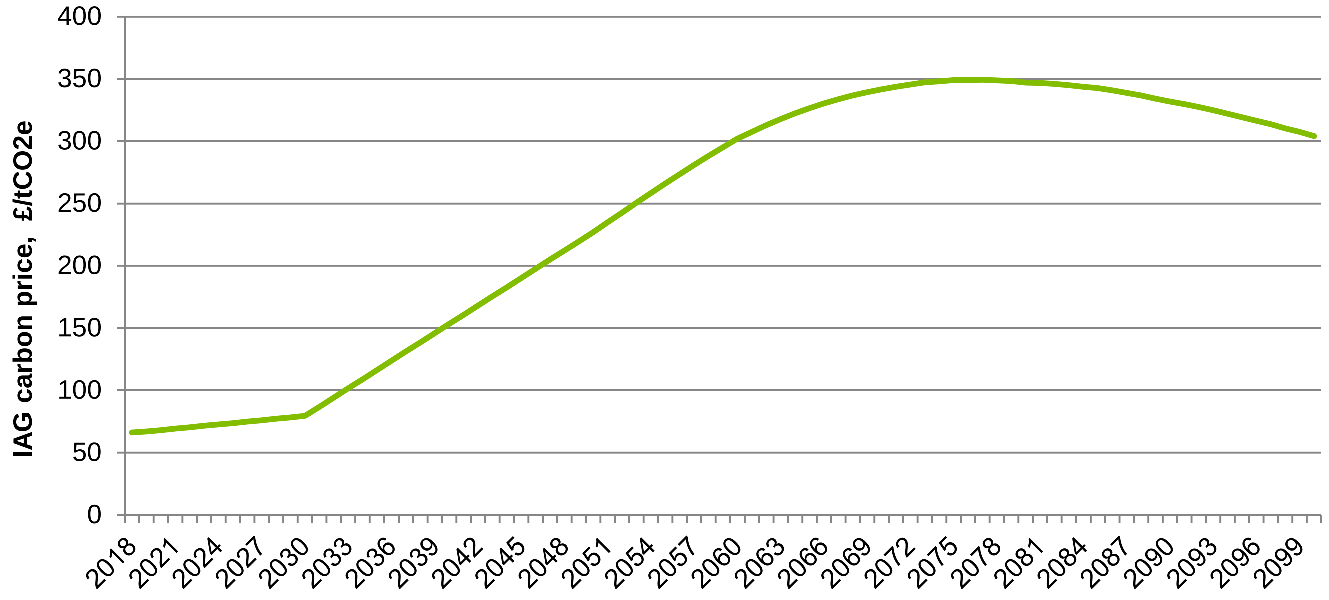
The carbon content of heat from EfW has been modelled with a present value of 0.050kgCO_2/kWh, evolving as shown in the graph below. This reflects assumptions made and shared with AECOM by Simon Woodward (SDEN Project Director). The carbon factors are based on heat from an ERF facility with Z ratio.



Carbon factors for electricity purchased, i.e. to power renewable technologies such as air source heat pumps, are modelled on IAG grid average emission factors. A present day this metric is given at 0.220 kgCO2e/kWh for commercial consumption, and drops by a factor of 10 by 2050.

Carbon savings have been valuated using the UK governments agreed carbon values, as seen in the HM's Treasury Green Book Supplementary Appraisal Guidance. Within the IAG carbon price tables, three bands of prices are given: High, Central and Low. For the purpose of the model, carbon is priced using the non-traded Central scenario, for which the trend is shown in the figure which follows this paragraph.

[34] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/446512/Emissions_Factors_for_Electricity_Displaced_by_Gas_CHP.xlsx



IAG projected non-traded carbon price

Appendix G – Policy Context

The key policies relating to reductions in CO_2 emissions and the development of district heat networks are summarised below. This is intended to provide an overview of relevant legislation and policies, thereby providing a contextual background to the study.

14.6 National Policy

Below illustrates a timeline of policies that have been implemented by the Government with respect to improving the efficiency of the built environment in order to combat global warming and climate change.

Our Energy Future – Creating a Low Carbon Economy, 2003 sets a target for 10% of electricity to be produced from renewable sources nationally by 2010 and twice this by 2020, with a 60% reduction in CO_2 emissions by 2050.

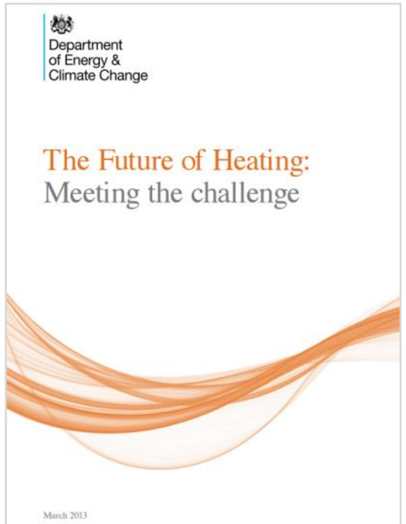
Climate Change and Sustainable Energy Act, 2006 enhances the contribution of the UK to combating climate change, alleviating fuel poverty and securing a diverse and viable long-term energy supply. The Climate Change and Sustainable Energy Act 2006 supports schemes whose purpose or effect is the promotion of community energy projects.

The Department of Transport (DoT) and Industry White Paper entitled 'Meeting the Energy Challenge', 2007 sets out UK energy strategy, recognising the need to tackle climate change and energy security by encouraging energy savings and supporting low carbon technologies.

The Climate Change Act, 2008 sets up a framework for the UK to achieve its long-term goals of reducing greenhouse gas emissions by 34% over the 1990s baseline by 2020 and by 80% by 2050 and to ensure steps are taken towards adapting to the impact of climate change. The Act introduces a market system of carbon budgeting which constrains the total amount of emissions in a given time period, and sets out a procedure for assessing the risks of the impact of climate change for the UK, and a requirement for the Government to develop an adaptation programme.

The Planning and Energy Act, 2008 enables local planning authorities to set requirements and targets for energy use and energy efficiency in local plans.

The Carbon Plan, 2011 sets out the Government's plans for achieving the emissions reductions committed to in the Climate Change Act, 2008, on a pathway consistent with meeting the 2050 target. This publication brings together the Government's strategy to curb greenhouse gas emissions and deliver on climate change targets, as well as updating actions and milestones for the following five years.



The Energy Act, 2013 makes a provision for the setting of a decarbonisation target range and duties in relation to it, and for the reforming of the electricity market for purposes of encouraging low carbon electricity generation and ensuring security of supply.

The Future of Heating: Meeting the challenge, 2013 sets out pathways for the transition to a low carbon heat supply. It sets out Department of Energy and Climate Change (DECC)[35] commitments to support local authorities in the development of heat networks in their areas through the establishment of a Heat Networks Delivery Unit (HNDU), support for technological innovation, provision of funding for feasibility work, exploration of potential additional financial incentives and Government funding for heat networks, and provision of a consumer protection scheme. Initial modelling undertaken by DECC suggests that heat networks could form an important part of the least cost mix of technologies by 2050, with the potential to serve 14% (or more) of domestic heating and hot water demand (41TWh) and 9% of non-domestic heating and hot water demand (11TWh) by 2050. It suggests that in the period to 2030 heat networks will predominantly be fuelled by gas-fired Combined Heat and Power (CHP).

[35] From July 2016, Department of Energy & Climate Change became part of Department for Business, Energy & Industrial Strategy

The Deregulation Act, 2015 reduces the legislative and regulatory burdens and repeals legislation that no longer has practical use. With regard to energy, the Deregulation Act 2015 states that local planning authorities can no longer require that developments in their area meet higher energy efficiency standards than are required by building regulations. However the Deregulation Act 2015 does not repeal the following two remaining clauses in Section 1 of the Planning and Energy Act 2008:

"A local planning authority [may] include policies imposing reasonable requirements for:

(a) a proportion of energy used in development in their area to be energy from renewable sources in the locality of the development;
(b) (b) a proportion of energy used in development in their area to be low carbon energy from sources in the locality of the development".

At the time of writing, this legislation has not yet been enacted.

The Productivity Plan, Fixing the Foundations: Creating a More Prosperous Nation, 2015 indicates that the Government does not intend to precede with the zero carbon Allowable Solutions carbon offsetting scheme, or the proposed 2016 increase in on-site energy efficiency standards via the Building Regulations. It will, however, keep energy efficiency standards under review, recognising that existing measures to increase energy efficiency of new buildings should be allowed time to become established.

The National Planning Policy Framework (NPPF), 2018 sets out the Government's planning policies for England and how these are expected to be applied. The NPPF must be taken into account in the preparation of local and neighbourhood plans, and is a material consideration in planning decisions. Local planning authorities are required to design policies which increase the use and supply of low carbon energy, have a positive strategy to promote energy from renewable and low carbon sources, support community-led initiatives for low carbon energy, and identify suitable areas for low carbon energy sources.

14.7 Regional & Local Policy

Regional and Local commitments to meet the climate change challenge and to move towards a thriving green economy is addressed by the following policies:

The current **London Plan, March 2016** sets out the spatial development strategy for London, consolidated with alterations since 2011. This is the Mayor's central policy document for London, outlining the Mayor's policies towards a range of responsibilities, including London's response to climate change and sustainability issues, in addition to other social priorities such as housing and transport.

The draft **New London Plan, December 2017** responds to the changing nature of issues given policy weight in the existing London Plan. Following a consultation period, the comments received will be discussed during an Examination in Public, which is expected to be held in the autumn of 2018. Adoption of the new policy will require consent by both the Secretary of State for Communities and Local Government (DCLG) and the London Assembly. The plan presents a heat hierarchy which places the use of heat pumps to access secondary heat sources ahead of other renewables such as solar and biomass, which in turn are ahead of fuel cells, which in turn are ahead of gas CHP, with gas boilers being at the bottom of the hierarchy. This draft also extends the zero-carbon target for major residential development to major non-residential developments.

The **London Environment Strategy** brings together key policy stances regarding London's environmental challenges, including air pollution, waste, noise pollution, the health and availability of green spaces, and climate change. The strategy was published in June 2018. It identifies nitrogen oxides (NO_x) as a pollution of concern for London, alongside particulate matter and black carbon, with many areas of London showing average NO_2 concentrations above the EU limit value. It also addresses the declining carbon savings of CHP and the need to consider CHP systems for large heat networks on a case by case basis.

The draft **Solar Action Plan for London, August 2017** explores the potential for solar PV to contribute towards London's energy mix, and summarises the Mayor's policies regarding solar technologies and the Mayor's actions to increase solar energy generation in London. The Action Plan has been out for consultation; the GLA is currently reviewing the responses and considering potential changes to the Action Plan. It is expected to be published in full in 2018.

The **Sutton Local Plan 2016-2031, February 2018** is the core development plan document for the London Borough of Sutton, and summarises the borough's policies on a range of planning matters, including carbon emissions, energy and environmental protection. It is required to be in compliance with the minimum standards set by the London Plan.

Appendix H - Solar PV

Listed below are the assumptions made when assessing solar PV potential in Sutton Town Centre:

- Roof area is 40% of site area
- PV is 30% of roof area
- kWp/m2 is 0.166kWp/m2 of roof area
- Annual output of 850kWh per kWp

Building list – STC sites:

LDF_ID_201	Property Name	Roof area	PV Area	kWp	Annual output (kWh)
STC1	THE OLD GAS WORKS	9253	2776	461	391633
STC2	Morrisons Local and Car Park	576	173	29	24378
STC3	FORMER BURGER KING SITE	804	241	40	34013
STC4	Sutton West Centre	4236	1271	211	179269
STC5	North of Lodge Place	846	254	42	35826
STC6	SOUTH OF LODGE PLACE	1586	476	79	67138
STC7	Kwikfit Site	348	105	17	14746
STC8	North of Greenford Road	293	88	15	12412
STC9	Civic Centre Site	3585	1076	179	151752
STC10	Secombe Theatre Site	1126	338	56	47662
STC11	Beech Tree Place	1738	521	87	73555
STC12	NORTH OF SUTTON COURT ROAD	863	259	43	36531
STC13	SOUTH OF SUTTON COURT ROAD	3392	1018	169	143570
STC14	Sutton Station	5349	1605	266	226383
STC15	Shops opposite Station	710	213	35	30047
STC16	Sutherland House	1050	315	52	44446
STC17	Petrol Station north of Subsea 7	3369	1011	168	142601
STC18	Sutton Superbowl Site	557	167	28	23571
STC19	Helena House	455	137	23	19267
STC20	HERALD HOUSE	209	63	10	8862
STC21	Sutton Park House	1028	308	51	43511
STC22	Old Inn House	336	101	17	14232
STC23	Bus Garage	2182	654	109	92333
STC24	Halfords Site	1083	325	54	45841
STC25	MATALAN BLOCK	2220	666	111	93961
STC26	31-35 ST NICHOLAS WAY	371	111	18	15713
STC28	ST NICHOLAS CENTRE CAR PARK	2020	606	101	85495
STC29	St Nicholas House	1252	376	62	52991
STC30	ROBIN HOOD LANE SITES	2245	674	112	95027
STC31	GIBSON ROAD CAR PARK	2672	802	133	113095
STC32	City House	713	214	36	30185
STC33	Land North of Grove Road	3978	1193	198	168360
STC34	GREENSLEEVES MANOR	1084	325	54	45893
STC35	LAND SOUTH OF GROVE ROAD	1990	597	99	84206
STC36	B&Q Site	8766	2630	436	371015
STC37	WILKO SITE	416	125	21	17605
STC38	Houses adjacent to Manor Park	2095	628	104	88659
STC39	LAND TO THE REAR OF TIMES SQUARE	292	87	15	12342
STC40	-	837	251	42	35444
STC41	Times Square Car Park	2907	872	145	123054
STC45	Elm Grove Estate	2467	740	123	104412
Total			24390	4048	3441037

Carbon Savings

		2013 Part L carbon factor	2016 consultation carbon factor
Carbon savings	kWh per year	0.519	0.398
STC (kg)	3,441,037	1,785,898	1,369,533

LCH assumptions:

- Roof area is 20% of site area
- PV is 30% of roof area
- kWp/m2 is 0.166kWp/m2 of roof area
- Annual output of 850kWh per kWp

Building list – LCH sites:

ID	Wave	Property_Name	Roof area	PV area	kWp	Annual output
2	0	ICR (CCDD)	1,600	480	80	67,720
3	0	The Royal Marsden (Maggie's Centre)	230	69	11	9,735
4	Wave 1	Commercial / research	4,561	1,368	227	193,045
5	0	Not for profit/charitable/academic	3,662	1,099	182	154,995
6	0	ICR	2,480	744	123	104,966
7	0	Patient hotel/accommodation	440	132	22	18,623
8	0	Community/leisure/retail	1,193	358	59	50,494
9	Wave 2 A	Commercial / research	7,778	2,333	387	329,205
10	0	Not for profit/charitable/academic	-	-	-	-
11	0	ICR	1,031	309	51	43,637
12	0	Co-located hospital	20,526	6,158	1,022	868,766
13	0	Community/leisure/retail	983	295	49	41,606
14	Wave 2 B	Commercial / research	12,622	3,787	629	534,228
15	0	Not for profit/charitable/academic	-	-	-	-
16	0	ICR	1,031	309	51	43,637
17	0	The Royal Marsden	15,682	4,705	781	663,743
18	0	Community/leisure/retail	983	295	49	41,606
19	Wave 3	Commercial / research	5,413	1,624	270	229,106
Total				14,969	2,485	2,111,898

Carbon Savings

		2013 Part L carbon factor	2016 consultation carbon factor
Carbon savings	kWh per year	0.519	0.398
LCH (kg)	2,111,898	1,096,075	840,535

Appendix I – Sensitivity Analysis

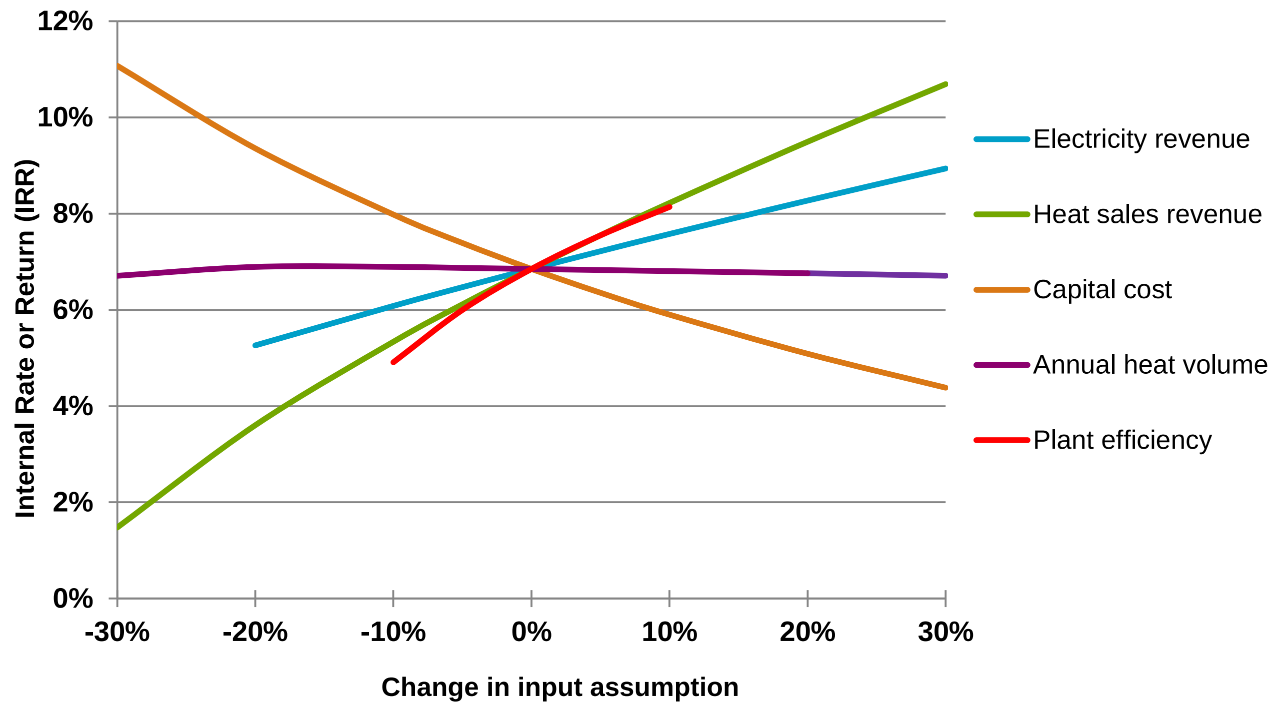
The results of the sensitivity analysis for each of the proposed DH network options are shown below. This covers the following sensitivities:

- Heat sales revenue
- Capital cost
- Annual heat volume
- Plant efficiency
- Gas costs
- Electricity revenue (where appropriate)

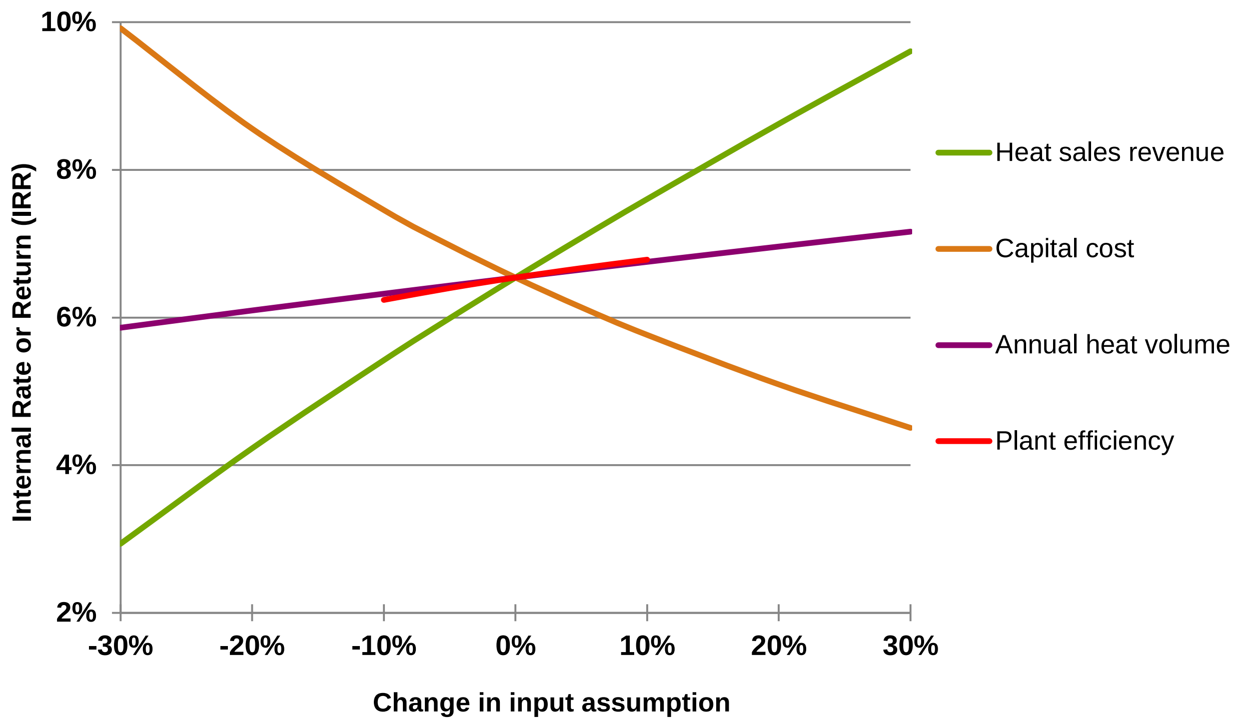
For the LCH, only options 4A and 5A are shown, as the results for 4B and 5B mirror their 'A' equivalent very closely.

Bespoke option sensitivities are covered within section 9.4 of this report.

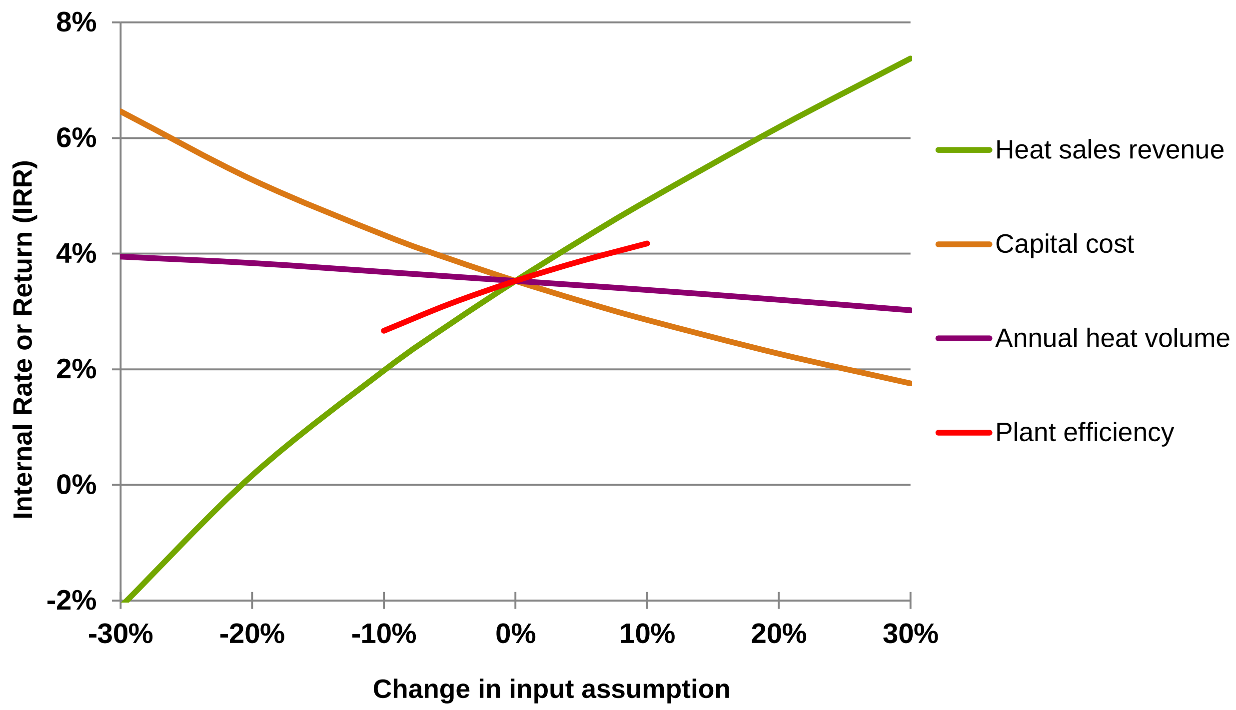
40 year IRR sensitivity - Option 1

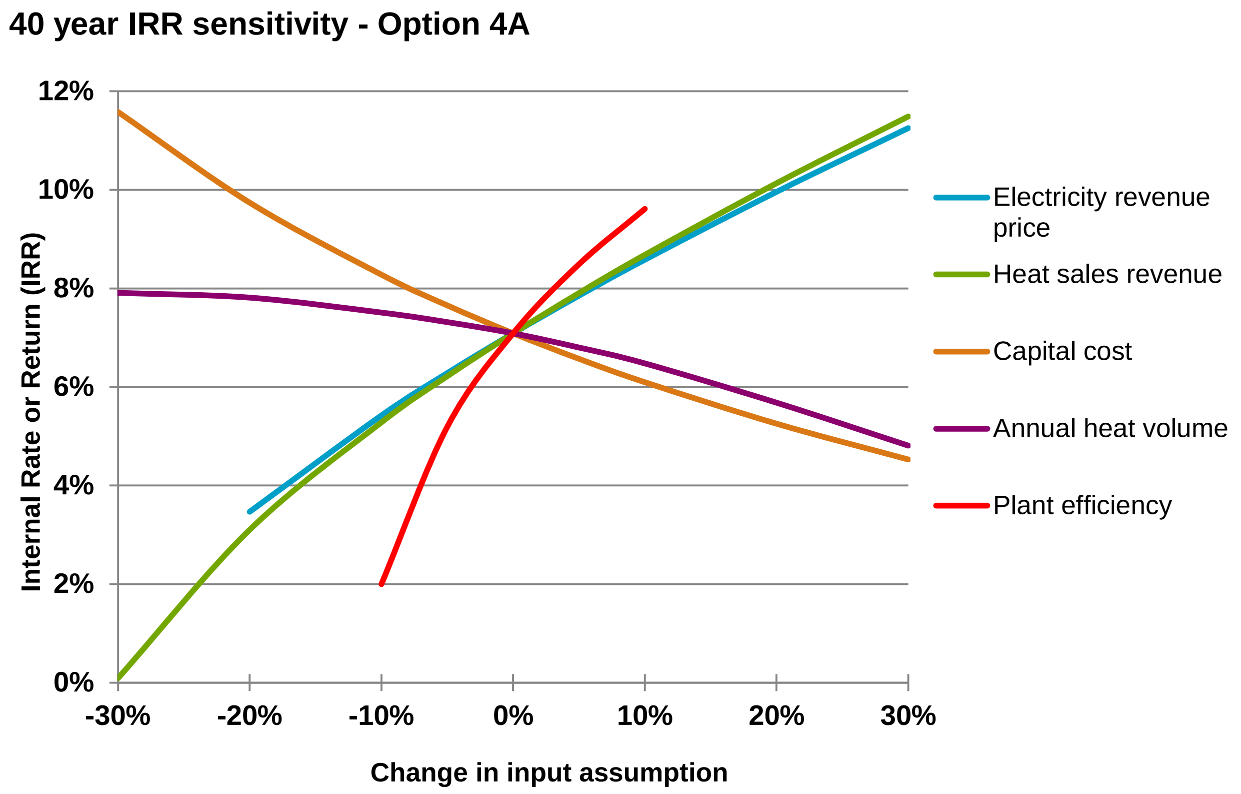


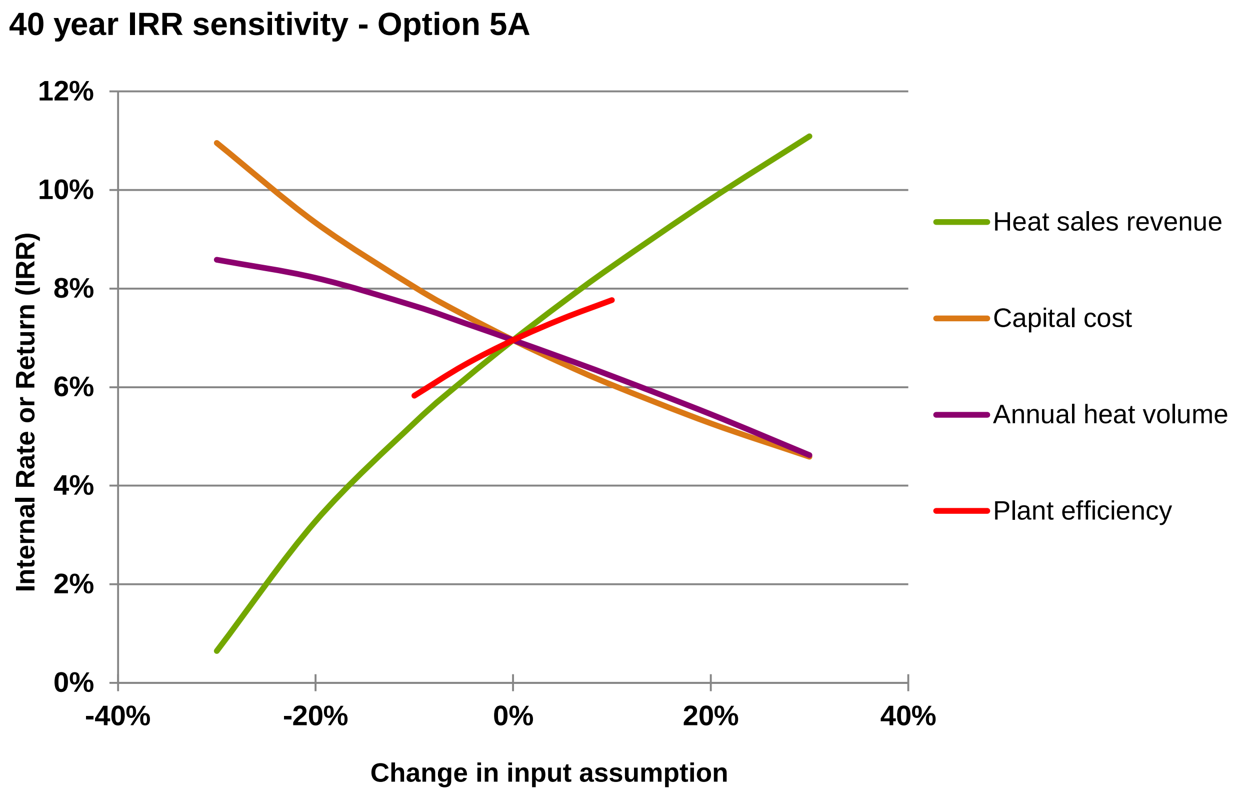
40 year IRR sensitivity -Option 2



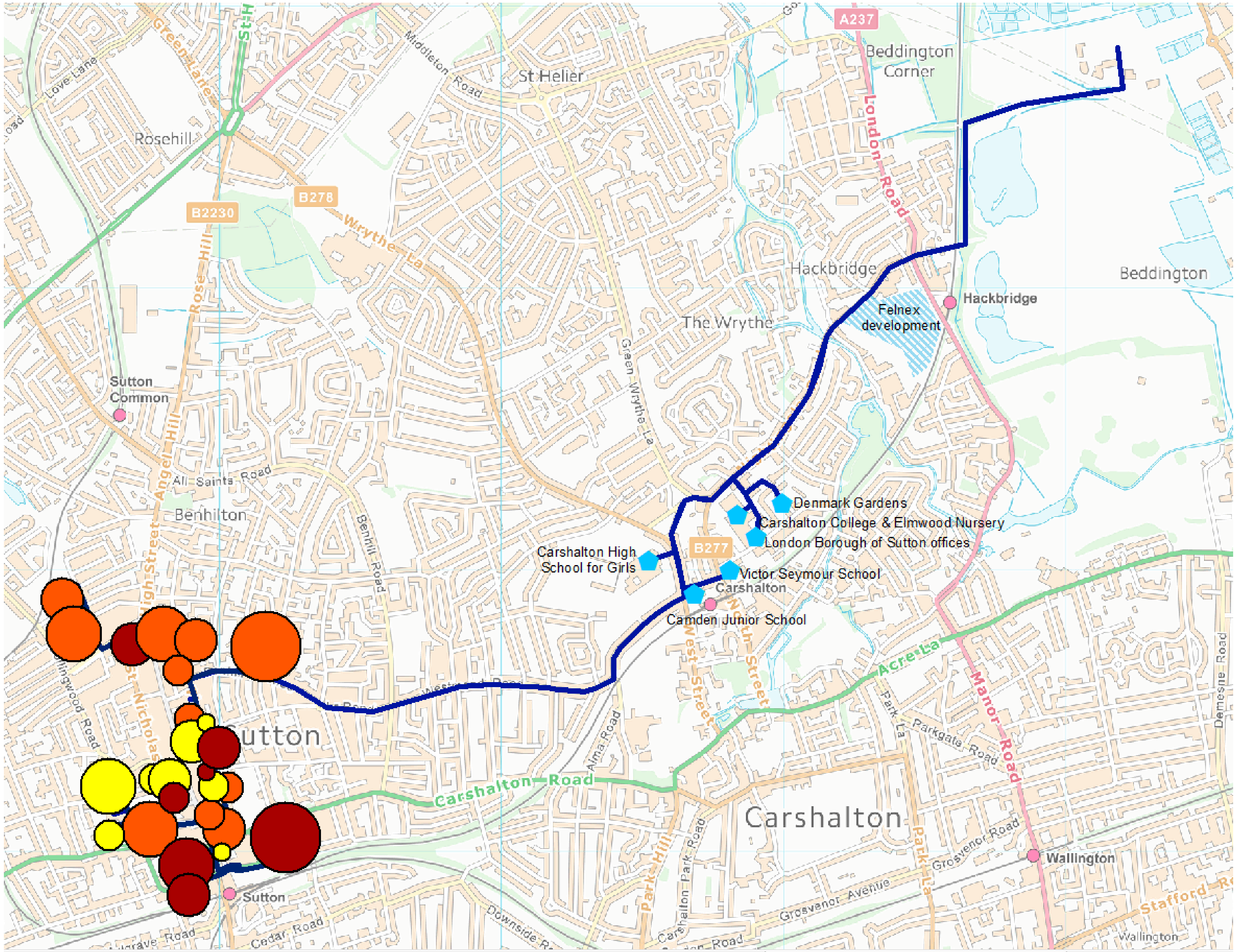
40 year IRR sensitivity - Option 3




40 year IRR sensitivity - Option 4A
12%
10%
8%
6%
4%
2%
0%
Internal Rate or Return (IRR)
-30%
-20%
-10%
0%
10%
20%
30%
Change in input assumption
Electricity revenue price
Heat sales revenue
Capital cost
Annual heat volume
Plant efficiency


40 year IRR sensitivity - Option 5A
12%
10%
8%
6%
4%
2%
0%
Internal Rate or Return (IRR)
-40%
-20%
0%
20%
40%
Change in input assumption
Heat sales revenue
Capital cost
Annual heat volume
Plant efficiency

Appendix J – EfW network route from Beddington site to STC



Six potential DH network opportunities have been identified in Carshalton. Connection to these could improve the feasibility of running a 3.5 km pipe from the Viridor ERF facility in Beddington to Sutton Town Centre. If this option is taken forward, additional opportunities such as these should be included in future analysis, given capacity constraints.

Appendix K – Pipework assumptions

Pipe cost rates are based on price per metre of single steel pipework. The table below shows the respective cost of steel pipework for varying diameters. For the STC and LCH sites hard-dig has been assumed. The only exception to this is for Option 2 where soft-dig was modelled for the portion of pipe between the Viridor ERF and the Hackbridge railway line.

Spec Pipe Size (DN)	Civil work Hard dig flow & return	Soft dig	Supply & installation flow	return	Hard-dig TOTAL	Soft-dig TOTAL
[mm]	[£/m]	[£/m]	[£/m]	[£/m]	[£/m]	[£/m]
25	302	156	113	113	527	381
32	328	182	121	121	571	425
40	339	208	137	137	612	481
50	351	214	143	143	638	500
65	377	224	156	156	690	537
80	423	234	165	165	753	565
100	488	245	193	193	873	630
125	547	252	216	216	979	685
150	618	261	241	241	1099	742
200	716	287	258	258	1232	802
250	719	307	330	330	1380	968
300	724	313	353	353	1430	1018
350	*745*	*365*	419	419	1584	1204
400	*802*	*417*	464	464	1731	1345
450	*834*	*469*	497	497	1827	1462
500	*886*	*521*	722	722	2330	1965
600	*912*	*573*	1084	1084	3079	2740
700	*1011*	*625*	1464	1464	3939	3553
800	*1110*	*834*	1695	1695	4499	4223

The table below shows the distribution of pipe diameters and lengths, and their respective costs, modelled for the Option 1 network in STC.

Pipe Size (id)	Soft-dig Pipe Run length required	% Over total Pipe Run length	Estimated cost	Hard-dig Pipe Run length required	% Over total Pipe Run length	Estimated cost
[mm]	[m]	[%]	[£]	[m]	[%]	[£]
25	-	0.0%	£ -	316	7.8%	£ 166,612
32	-	0.0%	£ -	10	0.2%	£ 5,710
40	-	0.0%	£ -	262	6.4%	£ 160,253
50	-	0.0%	£ -	261	6.4%	£ 166,441
65	-	0.0%	£ -	156	3.8%	£ 107,609
80	-	0.0%	£ -	920	22.6%	£ 693,097
100	-	0.0%	£ -	414	10.2%	£ 361,503
125	-	0.0%	£ -	489	12.0%	£ 478,966
150	-	0.0%	£ -	363	8.9%	£ 399,050
200	-	0.0%	£ -	435	10.7%	£ 535,765
250	-	0.0%	£ -	441	10.8%	£ 608,407
300	-	0.0%	£ -	5	0.1%	£ 7,148
350	-	0.0%	£ -	-	0.0%	£ -
400	-	0.0%	£ -	-	0.0%	£ -
450	-	0.0%	£ -	-	0.0%	£ -
500	-	0.0%	£ -	-	0.0%	£ -
600	-	0.0%	£ -	-	0.0%	£ -
700	-	0.0%	£ -	-	0.0%	£ -
800	-	0.0%	£ -	-	0.0%	£ -
900	-	0.0%	£ -	-	0.0%	£ -
	-	**0%**	**£ -**	**4,072**	**100%**	**£ 3,690,561**

Appendix L – Air Source Heat Pump Solution: STC

As an alternative to gas-fired CHP and energy from waste, air source heat pumps have been considered as a heat generation source for Sutton Town Centre. The sizing of the proposed system is explained below, along with key considerations regarding an ASHP solution.

L.1 Sizing of system

The central ASHP system should be sized to meet the base load of the DH network, with top-up boilers sized at 100% peak capacity for resilience. To enable appreciable carbon savings above the counterfactual, as well as making the scheme eligible for HNDU funding, the ASHP should generate more than 50% of the thermal demand. To deliver greater than 50% of the demand, the central ASHPs are designed to run in parallel to the top-up boilers. This means the ASHPs must achieve the full temperature lift from 40ºC to 70ºC.

With a typical refrigerant (e.g. R407C), heat pumps produce heat efficiently up to around 50/55ºC. However, the use of ammonia enables higher temperature heat pumps that can supply in excess of 90ºC, depending on the source. Unlike typical refrigerants, ammonia is both toxic and flammable, and hence its use requires that additional safety measures are taken, as discussed below. However, this alone should not be considered a barrier to their use.

An example high temperature ASHP unit is shown in the table below. This information was gathered through discussion with a Director of Innovation at Star Renewable Energy.

Detail	Metric
Product name	Neatpump
Refrigerant	Ammonia (R717)
Manufacturer	Star Refrigeration
Capacity of ASHP unit	400 kW
Flow/return temperature	62/40ºC
COP at ambient T	2.7
Length of unit	8 metres

The capacity of the ASHP solution is constrained by the space requirement for housing the units, as well as the proximity of each module to each other. After extracting heat from the air a heat pump unit will discharge colder air into the atmosphere. If placed upstream of another module this thermal pollution could negatively impact the efficiency of the system. High temperature heat pump technology also comes at a cost premium and is relatively expensive compared to other heat generation technologies per kW output. This report considers housing 4x400 kW units to achieve a capacity of 1.6 MW. To optimise this ASHP option, a network with a smaller peak and annual load is modelled. This has been achieved by excluding the large Benhill residential development from the network. In practice, alternative sites could be excluded in place of the Benhill development.

Total peak and annual demand of the network was input into an in-house load profiling tool to estimate the thermal profile of the scheme. This enabled a prediction on the proportion of heat demand that could be met by the chosen ASHP capacity, being 61.9%.

L.2 Key Considerations

The financial viability of an ASHP solution would benefit from RHI support. To be eligible for RHI, and assuming this support continues in its current form, heat pump systems must have a Coefficient of Performance of at least 2.9 and a design Seasonal Performance Factor of at least 2.5. From use of an AECOM in-house tool it is estimated that the COP of an ASHP capable of supplying temperatures at 70ºC would be approximately 2.7. Therefore a conservative approach of excluding RHI savings has been taken in the option modelling.

The health and safety aspects of ammonia are the main differentiators from the typical refrigerants used in heat pump systems. Having the ammonia system at roof level in an open space will provide an inherent level of safety in the event of a leak due to the fact ammonia is lighter than air. If ammonia units are placed on the roof of the proposed EC sites (STC 9, Civic Centre Site), this would have to be at a higher elevation than neighbouring buildings. If the ammonia system is to be enclosed a dedicated plant room should be used with specific ventilation and detection requirements. Each unit would need an integrated leak detector and an ammonia scrubber.

The use of a central ASHP system will limit the size of the DH network and will have implications for future expansion. This could be mitigated by identifying additional sites in Sutton Town Centre where a large ASHP unit could be located, effectively creating a distributed system of heat pumps. Alternatively, as the network grows a mix of distributed heat generation technologies could be connected to serve the scheme.

Appendix M – Ground Source Heat Pump Solution: LCH

Ground source heat pumps are a key consideration for heat generation at the London Cancer Hub. This is due to the potential large scale carbon savings associated with this technology, as well as the expected land area available at the LCH regeneration site.

M.1 Technology background

There are different categories of GSHP which include open loop, closed loop and hybrid systems. In open loop systems water is abstracted from the ground and passed through a system of heat exchangers before being reinjected back into the ground. For this, certain hydrogeological conditions need to be met by the site, including the presence of an aquifer of adequate water quality. Open loop systems can cause environmental impacts on the surrounding area and neighbouring sites. Therefore these systems are subject to regulation by the Environmental Agency and licences and permits are required for water abstraction and discharge.

In closed loop systems, a secondary fluid circulates between the ground and the heat pump, enabling the transfer of heat without abstraction of water from the ground. Closed loop systems can be either horizontal or vertical. The former relies on a significant open area of land, in which pipework can be installed in trenches of 1-2 metres deep. Vertical loops can be used where the land area is more constrained, and can even be incorporated into the building substructure itself. Boreholes for vertical systems can reach depths of around 150m, and are generally more expensive to install than horizontal systems. It is also important to understand the hydrogeological conditions of the site when designing a closed loop system to help achieve optimum system performance.

Due to reasonably stable ground temperatures at depths greater than 5m, the ground can be used as a heat sink in summer months, when temperatures are cooler than the surface air temperature, and conversely a heat source during winter. For GSHP's in the UK the primary energy source is the sun which irradiates the Earth's surface. Energy from the Earth's core is more significant for geothermal systems applicable in volcanic regions. The estimated temperature at 100m depth beneath the LCH is 13ºC[36]. The higher the source temperature or the lower the network temperature of the system, the higher efficiency and the COP of the heat pump. This is why GSHP's are particularly suited to low-temperature networks.

M.2 Application to LCH

For this report, a closed vertical GSHP heat pump system has been considered. Although this is more expensive than a horizontal system, horizontal loops tend to be more applicable to smaller heat demands due to the extensive land area required and lower ground temperatures at shallower depths. Moreover, the vertical boreholes can be incorporated into the LCH building piles, which could not only reduce the upfront cost but improve the system efficiency due to the agreeable thermal properties of concrete. Additional boreholes may be necessary if the available substructure is limited. For this solution, the buildings design team will need to be engaged very early on in the process.

An open loop system is not the preferred option due to the additional risks associated with water abstraction and rejection. Nonetheless, it is a potential viable solution for the LCH site and should not be discounted altogether at this early stage. The image below from the British Geological Survey GSHP screening tool[37] indicates the aquifer beneath the site is favourable for an open loop system. The area highlighted by the red circle being the LCH site, to the south of Sutton's centre. For large heat demands open loop systems can be more economic than closed. If the study is to be taken further this option should be considered if the hydrogeological conditions prove to be suitable. In this case the Environmental Agency should be engaged at an early stage to verify feasibility.

[36] Ground Source Heat Pumps, CIBSE TM51: 2013
[37] http://mapapps2.bgs.ac.uk/gshpnational/home.html

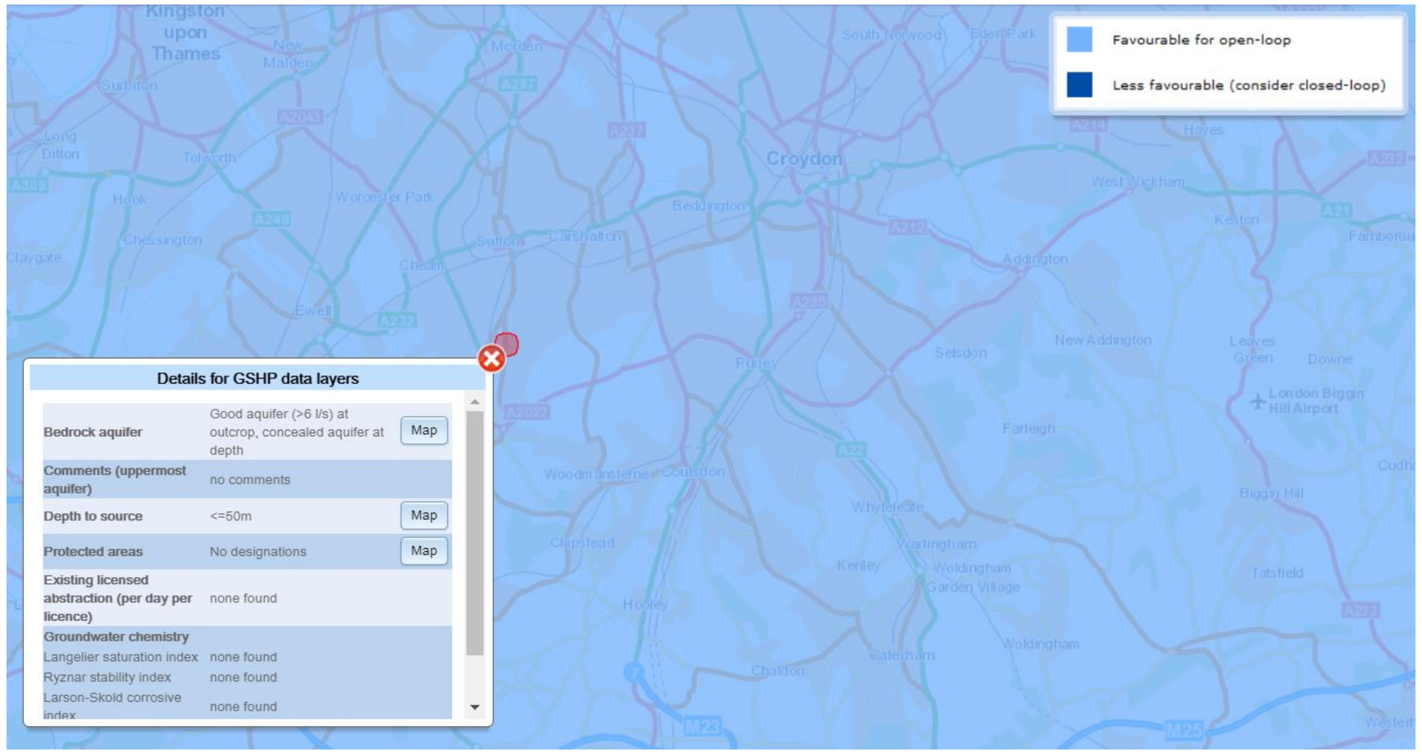


Image – British Geological Survey GSHP screening tool

M.3 Sizing of system

High level assumptions were made to estimate the potential GSHP yield from the LCH site, as displayed in the table below. This governs the proportion of peak load that can be met by the GSHP. It is assumed that the GSHPs would supply the base thermal load of the site, with top-up boilers sized to meet the peak.

Assumption	Metric	Description
Depth of boreholes	100 m	Borehole depths are typically between 50-200m below ground level – TM51
Output of borehole	50 W/m	Typical output of a closed loop system - Spon's Mechanical and Electrical Services Price Book, 2018
Output per borehole	5 kW	Calculated
Borehole spacing	8 m	Industry standard spacing
Area per boreholes	64 m²	Calculated from borehole spacing
Area of land	126,000 m²	Measured using GIS software – LCH site footprint, not including Wave 3 areas or the school
Area of land available for boreholes	31,500 m²	25% of measured land area
Number of boreholes	492	Calculated to meet heat output
Heat output	2,460 kW	Supplies approximately 60% (option 5A) and 70% (option 5B) of the annual heat load

For modelling purposes the GSHP system has been sized to 2.46 MW. The heat pumps will run in parallel with the systems boilers, and so will need to achieve a temperature lift from 35ºC to 65ºC. Because of the relatively high flow temperature required, the COP of such a system is expected to be around 3. Importantly this is high enough to achieve RHI support (minimum COP requirement of 2.9).

A 2.46 MW system is large for closed ground source heat pumps. It may be necessary to balance, on a seasonal basis, the extraction of heat from the ground (to meet heat loads) with the rejection of heat (to meet cooling loads). Prolonged heat extraction from the ground without active replenishment could lead to a drop in ground temperatures and hence would have a negative impact on the long term performance of the GSHP system. It may therefore be preferable to run a reversible heat pump that reinjects heat back into the ground during summer months, to ensure a balanced heat thermal profile across the year.

M.4 Key considerations

If a ground source heat pump solution for the LCH is taken forward, it is recommended that a more accurate estimate of the future heating and cooling loads of the site is undertaken, for example a departmental plan of the proposed hospital development. This would ensure the GSHP is appropriately sized to meet the base load of demand, without exceeding the long term capacity of the ground source system. Other concerns that would need to be considered are:

- The risk of the underground pipes/boreholes creating an undesirable pathway for water to flow between different water bearing strata
- Undesirable temperature changes in the aquifer that may result from the operation of a GSHP. This can be mitigated by balancing the use of the GSHP system to meet heating loads in winter and cooling loads in summer
- Pollution of groundwater that might occur from leakage of additive chemicals used in the system

Appendix N - Counterfactual

An onsite developer-led hybrid ASHP / gas boiler counterfactual has been developed for the Sutton network models. This is to predict future developer choices given the evolving policy landscape in London along with the decarbonisation of the grid.

N.1 Policy drivers

It has been assumed that the policies set out in the new draft London Plan will have been adopted into policy before investment into the Sutton DH networks commences, and will include the following:

- New homes will need to show a 10% reduction in regulated CO_2 emissions through efficiency alone and new non-domestic buildings will need to show a 15% reduction.
- A heat hierarchy that places using heat pumps to access secondary heat sources ahead of other renewable heat sources such as solar and biomass, which in turn are ahead of fuel cells, which in turn are ahead of gas CHP, with gas boilers being at the bottom of the hierarchy.
- A requirement for homes and non-domestic buildings to have zero regulated emissions and to achieved at least a 35% reduction in CO_2 emissions on-site, and to pay £95/tonne of residual regulated CO_2 emissions to be offset for 30 years, i.e. £2850/tonne of residual emissions (to be paid in lump sum(s) by the developer prior to practical completion).
- A requirement to contribute to air quality positive development for all development within Opportunity Areas (OAs).
- Developments in Opportunity Areas would need to deliver or enable the delivery of district heating networks.
- Development must seek to utilise renewable energy sources and in particular utilise solar energy in line with the Mayor's solar energy strategy.

The adoption in full of these policies is a significant assumption; there is the possibility that the London Plan in its current draft form could be challenged, as there are few technical solutions that would appear to fully meet the new policies.

N.2 Technology proposed

The proposed system consists of heat pumps and their associated evaporator units mounted at roof level to extract heat from the air. This heat will be boosted by the heat pumps and fed into the return water from the building's communal heating system. The temperature of the return water is then boosted further by gas boilers, supplying a communal network which delivers heat to each dwelling via a Heat Interface Unit.

It has been assumed that the air source heat pumps would account for 50% of the temperature lift, from 40 ºC to 55ºC. The gas boilers, operating in series with the ASHP, would then raise the water temperature from 55 ºC to 70ºC. This puts a theoretical maximum contribution from the heat pumps of 50%. In practice, the contribution from ASHP is likely to be lower due to technology constraints. For example, on very cold winter days, the air temperature may be too low for the heat pump to operate efficiently in which case gas boilers will operate. However, the counterfactual has been modelled on a 50% contribution from ASHP to take into consideration expected future technological advancement.

For systems to attract RHI they must currently have a Coefficient of Performance of at least 2.9 and a design Seasonal Performance Factor (SPF) of at least 2.5. Assuming the RHI support continues in its current form, this would drive designs that seek to limit operation during the coldest periods of the year to ensure that SPF is being met.

The air source heat pump coefficient of performance (CoP) will depend upon the temperature of the air and the temperature at which heat is delivered into the building. The lower the air temperature or the higher the temperature at which heat is delivered, the lower the performance of the heat pump. For the purpose of the counterfactual assessment, a seasonal CoP of 2.9 has been chosen. This represents a reasonable estimate of the performance of an ASHP by the anticipated operational dates of the Sutton networks.

It should be noted that heat pumps will take additional space at roof level. This may not be an issue if the roof space is regarded as having limited value for other uses.

An added benefit of heat pumps is that they could be used to provide cooling in summer. Ground source heat pumps would likely to be more effective for this purpose than air source heat pumps, as air temperatures will be highest when peak cooling loads are highest. However, it is assumed air source heat pumps are likely to be the preferred counterfactual choice of developers as there capital costs will be substantially lower than ground source heat pumps.

N.3 Standard development application

To model the counterfactual system for STC a 'standard' development has been selected based on the nature of the sites identified for the optimised networks. As over 80% of the annual load is domestic inn all cases, this standard development is a residential-retail mix, comprising of 155 domestic units with a ground floor retail area.

An in-house AECOM tool, using degree day analysis and suitable occupancy patterns for residential flats, was used to estimate the residential peak demand, taking into account diversification using the DS 439 Standard. This calculated a peak thermal demand of 600kW for the 155 unit development.

The peak demand was used to size the counterfactual system, with the ASHP being sized to meet 50% of this demand. An additional 10% plant capacity resilience was applied.

N.4 The London Cancer Hub

The nature of the LCH site is distinctly different from that of STC. The LCH thermal demand is dominated by a large co-located hospital. Therefore, in this case the counterfactual has been modelled with boilers sized to 100% of the peak demand, to ensure full resilience. However, ASHPs have been sized to meet 50% of the load in standard operation. The peak demand in this case has been calculate on a building by building basis, following the methodology in Appendix E.3.

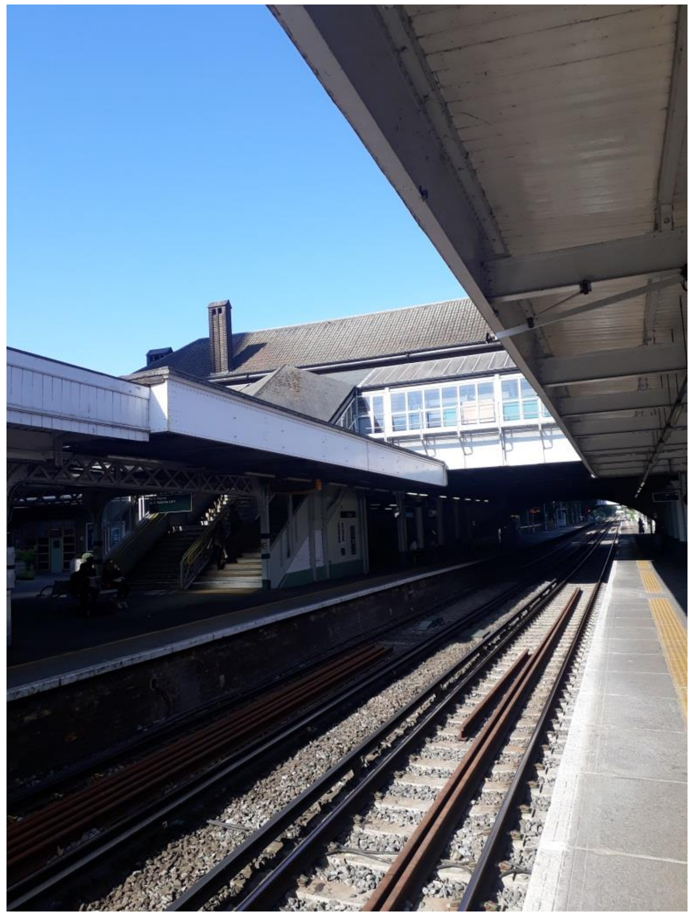
Appendix O – Site Surveys

A site survey was carried out for Sutton Town Centre. This involved a thorough visit of the red boundary catchment area by AECOM in July 2018. The purpose was to verify the existence and use of buildings to check for any diversions from mapping, and note any significant physical barriers within the locality.

Non-intrusive building surveys were carried out to look for evidence of what heating systems were currently employed in the buildings. Any buildings evidently heated electrically were omitted from the network. It was not possible to survey the internals of the identified existing buildings that had potential to connect to a network as they had not responded to the stakeholder engagement letter.

Key findings from the site survey of Sutton Town Centre are listed below, with supporting images where possible. A site survey of the London Cancer Hub site was not deemed necessary, due to the nature of the redevelopment.

Item	Observation	Decision	Image reference
Main line train track at the south end of the town centre	Two adjacent railway tracks would represent a fairly significant barrier to pipework	Preferable not to cross south of the railway line	a)
2 railway bridges over the train tracks at the south end of the town centre adjacent to the station	Both bridges had a relatively thin structure with limited scope for DH network pipes which could have internal diameters of 200-300mm	Concern over depth of bridge for pipework and competition of space from other utilities. Would require further investigation	b), c)
The A232 road that forms an island around some of the sites at the south end of the high street	Main road with moderate levels of traffic. Not particularly wide	Crossing road likely to incur reasonable but manageable disruption to town centre	d)
Pedestrianised high street	The pedestrianised high street was reasonably wide. Several service manholes were identified along its length. Narrow cut-through roads to Throwley Way observed	The high street is a potential alternative pipework route to Throwley Way	e), f)
Road junctions	Busy junctions next to the Civic Centre Site and to the south of Manor park as the A232 branches	Avoid works at these corners of the A232	g)
Roads	Roads of varying size around the site, none excessively wide	Potentially limited space to co-locate tram and DH pipework, may need to consider alternative routes such as along the high street	
Parks	Manor park situated to the east of the high street. Limited green space elsewhere in the site		h)
STC sites built or under construction	It was confirmed that the following STC sites have already been completed or are currently under construction: The Old Gas Works, North of Lodge Place, Sutton Super-bowl Site, North of Sutton Court Road, South of Sutton Court Road	These sites will be excluded from current modelling. There is potential for them to connect in the future upon replacement of existing/planned plant (approx. 15-25 years after completion)	i), j), k), l)



a) Sutton Train Station

b) Underside of bridge over railway line (Sutton Station)

c) Bridge over railway line (Sutton station)

1

d) A232, High Street Crossing

e) Pedestrianised high street

f) Roads off of high street

g) Junction of A232

h) Manor Park

i) The Old Gas Works site

j) North of Lodge Place site

k) North of Sutton Court Road site

l) South of Sutton Court Road site

Appendix P – Air Quality Report

Sutton Town Centre and London Cancer Hub Energy Masterplan

Air Quality Review

London Borough of Sutton

Project number: 60562200

04 July 2018

Quality information

Prepared by	Checked by	Approved by
Barry Roberts Associate Director	Patrick Froggatt Technical Director	Gareth Collins Technical Director

Revision History

Revision	Revision date	Details	Authorized	Name	Position
001	June 2018	Draft		Gareth Collins	Technical Director
002	July 2018	Revised		Patrick Froggatt	Technical Director

Distribution List

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Prepared for:

London Borough of Sutton

Prepared by:

Barry Roberts
Associate Director
E: barry.roberts@aecom.com

AECOM Infrastructure & Environment UK Limited
St. George's House
5 St. George's Road
London SW19 4DR
United Kingdom

T: +44 (207) 963 9800
aecom.com

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1. Introduction

1.1 Overview of Proposals

1.1.1 The London Borough of Sutton (LBS) is currently investigating options for the provision of district heating networks at two potential locations (refer to Figure 1 below):

- The Sutton Town Centre (STC); and
- The London Cancer Hub (LCH) (situated approximately 2 km south of the STC).

1.1.2 AECOM has been appointed to undertake a review of air quality related risks to securing future regulatory approvals for the proposals.

1.1.3 The proposals seek to implement Local Authority led district heat networks to provide secure and reliable sources of heat and hot water to residents within the Sutton area. Several potential options relating to the primary source of heat for the energy centres are currently under consideration for each site – these include:

- Gas-fired combined heat and power (CHP) units (reciprocating spark-ignition engine type);
- Air source heat pumps (ASHP);
- Ground source heat pumps (GSHP); and
- A tie into the heat supply from the nearby private Beddington energy recovery facility (ERF) (which has already been permitted and is currently under construction).

1.1.4 Any shortfall in heat generation (i.e. beyond the capacity of the primary heat sources) during peak periods shall be met through the use of high-efficiency gas boilers (as the secondary sources of heat).

1.1.5 Details of the various options under consideration are summarised in the table below.

Table 1. Summary of Options Under Consideration

	STC Site (Town Centre Location)			LCH Site (Edge of Town Location)		
Option	1	2	3	1	2	3
Total Approx. Heat Output	30,475 MWh	14,689 MWh	To be confirmed in subsequent design stage	33,984 MWh	32,403 MWh	26,334 MWh
Proposed Energy Sources	Primary: CHP Units • 1no. unit approx. 2.0 MW_{th} heat output; and • 2no. units approx. 1.5 MW_{th} heat output.	Primary: ASHP Unit of 1.6 MW capacity *(61.9% of heat load met by ASHP)*	Primary: Tie-in to Beddington ERF	Primary: CHP Units • 1no. unit approx. 2.0 MW_{th} heat output; • 1no. unit approx. 1.5 MW_{th} heat output; and • 1no. unit approx. 1.0 MW_{th} heat output.	Primary: GSHP Unit of 4.724 MW capacity *(73.4% of heat load met by ASHP)*	Primary: GSHP Unit of 4.274 MW capacity *(79.1% of heat load met by ASHP)*
	Secondary: Gas boilers to make up balance of heat requirement and act as backup should the primary heat source not be available	Secondary: Gas boilers to make up balance of heat requirement and act as backup should the primary heat source not be available	Secondary: Gas Boilers to make up balance of heat requirement and act as backup should the primary heat source not be available	Secondary: Gas Boilers to make up balance of heat requirement and act as backup should the primary heat source not be available	Secondary: Gas Boilers to make up balance of heat requirement and act as backup should the primary heat source not be available	Secondary: Gas Boilers to make up balance of heat requirement and act as backup should the primary heat source not be available

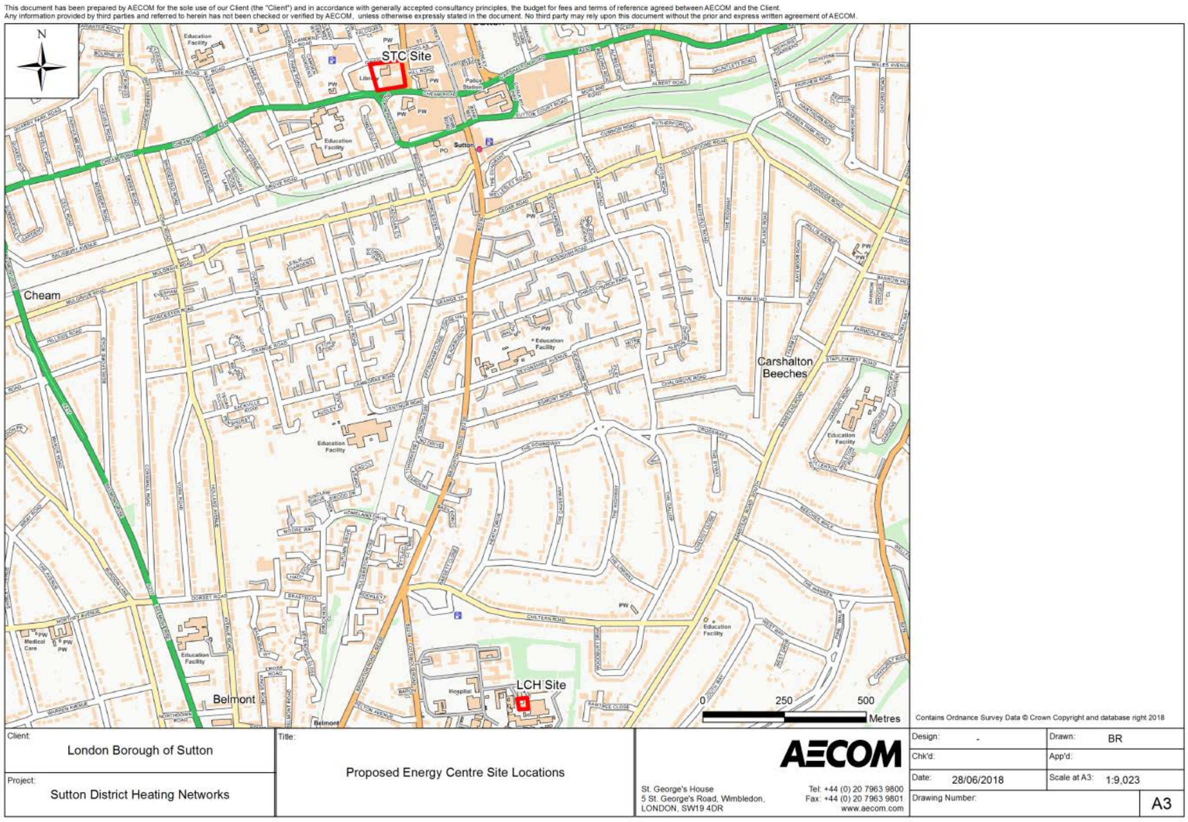

Figure 1. Location of Proposed Sites

1.2 Description of Proposed Sites

1.2.1 The exact locations of the proposed energy centres have not yet been determined, however general sites have been identified and are described in the following sections.

STC Site

1.2.2 The proposed STC site is within an existing block in Sutton, currently occupied by civic offices, Sutton College and the Central Library. The site is bound to the south by the A232 Cheam Road and to the east by St Nicholas Way. To the north are Gibson Road, a church and a nursery school, with residential dwellings beyond, whilst to the west are a hotel and car park. All of the existing buildings within the proposed site (i.e. offices, college and library) are multiple-storey structures, as are the hotel and car park.

1.2.3 Figure 2 shows the site context, with the general proposed location for the energy centre indicated by red hatching. Nearby surrounding land uses are primarily associated with commercial activities and public amenities (e.g. libraries, churches etc.) and residential dwellings. There is a nursery school within 50m of the proposed site. There are also residential suburbs incorporating blocks of flats to the south of the A232.

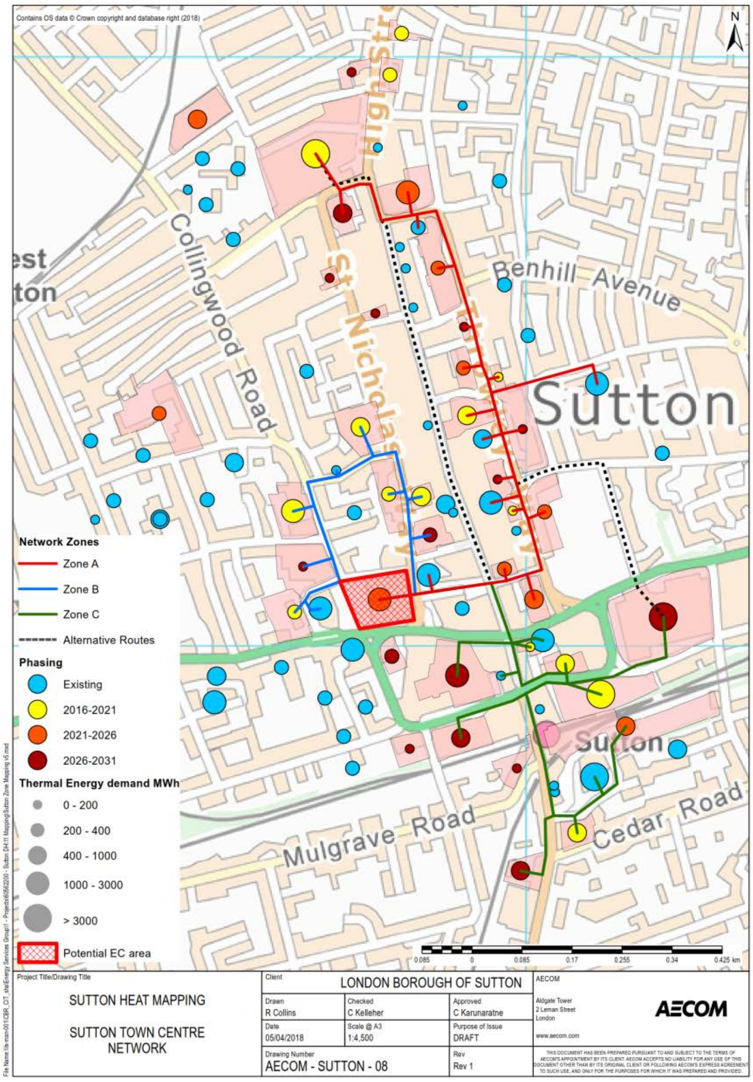

Figure 2. STC Site Location

LCH Site

1.2.4 The proposed LCH site is located within the greater health- and medical research-focused complex, near the village of Belmont. The 22.5 hectare complex incorporates various facilities primarily centred on cancer-related diagnosis, treatment and research. The proposed location for the energy centre is understood to be within an area currently occupied by utilities infrastructure serving the complex. The site is within close proximity to two existing multiple-storey buildings occupied by the Institute of Cancer Research, and other buildings of various heights to the south and west. To the east, beyond a building and car park is the complex boundary, beyond which there are residential dwellings (approximately 150m from the proposed site).

1.2.5 Figure 3 shows the site context, with the general proposed location for the energy centre indicated by red hatching. Nearby surrounding land uses relate to the medical/research fields within the complex, with predominantly residential thereafter.

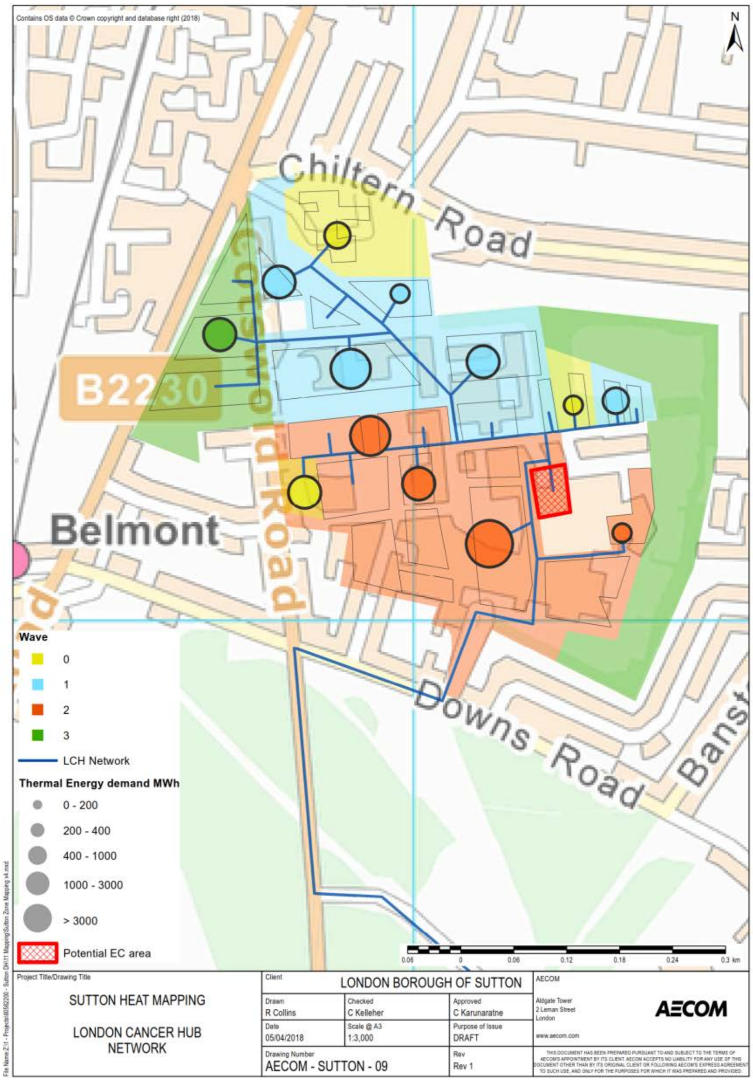

Figure 3. LCH Site Location

1.3 Study Scope and Objectives

1.3.1 The scope of this assessment included consideration of the potential air quality related planning risks associated with the proposed implementation and operation of the proposed energy centres.

1.3.2 The key objectives of this assessment were to:

- Review existing air quality at the proposed sites, to evaluate the sensitivity of each to potential increases in nitrogen dioxide (NO_2), particulate matter with aerodynamic diameter less than 10 µm (PM_{10}) and particulate matter with aerodynamic diameter less than 2.5 µm ($PM_{2.5}$);
- Review technical details relating to the proposals (mainly relating parameters influencing emissions to atmosphere) to gauge the likely scale of impacts to ambient air quality;
- Review the applicable regulatory framework to identify any potential areas where the proposals would either support or be contrarily to air quality legislation, policy and/or guidance; and
- Compile a proposed methodology to be followed when evaluating air quality impacts of the proposals during the regulatory approvals stage.

2. Methodology

2.1 Description of Baseline Air Quality

2.1.1 A description of baseline air quality was determined through a review and evaluation of data contained within the following publicly-available sources:

- LBS's latest Air Quality Annual Status Report [1][1];
- London Air Quality Network website [2];
- London Atmospheric Emissions Inventory (LAEI) 2013 dataset [3]; and
- The Department for Environment, Food and Rural Affairs (Defra) Air Quality Management Area database [4].

2.2 Regulatory Review

2.2.1 A review of applicable legislation, policy and guidance was undertaken. Whilst a detailed summary of the regulatory framework is not included within this report, the review covered the following:

- Legislation
  - Environmental Permitting (England and Wales) (Amendment) Regulations 2018 [5];
  - Air Quality Standards (Amendment) Regulations 2016 [6];
  - Air Quality Standards Regulations 2010 [7];
  - European Commission (EC) Ambient Air Quality Directive (2008/50/EC) [8], as amended by Directive 2015/1480 [9];
  - Environment Act 1995 [10];
  - National Air Quality Strategy (AQS) 2007 [11];
- Policy
  - National Planning Policy Framework (NPPF) [12];
  - The London Plan: Spatial Development Strategy for Greater London [13];
  - The Air Quality Strategy for London [14];
  - LBS Local Plan 2016 - 2031 [15];
  - LBS Air Quality Action Plan 2013 [16];
- Guidance
  - National Planning Practice Guidance [17];
  - Environmental Protection UK (EPUK) / Institute of Air Quality Management (IAQM) Land-Use Planning and Development Control: Planning for Air Quality [18] and an earlier version of EPUK's guidance [19];
  - London Local Air Quality Management Technical Guidance (LLAQM.TG(16)) [20];
  - The Mayor of London's Sustainable Design and Construction Supplementary Planning Guidance (SPG) [21]; and
  - London Councils Air Quality and Planning Guidance [22].

[1] LBS kindly provided a pre-publication version of its 2017 Annual Status Report to contribute information towards this report. It is therefore highlighted that at the time of compiling this report, the 2017 ASR was still awaiting feedback from Defra on the contents, and therefore results and figures relating to 2017 may still be revised prior to full public disclosure.

2.3 Consultation

2.3.1 The officer responsible for air quality within the LBS (Mr Dave Trew) was consulted via email and telephone on the scope of this review and the likely expectations for the content and approach to planning-stage air quality studies. He also kindly provided the most recent ambient air quality monitoring data held by the Council.

3. Baseline Conditions

3.1 Local Air Quality Management

3.1.1 Air quality within Sutton is influenced by emissions from significant numbers of vehicles utilising the local road network. Parts of the Borough are characterised by relatively high levels of car ownership, and consequently high dependency on private car transport [16]. Other contributors to local air pollution include point sources of combustion-related emissions such as domestic and commercial boilers and CHPs, as well as various industrial sources in the northeast of the Borough.

3.1.2 On the basis of excessive ambient concentrations (above national Air Quality Objectives) of NO_2 and PM_{10}, portions of the Borough were declared an Air Quality Management Area (AQMA) in March 2001, and were subsequently amended in 2004 and 2009 [4]. In June 2013, LBS declared the entire Borough an AQMA in respect of actual/likely exceedances of both the NO_2 and PM_{10} objectives.

3.1.3 As part of its statutory responsibilities, LBS has developed and implemented several measures aimed at improving air quality and reducing exposure within the Borough, under the auspices of several iterations of its Air Quality Action Plan. The current version of this Plan was adopted in 2013 [16], and is due for revision imminently.

3.1.4 Whilst there has been a general downward trend in ambient PM_{10} concentrations observed within the Borough in recent years (with measured levels well below the applicable ambient air quality limits), levels of NO_2 remain elevated in some areas, especially near busy roads [1].

3.2 Local Sources of Emissions

3.2.1 Air quality in the vicinity of the proposed sites is influenced by emissions from a range of sources. Emission data for nitrogen oxides (NOx - a generic term for the mono-nitrogen oxides NO and NO_2) from the most recent London Atmospheric Emission Inventory (LAEI) dataset [3] were reviewed. Interpretation of these data identified that the most significant sources of emissions for both the 2013 and 2020 modelled years at the STC site were buses and cars, and domestic and commercial gas combustion (e.g. boilers used for hot water and space heating, and potentially small-scale electricity production) (Figure 4). At the LCH site, emissions from domestic gas combustion dominate the contributions, followed by cars; these two source types make up more than half of the total contributions (Figure 5). Overall, a reduction in NOx emissions was predicted in both study areas between 2013 and 2020.

3.2.2 Equivalent data for PM_{10} have been presented in Figure 6 and Figure 7 for the STC and KCH sites respectively. These illustrate that the main sources of PM_{10} in the study areas were cars and resuspension (of particulate matter); together these sources contributed more than half of the total emissions. Small waste/accidental fires were also identified as significant contributors of PM_{10} emissions at both sites, and at the STC site only, buses also made a significant contribution. Overall, a minor increase in PM_{10} emissions was predicted to occur within the STC site study area between 2013 and 2020 (likely attributable to a forecasted increase in construction-related activities in the future scenario), whilst a minor reduction was predicted within the LCH site study area.

Figure 4. STC Site - Local Sources of NOx (tonnes per annum) – LAEI Data for 2013 and 2020 [3]

Figure 5. LCH Site - Local Sources of NOx (tonnes per annum) – LAEI Data for 2013 and 2020 [3]

Figure 6. STC Site - Local Sources of PM_{10} (tonnes per annum) – LAEI Data for 2013 and 2020 [3]

Figure 7. LCH Site - Local Sources of PM_{10} (tonnes per annum) – LAEI Data for 2013 and 2020 [3]

3.3 Baseline Air Quality

Local Authority Measurement Data

3.3.1 As of the most recent completed year for which data is available (2017), LBS operated four continuous air quality monitoring stations; summary details of these are presented in Table 2. The two kerbside stations are located immediately adjacent to heavily trafficked roads and therefore represent worst-case exposure locations.

Table 2. Summary Details of LBS Continuous Monitoring Sites (as of 2017)

Station Name	Site Type	Pollutants Monitored	Distance and Direction from Proposed Sites
Wallington (ST4)	Kerbside	NO_2; PM_{10}	3.2 km; E/NE
Beddington Lane (North) (ST5)	Industrial	NO_2; PM_{10}; $PM_{2.5}$	4.5 – 6.0 km; NE
Worcester Park (ST6)	Kerbside	NO_2; PM_{10}	3.6 – 5.1 km; NW
Beddington Lane (ST8)	Industrial	NO_2; PM_{10}	4.7 – 5.7 km; NE

3.3.2 Historic NO_2 monitoring data and key statistics from these stations are presented in Table 3. Ambient concentrations at the two kerbside locations have consistently exceeded the annual mean limit. Whilst not shown, there were less than the 18 allowable exceedances of the 1-hour mean ambient limit at all of the sites during 2017 [1].

Table 3. NO_2 Monitoring Results - LBS 2012 - 2017

Station Name	Annual Mean Concentration (µg/m^3) (# of exceedances of hourly mean objective shown in brackets)					
	2012	2013	2014	2015	2016	2017 [2]
Wallington (ST4)	**71.8 (133)**	**69.6 (69)**	**66.6** (10)	**61.4** (9)	**63.2 (22)**	**53** (1)
Beddington Lane (North) (ST5)	39.0 (2)	-	36.4 (0)	32.0 (0)	36.3 (0)	32 (0)
Worcester Park (ST6)	**54.5** (13)	**49.0** (8)	**53.5** (3)	**52.0** (11)	**57.1 (24)**	**52** (11)
Beddington Lane (ST8)	35.7 (0)	36.0 (9)	30.5 (0)	27.0 (0)	30.1 (0)	25 (0)

Source: LBS, 2018 [1].
Emboldened figures indicate an exceedance of the UK Air Quality Objectives

3.3.3 Whilst the data are not presented in this report, all of the continuous monitoring sites returned PM_{10} concentrations which were compliant with both the annual and 24-hour mean ambient air quality limits during 2012 to 2017. PM_{10} (and indeed $PM_{2.5}$) are considered less relevant than NO_2 within the context of this air quality risk review, given that all of the combustion equipment envisaged to be operated within the proposed energy centres shall be fired on natural gas (i.e. particulate matter emissions will be negligible).

3.3.4 The data from the continuous monitoring sites provide an indication of the general ambient air quality context within the Borough, however, based on the relative locations of these sites to the proposed energy centre locations, it was considered that none of these were suitably representative of conditions at the proposed sites.

3.3.5 LBS also operates a network NO_2 diffusion tube monitoring sites across the Borough. The details of the monitoring locations nearest to the proposed energy centre sites are presented in Table 4.

[2] As described above, at the time of compiling this report, the 2017 ASR was still awaiting feedback from Defra on the contents, and therefore results and figures relating to 2017 may still be revised prior to full public disclosure.

3.3.6 Figure 8 shows the relative locations of the LBS continuous monitoring sites and selected diffusion tube monitoring sites (those nearest to the proposed energy centres).

Table 4. Summary Details of Selected LBS NO_2 Diffusion Tube Monitoring Sites (2014 – 2017)

Station Name	Site Type	Distance and Direction from Proposed Sites	Annual Mean Concentration (µg/m^3)			
			2014	2015	2016	2017 [3]
Carshalton Road (ST33)	Roadside	250m East of STC	**42.8**	37.2	38.8	33.2
Brighton Road, Sutton (ST38)	Roadside	475m South of STC	38.9	34.7	36.8	34.6
Haddon Road/St Nicholas Way (ST27)	Roadside	500m North of STC	-	36.8	39.6	36.1
Dorset Road, Belmont (ST22)	Roadside	1.1 km West of LCH	-	37.3	37.2	38.6

Source: LBS, 2018 [1]
Emboldened figures indicate an exceedance of the UK Air Quality Objectives

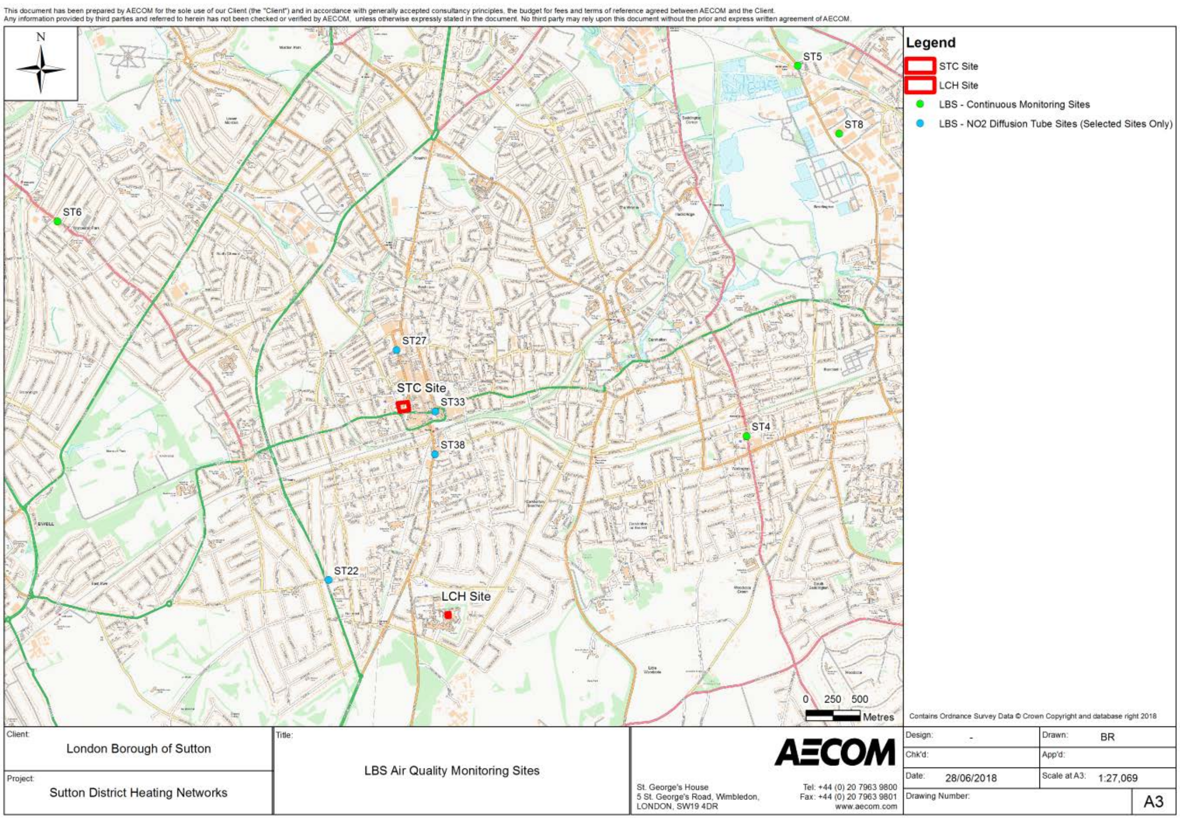

Figure 8. LBS Air Quality Monitoring Sites

3.3.7 The data presented above indicate that roadside annual mean NO_2 concentrations in the vicinity of the STC and LCH sites were below the corresponding ambient limit in recent years. That said however, it was noted that the Dorset Road (ST22) monitoring site is located in very close proximity (2m) to a busy road, whereas the proposed LCH site is distant from any significant roads; therefore NO_2 concentrations at the LCH site may reasonably be expected to be lower than those at Dorset Road.

[3] As described above, at the time of compiling this report, the 2017 ASR was still awaiting feedback from Defra on the contents, and therefore results and figures relating to 2017 may still be revised prior to full public disclosure.

London Atmospheric Emission Inventory Background Data

3.3.8 The LAEI dataset [3] incorporates modelled concentrations of key pollutants based on all known emissions sources across London, at an output receptor grid resolution of 20m. It is highlighted that the model does not take into account the channelling / shielding effects of buildings.

3.3.9 Table 5 presents the average of the modelled NO_2 concentrations at each of the proposed sites for both the 2013 and 2020 modelled years. The values presented are the average of all modelled values geographically overlapping the proposed site footprints.

3.3.10 Modelled annual average background concentrations of NO_2 were predicted to be below the corresponding air quality objectives for both the 2013 and 2020 model years.

Table 5. LAEI Background Concentrations at Proposed Sites (Average Across Each Site)

	Annual Mean Background NO_2 Concentration ($\mu g/m^3$)	
Model Year	**STC Site**	**LCH Site**
2013	33.5	27.3
2020	28.1	23.0

Source: Derived from GLA, 2017 [3]

4. Discussion

4.1 Legislative Considerations

4.1.1 Ultimately, it would need to be demonstrated (by means of air dispersion modelling studies) that the proposals would not cause any exceedance of legislated ambient air quality limits [7] [6], nor have a significant adverse effect on the attainment of the air quality objectives set out in the national Air Quality Strategy [11].

4.1.2 It is anticipated that the proposed CHP plant would be considered "specified generators" under the Medium Combustion Plant Directive (MCPD) recently enacted under the Environmental Protection (England and Wales) (Amendment) Regulations [5]. This effectively imposes permitting requirements, source emission limits and ongoing monitoring responsibilities on such plant. A summary of the requirements considered likely to apply to the proposals is provided below:

- An environmental permit from the Environment Agency would be required to operate the CHPs;
  - This application may need to be supported by an air emissions risk assessment incorporating air dispersion modelling to determine the likely impact of emissions on local air quality and/or define appropriate stack height requirements;
- Emissions of NOx from the CHPs would need to comply with the applicable emission limit value of 95 $\mu g/Nm^3$ set out in the MCPD, see footnote[4];
- Emissions would need to be independently verified through undertaking an MCERTS[5] accredited monitoring process at least every three years (but potentially annually, or even continuously, guided by several factors and specified as a condition of the issued environmental permit).

4.2 Planning Considerations

National Level

4.2.1 The NPPF [12] does not specify any particular air quality related requirements in respect of district heating projects, but defines a broad aim of the planning system to:

> *"…contribute to and enhance the natural and local environment by…preventing both new and existing development from contributing to…unacceptable levels of soil, air, water or noise pollution…".*

4.2.2 Furthermore the NPPF requires consideration to be taken of the presence of AQMAs and the cumulative impacts on air quality from individual sites in local areas during development planning. It also highlights the need for planning decisions on developments within AQMAs (as is the case of the proposed district heating network energy centres) to be consistent with the local air quality action plan.

Regional / Local Level

GLA Requirements

4.2.3 The London Plan [13] promotes the implementation of decentralised energy initiatives such as district heating and CHP, though in this context, is primarily driven based on a targeted reduction in greenhouse gas emissions. The Plan envisages future district heating networks evolving from being based on natural gas CHP to being supplied by energy from waste systems. This point is pertinent to the current proposals, as the potential STC site tie-in to the Beddington ERF represents an alignment to this goal, as well as an opportunity to reduce the magnitude of on-site emissions at the STC site compared to the scenario whereby all heat is generated on-site by gas-fired appliances. It is highlighted that a similar outcome of reduced on-site emissions may be achieved in the event that the ASHP or GSHP options are selected.

[4] At reference conditions of 273 K, 101.3 kPa, 15% O_2, dry gas. This equates to approximately 250 mg/Nm^3 if referenced to the same conditions except at 5% O_2 i.e. this limit is effectively equivalent to "Band A", see Table 7, that is specified by the GLA.

[5] MCERTS is the Environment Agency's Monitoring Certification Scheme, covering emissions to air, land and water.

4.2.4 A draft version of a New London Plan [23] was circulated for public consultation in late 2017. Proposed Policy SI3 *Energy Infrastructure* states that:

"CHP and ultra-low NOx gas boiler communal or district heating systems should be designed to ensure that there is no significant impact on local air quality"

This would not necessarily introduce any fundamentally new requirements to the proposals, though the draft Plan does contain certain language which infers that currently-available gas-fired CHP technology may not be able to deliver the emissions performance required to secure compliance to relevant standards in areas of existing poor air quality.

4.2.5 The Mayor's Air Quality Strategy for London [14] set out the intentions to prescribe emission standards for CHPs for new developments (realised in the subsequent Sustainable Design and Construction SPG – refer to the following section) and to require emissions assessments to accompany planning applications for developments incorporating CHPs. The AQS recognised that whilst CHPs were a key component in reducing London's carbon emissions, the potential air quality impacts from operation of such technology must be considered.

4.2.6 The GLA's Sustainable Design and Construction SPG [21] prescribes emission standards for both CHPs and gas boilers introduced as part of new developments within Greater London; a summary of these requirements is provided below.

CHPs

4.2.7 Emission standards for new CHP installations within the thermal input range 50 kW_{th} to 20 MW_{th} are specified based on the type of combustion appliance (governed by fuel type) and the baseline air quality at the proposed installation site. The latter requires classification into one of two "bands" according to the criteria presented in Table 6.

Table 6. Baseline Air Quality Banding Criteria (for Determining Applicable Emission Standards for CHP)

	Applicable Range	
Band	**Baseline Annual Mean NO_2 and PM_{10}**	**Baseline 24-Hour Mean PM_{10}**
Band A	> 5% below national objective	> 1-day less than national objective
Band B	Between 5% below or above national objective	1 day below or above national objective

4.2.8 The most recent data presented in Table 5 suggest that baseline levels of NO_2 and PM_{10} at both the proposed sites would likely align with the criteria for applying the "Band A" CHP emission standards. Given that the proposed CHPs will run on natural gas fuel, the emission standards for spark ignition engines would apply.

4.2.9 The summarised emission factors which are therefore considered to be applicable to the proposals are presented in Table 7.

Table 7. Applicable GLA Emission Standards for CHP (Band A)

Combustion Appliance	Pollutant / Parameter	Emission Standard at Reference O_2 (mg/Nm^3)	Equivalent Concentration at 0% O_2 (mg/Nm^3)	Likely Technique Required to Meet Emission Standard
Spark Ignition Engine (natural gas/biogas) Note A	NOx	250	329	Advanced lean burn operation (lean burn engines). Non-selective catalytic reduction (NSCR) (rich burn engines).
All (stack heat release less than 1 MW) Note B	Stack discharge velocity	10 m/s	N/A	Appropriate design of stack discharge diameter to achieve required velocity.
All (stack heat release greater than or equal to than 1 MW) Note B	Stack discharge velocity	15 m/s	N/A	Appropriate design of stack discharge diameter to achieve required velocity.

Combustion Appliance	Pollutant / Parameter	Emission Standard at Reference O_2 (mg/Nm[3])	Equivalent Concentration at 0% O_2 (mg/Nm[3])	Likely Technique Required to Meet Emission Standard

Notes:
A Emission standard quoted at reference conditions 273 K, 101.3 kPa, 5% O_2, dry gas
B The stack heat release can be calculated as per equation (3) in the Technical Guidance Note D1 (Dispersion) 'Guidelines on Discharge Stack Heights for Polluting Emissions'.

Source: GLA Sustainable Design and Construction SPG, 2014 [21]

4.2.10 Preliminary specifications of CHPs envisaged to serve the proposed energy centres (refer to **Error! Reference source not found.** and Appendix A) appear to indicate that meeting the GLA's prescribed NOx emission standard should be feasible. Further technical specifications for the CHPs would be required to determine the likelihood of compliance with the prescribed stack discharge velocity standard, however based on experience, this should be feasible.

Gas Boilers

4.2.11 The GLA's SPG [21] states that the emission standards which it prescribes for gas boilers apply to:

"…individual and/or communal gas boilers…installed in commercial and domestic buildings".

4.2.12 Consultation was made with the officer responsible for air quality at the LBS regarding whether the particular application of gas boilers for the purpose of council-led district heating would be exempted from this requirement, given that the appliances would not be installed in buildings for "commercial or domestic" purposes. Whilst it could not be definitively determined whether this represented a potential regulatory gap, the Council would almost certainly be expected to implement its proposals in-line with best practices to demonstrate its own commitment to managing air quality.

4.2.13 The emission standard requires all new appliances in the above-mentioned applications to achieve NOx emissions below 40 mg/kWh. Whilst this standard is considered readily achievable for smaller gas boilers, NOx emissions generally tend to be higher in larger package units. Notwithstanding this, there are units on the market with standalone outputs in the region of 1 MW (or 2 MW in paired sets) which would be able to comply with the GLA's emission standard, and it would therefore be highly recommended that such boilers are selected.

Air Quality Neutral

4.2.14 Both the London Plan [13] and the Mayor's Air Quality Strategy [14] prescribe that developments are to be at least 'air quality neutral'. The GLA's Sustainable Design and Construction SPG [21] enables the implementation of this policy, through the provision of emission benchmarks for building- and transport-related emission sources in London, based on the latest technology. Consequently, developers are required to calculate emissions of NO_x and/or PM_{10} from key elements of their developments and to compare these to the corresponding benchmark values presented in the SPG.

4.2.15 Developments with emissions below the benchmarks are considered to be 'air quality neutral', whereas developments with exceedances of the benchmarks will be required to consider adoption of appropriate mitigation measures.

4.2.16 The type of proposals being considered (i.e. CHP and gas boiler based district heating scheme) are not provided with benchmarks for undertaking air quality neutral assessments. There is an inherent complexity and uncertainty when trying to evaluate emissions arising from the proposed energy centres within the context of a largely unknown heat user network. Therefore, the proposals are not amenable to such assessment, an opinion supported by the LBS air quality officer [24], but awaiting formal confirmation following further consultation.

LBS Requirements

4.2.17 The Sutton Local Plan [15] identifies, within Policy 34 *Environmental Protection*, the need for development proposals incorporating CHP to be accompanied by an air quality assessment (and goes on to prescribe specific requirements which are elaborated on in Section 5.2). This Policy also cites requirements relating to CHP and gas boiler emission standards, and the need for new developments to be Air Quality Neutral, in line with the GLA specifications (refer to previous section).

4.2.18 The Local Plan also reinforces the GLA's objective of promoting the development and implementation of decentralised energy networks, and specifically cites the Sutton Town Centre as a priority opportunity in this respect.

4.2.19 Finally, the Local Plan also describes that part of the greater London Cancer Hub complex land has been purchased by the Council to be redeveloped as a secondary school (subject to securing planning permission). This potential introduction of nearby sensitive receptors would need to be adequately considered as part of the air quality assessment undertaken in planning stage of the proposed energy centres/heating networks. There are also several other envisaged development opportunities within the greater complex, earmarked to come forward within the next 15-20 years; it is therefore considered likely that cumulative effects of the proposals in conjunction with certain planned/committed developments would need to be considered at planning stage.

4.2.20 It is highlighted that under the planning regime, Local Authority level interventions (such as commitments made within Air Quality Action Plans) could override the minimum legislated standards, provided that the former are more stringent. Whilst the LBS's current AQAP does not contain any specific stipulations relating to, for example, emission standards for CHP, were it to include such standards in subsequent versions of the AQAP, these could impose lower limits than those prescribed in the MCPD. LBS is currently in the process of updating its AQAP [24], however this has not yet been released for consultation or publishing, and therefore remains unseen.

4.3 Technical Considerations

4.3.1 It is considered that the prospect of potentially connecting the STC energy centre to the Beddington ERF represents a preferred environmental option from an air quality perspective, based on:

- A reduced reliance on fossil fuel;
- A reduced increment of "new" fuel combustion sought to be permitted (given that the ERF is already permitted); and
- More effective decentralisation of combustion processes.

4.3.2 The CHPs and gas boilers for the proposed energy centres will be subject to certain performance criteria, including source emission limits. Given that such performance varies between different sizes, makes and models of plant, due consideration shall be required to identify suitable plant which has adequate environmental performance and satisfies operational demands.

4.3.3 At the time of compiling this review, no details regarding the exact locations, configurations and heights of the combustion plant exhaust flues were available. As noted earlier however, each of the proposed energy centre sites has buildings nearby which could:

- Influence the dispersion and dilution of emissions from the energy plant exhaust flues; and
- Represent the presence of sensitive human receptor locations at height (e.g. windows and balconies of flats), and rooftop building ventilation plant intakes.

5. Conclusions

5.1 Overview

5.1.1 The gas-fired CHP led proposals would appear to require two-stages of regulatory authorisations in order to proceed; namely local planning permission and a nationally-administered environmental permit. Based on the review of information undertaken as part of this study, no fundamental constraints in terms of air quality were identified which would prevent the proposals being brought forward to planning. However, further study shall be required to determine the suitability and ultimate acceptability of the proposals and subsequently secure the required legal permissions.

5.1.2 In the event that either energy centre relies on ASHP, GSHP or the connection to the Beddington ERF as the primary source of heat (and consequently the need for on-site CHP is avoided), it is considered unlikely that an environmental permit would be required for this site (as the MCPD focuses on *combustion plant* which generate electricity).

5.1.3 The envisaged scope for future air quality study and key technical considerations for project designs are outlined in the following sections.

5.2 Air Quality Assessment for Planning

5.2.1 As per the requirements of Policy 34 of the Sutton Local Plan [15], an air quality assessment/s will be required to support the planning application/s. The scope and methodology of such studies is expected to include:

- Desktop characterisation and description of baseline air quality conditions and overview of sensitive receptors;
- Review of relevant legislation and air quality planning policy;
- Qualitative assessment of demolition and construction dust (Air Quality and Dust Risk Assessment - AQDRA) according to the guidance published by the GLA in its Control of Dust and Emissions During Construction and Demolition SPG [25];
- It is likely that the modelling of construction phase traffic emissions could be scoped out (when contextualised against threshold criteria published by EPUK/IAQM [19]), however, if this is not possible dependent on the level of traffic or other factors, construction traffic would most likely need to be assessed using a detailed dispersion model, e.g. ADMS Roads. Construction plant emissions and Non-Road Mobile Machinery (NRMM) emissions are not anticipated to be significant enough to require quantitative assessment and are expected to be scoped out;
- Emissions of NOx from the proposed on-site combustion plant will most likely need to be assessed using an air dispersion model, such as ADMS-5 or AERMOD, to predict ambient concentrations of NO_2 at identified sensitive receptor locations. Consideration shall be given to the need to model elevated sensitive receptor locations (e.g. facades of nearby flats, roof terraces, rooftop ventilation plant intakes etc.);
- Cumulative impacts and constraints from other committed development with significant point source combustion plant in the vicinity (where feasible); and
- Recommendation of appropriate mitigation measures for air quality impacts.

5.2.2 The assessment/s should take into account standards and guidance published by the GLA [21] [25] and specialist bodies such as the EPUK and IAQM [18] [19].

5.2.3 Whilst not considered to be relevant/necessary, the need to undertake an Air Quality Neutral assessment should be confirmed through further formal consultations with the relevant officers at LBS and potentially the GLA. Emerging revised Air Quality Neutral guidance (alluded to in the latest Draft London Plan [23]) will also need to be considered, once published.

5.3 Air Emissions Risk Assessment for Environmental Permitting

5.3.1 This element of study would only be required in the event that CHPs form part of the proposed energy centres.

5.3.2 The expected content and approach to compiling an air emissions risk assessment for environmental permitting and air dispersion modelling reports are well-defined in information published by the Environment Agency.

5.3.3 It is highlighted that the Environment Agency has just closed a consultation period on its proposals to implement a system of "standard permits" supported by "standard rules" for the management of airborne emissions from medium combustion plant. This would mean that medium combustion plant would be categorised into one of several pre-defined categories (each with its own set of commensurate rules) based on a number of factors such as fuel type, the quality of local air quality etc. This process, if implemented, should simplify and expedite the process of applying for and granting permits.

5.4 Technical Considerations

5.4.1 The CHPs (if applicable) and gas boilers for the proposed energy centres would need to be selected and specified to comply with the source emission standards presented in Table 7 and Paragraph 4.2.13 respectively. Given that all of the proposed combustion appliances would utilise natural gas fuel, the only pollutant of relevance would be NOx/NO_2.

5.4.2 The energy plant exhaust flues for both sites will need to be of an adequate height and be suitably sited to optimise dispersion and dilution, and to align with good engineering practice. This is particularly relevant to both of the proposed sites, as there are existing surrounding buildings of multiple storeys.

5.4.3 Based on first principles, the flues will likely be required to discharge to atmosphere at an elevated point (typically above parapet height of the nearest tallest building, and no less than 3m higher than any adjacent area to which there is general access (e.g. roof terrace), nearby openable windows and/or ventilation plant intakes). Therefore, it is highly recommended that air quality factors are taken into account at an early stage of determining the location and design of the flues.

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Appendix A – CHP Technical Information

STC Site	Heat output (MWh)	Run hours
CHP	22,666	4,724
Gas boilers	7,809	

Quanity	Manufacturer	Model	Supporting Datasheet Publication Year	Fuel Type	Total Electrical Power Output (kW)	Total Heat Output (kW)	Exhaust Temperature	NOx Emissions		O_2 content
2	Ener-G	1520 250 Nox	2017	Natural Gas	1523	1456	120	250	mg/Nm3	5
1	Ener-G	2020 250 Nox	2017	Natural Gas	2028	1979	120	250	mg/Nm3	5

LCH Site	Heat output (MWh)	Run hours
CHP	25,311	5,748
Gas boiler	8,673	

Quanity	Manufacturer	Model	Supporting Datasheet Publication Year	Fuel Type	Total Electrical Power Output (kW)	Total Heat Output (kW)	Exhaust Temperature	NOx Emissions		O_2 content
1	Ener-G	2020 250 Nox	2017	Natural Gas	2028	1979	120	250	mg/Nm3	5
1	Ener-G	1520 250 Nox	2017	Natural Gas	1523	1456	120	250	mg/Nm3	5
1	Ener-G	1010 250 NOx	2017	Natural Gas	1013	1019	120	250	mg/Nm3	5

TECHNICAL DATASHEET

Natural Gas CHP Range Guide 2017 UK & Ireland – Large Scale (>600kW$_e$)

ENER-G Large CHP Range Guide (400V 3ph & 500NOx/Nm^3(1,2))

Product Reference	Electrical Output kW$_e$ (400V)(3,6)	Generation Voltage (3-ph) V	NOx Emissions mg/Nm^3 (5% O_2)	Methane Number MN(4)	Output Break kW$_b$	Output Jacket Water kW$_{th}$(7,8)	Output Exhaust Gas kW$_{th}$(8,9)	Total Heat Output kW$_{th}$	Fuel Input (LHV) kW(11)	Fuel Input (HHV) kW(12)	Steam Output kg/h(8,9,10)	Electrical Unit Efficiency (LHV) %(13)	Thermal Unit Efficiency (LHV) %(13)	Overall Unit Efficiency (LHV) %(13)
ENER-G 770 500NOx	776	400	≤500	≥70(5)	800	401	422	823	1,832	2,026	534	42.4	44.9	87.3
ENER-G 850 500NOx	854	400	≤500	≥80	880	443	448	891	1,993	2,204	564	42.8	44.7	87.6
ENER-G 1010 500NOx	1,013	400	≤500	≥80	1,040	495	492	987	2,331	2,578	575	43.5	42.3	85.8
ENER-G 1165 500NOx	1,169	400	≤500	≥70(5)	1,200	600	628	1,228	2,731	3,020	795	42.8	45.0	87.8
ENER-G 1280 500NOx	1,286	400	≤500	≥80	1,320	664	659	1,323	2,974	3,289	852	43.2	44.5	87.7
ENER-G 1520 500NOx	1,523	400	≤500	≥80	1,560	712	691	1,403	3,438	3,802	852	44.3	40.8	85.1
ENER-G 1560 500NOx	1,560	400	≤500	≥70(5)	1,600	885	777	1,662	3,649	4,036	976	42.8	45.5	88.3
ENER-G 1710 500NOx	1,718	400	≤500	≥80	1,760	974	821	1,795	3,991	4,414	1,023	43.0	45.0	88.0
ENER-G 1950 500NOx	1,948	400	≤500	≥70(5)	2,000	1,048	1,016	2,064	4,555	5,038	1,285	42.8	45.3	88.1
ENER-G 2020 500NOx	2,028	400	≤500	≥80	2,080	965	936	1,901	4,573	5,058	1,159	44.3	41.6	85.9
ENER-G 2150 500NOx	2,145	400	≤500	≥80	2,200	1,161	1,078	2,239	4,990	5,519	1,356	43.0	44.9	87.9
ENER-G 2535 500NOx	2,535	400	≤500	≥80	2,600	1,186	1,212	2,398	5,751	6,361	1,426	44.1	41.7	85.8

ENER-G Large CHP Range Guide (400V 3ph & 250NOx/Nm^3(1,2))

Product Reference	Electrical Output kW$_e$ (400V)(3,6)	Generation Voltage (3-ph) V	NOx Emissions mg/Nm^3 (5% O_2)	Methane Number MN(4)	Output Break kW$_b$	Output Jacket Water kW$_{th}$(7,8)	Output Exhaust Gas kW$_{th}$(8,9)	Total Heat Output kW$_{th}$	Fuel Input (LHV) kW(11)	Fuel Input (HHV) kW(12)	Steam Output kg/h(8,9,10)	Electrical Unit Efficiency (LHV) %(13)	Thermal Unit Efficiency (LHV) %(13)	Overall Unit Efficiency (LHV) %(13)
ENER-G 770 250NOx	776	400	≤250	≥70(5)	800	416	443	859	1,883	2,083	562	41.2	45.6	86.8
ENER-G 850 250NOx	854	400	≤250	≥80	880	462	469	931	2,053	2,271	591	41.6	45.3	86.8
ENER-G 1010 250NOx	1,013	400	≤250	≥80	1,040	512	507	1,019	2,413	2,669	631	42.0	42.2	84.2
ENER-G 1165 250NOx	1,169	400	≤250	≥70(5)	1,200	622	652	1,274	2,795	3,091	826	41.8	45.6	87.4
ENER-G 1280 250NOx	1,286	400	≤250	≥80	1,320	690	687	1,377	3,054	3,378	863	42.1	45.1	87.2
ENER-G 1520 250NOx	1,523	400	≤250	≥80	1,560	743	713	1,456	3,551	3,927	878	42.9	41.0	83.9
ENER-G 1560 250NOx	1,560	400	≤250	≥70(5)	1,600	884	844	1,728	3,722	4,117	1,063	41.9	46.4	88.3
ENER-G 1710 250NOx	1,718	400	≤250	≥80	1,760	1,014	863	1,877	4,100	4,535	1,077	41.9	45.8	87.7
ENER-G 1950 250NOx							TBC							
ENER-G 2020 250NOx	2,028	400	≤250	≥80	2,080	1,010	969	1,979	4,748	5,251	1,196	42.7	41.7	84.4
ENER-G 2150 250NOx	2,145	400	≤250	≥80	2,200	1,215	1,123	2,338	5,126	5,669	1,415	41.8	45.6	87.5
ENER-G 2535 250NOx	2,535	400	≤250	≥80	2,600	1,245	1,183	2,428	5,933	6,562	1,455	42.7	40.9	83.7

1. NOx number at 5% O_2. Lower levels than 250mgNOx/Nm^3 requires additional ancillaries;
2. Normal cubic meter is 1013.25mbar and 273.15K;
3. Based on standard reference conditions according to ISO 3046-1: P_{atm} = 1000mbar, T_{air} = 25°C & RH_{air} = 30%;
4. If the minimum methane number (MN) can't be attained, power de-rates will apply;
5. Variant is available for high ambient temperatures with the second stage aftercooler at 53°C. This variant requires MN≥80 for same mechanical and electrical power output;
6. Gross power as measured at the generator terminals at nominal voltage and frequency & PF = 1.00;
7. Inclusive of recovered heat from engine block, lube oil and first stage aftercooler only (ie second stage aftercooler at 42°C omitted);
8. Subject to ISO 3046 tolerances (+/- 8%);
9. Exhaust heat recovered to 120°C;
10. Estimated values based on 7bar$_g$ dry saturated steam (T_{sat} = 170.43°C), boiler feedwater at 85°C & no economiser on boiler. The exact available steam needs to be calculated based on site conditions;
11. Subject to ISO 3046 tolerances (+ 5%) using natural gas;
12. Derived from LHV figure with additional 10.6% to allow for latent heat of vaporisation - this figure to be used for economic calculations;
13. Calculation based off LHV gas figure.

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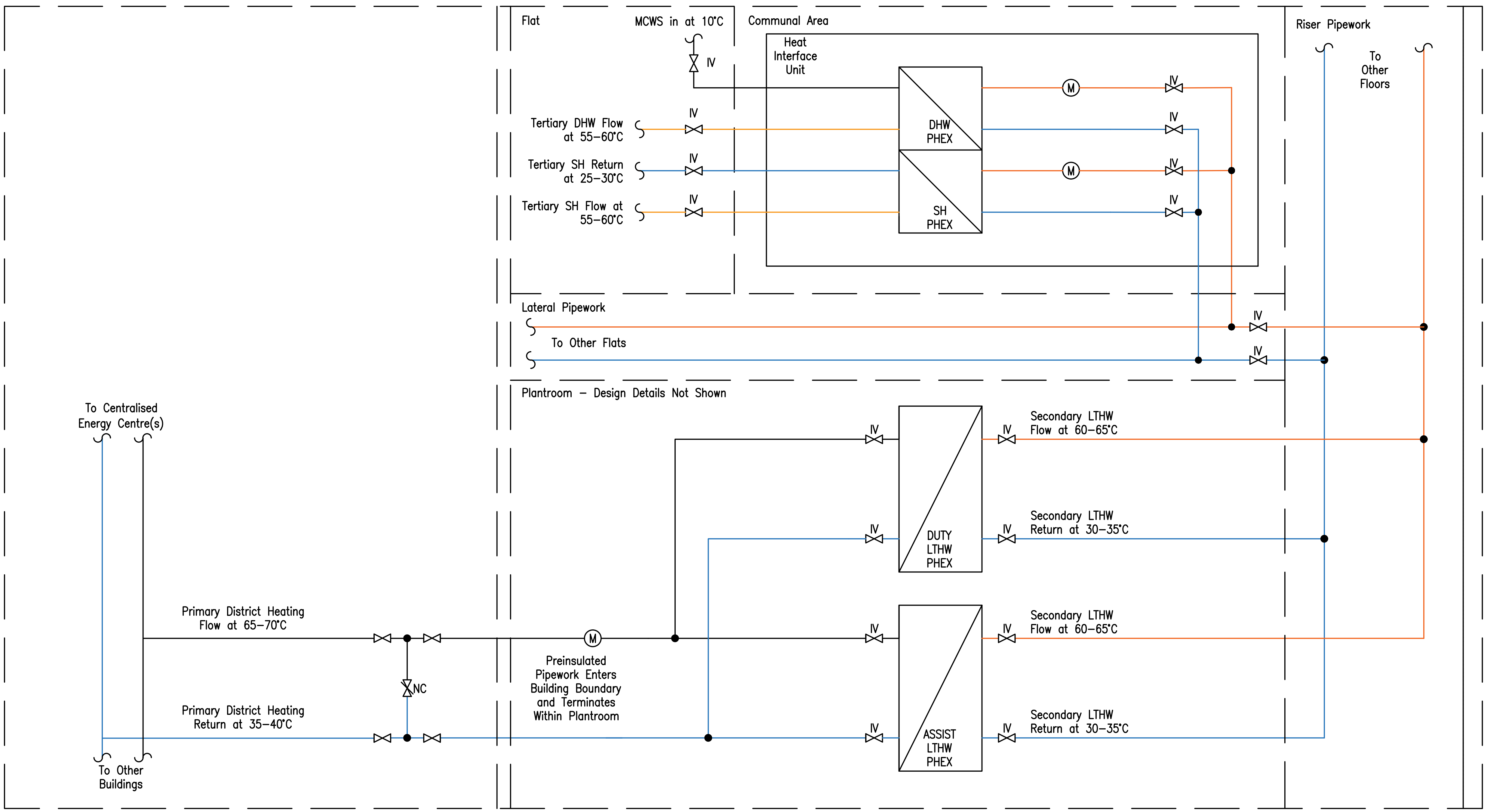
Appendix Q – Drawings



NOTES

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3. Spatial allowance has been provided for Switch Rooms/panels and Transformers (If necessary).
4. Please note that sizes are indicative and subject to change during detailed design stage.

1	09/07/2018	Report Issue	SS	CK	RB

Client: London Borough of Sutton

Project: Sutton Borough Heat Mapping & Energy Masterplanning Study 60562200

Title: Energy Centre Option 1 Distribution System Schematic

Reason for issue: Concept DH Design

Design: SS	CAD: SS
Chk'd: CK	App'd: RB
Date: 05/07/2018	Scale: NTS

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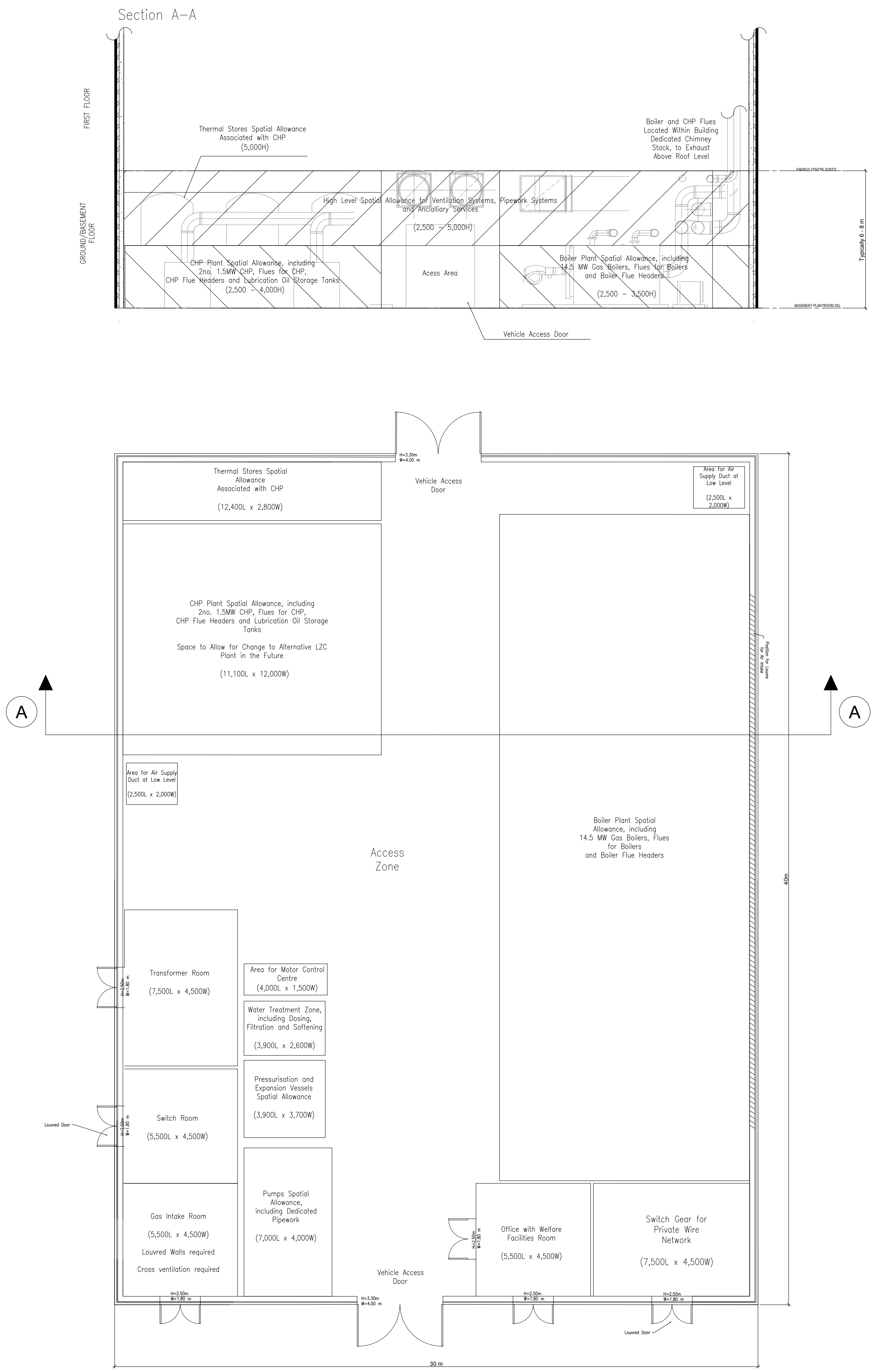

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4. Please note that sizes are indicative and subject to change during detailed design stage.

1	09/07/2018	Report Issue	SS	CK	RB

Client: London Borough of Sutton

Project: Sutton Borough Heat Mapping & Energy Masterplanning Study 60562200

Title: Energy Centre Layout Option 1 General Arrangement

Reason for issue: Concept EC Design

Design: SS	CAD: SS
Chk'd: CK	App'd: RB
Date: 05/07/2018	Scale: NTS

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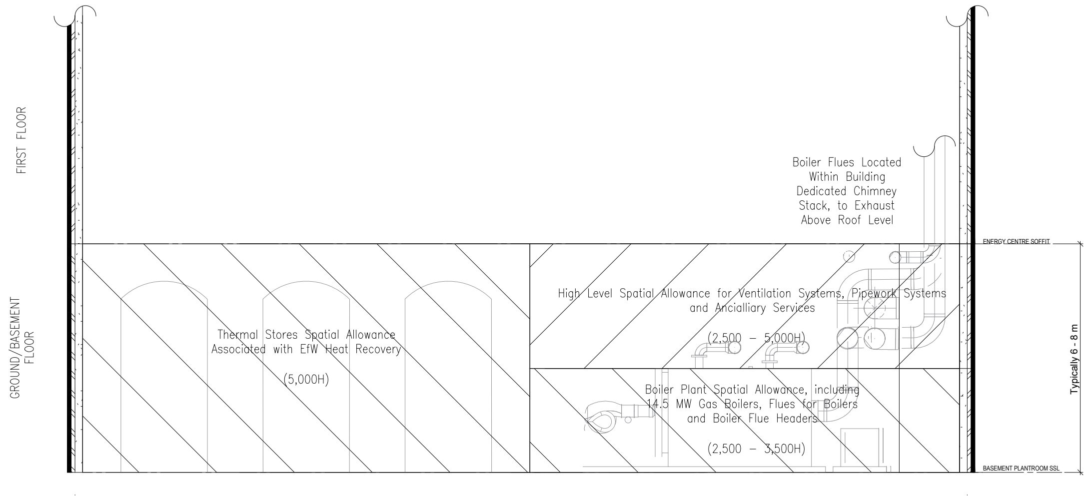

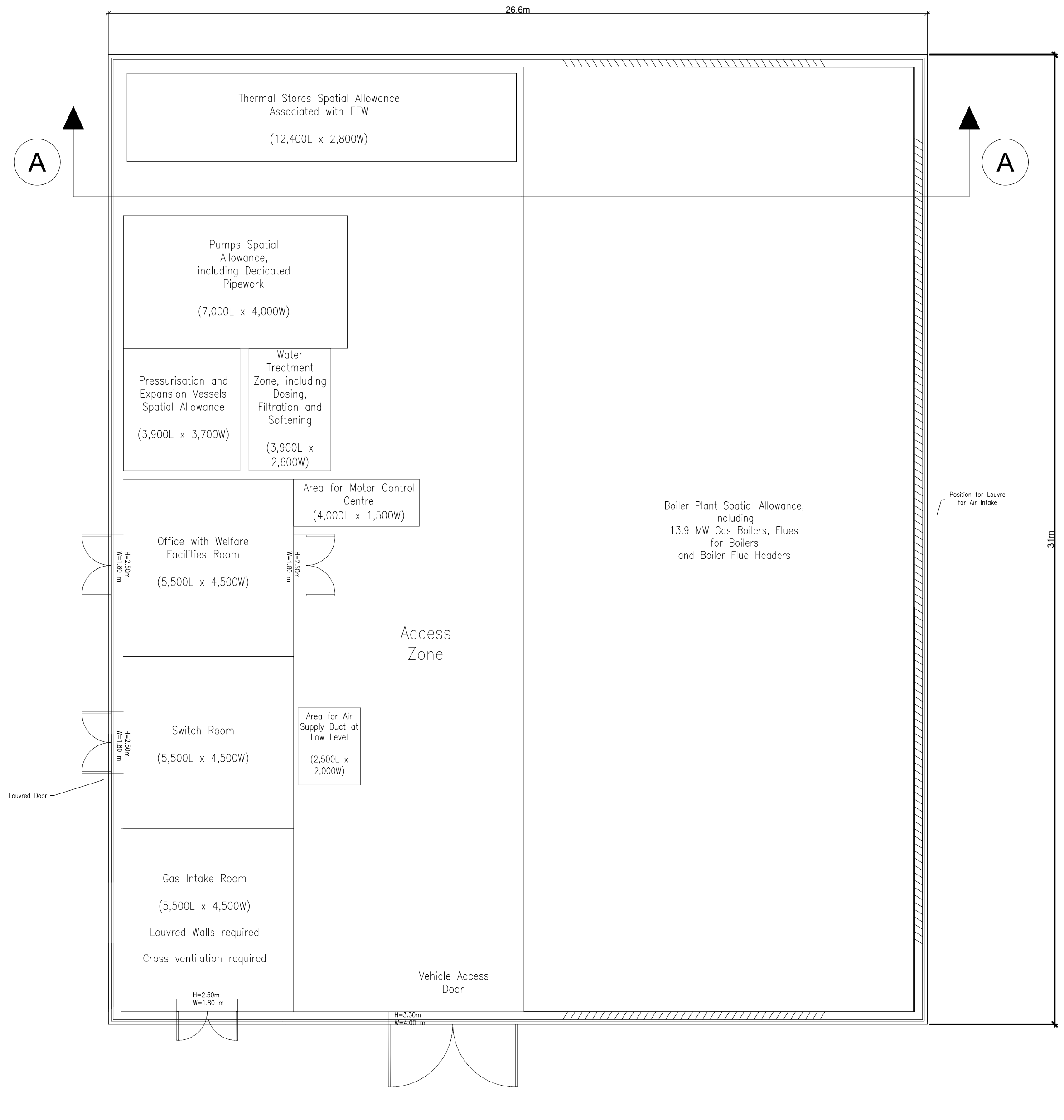

NOTES

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1	09/07/2018	Report Issue	SS	CK	RB

Client:
London Borough of Sutton

Project:
Sutton Borough
Heat Mapping & Energy
Masterplanning Study
60562200

Title:
Energy Centre Layout Option 2
General Arrangement

Reason for issue:
Concept EC Design

Design: SS	CAD: SS
Chk'd: CK	App'd: RB
Date: 05/07/2018	Scale: NTS

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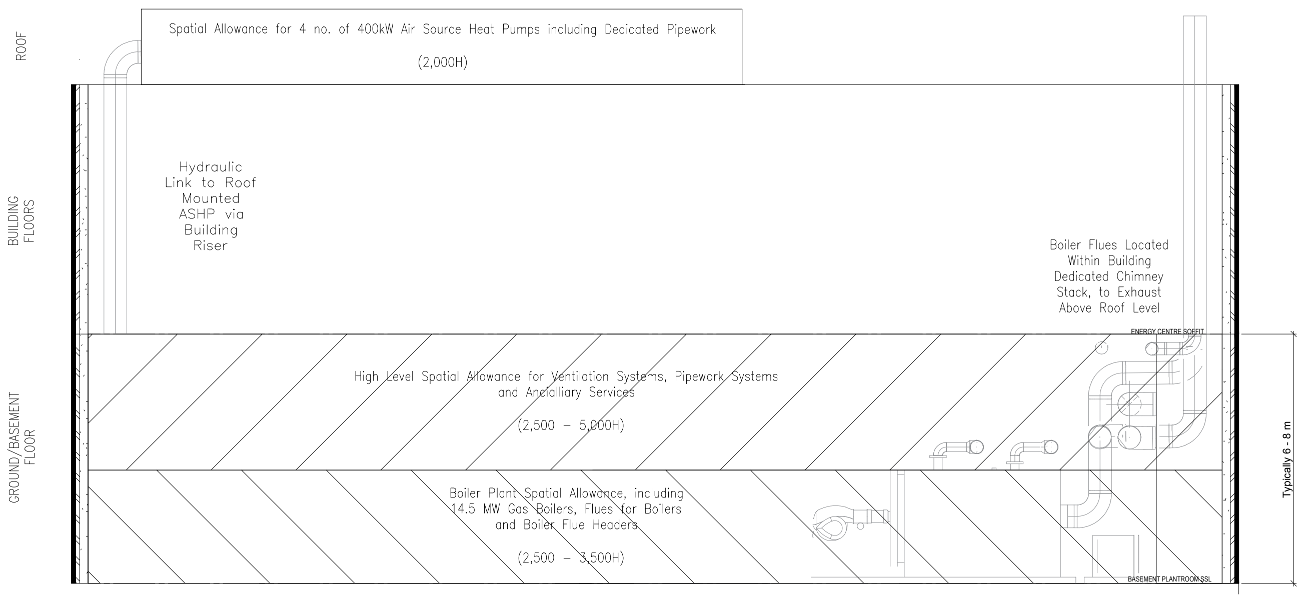
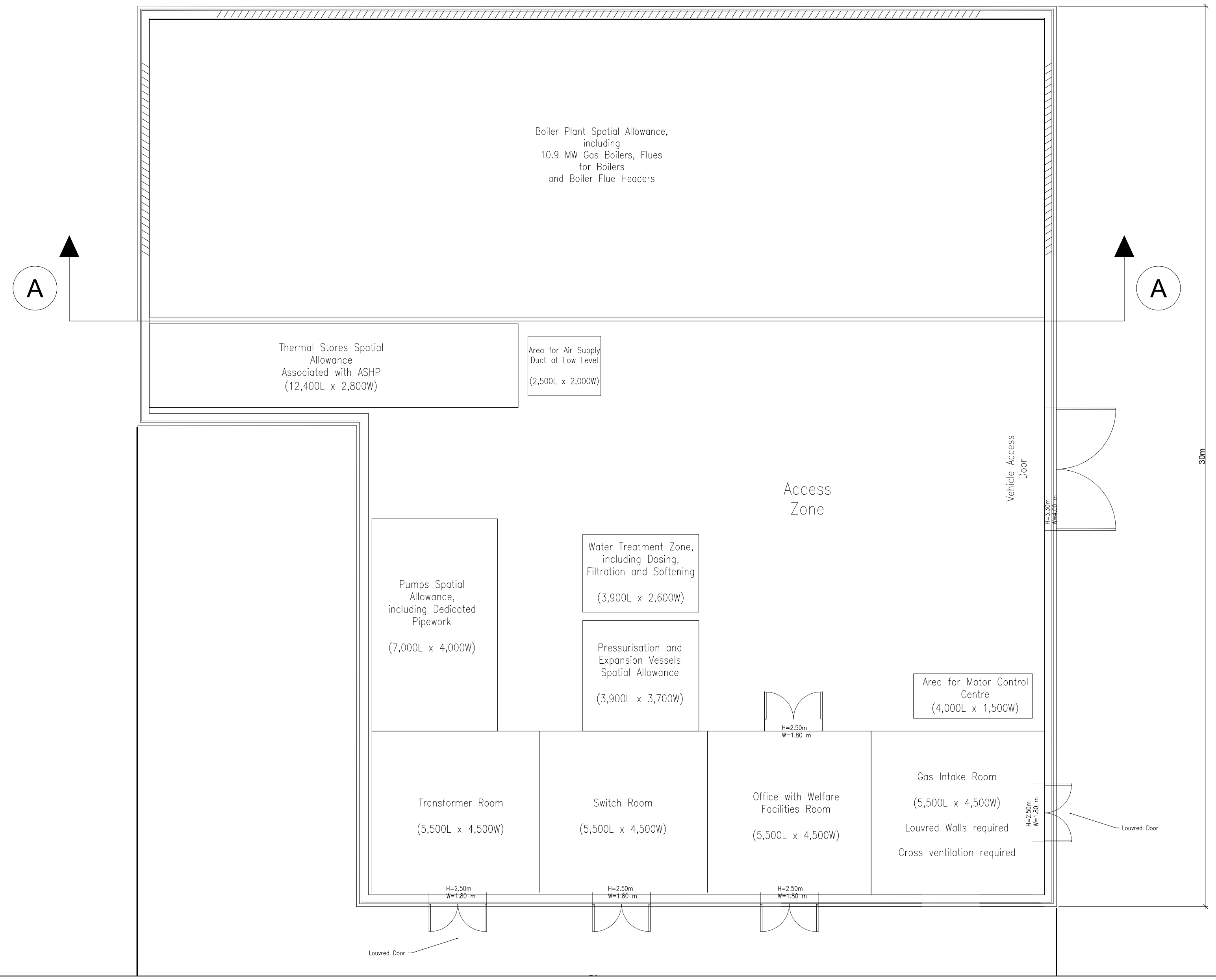
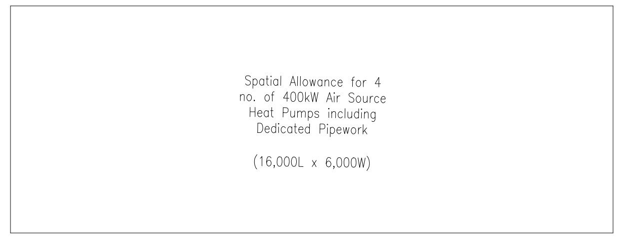
Section A–A



Basement/Ground Level



Roof Level



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4. Please note that sizes are indicative and subject to change during detailed design stage.

1	09/07/2018	Report Issue	SS	CK	RB

Client: London Borough of Sutton

Project: Sutton Borough Heat Mapping & Energy Masterplanning Study 60562200

Title: Energy Centre Layout Option 3 General Arrangement

Reason for issue: Concept EC Design

Design: SS	CAD: SS
Chk'd: CK	App'd: RB
Date: 05/07/2018	Scale: NTS

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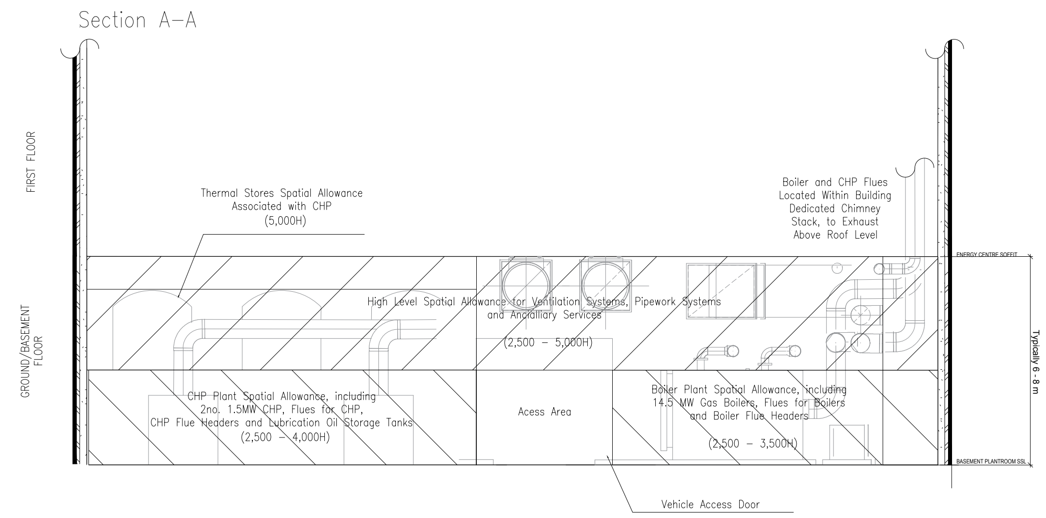

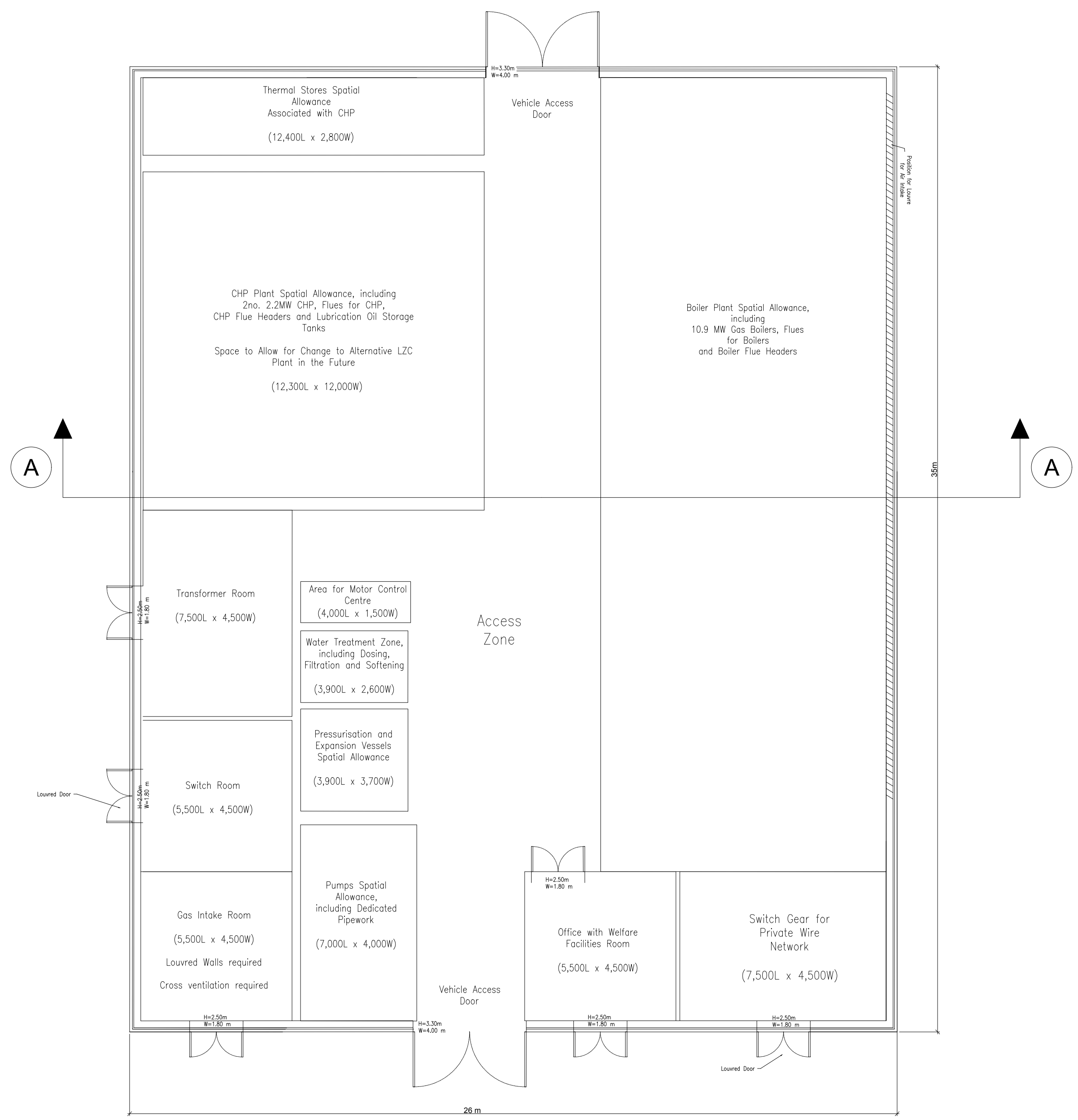

NOTES

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3. Spatial allowance has been provided for Switch Rooms/panels and Transformers (If necessary).
4. Please note that sizes are indicative and subject to change during detailed design stage.

1	09/07/2018	Report Issue	SS	CK	RB

Client: London Borough of Sutton

Project: Sutton Borough Heat Mapping & Energy Masterplanning Study 60562200

Title: Energy Centre Layout Option 4a General Arrangement

Reason for issue: Concept EC Design

Design: SS	CAD: SS
Chk'd: CK	App'd: RB
Date: 05/07/2018	Scale: NTS

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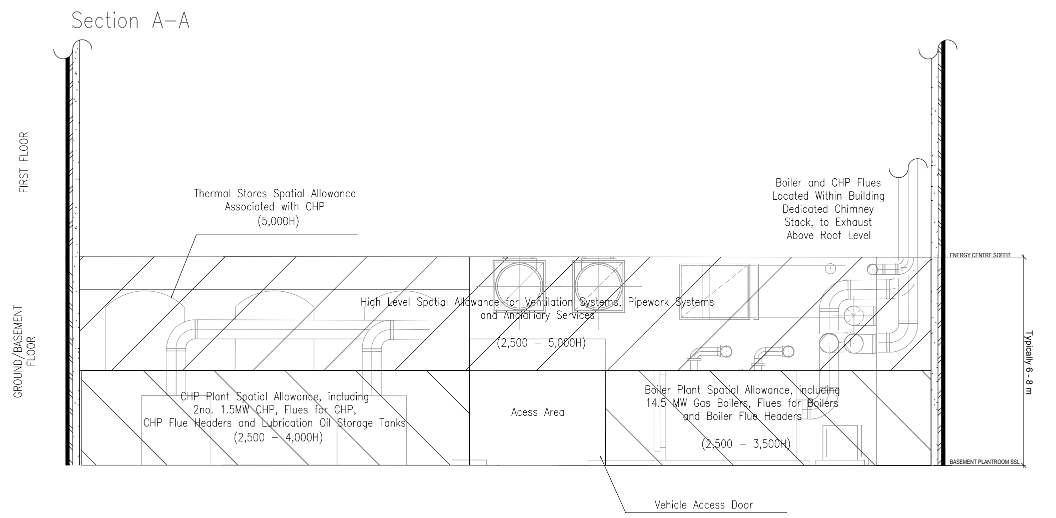

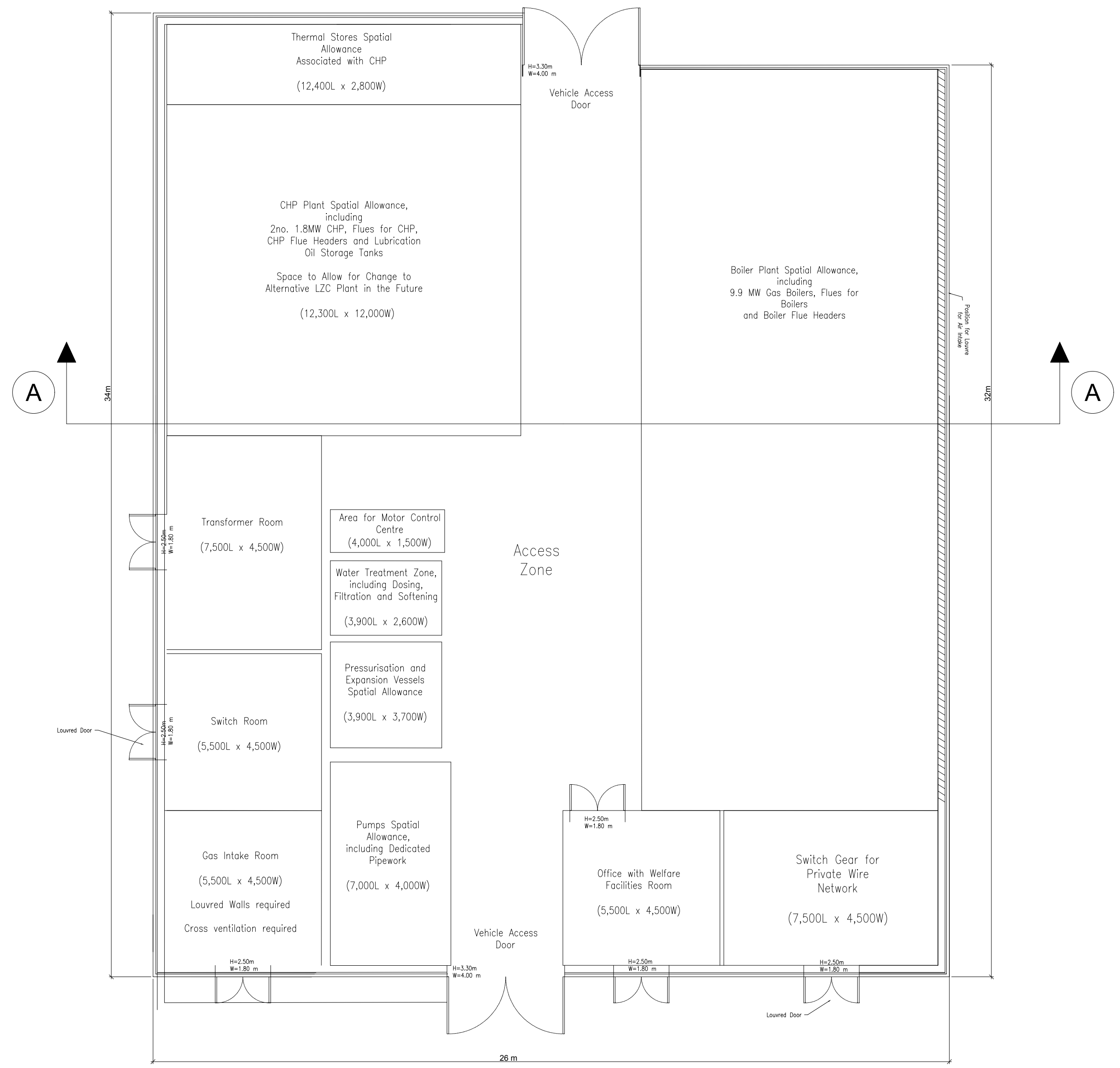

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1	09/07/2018	Report Issue	SS	CK	RB

Client:
London Borough of Sutton

Project:
Sutton Borough
Heat Mapping & Energy
Masterplanning Study
60562200

Title:
Energy Centre Layout Option 4b
General Arrangement

Reason for issue:
Concept EC Design

Design: SS	CAD: SS
Chk'd: CK	App'd: RB
Date: 05/07/2018	Scale: NTS

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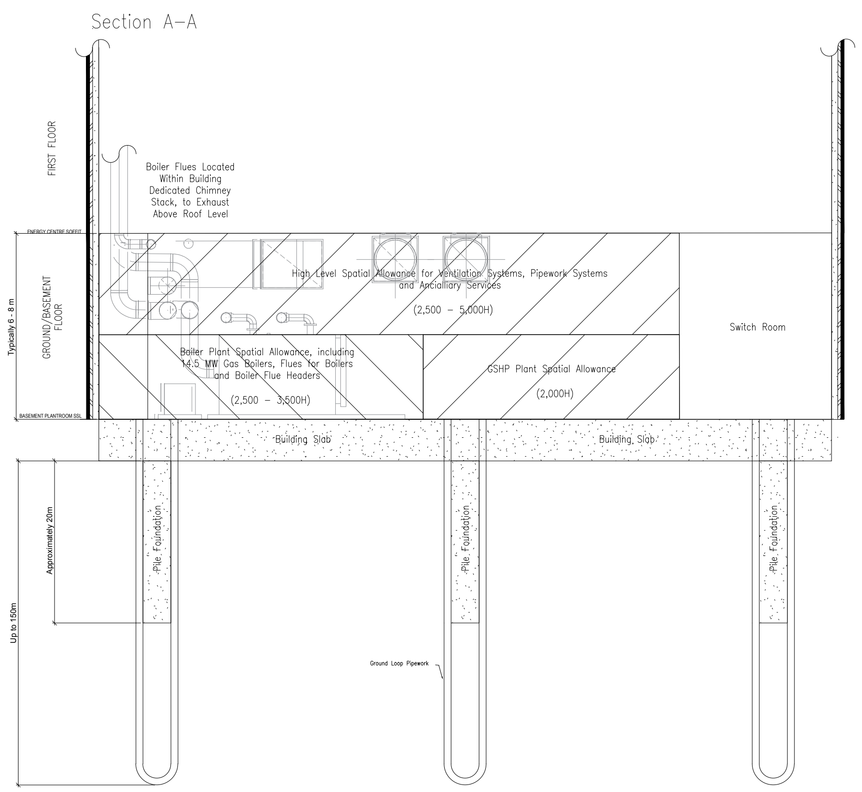

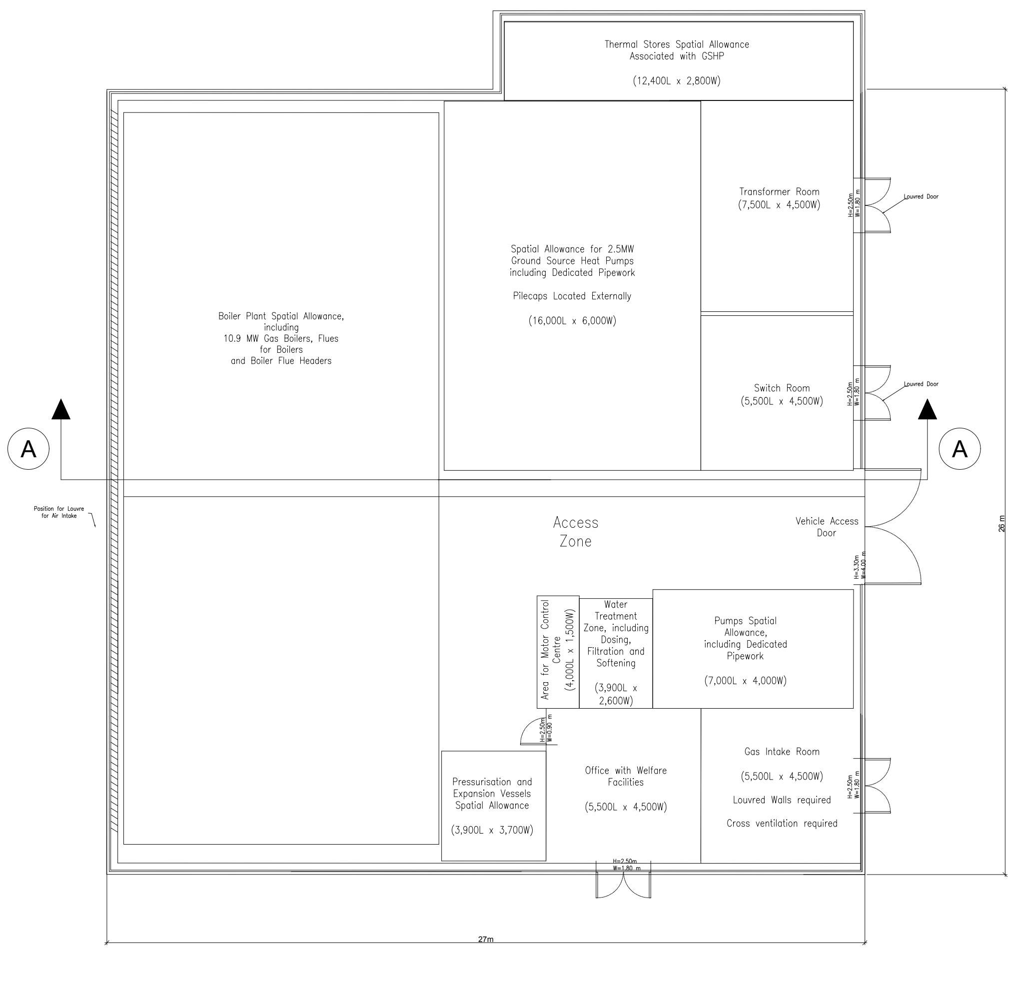

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1	09/07/2018	Report Issue	SS	CK	RB

Client:
London Borough of Sutton

Project:
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Heat Mapping & Energy
Masterplanning Study
60562200

Title:
Energy Centre Layout Option 5a
General Arrangement

Reason for issue:
Concept EC Design

Design: SS	CAD: SS
Chk'd: CK	App'd: RB
Date: 05/07/2018	Scale: NTS

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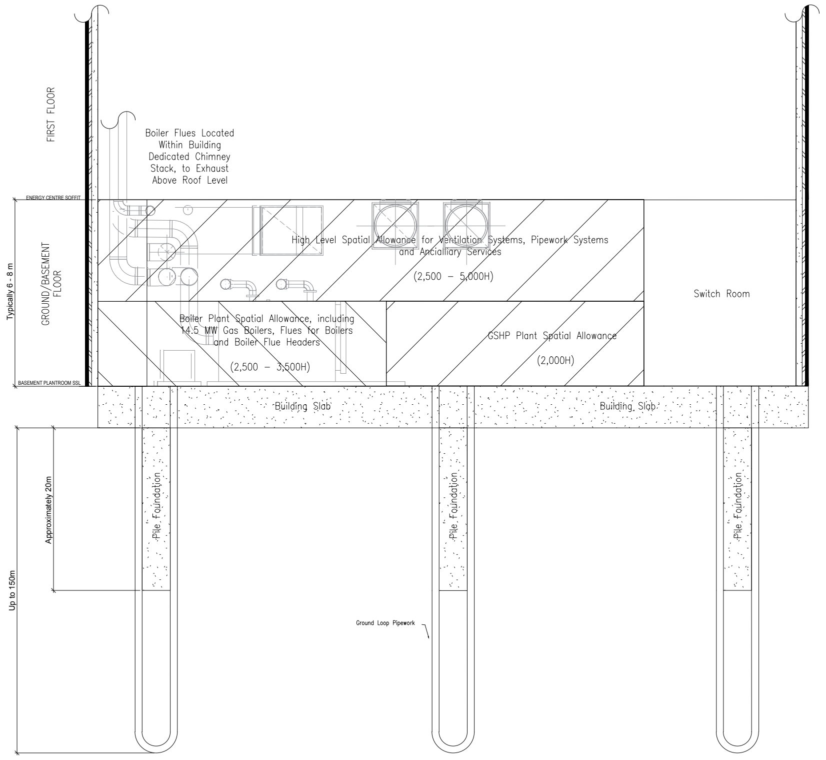
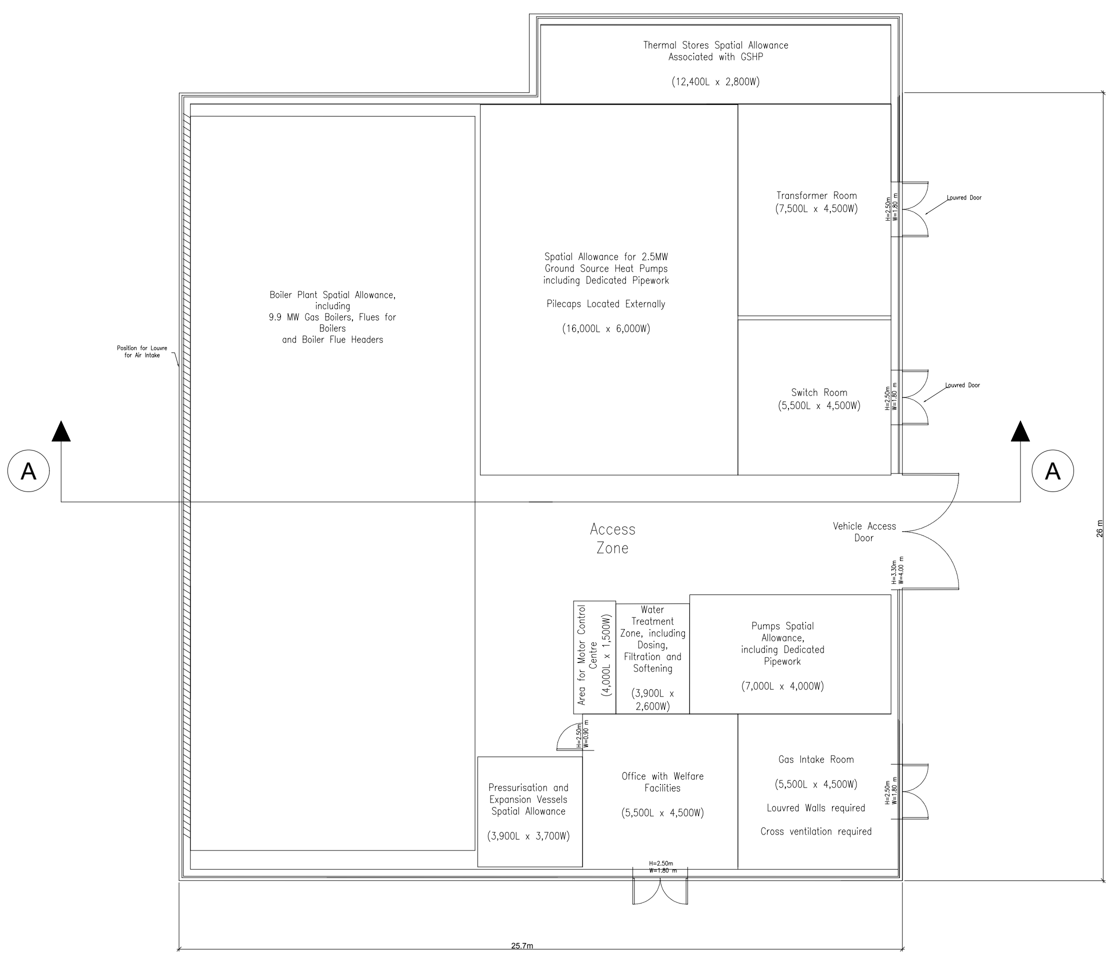
Section A-A





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1	09/07/2018	Report Issue	SS	CK	RB

Client:
London Borough of Sutton

Project:
Sutton Borough Heat Mapping & Energy Masterplanning Study 60562200

Title:
Energy Centre Layout Option 5b General Arrangement

Reason for issue:
Concept EC Design

Design: SS	CAD: SS
Chk'd: CK	App'd: RB
Date: 05/07/2018	Scale: NTS

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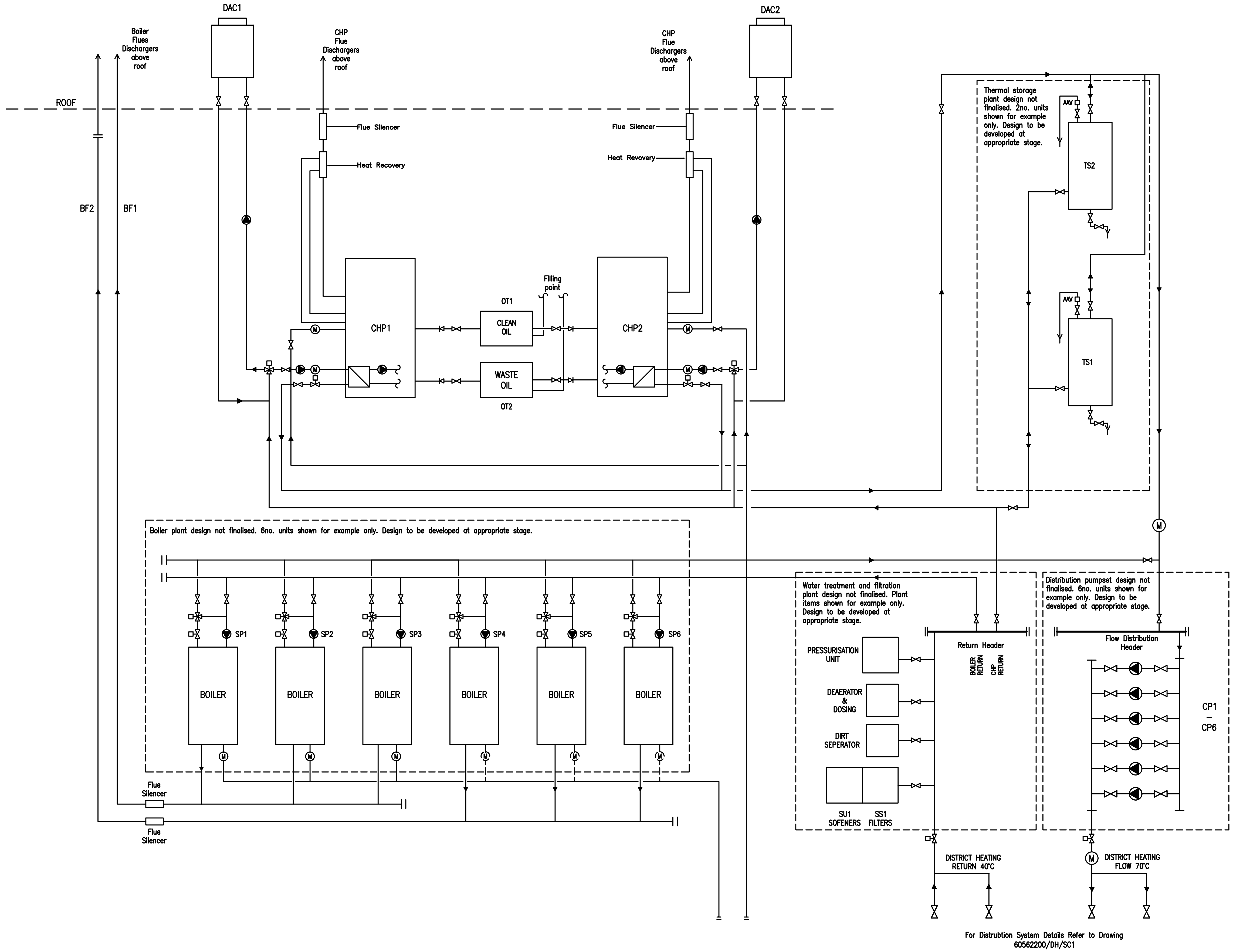

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1	09/07/2018	Report Issue	SS	CK	RB

Client:
London Borough of Sutton

Project:
Sutton Borough
Heat Mapping & Energy
Masterplanning Study
60562200

Title:
Energy Centre Option 1
Heating Plant Schematic

Reason for issue:
Concept EC Design

Design: SS	CAD: SS
Chk'd: CK	App'd: RB
Date: 05/07/2018	Scale: NTS

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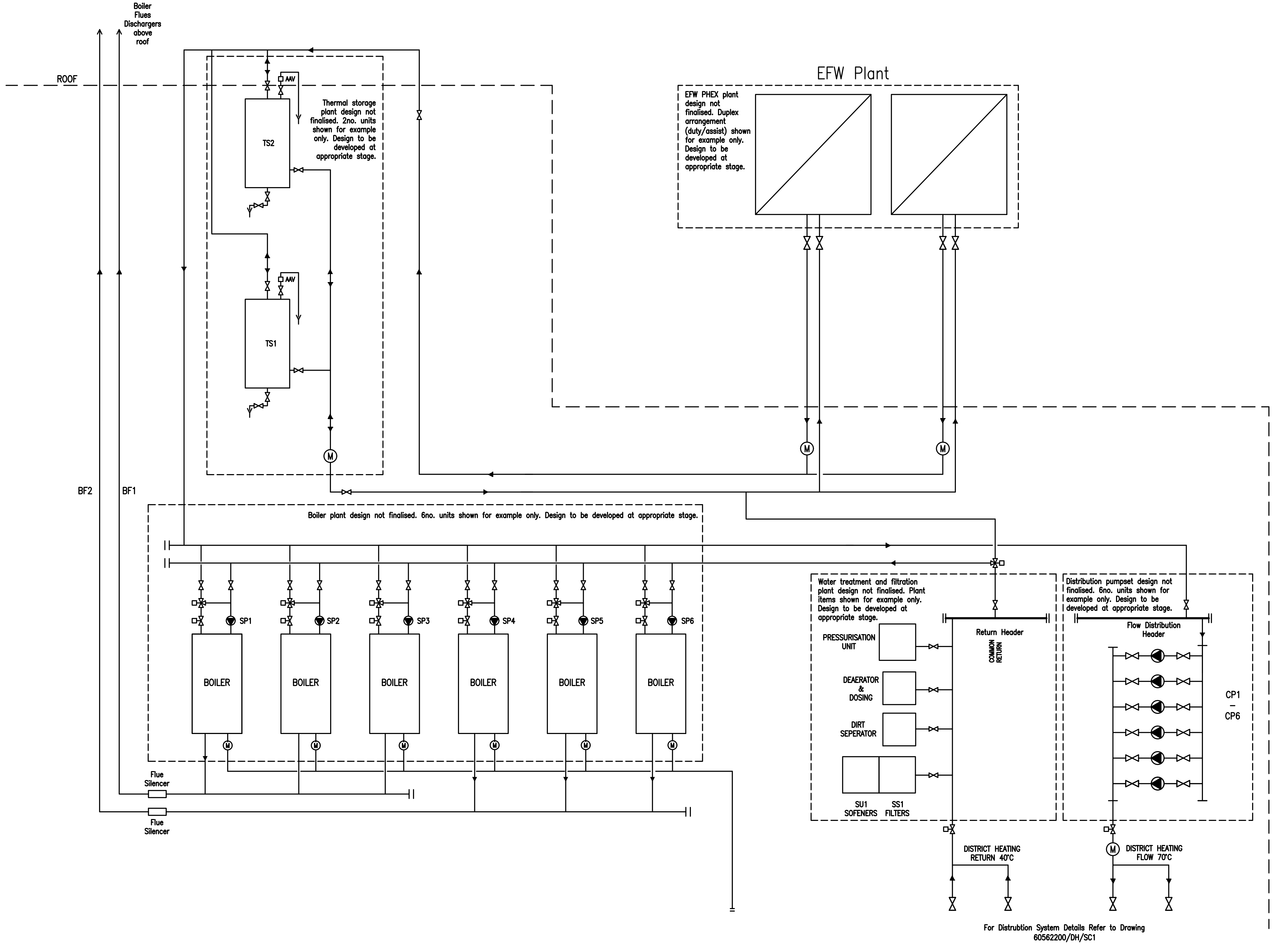

NOTES

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1	09/07/2018	Report Issue	SS	CK	RB

Client: London Borough of Sutton

Project: Sutton Borough Heat Mapping & Energy Masterplanning Study 60562200

Title: Energy Centre Option 2 Heating Plant Schematic

Reason for issue: Concept EC Design

Design: SS	CAD: SS
Chk'd: CK	App'd: RB
Date: 05/07/2018	Scale: NTS

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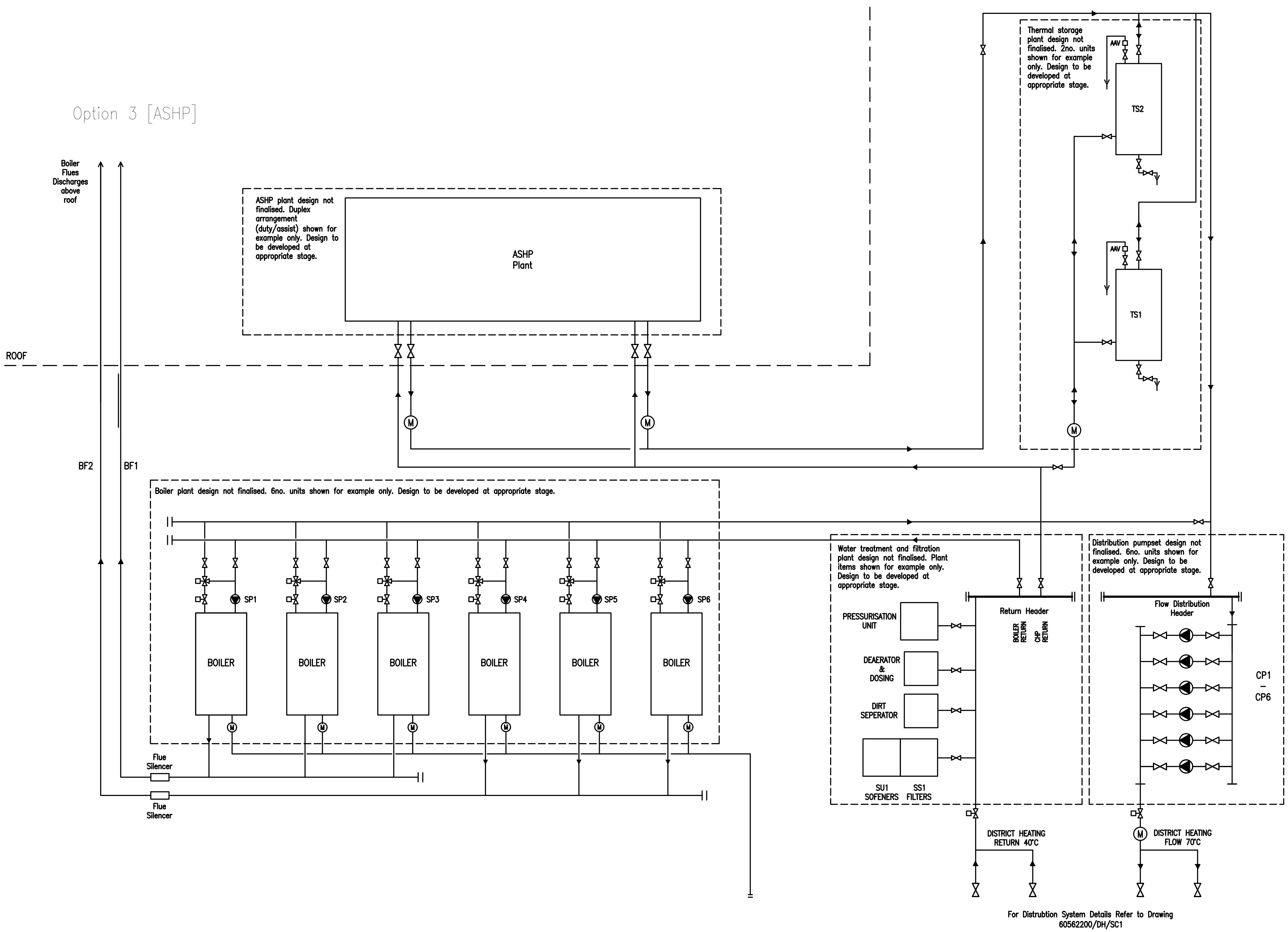

NOTES

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1	09/07/2018	Report Issue	SS	CK	RB

Client: London Borough of Sutton

Project: Sutton Borough Heat Mapping & Energy Masterplanning Study 60562200

Title: Energy Centre Option 3 Heating Plant Schematic

Reason for issue: Concept EC Design

Design: SS	CAD: SS
Chk'd: CK	App'd: RB
Date: 05/07/2018	Scale: NTS

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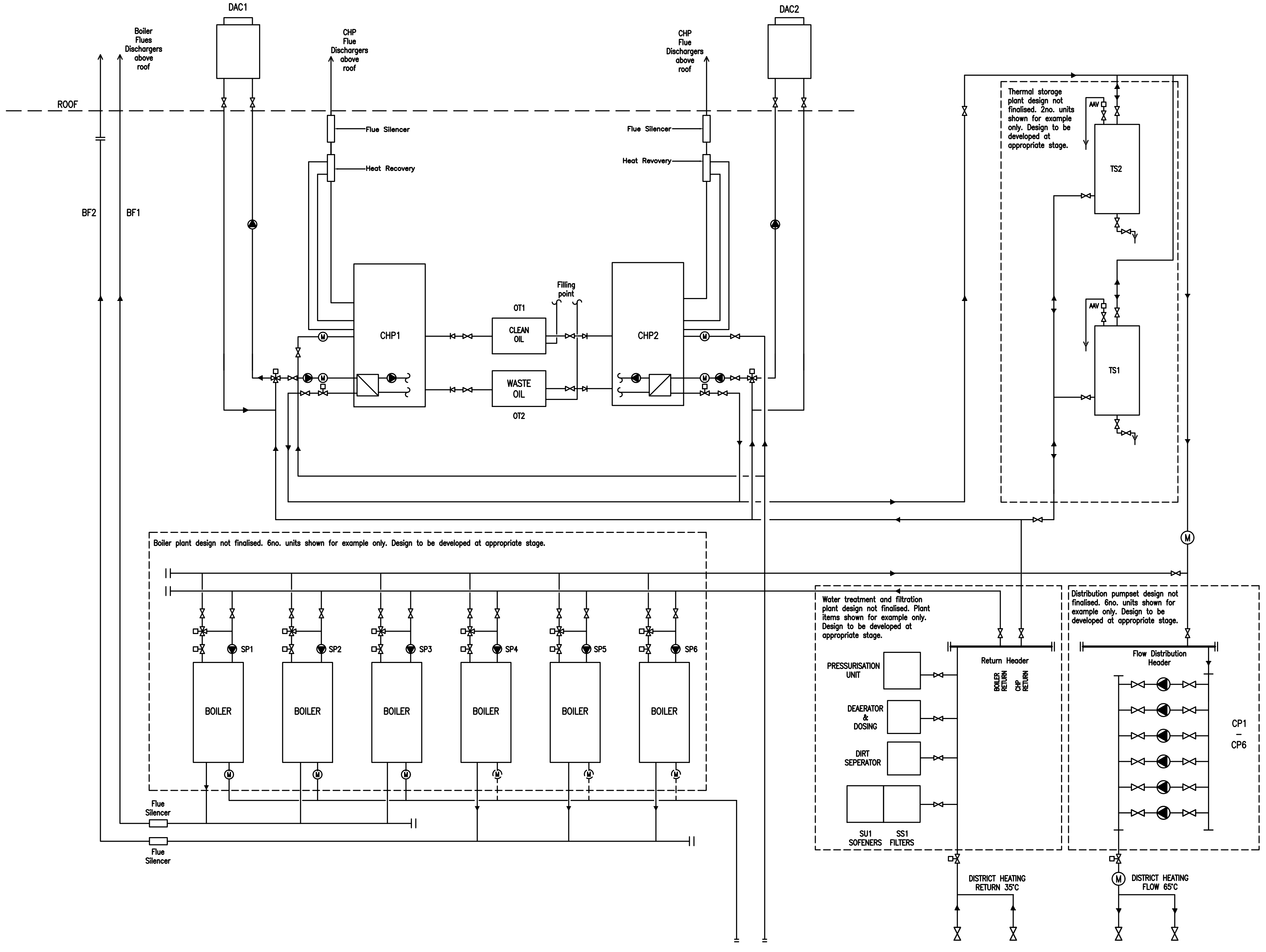
No. 60562200/EC/SCH3 Rev: 01

Option 4 [CHP]



For Distrubtion System Details Refer to Drawing 60562200/DH/SC1

NOTES

PRELIMINARY DRAWING: Please note that this drawing is for preliminary purposes only and must not be read as a construction issue. It indicates design intent for early stages only and it is subject to amendment during detailed design stage.

1. This drawing is to be read in conjunction with all other relevant documentation.
2. Do not scale from this drawing, use only stated dimensions.
3. Spatial allowance has been provided for Switch Rooms/panels and Transformers (If necessary).
4. Please note that sizes are indicative and subject to change during detailed design stage.

1	09/07/2018	Report Issue	SS	CK	RB

Client: London Borough of Sutton

Project: Sutton Borough Heat Mapping & Energy Masterplanning Study 60562200

Title: Energy Centre Option 4 Heating Plant Schematic

Reason for issue: Concept EC Design

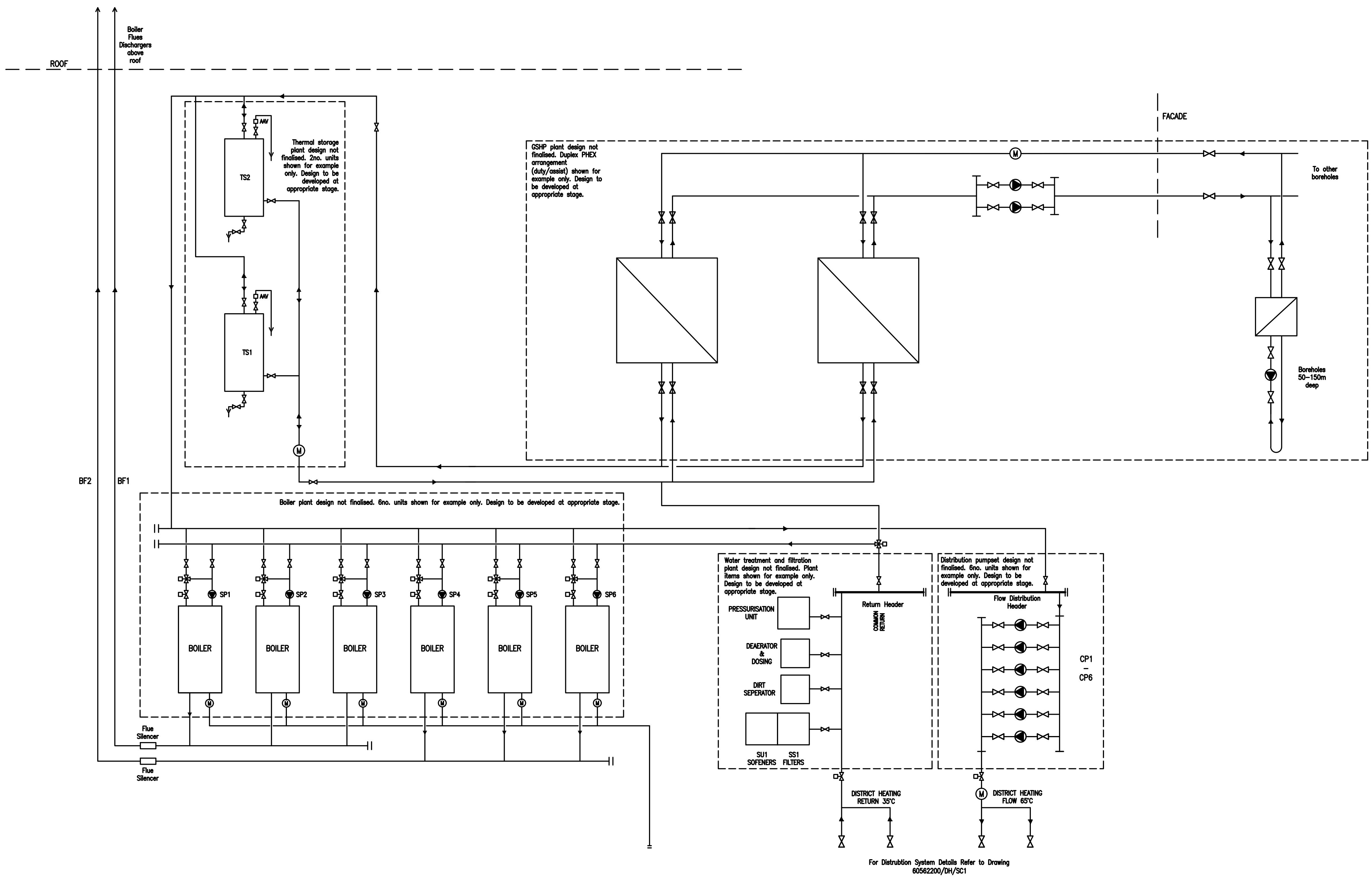
Design: SS	CAD: SS
Chk'd: CK	App'd: RB
Date: 05/07/2018	Scale: NTS

AECOM

2 City Walk Leeds
LS11 9AR, UK
Tel: +44-(0)113-391-6800
www.aecom.com

No. 60562200/EC/SCH4 Rev: 01

Option 5 [GSHP]



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1	09/07/2018	Report Issue	SS	CK	RB

Client: London Borough of Sutton

Project: Sutton Borough Heat Mapping & Energy Masterplanning Study 60562200

Title: Energy Centre Option 5 Heating Plant Schematic

Reason for issue: Concept EC Design

Design: SS	CAD: SS
Chk'd: CK	App'd: RB
Date: 05/07/2018	Scale: NTS

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2 City Walk Leeds
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Appendix R Risk assessment

Ref.	Risk	Risk Category	Action Champion	Commentary	Risk Probability	Risk Severity	Risk Impact	Suggested Risk Mitigation	Risk Probability	Risk Severity	Risk Impact
R/01	**Energy Centre location**	**Construction**	Land Owner	It has been suggested to locate the energy centre in the Civic Centre Site. While there is space available in this location, its availability for use to host the EC is unknown. It has been assumed and agreed for the current study that EC would be located a this site. However, risk remains that site will not be able to accommodate the energy centre subject to future development plans.	2	3	6	1. Engage with stakeholders and land owners from the outset if it is decided to pursue the STC network further. 2. Provide details on Energy Centre design to stakeholders at the earliest opportunity to ensure they understand energy centre particulars and included in future development plans. 3. Seek explicit consent for the location at earliest opportunity	1	2	2
R/02	**Residential customer satisfaction**	**Operation**	Governance	Residential customer satisfaction and retention will depend to a large degree on having fair and equitable contracts. It is important that the service level for the heat supplied is defined as this will ultimately determine the design and hence the costs of delivering the heat.	4	2	8	1. Engage with customers were education is required to communicate what a Heat Network is and how it operates 2. Provide reports on energy supply and use and bills that are clear and informative; 3. Develop communications with customers that meet customer expectations; 4. State levels of service provision and response times to reported failures: 5. Customers to meet agreed obligations. 6. Consider adoption of a Code of Conduct scheme such as Heat Trust 7. Adoption of agreed performance guarantees to be monitored and reviewed	2	2	4
R/03	**Non residential customer satisfaction**	**Operation**	Governance	Non-residential customer satisfaction and retention will depend to a large degree on having fair and equitable contracts. It is important that the service level for the heat supplied is defined as this will ultimately determine the design and hence the costs of delivering the heat.	2	4	8	1. Engage with customers were education is required to communicate what a Heat Network is and how it operates 2. Provide reports on energy supply and use and bills that are clear and informative; 3. Develop communications with customers that meet customer expectations; 4. State levels of service provision and response times to reported failures: 5. Customers to meet agreed obligations. 6. Consider adoption of a Code of Conduct scheme such as Heat Trust 7. Adoption of agreed performance guarantees to be monitored and reviewed	1	4	4
R/04	**Heat Tariff**	**Operation**	Governance	Heat tariff may require change due to external influences, in order to remain attractive or compliant with future guidance	5	5	25	1. Establish proposed heat tariff (fixed and variable element) and demonstrate current cost effectiveness against identified counterfactual 2. Conduct sensitivity analysis on future heat tariff rates based on risk identified within this document 3. Consider within sensitivity testing that future heat rate tariffs may be capped against identified metrics	5	3	15
R/05	**Residential - Customer bad debt**	**Operation**	Metering and billing	Residential customer(s) fail to pay on submitted bills and falls into Debt.	5	4	20	1. Establish whom holds debt risk within commercial structure 2. Identify possible level of debt risk 3. Conduct sensitivity analysis and establish level of debt that could be accommodated within the heat tariff 3. Develop revenue protection strategy that can be applied throughout the lifespan of the system 4. Establish suitable heat sale agreements. 5. Consider adoption of Heat Trust scheme. 6. Facilitate installation of pre-payment systems	5	2	10

Ref.	Risk	Risk Category	Action Champion	Commentary	Risk Probability	Risk Severity	Risk Impact	Suggested Risk Mitigation	Risk Probability	Risk Severity	Risk Impact
R/06	**Non Residential - Customer bad debt**	**Operation**	Metering and billing	Non-residential customer(s) fail to pay on submitted bills and falls into Debt.	2	5	10	1. Establish whom holds debt risk within commercial structure 2. Identify possible level of debt risk 3. Conduct sensitivity analysis and establish level of debt that could be accommodated within the heat tariff 3. Develop revenue protection strategy that can be applied throughout the lifespan of the system 4. Establish suitable heat sale agreements. 5. Consider adoption of Heat Trust scheme.	1	5	5
R/07	**Assessment of thermal loads**	**Pre-construction**	Promoter	The peak heat demand drive capital costs as plant and network capacity increases. Oversized assets also lead to increased operational costs. The annual heat consumption determines the heat revenues to the scheme and, together with the daily and annual profiles of this consumption will determine the capacity of the low carbon plant which will supply the majority of the heat. Oversizing is more likely to occur than under sizing.	5	5	25	1. Establish peak and annual loads based on best available data as defined within Heat Networks Code of Practice. If potential loads are unknown, document assessment basis. 2. Conduct sensitivity analysis on the projected loads based on the level of certainty of projected loads being present and connecting 3. Establish likelihood of load being connected by engaging with responsible representative 4. Confirm projected loads with responsible representative; occupation rates, periods of occupation etc.	2	3	6
R/08	**Connection of thermal loads**	**Operation**	Promoter	The projected peak and annual thermal loads do not occur due to some of the buildings identified for connection to the networks not being interested, or the connection is technically unviable.	5	4	20	1. Engage with operators of the identified existing private buildings as early on in the network development as possible. 2. For any council owned buildings on networks pursued, engage with the facilities managers and relevant stakeholders early on in the process. 3. Carry out full buildings audits to assess technical viability. 4. Maintain dialogue until connection is made 5. Identify heat sale agreements with commercial information being made available 6. Ensure that the heat network offering is competitive with the counter factual 7. Draft Heads of Terms at feasibility stage with proposed customers	2	4	8
R/09	**Realisation of thermal load**	**Operation**	Promoter	The projected thermal loads of connected customers fail to be realised.	5	5	25	1. Establish peak and annual loads based on best available data as defined within HNCoP. If potential loads are unknown, document assessment basis. 2. Conduct sensitivity analysis on the projected loads based on the level of certainty of projected loads being present and connecting 3. Establish likelihood of load being connected by engaging with responsible representative 4. Confirm projected loads with responsible representative; occupation rates, periods of occupation etc. 5. Develop heat sales agreements with consideration of guaranteed annual thermal energy purchase with a minimum connection duration	3	3	9
R/010	**Change of connected thermal loads**	**Operation**	Governance	Connected thermal loads change due to alteration of building usage, improvement in energy performance or connection termination	5	4	20	1. Maintain dialogue with customer to identify potential for future change 2. Develop heat sales agreements with consideration of guaranteed annual thermal energy purchase with a minimum connection duration	5	3	15
R/011	**Network operating temperatures**	**Pre-construction**	Promoter	Operating temperatures are a key aspect of heat network design and will determine both the capital cost of the network and the heat losses and pumping energy. Designing for a future proofed network with lower operating temperatures can result in higher efficiencies, but this depends on the design of the buildings on the network and their eligibility for accepting lower than conventional supply temperatures.	5	5	25	Through engagement with the owners/occupiers of eligible buildings, LBS shall need to ascertain the temperature requirements of the buildings proposed for connection. This assessment will inform the lowest available operating temperature of the networks. The designer has also to consider constraints such as the temperatures used for existing heating systems and the degree that these can be varied. Local policy should reflect operating guidance for future developments in STC and LCH.	2	2	4

Ref.	Risk	Risk Category	Action Champion	Commentary	Risk Probability	Risk Severity	Risk Impact	Suggested Risk Mitigation	Risk Probability	Risk Severity	Risk Impact
R/012	**Heat losses**	**Pre-construction**	Promoter	Losses (proportion of annual thermal energy lost in kWh or MWh) are often incorrect leading to inaccurate energy centre plant and financial planning. The HNCoP states a best practice of 10% annual thermal production is lost to below ground pipework (energy centre to building). The HNCoP states a best practice of 10% annual thermal loss of vertical and lateral pipework, up to and including the HIU.	5	4	20	Detailed assessment of below ground and above ground losses. Review of insulation applied, pipework diameter, length of pipe and operating temperatures. 10% for the primary network and 20% within the building distribution systems has been assumed as part of the modelling in order to provide more conservative estimates on performance	2	1	2
R/013	**Combustion plant size**	**Pre-construction**	Promoter	Benchmarking energy use of buildings can often lead to overestimating the peak demand requirements of buildings. When this is the case for a number of buildings on a network, this can lead to significant oversizing of thermal generation equipment. This adds unnecessary cost and can reduce operating efficiencies.	5	5	25	1. Identify and agree peak thermal loads assessment 2. Consider development of the peak thermal load if the system is to have phased completion 3. Identify thermal resilience strategy with specific consideration of boiler capacity and low carbon system capacity. Boilers at N+1 with CHP as supplementary heat (not considered in peak capacity) is common. 4. Review impact of capex inclusive of material, labour, maintenance as well as spatial impact 5. Ensure design continues to develop in accordance with the HNCoP	4	3	12
R/014	**Heat controls**	**Pre-construction**	Promoter	Heat controls result in poor operation of the system at generation, distribution and customer level. Key issues are optimisation of the system's resultant heat carbon factor and maintenance of flow and return temperatures.	5	5	25	Appropriate generation, distribution (primary and secondary) and customer side controls should be designed, installed, commissioned and monitored. Employ suitable designers and operators and review proposals with Commissioning Manager. Ensure the systems are put in place, commissioned and operate as intended	2	4	8
R/015	**Inefficient heat network routes, pipe sizes and reliability**	**Pre-construction**	Promoter	The capital cost of the heat network is likely to be a major component of the project cost. The routes for the network will define the length, installation difficulty and hence cost.	5	5	25	The quality of materials, design, construction and operation of the heat network are important in determining the reliability of the system. An optimisation study shall be carried out under high standards to achieve: 1. Energy efficient heat network; 2. Low cost network - optimisation of routes and pipe sizing for minimum lifecycle cost; 3. Reliable network with a long life and low maintenance requirements; 4. Efficient heat distribution system within a multi-residential building; 5. Other buried utility coordination; 6. Geographical obstacle review; 7. Land ownership	2	2	4
R/016	**Inappropriate building interface connection**	**Pre-construction**	Promoter	A fundamental design choice is whether the buildings or dwellings are directly connected to the heat network (where the water in the network flows directly through the heating circuits of the building) or indirectly where a heat exchanger is used to provide a physical barrier to the water. The choice has an impact on cost and operating temperatures and pressures. Decision has the potential to impact commercial viability of connection due to asset responsibility.	5	5	25	1. A study shall be carried out to assess the costs and benefits of each connection methods at a building level and at an individual dwelling level; 2. Where indirect connection is used the heat exchanger shall be sized with an approach temperature (primary return (outlet) temperature – secondary return (inlet) temperature) of less than 5 °C; 3. Where boilers are being planned within the building for use at times of high demand the connection design shall ensure that the heat network heat supply is prioritised and the boilers used only when required to supplement this; 4. Large bodied strainers with fine mesh shall be specified to reduce the risk of dirt accumulating on valves and heat exchangers; 5. Control valves shall be two-port so that a variable volume control principle is established; 6. The design of plantrooms for the heat network interface substations shall provide sufficient space for maintenance access and for future replacement of equipment. It shall provide suitable power supplies including for use when carrying out maintenance, lighting, ventilation, water supply and drainage facilities.	4	2	8

Ref.	Risk	Risk Category	Action Champion	Commentary	Risk Probability	Risk Severity	Risk Impact	Suggested Risk Mitigation	Risk Probability	Risk Severity	Risk Impact
R/017	**Assessment of Environmental Impacts**	**Pre-construction**	Promoter	The potential for negative environmental impacts that need to be considered, in particular there may be additional NOX and particulate emissions, increased noise and visual impact restrictions.	5	3	15	A more detailed evaluation of environmental impacts and benefits will be required at the design stage to support a planning application, to comply with legislation and to make the case for the project in terms of CO2 reductions. Detailed air quality study will be required to ensure any proposed network has a positive contribution on local air quality.	5	2	10
R/018	**Assessment of Environmental Impacts**	**Operation**	Governance	In the case of the inclusion of an element of CHP within the scheme, there is the potential for CHP operation to be restricted or prevented due to a change in the environmental impacts and particulate emission legislation.	4	5	20	A more detailed evaluation of environmental impacts and benefits will be required at the design stage to support a planning application, to comply with legislation and to make the case for the project in terms of CO2 reductions. Design to include ability to swap CHP plant to an alternative technology(s). Robustly model the economic impact of an alternative technology driver at the feasibility stage.	4	4	16
R/019	**Air quality requirements**	**Pre-construction**	Promoter	Optimism that emissions standards can be met with ease, without any flue scrubbing and emissions reduction technologies (which are costly)	5	5	25	1. Assess local planning requirements in addition to any environmental permitting 2. Analyse plant flue gas performance 3. Develop mitigation strategy as required i.e. change plant or install flue treatment systems 4. Financially plan for proposed approach 5. Conduct appropriate flue gas/air quality assessment 6. Confirm final solution 7. Demonstrate operational performance when appropriate	2	3	6
R/020	**Health and safety issues in construction, operation and maintenance**	**Pre-construction**	Promoter	Reducing health and safety risks is of primary importance in any project. The health and safety of the general public during construction must be considered particularly as heat networks are often installed through publicly accessible areas.	5	5	25	1. The client body shall recognise their role and obligations under the CDM Regulations and register the project as one governed by the CDM Regulations prior to the start of the design process. 2. The designer has a key role to carry out a designer's risk assessment and then to mitigate these risks by taking appropriate design decisions. The requirements of the COSHH and DSEAR Regulations shall be taken into account in developing the design. Consider undertaking a HAZOP assessment	2	2	4
R/021	**Poor performance of central plant**	**Pre-construction**	Promoter	The principal rationale for any heat network is that heat can be produced at lower cost and with a lower carbon content at a central plant than at a building level. In particular certain heat sources are only feasible at scale (e.g. deep geothermal). The economic case for the heat network will depend on achieving the cost and environmental benefits at the central plant.	5	5	25	1. Designers will need to refer to detailed guidance on various aspects of central plant design as appropriate and identify a performance level 2. Monitor the operation of the central plant and to provide regular reports to the owner/developer so that a high standard of performance can be maintained. 3. Conduct sensitivity analysis based on the poor performance of the plant	4	4	16
R/022	**Inadequate thermal energy supply**	**Operation**	Operator	Failure to deliver the required amount of heat to each customer, critically at the times of peak demand.	3	5	15	1. ensuring that each customer cannot take more than the design flow rate that has been set in the supply contract (typically defined as a kW supply rate at defined flow and return temperatures); 2. For residential properties, a hydraulic interface unit (HIU) is often used to provide a central control and metering point at each dwelling; 3. Commission cost effective, accurate and reliable heat meters in accordance with the Measuring Instruments Directive (MID) and shall be Class 2 accuracy; 4. Implement guaranteed performance standards within the contract	2	2	4
R/023	**Thermal Connection Arrangements**	**Pre-construction**	Promoter	Anchor load customers/developers can prove key to the financial success of a network. Failure to secure these connections can result in financial failure of the heat network	5	5	25	Discussions with key anchor load customers should be undertaken as early as possible in order to establish both the technical and the commercial viability of providing heat utilities to them. Time and resource should be itemised in the business plan to allow for these. Negotiations may be required in order to secure connections. Draft up Heads of Terms at earliest possible opportunity.	2	5	10

Ref.	Risk	Risk Category	Action Champion	Commentary	Risk			Suggested Risk Mitigation	Risk		
					Probability	Severity	Impact		Probability	Severity	Impact
R/024	**Future fuel price variation**	**Pre-construction**	Promoter	The price of heat would include fuel cost, standing charge, maintenance cost, etc. These cost are significant parts of Opex, variation of which will impact the revenue.	5	5	25	Conduct sensitivity analysis on projections of future fuel and electricity prices such as those published by the Inter-departmental Analysts Group (IAG), HM Treasury. Operator can help mitigate risk through use of future heat sale prices and linking to identified and agreed indices.	3	2	6
R/025	**Change of regulation**	**Pre-construction**	Promoter	Financial incentives and various funding scheme have significant impact on the case financial model. RHI has been considered for the LCH GSHP option. Sensitivity analysis shows that the GSHP option for LCH would have a negative return without RHI.	5	5	25	Financial analysis based on both current regulations. Sensitivity has been carried out to show change in IRR with or without key funding schemes.	4	4	16
R/026	**Industry Regulation**	**Pre-construction**	Promoter	The heat industry is not regulated by an external third party. Formation of external regulatory body will incur additional management costs	5	5	25	Whilst the industry is currently unregulated, there have been a number of motions that have been applied by central Government, independent trade groups and professional bodies to improve the base level quality of the industry. Future external regulation is due to be implemented given the current and predicted state of the market. Conduct sensitivity analysis on the potential for increased management/governance costs in the future. Sensitivity should be higher if not already assessing costs associated with current schemes i.e. CHPQA, Heat Trust, Heat Network Regulations	5	4	20
R/027	**Professional experience**	**Construction**	Promoter	Without the correct set of skills or experience within the delivery team, a potential project may face increased costs at any stage of the project.	5	4	20	1. Promoter role can include the review of project requirement's and develop a delivery team that covers the identified roles with sufficient expertise; 2. Ensure companies and individuals have sufficient experience by reviewing CVs, case studies, references and training; 3. Consider specifying project to be delivered under the requirements of a formal structure, such as the Heat Networks Code of Practice.	1	2	2
R/028	**Fuel incomer requirement**	**Pre-construction**	Promoter	Risk that gas main infrastructure near chosen scheme site is not of sufficient pressures and kW capacity to service energy centre.	5	5	25	Energy centres often require significant gas main peak capacity and pressure which cannot always be readily provided locally from the existing in situ pipework. Further investigations into the MP mains line located within Sutton need to be undertaken at the next stage.	3	5	15
R/029	**Fuel incomers costs**	**Pre-construction**	Promoter	Assumed that connection of gas network to Energy Centre is straightforward when it can be onerous and costly	4	4	16	Early investigation of gas mains infrastructure recommended, with outline designs generated for potential solutions.	2	3	6
R/030	**Water quality**	**Pre-construction**	Promoter	Water treatment is sometimes not considered, impacting CAPEX and OPEX. Hard water means extensive water treatment is required to reduce mineral content of the water. Without water treatment, plant lifespans will be reduced which is unlikely to be considered in life-cycle costs. Hard water is found in Sutton which may cause some concern.	5	5	25	1. Level of water treatment required should be investigated early. 2. Water treatment plant to be identified along with capex and opex costs 3. Water quality to be maintained whilst the system is operational.	5	2	10

Ref.	Risk	Risk Category	Action Champion	Commentary	Risk Probability	Risk Severity	Risk Impact	Suggested Risk Mitigation	Risk Probability	Risk Severity	Risk Impact
R/031	**DNO electrical connection**	**Pre-construction**	Promoter	Electric DNO fee to connect and export to grid is underestimated/unknown at design stage (can often lead to huge one-off expense to connect for grid reinforcement works). Initial budget costs are often not tested soon enough within the project life cycle. Requirement to undertaken lengthy G59 application means it's often not done at early feasibility stages, which can lead to optimism on DNO connection cost/procedure. Occasionally, DNO infrastructure connection requirements/costs can halt a project completely.	5	4	20	Initial budget costs to be developed based on knowledge and experience of the local utilities. Identify changes in the current connection; increased import capacity (Heat Pumps) or ability to export (CHP) and amend price accordingly Seek quotations as soon as practically possible Identify key technical requirements are addressed within and quotations; security of supply, faults, capacity. Ensure cost of connection is contained within the business case and verified. Continue to engage with the market to ensure prices remain accurate and fit-for-purpose Initial feedback from G59 applicant shows that exporting 5MW will be very costly. Project to undertake further engagement with utility once option is selected for feasibility study.	3	4	12
R/032	**No private wire customers identified**	**Pre-construction**	Promoter	The revenues associated with private wire are much higher than exporting to the grid. For options developed that include elements of sale of power via private wire or sole fallback customers (i.e. GLA), the financial viability of the network is underpinned by the assumption that all of the electricity is sold to the GLA via licence lite. The sale of electricity from CHP via private wire significantly improves the viability of a CHP led scheme.	5	3	15	During the commercialisation phase of the project relevant stakeholder engagement must be carried out early enough in the process to secure the private sale of sufficient electricity to back up the financial performance of the network. Continued discussions with the GLA going forward and appreciation of the licence lite legislation period	3	3	9
R/033	**Electrical load available for sleeving/private wire**	**Pre-construction**	Promoter	Sleeving/private wire end customer might not have the electric load requirement it is assumed to have or be willing to enter contract due to pre-existing electrical supply arrangements	3	3	9	Current model assumes all electricity from CHP option is sold to GLA via licence lite in the base case for use by TFL.	5	2	10
R/035	**Electrical export**	**Pre-construction**	Promoter	Parasitic loads, transmission losses and transformer inefficiency often under-estimated/ignored.	4	3	12	Assess potential parasitic loads and losses that could impact the quantity of electrical energy available for sale. Continue to assess anticipated requirements as design develops.	3	2	6
R/037	**Heat meters**	**Pre-construction**	Promoter	Heat meters either not present, not installed properly or unable to transmit recorded information	5	5	25	Suitable heat meters are to be installed in accordance with the relevant regulations and Heat Networks Code of Practice. The heat meter should be appropriate to the system design and installed in accordance with the manufacturer's requirements. Installed meters are to be commissioned and proven to operate over a continuing period of time, including data transmission. Meters will require on-going maintenance and possible recalibration, as identified during the planned maintenance process.	2	5	10
R/038	**Energy Centre size and cost metrics**	**Pre-construction**	Promoter	No industry standard benchmark on physical size requirements, so often energy centres can be under-estimated. When at design stage, these errors can impact construction costs, cause programme delay and land use/developer availability. Furthermore, no industry standard benchmarks are available for construction/procurement costs (£/m2). Energy centre design at this stage is based on a RIBA Stage 1 design.	5	3	15	Limited information or specific published metrics available therefore assessment to consider plant size, movement and maintenance. Internal heights and location of heavy plant also to be considered. Design to consider changes to space requirements as project progresses.	5	2	10

Ref.	Risk	Risk Category	Action Champion	Commentary	Risk Probability	Risk Severity	Risk Impact	Suggested Risk Mitigation	Risk Probability	Risk Severity	Risk Impact
R/041	**DH pipework design**	**Pre-construction**	Promoter	Pipe lengths often assumed to be too short than is necessary Installation of pipework is assumed to be straightforward, without the need to coordinate with utilities/highways which is rarely the case Pipework insulation performance overestimated, impacting energy losses and load on Energy Centre Inappropriate DeltaT can result in larger (increased capital and operational costs) Adverse design parameters can result in the shortening of the systems lifespan AECOM has currently undertaken a RIBA stage 1 level of network routing design.	4	5	20	Principles of network design (pipe sizing, DeltaTs, velocities, stress) should be based on agreed standards i.e. HNCoP and manufacturers recommendations. Networks should be designed for identified connected loads and documented allowance for any future expansion (increase in diversified peak capacity). Routes of pipework are to be established at any early stage with an identified allowance for additional pipework that has yet to be accounted for i.e. inaccuracy in routing and expansion loops. As the design progresses, routes detailed and confirmed, the additional allowance proportion should be reduced to zero. Continue to develop as design progresses.	4	3	12
R/042	**DH pipework costs**	**Pre-construction**	Promoter	Pipework costs often underestimated at early stages of the project until installation. Additional costs arise from the location of the pipework; soft dig, sub-urban, urban or central urban hard dig. AECOM has undertaken a site survey and has developed cost metrics suitable to the project.	3	3	9	Establish lengths, sizes and routes at Feasibility stage and apply appropriate metrics dependant on dig type, location and obstacles Engage with manufacturers and installers to review and improve pricing accuracy when detail is available. This should be conducted as early as possible and prior to completion of the outline business case.	2	3	6
R/043	**DH pipework maintenance**	**Operation**	Promoter	Pipe failures are not accounted for. If they are accounted for, they are assumed to be easy to maintain. In reality, to fix a failed pipe is difficult, takes time and is costly - due to ground excavation works, welding costs etc. Servicing of loads from DH network will be interrupted, requiring a short-term servicing strategy to be put in place and temporary plant to be brought onto site - this is often unaccounted for.	3	5	15	OPEX cost estimates for pipework failure/servicing should be allowed for in the economic model. Consider use of leak detection, water quality monitoring and extended warrantees	2	2	4
R/044	**Secondary/Tertiary system compatibility (existing buildings)**	**Pre-construction**	Promoter	Within existing buildings it can be assumed to be easy to convert/changeover secondary side systems to be compatible with network connection. Cost of ensuring technical compatibility to be considered In new build, how SH and DHW services are designed can have a significant impact on the capital costs and operating costs of the heat network. For example, achieving consistently low return temperatures will reduce capital costs for the network and thermal store, result in lower heat losses and pumping energy and in some cases reduce the cost of low carbon heat production.	5	2	10	1. Identify existing buildings that may wish to connect to the heat network 2. Estimate initial cost of connection based on anticipated supply arrangement 3. Confirm and validate operational parameters of the existing system 4. Confirm age and condition of existing/retained assets 5. Develop costs to reflect works to be undertaken and risk levels present i.e. re-commissioning of customer system from 82^{o}C/71^{o}C to 70^{o}C/40^{o}C flow and return temperatures.	3	2	6
R/045	**Secondary/Tertiary system compatibility (new buildings)**	**Pre-construction**	Promoter	How SH and DHW services are designed can have a significant impact on the capital costs and operating costs of the heat network. For example, achieving consistently low return temperatures will reduce capital costs for the network and thermal store, result in lower heat losses and pumping energy and in some cases reduce the cost of low carbon heat production.	3	2	6	1. Conduct specific design study to review the various options available for space heating and DHWS in relation to supply from heat networks.2. Implement agreed design, installation, commissioning standards and review their implementation3. Operator and Land Developers, or persons responsible for customer heat systems, to coordinate and ensure compatibility. 3. Local planning policy to include CP1 guidance.	2	2	4
R/046	**Secondary/Tertiary systems operation**	**Construction**	Governance	Poor secondary/teritiary side operation can result in high return temperatures, corridor overheating and poor system performance	3	2	6	1. Develop and agree a heat network design manual that covers design, installation, commissioning and operation. 2. Consider making technically measurable items contractually binding i.e. return temperatures during summer and low loads 3. Review operational interface if customer plant is being retained. 4. Ensure that the heat taken from the network is maximised, measured and monitored. Emphasis to be placed on measuring return temperatures to the network.	2	2	4

Ref.	Risk	Risk Category	Action Champion	Commentary	Risk: Probability	Risk: Severity	Risk: Impact	Suggested Risk Mitigation	Risk: Probability	Risk: Severity	Risk: Impact
R/047	**Secondary/Tertiary systems commissioning**	**Construction**	Governance	Poor secondary/tertiary side commissioning can result in high return temperatures, corridor overheating and poor system performance	3	4	12	Potentially significant risk. Impact can be reduced by incentivising downstream system owners to optimise their systems, or by commissioning systems as part of the network (this would require associated costs to be included in the business case). Network operator may not wish to undertake downstream side systems.	2	3	6
R/048	**Planning consent and Way leave agreements**	**Pre-construction**	Promoter	Planning process often not considered, or are assumed to be straightforward. Energy Centre building planning performance requirements often not considered. Assumption that way leave consent for preferred pipework routing will be granted, meaning in reality the required pipework lengths may increase and/or target anchor heat loads may not be connectable.	4	4	16	Often overlooked. Early engagement with relevant bodies within local authority recommended (planning, highways etc.) to establish requirements for the energy centre, environmental performance and routing option viability. If above ground pipework (pipe bridges) are being considered, additional Planning engagement may be required. Energy centre is currently proposed to be included in new development. Way leaves agreement may take considerably longer than anticipated.	2	2	4
R/049	**Carbon content of fuels**	**Operation**	Promoter	Future carbon content of electric offset is uncertain, potentially impacting future carbon tax abatement. Unknown carbon content of future fuel used in the Energy Centre, impacts the carbon content of electrical/heat export.	4	3	12	Whilst utility carbon content is projected to reduce, the exact reductions are unknown. Use of DECC projections is recommended for initial assessment and DECC CHP bespoke carbon factors.	2	2	4
R/050	**Technology costs with maturity**	**Pre-construction**	Promoter	Expectations of significant reductions in technology costs, particularly for technologies that currently are only marginally viable that may not have much scope for quick price reductions (e.g. platinum content fuel cells). Impacts the technologies that are considered in current studies.	4	3	12	Significant unknowns. Conservative estimates recommended. Review opportunities to future proof the heat network both technically and commercially. Consider heat network suitability for current alternative technologies that are not yet commercially viable.	2	2	4
R/051	**Technology availability**	**Pre-construction**	Promoter	Expectation that future technologies that replace CHP as a prime mover become available at scale, and are compatible with designed and installed network.	4	3	12	Cost allowances should be made in the business case to allow technology changeover. Review opportunities to future proof the heat network both technically and commercially. Heat pump based options have been included in report.	2	2	4
R/052	**New energy centre location**	**Pre-construction**	Promoter	Should the initial chosen location not prove viable in future discussions and negotiations, an alternative location will need to be sought. The risks associated with adopting an alternative location include potentially increased CAPEX costs (depending on land ownership, location and nearby utilities, particularly MP gas mains), and OPEX costs (through increases in pumping energy and heat losses through increased pipework lengths).	3	4	12	Alternative locations must be identified at the earliest possible stage. It is recommended that any change in Energy Centre location considers the impact on its proximity to the MP gas main and the potential increase in DH network length required to service the customer buildings. Additionally, any Energy Centre location will have to consider the impact on the lengths required to provide private wire services where required. Visual impacts should also be considered.	2	3	6

Ref.	Risk	Risk Category	Action Champion	Commentary	Risk Probability	Risk Severity	Risk Impact	Suggested Risk Mitigation	Risk Probability	Risk Severity	Risk Impact
R/053	**Future-proofing of the network**	**Pre-construction**	Promoter	The approach taken to future-proofing of the network to accommodate potential future demand expansion is inadequate (this concerns projects that haven't yet been considered and/or approved). Future development does not have the opportunity to connect due to the inadequate future-proofing, or its connection would make the scheme sub-optimal. Not accounting for future expansion, could lead to increased O+M or capital costs, or missed opportunities and future savings.	4	4	16	Development plans have been requested, to ensure best prediction for future. Any future newbuilds to be obliged to connect to the scheme, with information to be provided to stakeholders (including contractors) as early as possible. Options to future proof design have been identified at feasibility stage. To be further considered at procurement stage and require contractor to future proof design e.g. through oversizing pipes, planning for nodal system. Consider potential contractual issues involved in connecting with other existing networks. Take into account future potential of new nearby developments. Must weigh up initial investment vs future impact/costs, but ensure no sacrificial plant, and existing scheme plant not oversized (to cater for future unconfirmed demand).	2	4	8
R/054	**Insufficient gas supply to the energy centre available.**	**Pre-construction**	Promoter	May influence scheme size if fuel supply is limited	3	4	12	Medium pressure gas main has been identified for STC. Further consultation required during a feasibility study.	2	3	6
R/055	**Failure to gain approvals/political sign-off**	**Pre-construction**	Promoter	Programme delay or overall threat to connection	4	5	20	Ensure the local council leadership is included in the decision making process and kept update of the project process.	2	3	6
R/056	**Scheme fails to achieve an acceptable debt rate with customers**	**Operation**	Metering & Billing	This would result in high charges for heat. High charges for heat would result in no (or insufficient) take-up of the scheme.	4	4	16	As only a small number of customers expected, an acceptable debt rate should emerge as a result of the feasibility and design process.	2	2	4
R/057	**Economic performance insufficient**	**Pre-construction**	Promoter	It cannot provide discounted heat sales and the marginal business case fails to attract investment, whether from the council or a third party. If the network cannot give an economic benefit over the status quo, it is unlikely to be adopted.	4	5	20	This is of lower risk where there is larger public sector involvement and likelihood of accepting a smaller heat price discount. If the case is marginal, the council may need to raise the capital for the development. Negotiation with potential customers will be needed based on feasibility results and options identified. If the scheme does not achieve the desired IRR then an emphasis on the 'bigger picture' may be required to attract customers. e.g. being part of the first phase of an expanding low carbon network.	3	3	9
R/058	**Sub-optimal capital programme**	**Pre-construction**	Promoter	Release/availability of funding drives phasing and impacts design decisions	4	4	16	Capture as much information as possible for the feasibility study. Communicate modelling assumptions and understanding regularly to check future plans are appropriately captured. Identify alternative funding sources.	2	3	6

Ref.	Risk	Risk Category	Action Champion	Commentary	Risk Probability	Risk Severity	Risk Impact	Suggested Risk Mitigation	Risk Probability	Risk Severity	Risk Impact
R/059	**Uncertainty over capital cost**	**Pre-construction**	Promoter	This can lead to funding issues. This could be, for instance, contractor costs increase. Reduced NPV or IRR for the scheme, or scheme is mothballed.	3	4	12	Costs to be reviewed through process. Further work will be needed at detailed design stage to determine capital costs. Specific items such as energy centre or distribution network costs need further negotiation.	3	3	9
R/060	**Operation and maintenance costs of DH network**	**Pre-construction**	Promoter	If the capital spend profile included for maintenance and cyclical plant replacement is too low, scheme will suffer from reduced returns and increased operational costs	4	5	20	The initial phase scheme proposals are for to be determined by the promoter. Costs to be reviewed through process. Further work will be needed at detailed design stage to determine capital costs. Specific items such as O&M costs need further negotiation.	3	3	9
R/061	**Cost of carbon and available subsidies.**	**Pre-construction**	Promoter	If the cost of carbon emissions increases, this might result in reduced returns and increased operational costs	3	4	12	Costs to be reviewed through process, with any changes to Government policy and the utilities markets noted. Further work will be needed at detailed design stage to determine such costs.	3	3	9
R/062	**Selection of sub-optimal procurement option**	**Pre-construction**	Promoter	Lack of understanding of procurement options available may lead to selecting sub-optimal supply chain partner	3	4	12	Procurement workshops; soft market testing. Engage with potential procurement partners as early as possible.	2	2	4
R/063	**Costs of metering and billing for heat sales with customers.**	**Operation**	Metering & Billing	Impacts on scheme viability	3	3	9	Review requirement in next stage. Use cost metric from other council operated schemes and include in feasibility model.	2	2	4
R/064	**TRIAD and STOR value not achieved**	**Operation**	Operator	The current generation models have not consider the revenue from TRIAD payments. The current CHP model is not assessed to be applicable for STOR and therefore no value has been applied. Future design development could lead to the inclusion of STOR but should only be considered if the CHP option is developed.	1	1	1	Future changes to TRIAD are to be reviewed as they may result in increased revenue potential. Current CHP scheme not considered for STOR. If STOR were to be sought, a parallel battery solution would require development. This has not currently been considered due to the environmental performance (Carbon and NOx) of CHP within the context of London.	1	1	1
R/065	**Assumptions about avoidance of carbon costs wrong**	**Pre-construction**	Promoter	Impact on modelled financial performance, potentially resulting in lower returns.	3	3	9	Use existing site data, and also lessons learnt from previous projects. Use worst case assumptions. Undertake sensitivity analysis	2	2	4
R/066	**The proposed scheme gas consumption is significantly increased**	**Pre-construction**	Promoter	Insufficient network capacity may be available for a large increase in gas consumption.	3	4	12	Further investigate network capacity and utility information.	2	2	4
R/067	**Failure to manage stakeholder expectations**	**Pre-construction**	Governance	Stakeholders may pull out of agreement at an advanced stage. Uncertain scheme uptake would threaten the technical and economic viability of the scheme	4	4	16	Regular and clear contact with key stakeholders. Key customers are public sector which should reduce risk. Ongoing consultation and early negotiation of contract terms and signing of contract.	2	2	4
R/068	**Proposed energy centre(s) building not big enough to accommodate required energy source in future (no spare space for expansion).**	**Pre-construction**	Promoter	Missed potential to connect future development and concurrently improve performance of the proposed scheme.	3	4	12	If possible, building to be designed to be able to extend. Other site(s) may be needed for future expansion, and the team should continue to consider these alternative locations.	2	2	4

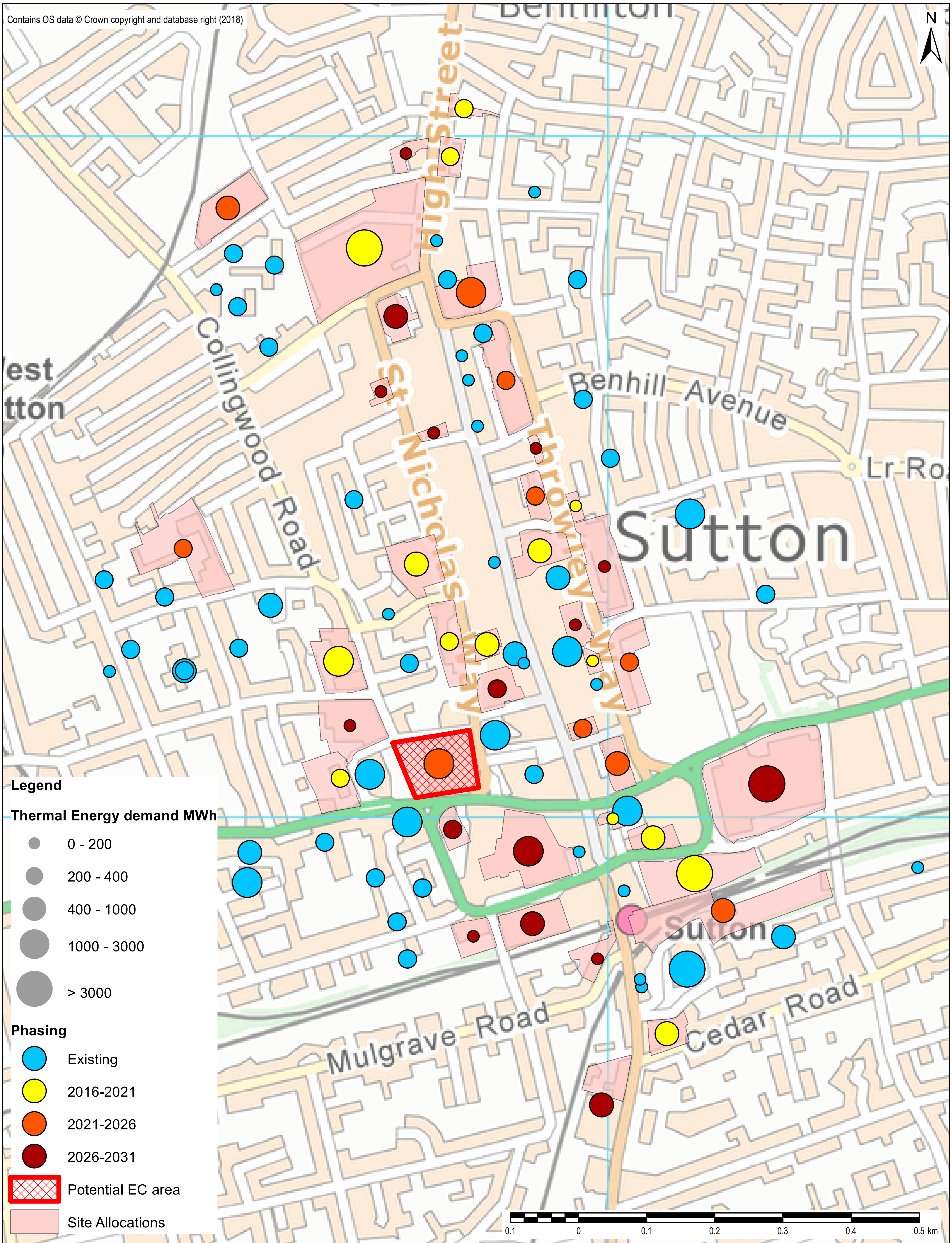
Ref.	Risk	Risk Category	Action Champion	Commentary	Risk Probability	Risk Severity	Risk Impact	Suggested Risk Mitigation	Risk Probability	Risk Severity	Risk Impact
R/069	**Lack of integration with existing and planned future minor works (e.g. repair and replacement) or site activities that might disrupt DH scheme works.**	**Pre-construction**	Promoter	Potential lost revenue, unnecessary costs or delayed programme	4	4	16	Consider key potential constraints. Coordinate works with existing projects such as tram and gyratory, work with stakeholders to ensure aware of these. Stakeholder activity constraints may include busy periods/ events.	3	2	6
R/070	**Remaining life of existing plant may be good. Risk of 'sunk' costs to connect to heat network**	**Pre-construction**	Promoter	Potential customers may be less likely to join up, or would want to get some use out of their existing plant or some costs recouped.	4	3	12	Will need to negotiate with customers on these points. Potential customers in private sector are likely to have new plant. Possibly the scheme might pay to adopt decentralised plant, or use temporary plant until the network is operational. Could let people connect as and when, but this impacts the financial case. Detailed engagement and contractual negotiations required.	3	2	6
R/071	**Ability to retain customers on longer term contracts.**	**Pre-construction**	Promoter	Uncertain scheme uptake would threaten the sustained technical and economic viability of the scheme	3	4	12	Heat sales prices and contracts will need to be robust and attractive, and without break clauses. Draft Head of Terms to be developed under next stage and explored with stakeholders	2	3	6
R/072	**Complex works access to the selected Energy Centre(s).**	**Construction**	Installer	1. Delays to the programme schedule 2. Additional costs 3. Potential to be picked up by the media	3	3	9	Define costs (allow for high estimate) and works clearly, Early engagement with contractor and engagement with other stakeholders e.g. FM, Soft testing	2	2	4
R/073	**Programme delays at construction stage (e.g. due to getting approval for works in roads, delivery delays, requirements for limiting work timescales due to events or building requirements).**	**Construction**	Installer	Cost and programme	4	4	16	Careful forward planning and management should be undertaken to manage and minimise delays. Detailed procurement programme to be presented with TC documents. If completion date is not met, buildings due to connect will need to be able to utilise their existing heat systems. Ensure programme not too tight and managed appropriately.	3	3	9
R/074	**Risks which may impact on programme e.g. discovering asbestos or ground conditions**	**Pre-construction**	Promoter	Cost, programme, technical and economic viability	4	5	20	Detailed surveys of each building to be undertaken where builders work is to be carried out, including asbestos survey, and GPR survey. Tio be undertaken in the next stage of design works	3	4	12
R/075	**Local political risk**	**Pre-construction**	Promoter	Changes to council administrations results in lower priority for heat networks or even abandonments through removal of resource. Reduction in long-term scheme support	3	4	12	Continued engagement with the Council senior management is essential for the scheme to be given the resources and priority required. Reduce risk by contractually mandating this.	3	3	9
R/076	**National political risk**	**Pre-construction**	Promoter	Changes to national administration or strategy results in move away from heat networks, or powers which allow local authorities to develop and invest in heat networks. Reduction in available funding, incentives or difficulty in achieving planning for this strategy.	2	4	8	This may place a greater emphasis on schemes being economically attractive for commercial investment. Engagement with national government required. Scheme to be optimised and future-proofed as far as possible to ensure long term viability.	2	3	6
R/077	**Risk of obsolete components needing replacing over the lifetime of the scheme.**	**Operation**	Operator	Increased replacement costs	3	3	9	Ensure spares will be available for long period.	2	2	4

Ref.	Risk	Risk Category	Action Champion	Commentary	Risk Probability	Risk Severity	Risk Impact	Suggested Risk Mitigation	Risk Probability	Risk Severity	Risk Impact
R/078	**Financial incentives and various funding schemes have significant impact on the long term financial model.**	**Pre-construction**	Governance	The financial case may change based on future regulation, negatively impacting the performance of the scheme.	4	3	12	Financial analysis based on both current regulations. Feasibility study should consider changes to policy.	3	2	6
R/079	**Available heat for import - reliance on third party**	**Pre-construction**	Promoter	For the connection to the EfW facility, heat will be generated and supplied from a third party, specifically the Beddington Energy from Waste facility. This leads to additional risk both in the timely delivery of the network and security of heat supply. The availability of heat in reality may differ from that modelled by AECOM.	3	4	12	Information provided by SDEN allowed AECOM to sense check the heat output and availability figures provided. Further confirmation and consultation will need to be carried out at the next stage.	3	3	9
R/080	**Insufficient cash flow and revenue streams**	**Pre-construction**	Promoter	Financial risk due to uncertainty in revenue streams.	4	5	20	Phased installation of network over several years, allowing initial network operation to be established and cash flow demonstrated. . Additional heat generation plants can be added later in order to meet the network's developing heat load.	3	3	9
R/081	**Third party heat and electricity costs**	**Pre-construction**	Promoter	The cost of heat highly affects the network financial viability . For the EfW network option it is assumed that the third party energy suppliers will charge for heat and electricity where appropriate, i.e. the EfW operator. For modelling purposes, the year 1 heat cost for these networks has been set based on the ARUP report provided by LBS. However in practice it will depend on the third party supplier.	3	4	12	Confirm costs with the associated party as early as possible during feasibility.	2	2	4
R/082	**Projection of energy prices**	**Pre-construction**	Promoter	Trend projections of future energy prices are taken from the BEIS Green Book supplementary guidance. However, the projections made in the Green Book do not show any change to price beyond c. 2027, which is an unlikely scenario and could affect the viability of the networks going forward	4	4	16	Trend predictions to be updated during feasibility stage to current predictions.	2	3	6
R/083	**Site topology**	**Pre-construction**	Promoter	Sutton High Street has a significant gradient change. Laying pipework over large variations in altitude entails certain risks. Firstly, pipework has to be installed that is capable at operating at higher pressures. Every 10m of altitude will add approximately 1 Bar of operating pressure to the system. Higher pressures also require pumps to be larger in size, in order to overcome the additional head pressure. Cost allowances provided in this study are for pipework rated to around 10Bar.	3	3	9	The network operator/designer needs to pursue a detailed topological survey to inform the pressure requirements of the network(s) and to ensure equipment and pipework is selected properly.	2	2	4
R/084	**RHI and HNIP funding routes**	**Pre-construction**	Promoter	If a proposed scheme were to apply for more than one mode of state aid funding (i.e. both RHI and HNIP funding), there is a potential confliction of state aid rules. As part of the pilot HNIP scheme, HNIP funding cannot be used to for costs of generation equipment that is supported by the RHI but it can fund costs of the heat network infrastructure that is connected to that generation plant. At the time of writing, final HNIP funding rules are yet to be finalised beyond those used in the pilot scheme.	3	4	12	Sensitivity analysis has been carried out for the use of RHI and HNIP. Additional analysis to be conducted with and without each incentive of funding scheme, allowing analysis of the specific importance to any network.	2	2	4
R/085	**RHI and HNIP funding requirements**	**Pre-construction**	Promoter	Both RHI and HNIP require certain performance criteria to be demonstrated prior to being awarded. These are based around a schemes carbon performance, social NPV and potential customer benefits.	4	4	16	Detailed technical and economic performance analysis to be conducted prior to the applications for the schemes to reduce the risks of not meeting the criteria. Where the need for these funding routes is an essential requirements in terms of the financial viability of the scheme, suitability must be ensure before progressing the project.	3	3	9

Ref.	Risk	Risk Category	Action Champion	Commentary	Risk			Suggested Risk Mitigation	Risk		
					Probability	Severity	Impact		Probability	Severity	Impact
R/086	**STC and LCH Development timelines**	**Pre-construction**	Promoter	The primary requirement for the development of any DEN network centred around STC/LCH is the need to be able to supply heat to the development on the dates which it will be required. At the time of writing, the build out of STC and LCH has begun with several opportunities for connection missed.	4	4	16	Decisions regarding the development of a network to be made as early as possible to ensure timelines can be met.	3	3	9
R/087	**Cost of land required for EC(s)**	**Pre-construction**	Promoter	No land grab cost has been accounted for within the models within this report.	2	3	6	Decisions regarding the potential location(s) sought for the placement of ECs to be identified at the earliest possible opportunity, with suitable costs established if required. These costs are then to be included within any detailed business model.	2	2	4
R/088	**EFW plant not completed**	**Pre-construction**	Promoter	Beddington EfW plant is currently under construction.	3	4	12	Continuously monitor and engage with EfW through the project programme.	2	4	8
R/089	**Use of heat pump system using ammonia (risk of interaction with public)**	**Pre-construction**	Promoter	Ammonia is a toxic gas and can cause harm.	3	5	15	Design to appropriate BS standards and design out risk of ammonia coming in contact with the public in the event of a leak.	2	2	4
R/090	**Ground source heat pump potential heat capacity unknown, subterranean restrictions as yet unknown**	**Pre-construction**	Promoter	The potential heat generation capacity for the modelled ground source heat pumps are only estimates, with the actual capacity as yet unconfirmed. In the absence of a full GPR survey being undertaken, the identification of potential subterranean restrictions that may inhibit the system installation and function is also unknown.	4	3	12	Carry out test bore holes for LCH site during feasibility	2	2	4
R/091	**Counterfactual case development not applicable to the new London plan**	**Pre-construction**	Promoter	The development of the Counterfactual case used for financial and carbon analysis is not applicable to the new London plan (where the inclusion of new developments have been considered)	3	4	12	Develop a counterfactual heat price bespoke to Sutton during the feasibility study. Monitor industry trends in response to the draft London Plan.	2	2	4
R/092	**New development construction**	**Pre-construction**	Promoter	New development construction comes forward at a time different to the current masterplan and the form of the development reduces the demand for heat and connection opportunities.	4	3	12	Monitor developer plans to bring forward developments and development stakeholder engagement plan for developers.	3	2	6
R/093	**Primary flow temperatures**	**Pre-construction**	Promoter	Primary flow temperatures are not suitable for some or all of the developments that are due to connect to the network(s).	3	3	9	Encourage similar design temperatures for all sites coming forward. All design to be in line with CP1.	2	2	4
R/094	**Engagement with the health trust**	**Pre-construction**	Promoter	The health trust for the LCH site is one of the key loads and stakeholder for the LCH site.	3	3	9	At feasibility stage, undertake stakeholder engagement with trust to ensure proposal match the further development strategy for the site.	2	2	4
R/095	**Customer satisfaction with regards to the price of running any heat pumps**	**Operation**	Operator	Customer satisfaction with regards to the price of running any heat pumps is low as a result of potentially high plant operational costs. Heat pumps are not the current industry solution for providing heat across London for residential scheme.	4	3	12	Heat price to meet Heat Trust criteria. Additional work to be carried out at feasibility.	2	2	4
R/096	**Programme time changes**	**Pre-construction**	Promoter	The programme for STC and LCH changes and this impacts on the delivery of any proposed heat network.	4	4	16	Robust project programme to be in place with conditions monitoring of masterplan implementation.	2	2	4
R/097	**Technology development prior to the commencement of the project**	**Pre-construction**	Promoter	The development of technology such as ASHP or GSHP might change over the coming years prior to the implementation of the a heat network.	3	4	12	Network and energy centre to be future proofed for changes in technology and other technical criteria e.g. low operating temperatures	2	3	6
R/098	**Accuracy of modelling information and applicability to the marketplace relevant to timelines**	**Pre-construction**	Promoter	Accuracy of modelling information and applicability to the marketplace relevant to timelines	4	3	12	Further increase accuracy of modelling during feasibility study and subsequent stages.	2	2	4
R/099	**Unforeseen developments coming forward**	**Pre-construction**	Promoter	Unforeseen developments coming forward could add additional load to the scheme or create addition constraints in the development areas.	4	3	12	Regular contact with Sutton planning team to ensure all development are included in the heat network calculations and planning.	2	2	4
R/0100	**Tramline providing a risk to network development**	**Pre-construction**	Promoter	Tramline development may create additional risk to network development relating to potential network routing strategy.	3	5	15	Develop alternative route. Review tramline development in line with DH network development.	2	3	6
R/0101	**Supporting information.**	**Pre-construction**	**Promoter**	STC and LCH information is based around existing Master plan and development road map. These documents may now be outdated with regards to the stakeholders intentions for the projects, which would influence the accuracy of the energy profiles developed as part of the pre-construction design	4	4	16	Review stakeholder intentions at next stage. Issue DH study report and hold workshop with relevant stakeholders and included feedback in next stage of work.	2	2	4

Ref.	Risk	Risk Category	Action Champion	Commentary	Risk			Suggested Risk Mitigation	Risk		
					Probability	Severity	Impact		Probability	Severity	Impact
				development.							

Appendix S - Mapping



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	Drawn R Collins	Checked C Kelleher	Approved C Karunaratne	
	Date 26/02/2018	Scale @ A3 1:5,000	Purpose of Issue DRAFT	
	Drawing Number AECOM - SUTTON - 01		Rev Rev 1	THIS DOCUMENT HAS BEEN PREPARED PURSUANT TO AND SUBJECT TO THE TERMS OF AECOM'S APPOINTMENT BY ITS CLIENT. AECOM ACCEPTS NO LIABILITY FOR ANY USE OF THIS DOCUMENT OTHER THAN BY ITS ORIGINAL CLIENT OR FOLLOWING AECOM'S EXPRESS AGREEMENT TO SUCH USE, AND ONLY FOR THE PURPOSES FOR WHICH IT WAS PREPARED AND PROVIDED.

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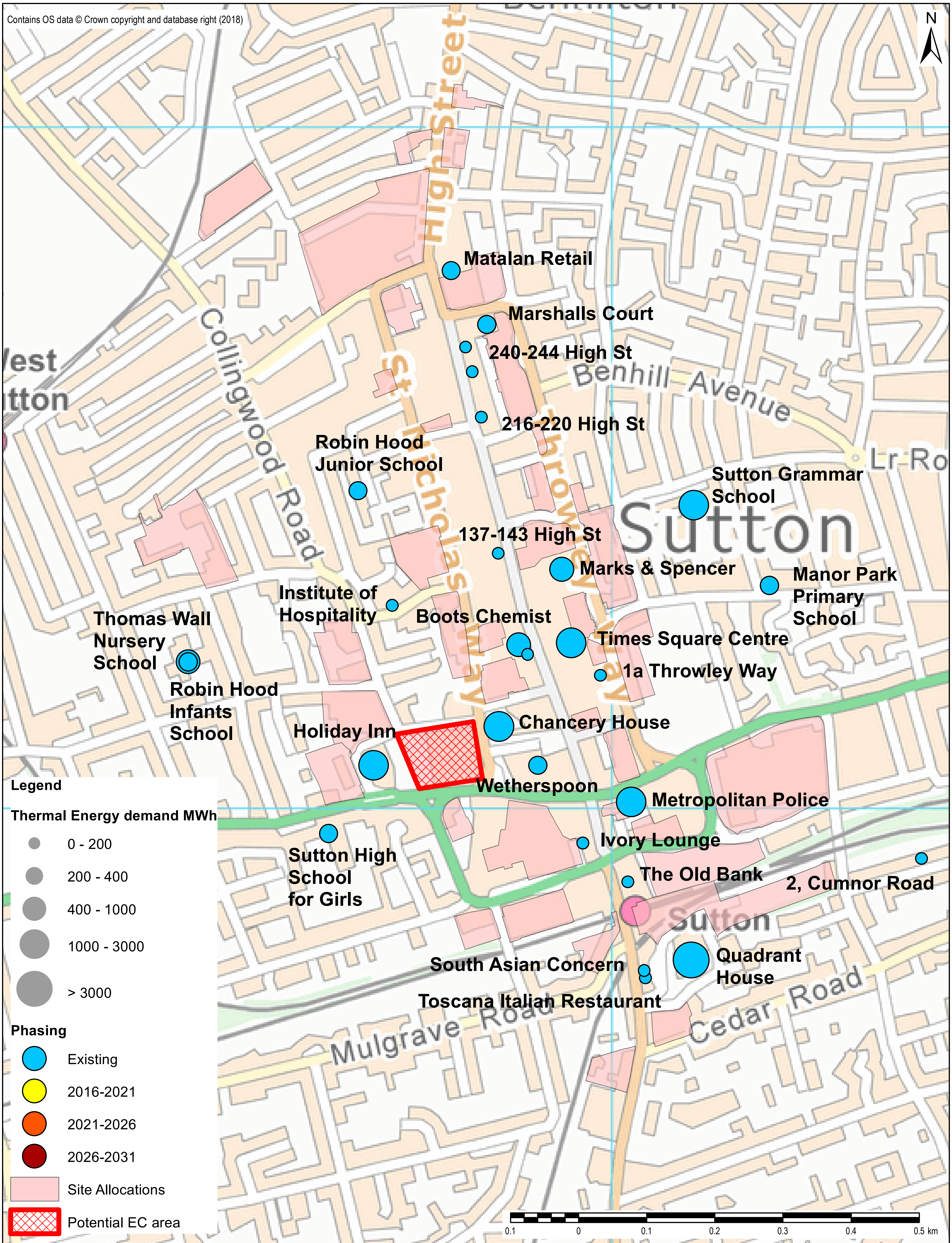

Project Title/Drawing Title	Client			
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	Drawn R Collins	Checked C Kelleher	Approved C Karunaratne	
	Date 26/02/2018	Scale @ A3 1:5,000	Purpose of Issue DRAFT	
	Drawing Number AECOM - SUTTON - 02		Rev Rev 1	THIS DOCUMENT HAS BEEN PREPARED PURSUANT TO AND SUBJECT TO THE TERMS OF AECOM'S APPOINTMENT BY ITS CLIENT. AECOM ACCEPTS NO LIABILITY FOR ANY USE OF THIS DOCUMENT OTHER THAN BY ITS ORIGINAL CLIENT OR FOLLOWING AECOM'S EXPRESS AGREEMENT TO SUCH USE, AND ONLY FOR THE PURPOSES FOR WHICH IT WAS PREPARED AND PROVIDED.

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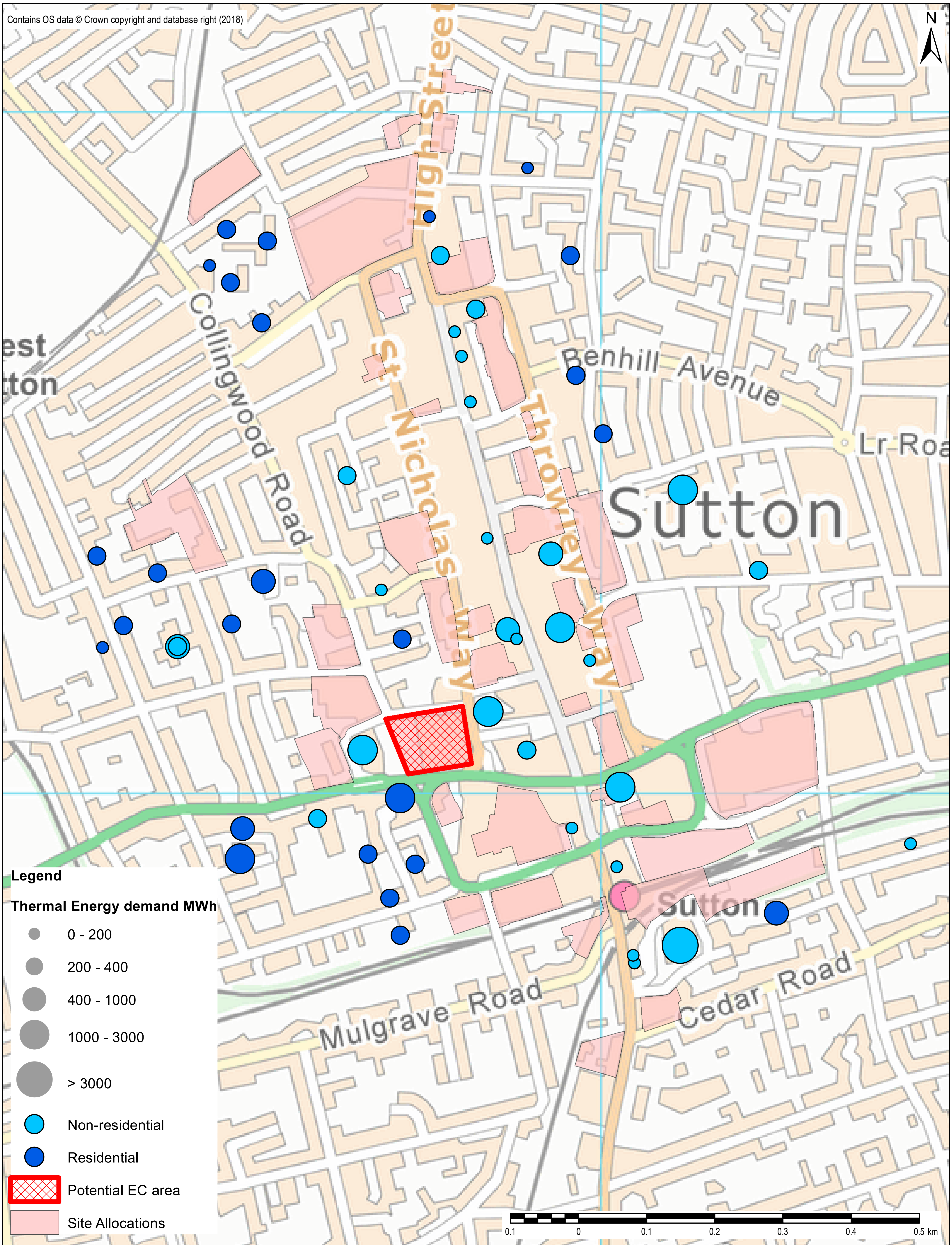

Project Title/Drawing Title	Client			AECOM
SUTTON HEAT MAPPING SUTTON TOWN CENTRE EXISTING DEMAND	LONDON BOROUGH OF SUTTON			
	Drawn R Collins	Checked C Kelleher	Approved C Karunaratne	Aldgate Tower 2 Leman Street London www.aecom.com
	Date 26/02/2018	Scale @ A3 1:5,000	Purpose of Issue DRAFT	
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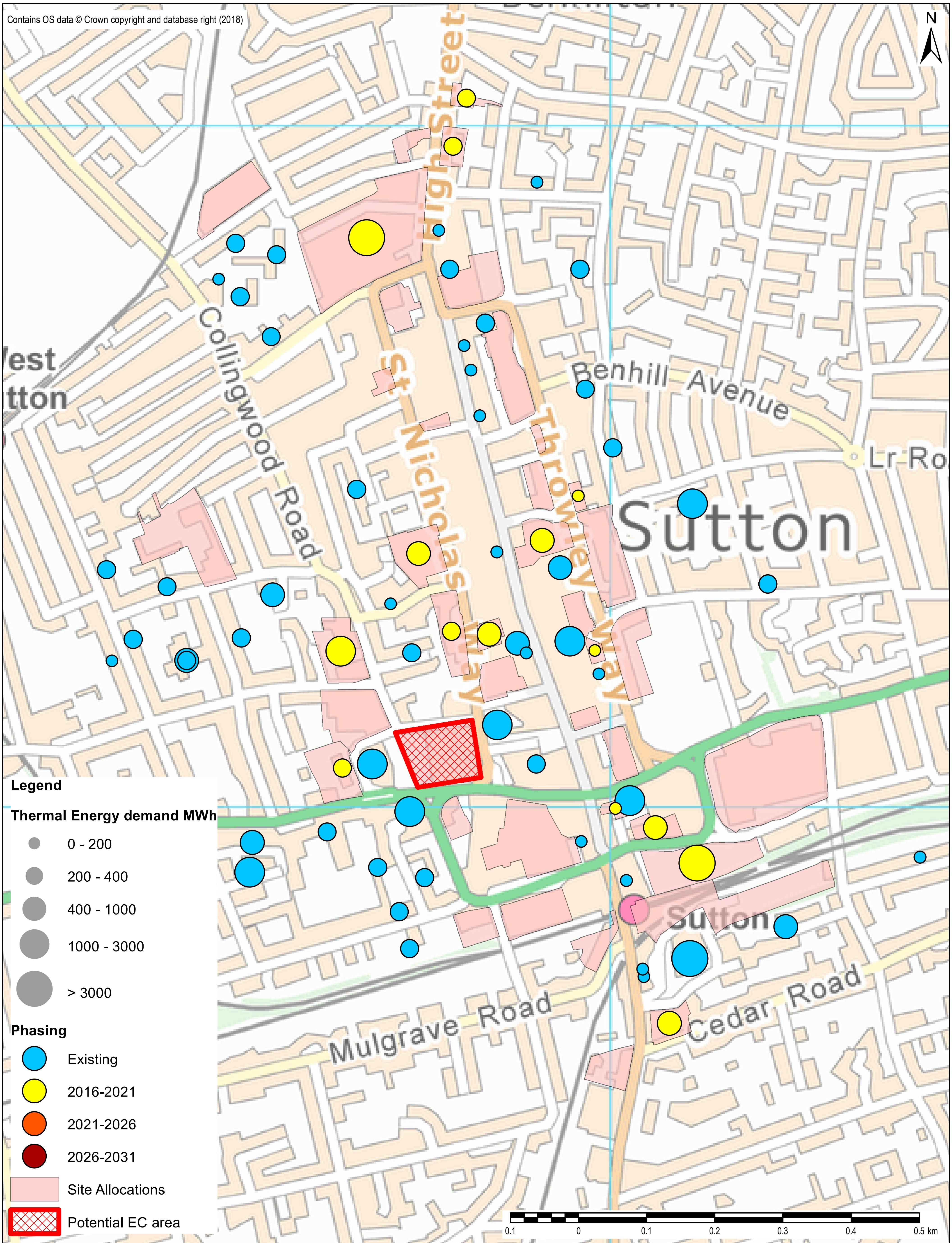

Project Title/Drawing Title	Client			AECOM
SUTTON HEAT MAPPING SUTTON TOWN CENTRE 2016 - 2021	LONDON BOROUGH OF SUTTON			
	Drawn R Collins	Checked C Kelleher	Approved C Karunaratne	Aldgate Tower 2 Leman Street London AECOM
	Date 26/02/2018	Scale @ A3 1:5,000	Purpose of Issue DRAFT	www.aecom.com
	Drawing Number AECOM - SUTTON - 04		Rev Rev 1	THIS DOCUMENT HAS BEEN PREPARED PURSUANT TO AND SUBJECT TO THE TERMS OF AECOM'S APPOINTMENT BY ITS CLIENT. AECOM ACCEPTS NO LIABILITY FOR ANY USE OF THIS DOCUMENT OTHER THAN BY ITS ORIGINAL CLIENT OR FOLLOWING AECOM'S EXPRESS AGREEMENT TO SUCH USE, AND ONLY FOR THE PURPOSES FOR WHICH IT WAS PREPARED AND PROVIDED.

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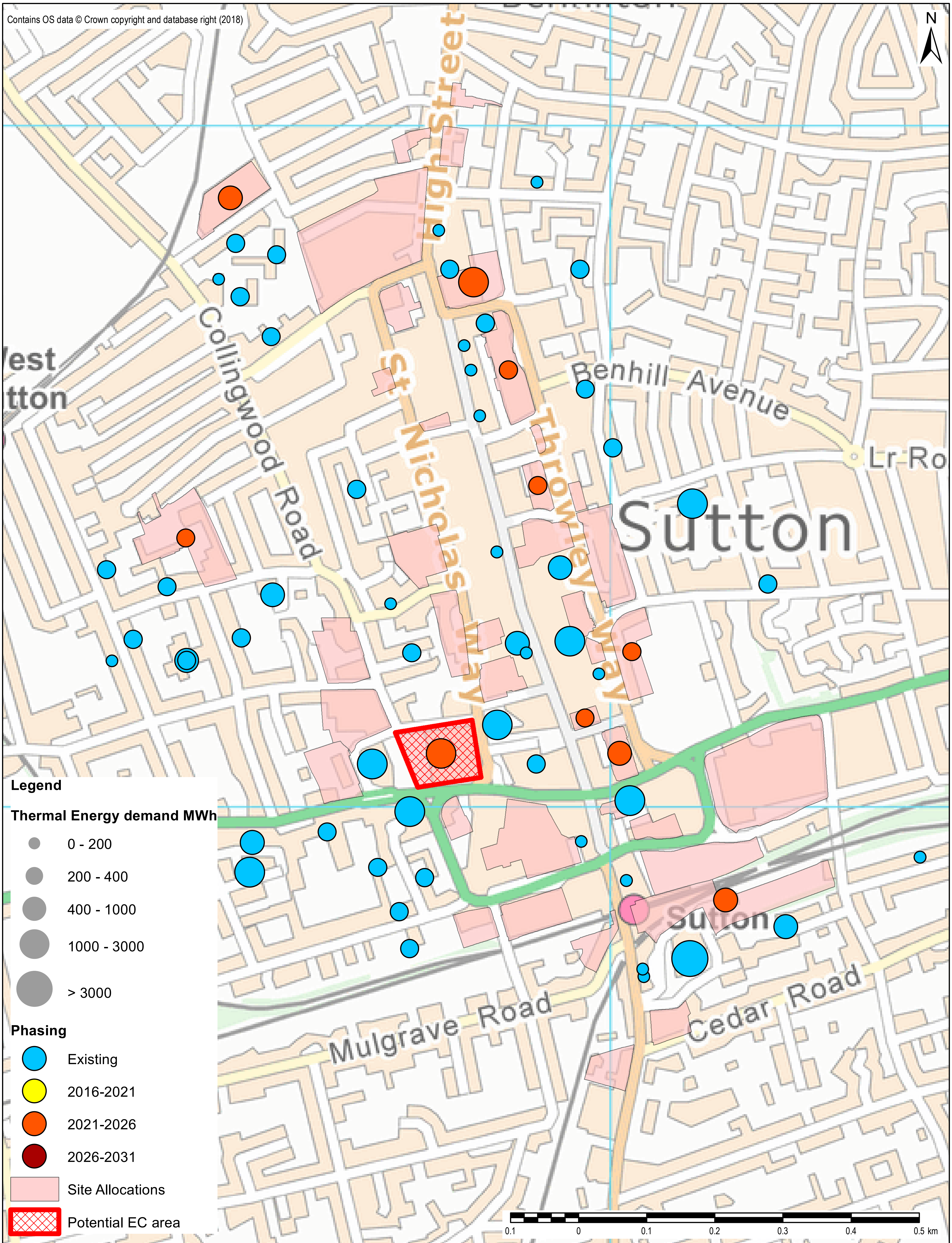

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SUTTON HEAT MAPPING SUTTON TOWN CENTRE 2021 - 2026	LONDON BOROUGH OF SUTTON			Aldgate Tower 2 Leman Street London www.aecom.com AECOM
	Drawn R Collins	Checked C Kelleher	Approved C Karunaratne	
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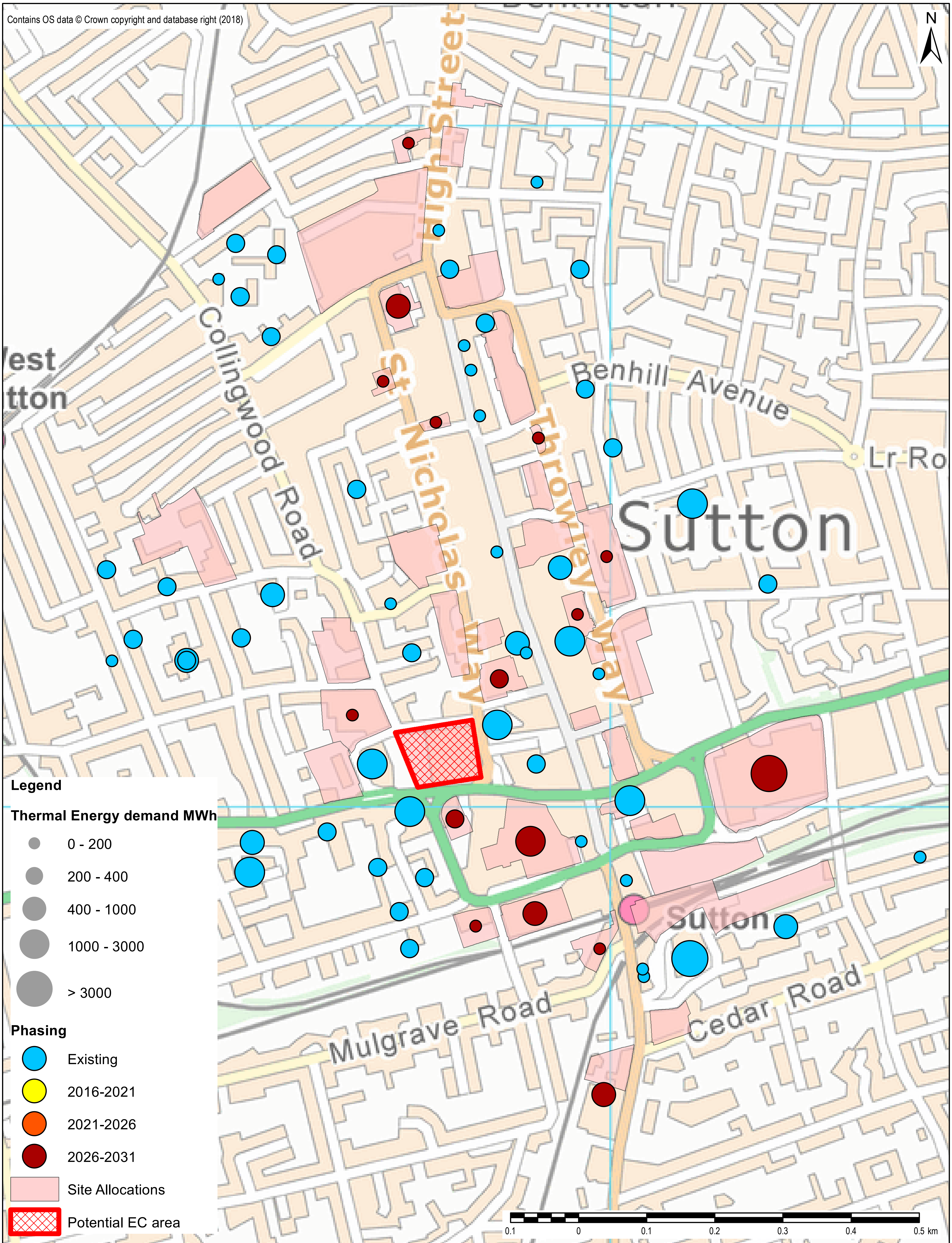

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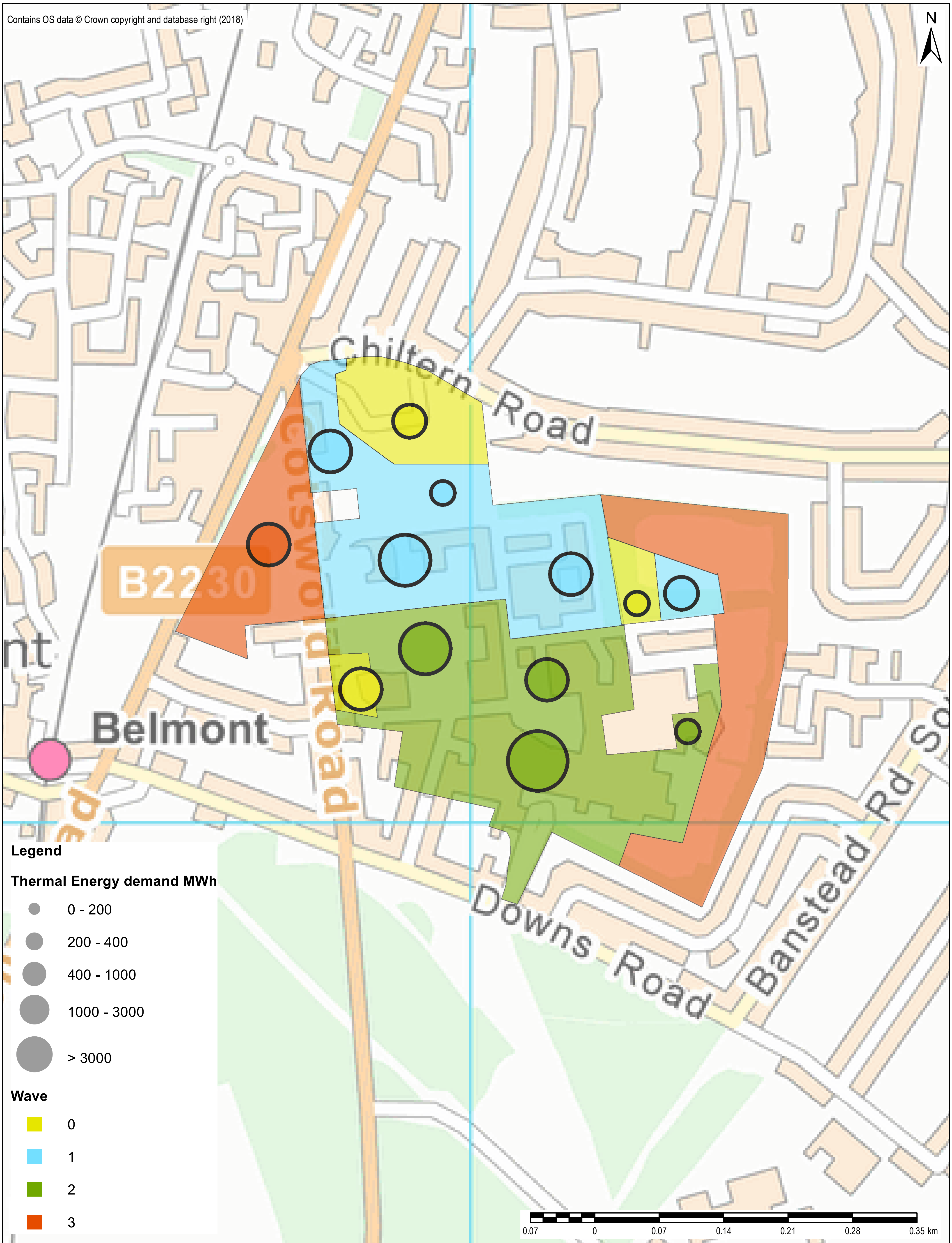
Project Title/Drawing Title SUTTON HEAT MAPPING SUTTON TOWN CENTRE 2026 - 2031	Client LONDON BOROUGH OF SUTTON			AECOM Aldgate Tower 2 Leman Street London www.aecom.com
	Drawn R Collins	Checked C Kelleher	Approved C Karunaratne	
	Date 26/02/2018	Scale @ A3 1:5,000	Purpose of Issue DRAFT	
	Drawing Number AECOM - SUTTON - 06		Rev Rev 1	THIS DOCUMENT HAS BEEN PREPARED PURSUANT TO AND SUBJECT TO THE TERMS OF AECOM'S APPOINTMENT BY ITS CLIENT. AECOM ACCEPTS NO LIABILITY FOR ANY USE OF THIS DOCUMENT OTHER THAN BY ITS ORIGINAL CLIENT OR FOLLOWING AECOM'S EXPRESS AGREEMENT TO SUCH USE, AND ONLY FOR THE PURPOSES FOR WHICH IT WAS PREPARED AND PROVIDED.



Project Title/Drawing Title	Client			AECOM
SUTTON HEAT MAPPING THE LONDON CANCER HUB	LONDON BOROUGH OF SUTTON			Aldgate Tower 2 Leman Street London www.aecom.com AECOM
	Drawn R Collins	Checked C Kelleher	Approved C Karunaratne	
	Date 26/02/2018	Scale @ A3 1:3,700	Purpose of Issue DRAFT	
	Drawing Number AECOM - SUTTON - 07		Rev Rev 1	

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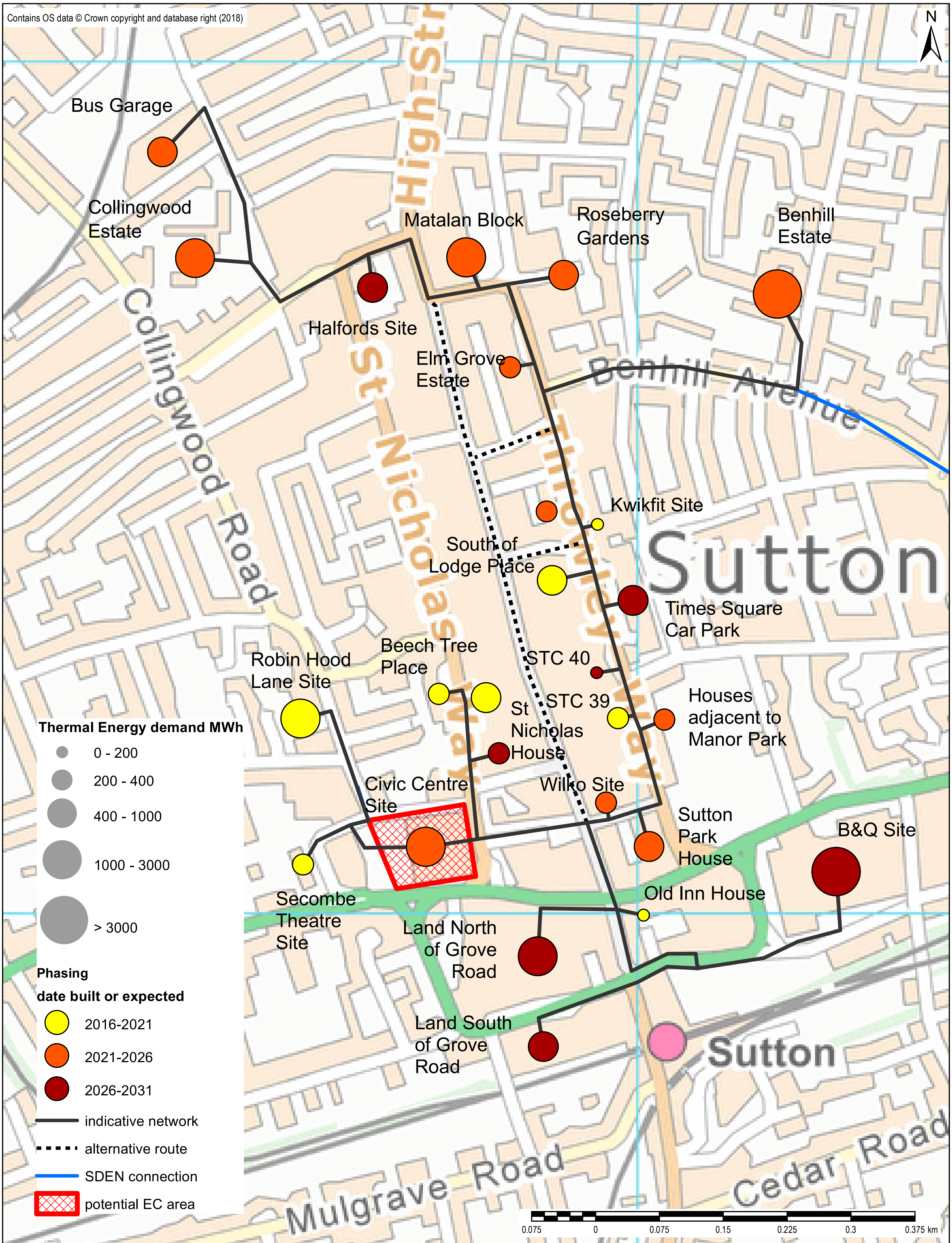

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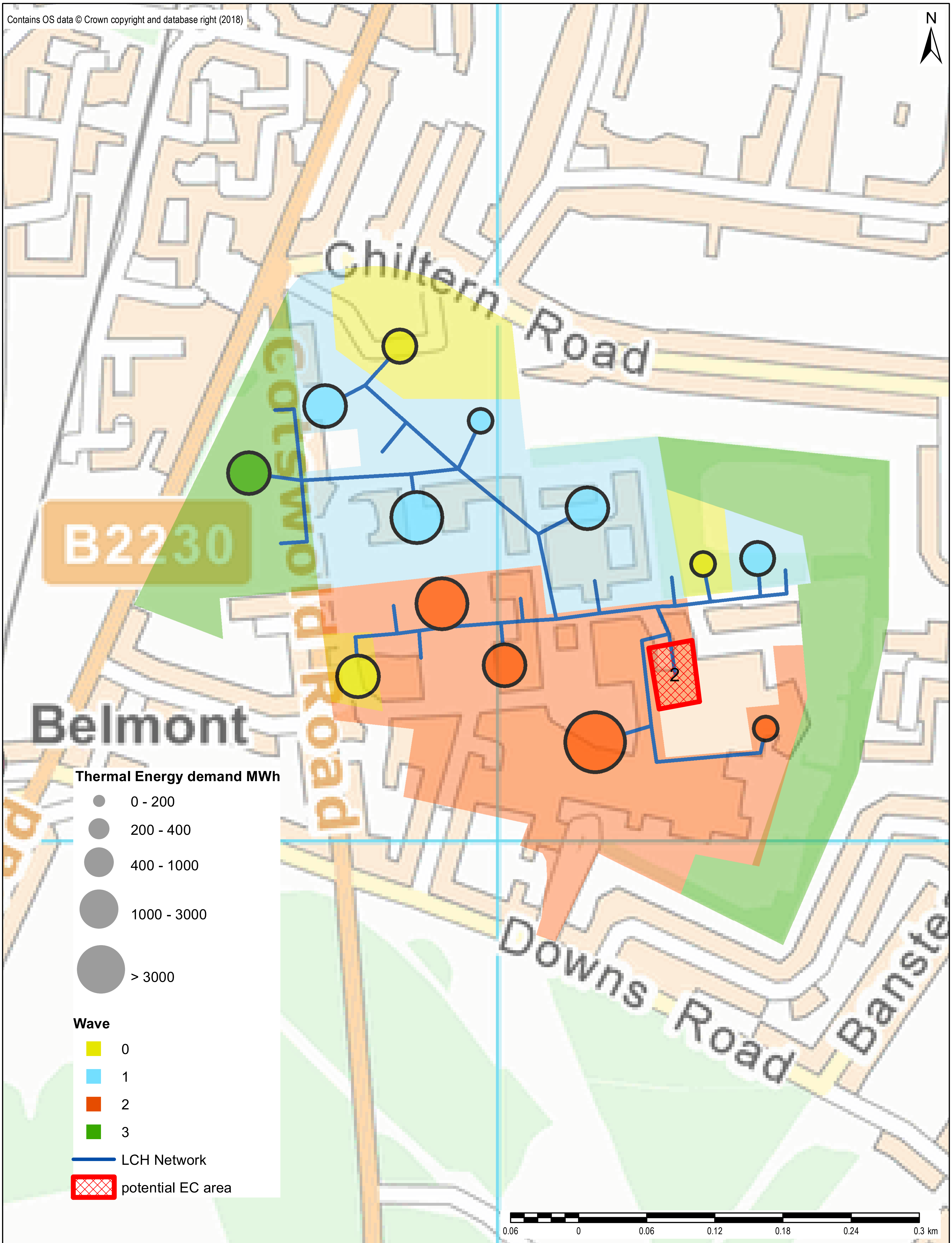
Project Title/Drawing Title	Client: LONDON BOROUGH OF SUTTON			AECOM
SUTTON HEAT MAPPING SUTTON TOWN CENTRE NETWORK	Drawn R Collins	Checked C Kelleher	Approved C Karunaratne	Aldgate Tower 2 Leman Street London www.aecom.com AECOM
	Date 11/07/2018	Scale @ A3 1:4,000	Purpose of Issue DRAFT	
	Drawing Number AECOM - SUTTON - 8		Rev Rev 1	THIS DOCUMENT HAS BEEN PREPARED PURSUANT TO AND SUBJECT TO THE TERMS OF AECOM'S APPOINTMENT BY ITS CLIENT. AECOM ACCEPTS NO LIABILITY FOR ANY USE OF THIS DOCUMENT OTHER THAN BY ITS ORIGINAL CLIENT OR FOLLOWING AECOM'S EXPRESS AGREEMENT TO SUCH USE, AND ONLY FOR THE PURPOSES FOR WHICH IT WAS PREPARED AND PROVIDED.



Project Title/Drawing Title	Client			AECOM
SUTTON HEAT MAPPING LONDON CANCER HUB NETWORK	LONDON BOROUGH OF SUTTON			
	Drawn R Collins	Checked C Kelleher	Approved C Karunaratne	Aldgate Tower 2 Leman Street London
	Date 11/07/2018	Scale @ A3 1:3,000	Purpose of Issue DRAFT	www.aecom.com
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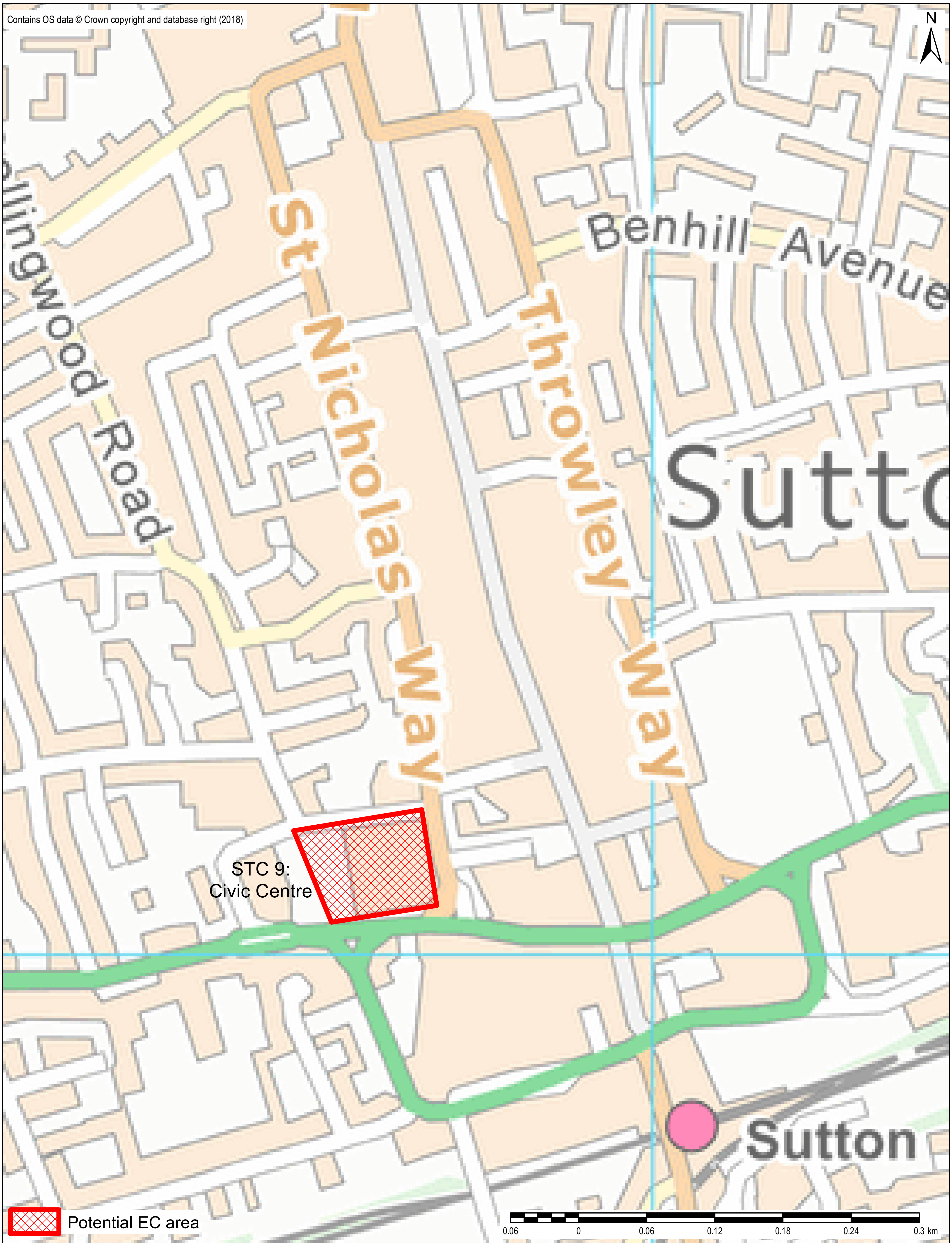

Project Title/Drawing Title	Client			AECOM
SUTTON HEAT MAPPING SUTTON TOWN CENTRE CIVIC CENTRE SITE	LONDON BOROUGH OF SUTTON			Aldgate Tower 2 Leman Street London www.aecom.com AECOM
	Drawn R Collins	Checked C Kelleher	Approved C Karunaratne	
	Date 04/05/2018	Scale @ A3 1:3,000	Purpose of Issue DRAFT	
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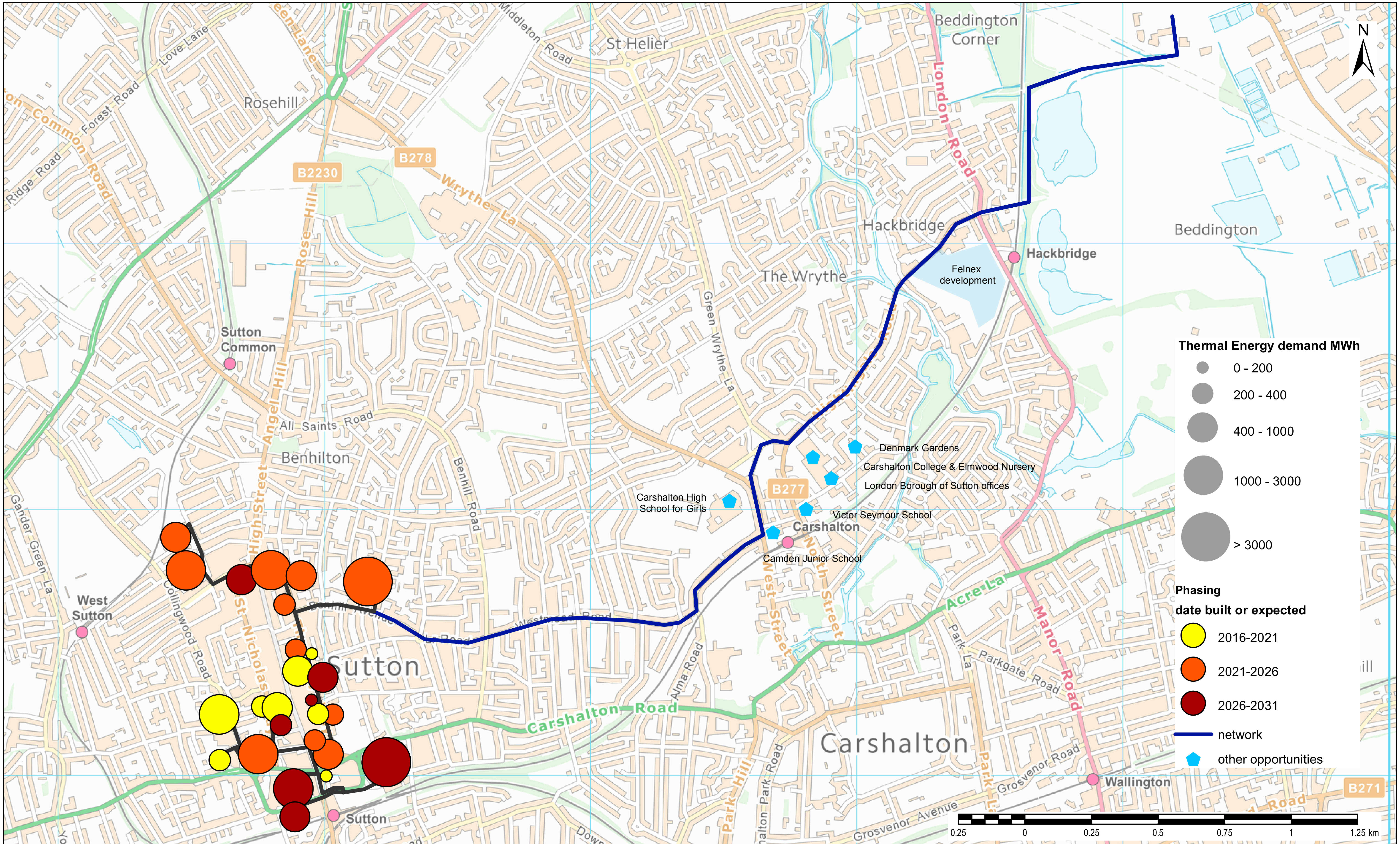

Project Title/Drawing Title	Client			AECOM
SUTTON HEAT MAPPING SUTTON TOWN CENTRE EFW NETWORK	LONDON BOROUGH OF SUTTON			Aldgate Tower 2 Leman Street London www.aecom.com
	Drawn R Collins	Checked C Kelleher	Approved C Karunaratne	
	Date 11/07/2018	Scale @ A3 1:13,000	Purpose of Issue DRAFT	
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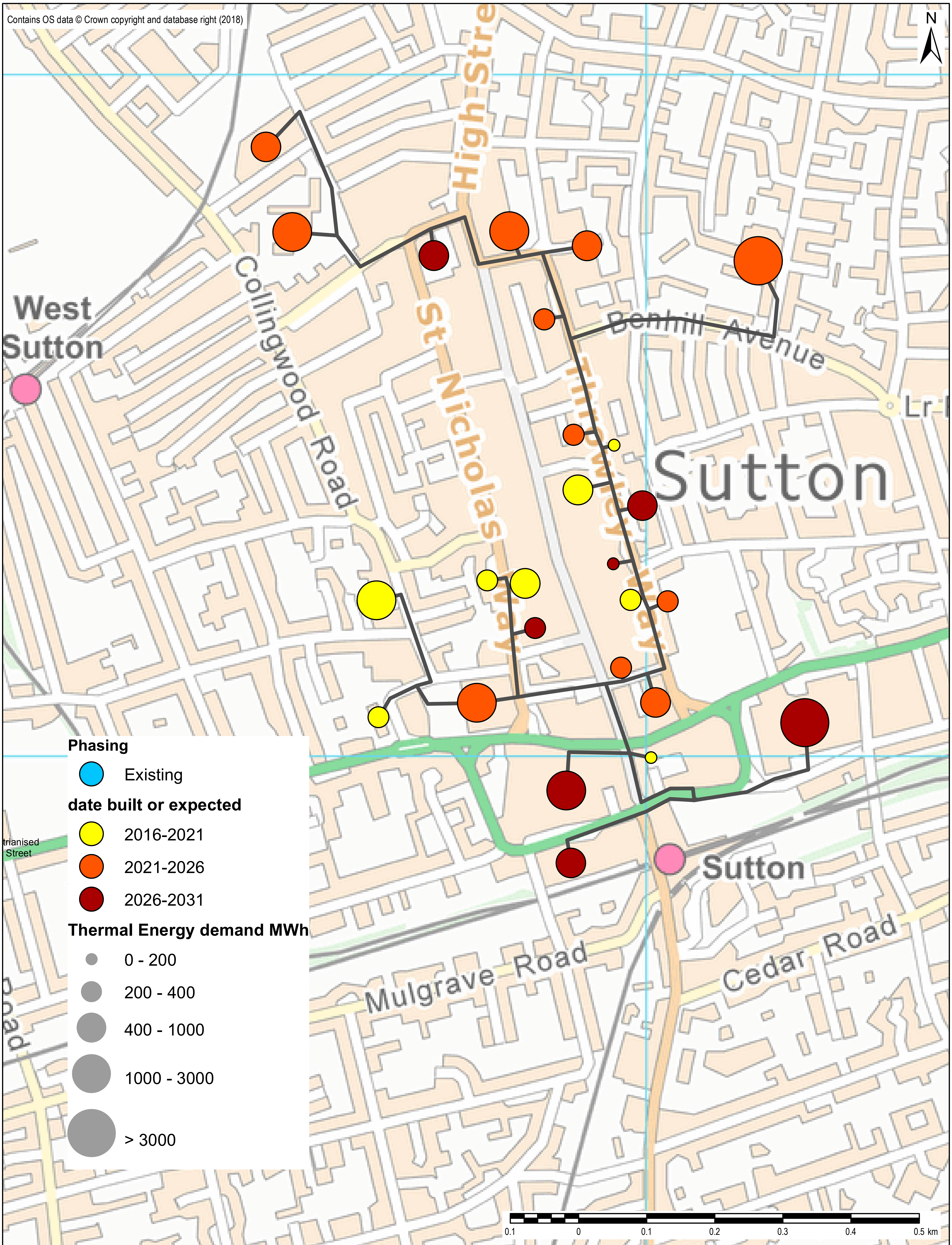

Project Title/Drawing Title	Client			AECOM
SUTTON HEAT MAPPING SUTTON TOWN CENTRE CHP NETWORK	LONDON BOROUGH OF SUTTON			Aldgate Tower 2 Leman Street London www.aecom.com
	Drawn R Collins	Checked C Kelleher	Approved C Karunaratne	AECOM
	Date 07/06/2018	Scale @ A3 1:5,000	Purpose of Issue DRAFT	
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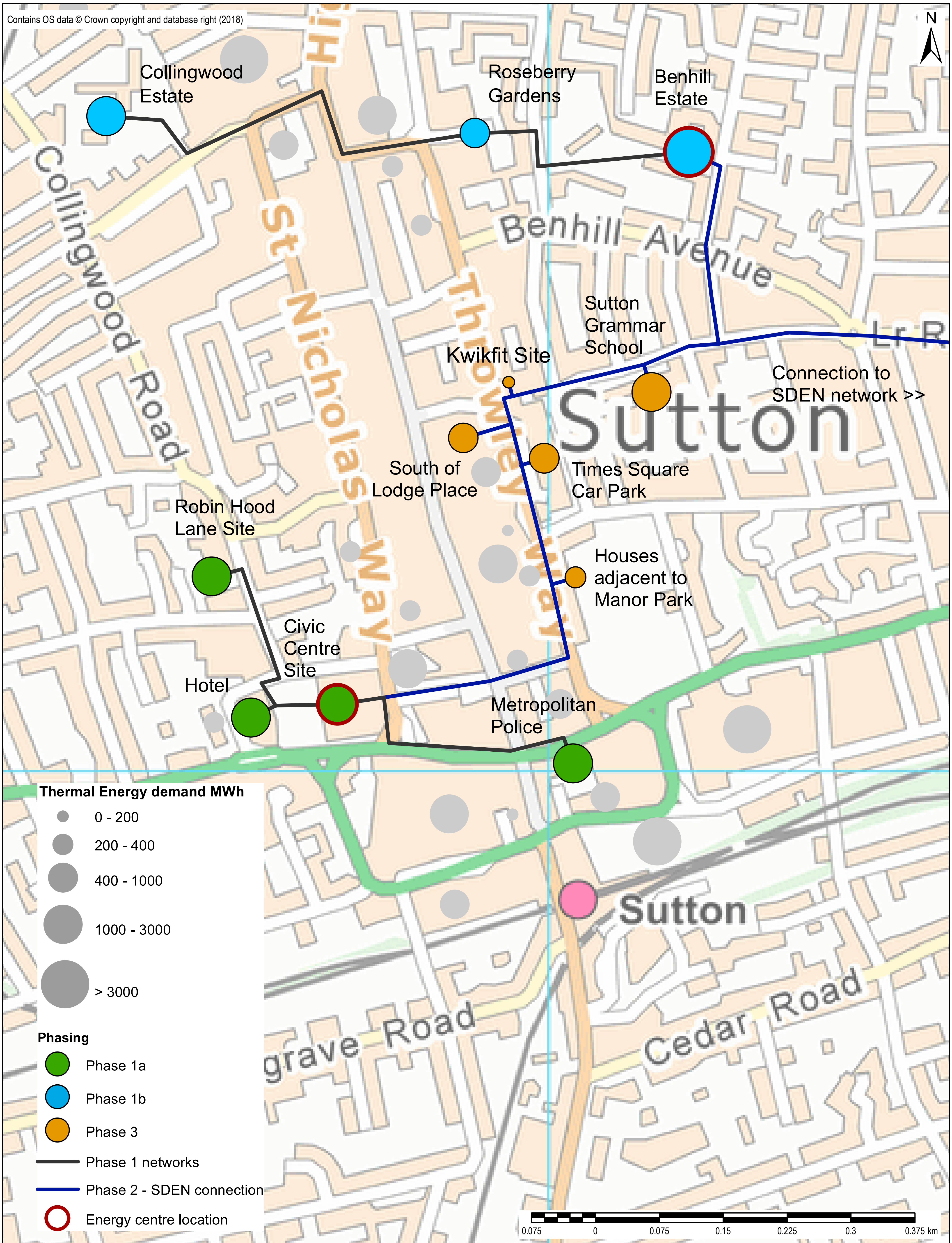

Project Title/Drawing Title	Client			AECOM
SUTTON HEAT MAPPING SUTTON TOWN CENTRE ROUTE MAP	LONDON BOROUGH OF SUTTON			Aldgate Tower 2 Leman Street London www.aecom.com AECOM
	Drawn R Collins	Checked C Kelleher	Approved C Karunaratne	
	Date 02/01/2019	Scale @ A3 1:4,000	Purpose of Issue DRAFT	
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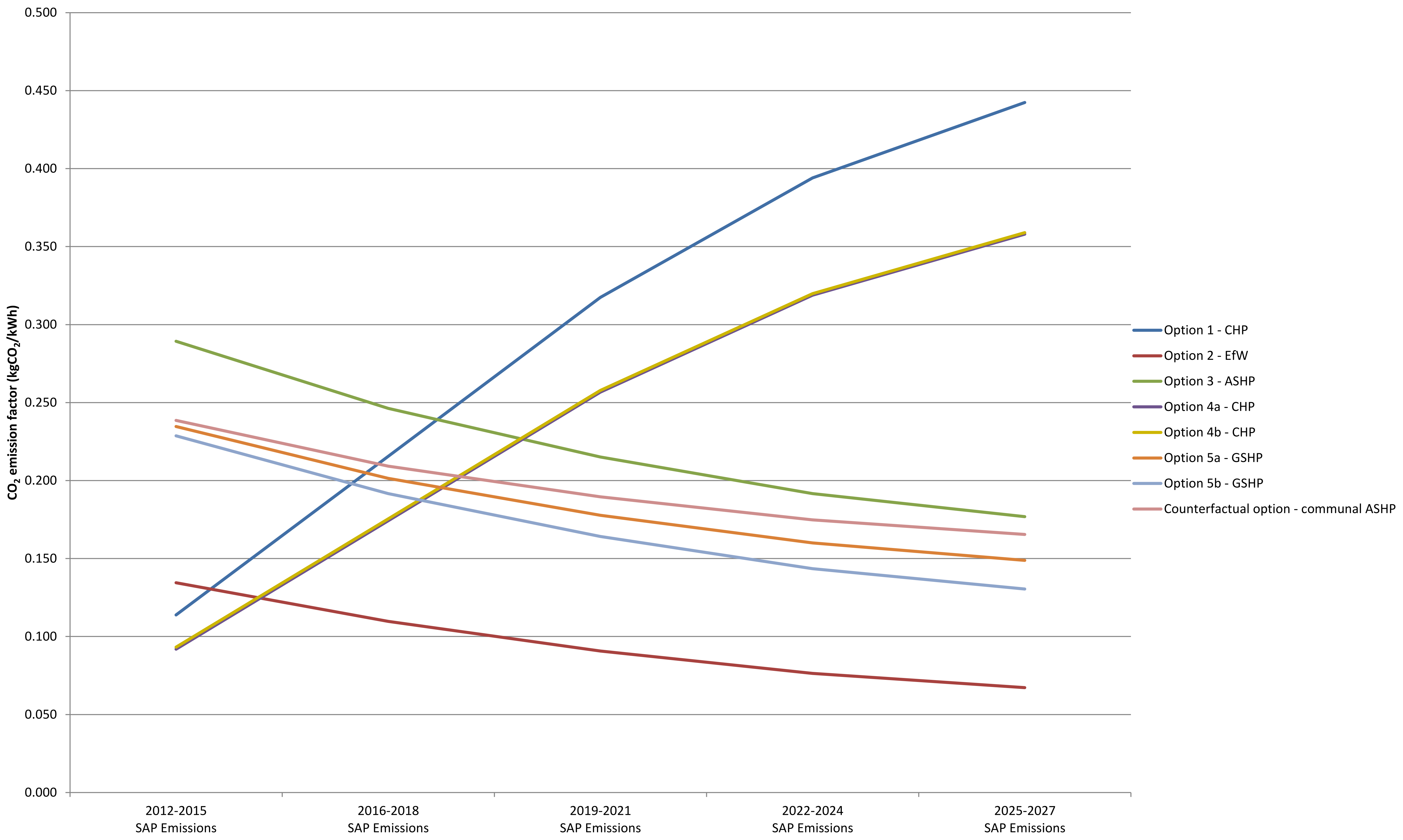
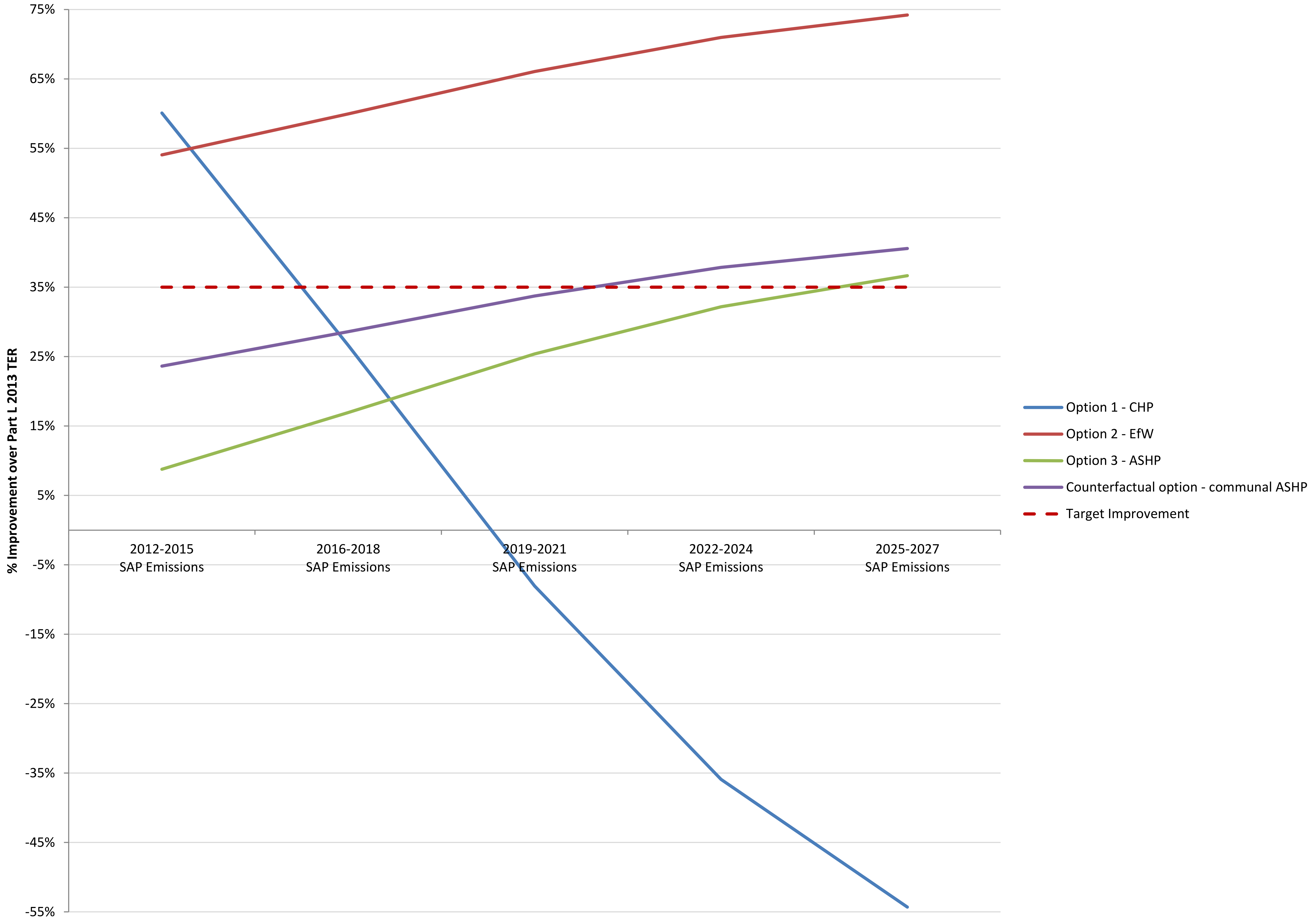
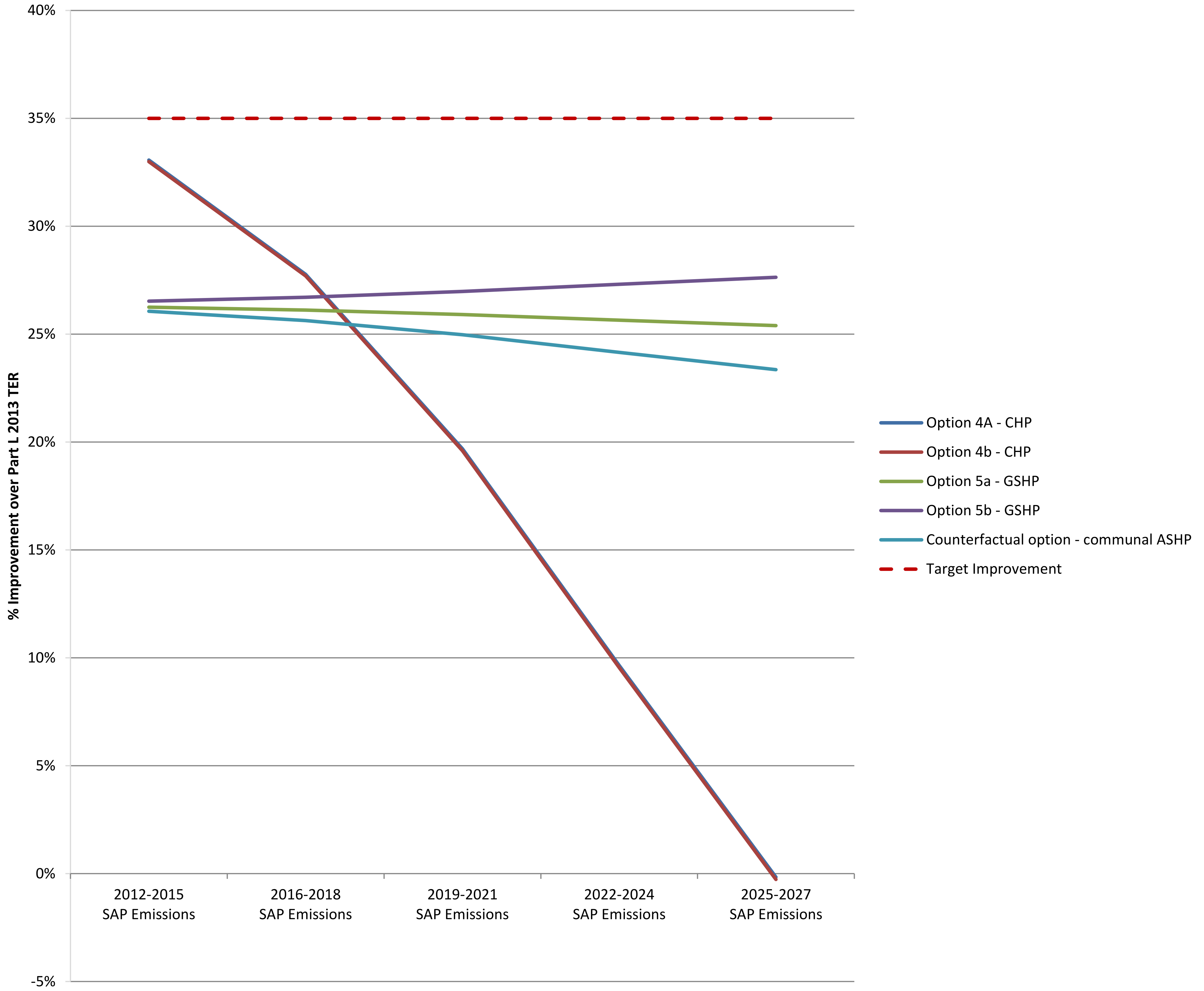
Appendix T - Planning review – carbon figures



Graph to show estimate carbon intensity of each network option (Figure 10-1). Note that the line for option 4a closely mirrors the line for option 4b.



Estimate of CO_2 emission improvements for STC (Figure 10-2)



Estimate of CO_2 emission improvements for LCH (Figure 10-3)

AECOM Limited
Aldgate Tower
2 Leman Street
London E1 8FA
United Kingdom
aecom.com