District Heating Feasibility

Phase 1: Heat Mapping and Energy Masterplanning

Prepared for:

London Borough of Merton

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Notation

Abbreviation	Meaning
CIBSE	Chartered Institute of Building Services Engineers
CO_2	Carbon Dioxide
CWSW	Colliers Wood and South Wimbledon
D	Diversity factor
DC	District Cooling
BEIS	Department of Business, Energy and Industrial Strategy (formerly DECC – see below)
DEC	Display Energy Certificate
DECC	Department of Energy and Climate Change
DHN	District Heating Network
DHW	Domestic Hot water
DNO	District Network Operator
DSM	Dynamic Simulation Modelling
EC	Energy Centre
EfW	Energy from Waste
EPC	Energy Performance Certificate
ERF	Energy Recovery Facility
ESCO	Energy Services Company
FEE	Fabric Energy Efficiency
GIA	Gross Internal Area
GLA	Greater London Authority
HNCoP	Heat networks Code of Practice
IRR	Internal Rate of Return
kWe	Kilowatt electric
kWth	Kilowatt thermal
LBM	London Borough of Merton
MTCML	Morden Town Centre and Morden Leisure Centre
NOx	Nitrogen Dioxide
NPV	Net Present Value
OPEX	Operation Expenditure
RHI	Renewable Heat Incentive
SAP	Standard Assessment Procedure
SCR	Selective Catalytic Reduction
SDEN	Sutton District Energy Network
TfL	Transport for London
TM	Technical Memorandum
UKPN	United Kingdom Power Networks
VOA	Valuation Office Agency

Executive Summary

This study investigates the feasibility of implementing district heating and cooling in the London Borough of Merton, with the aim of providing low cost energy and increased energy security to residents and businesses in the area, whilst also delivering carbon emissions savings and environmental benefits.

Initially, the heating, cooling and electrical requirements of commercial, industrial and residential buildings in the Borough were assessed and illustrated graphically on maps of the area. Key opportunity areas (Colliers Wood and South Wimbledon; Morden Town Centre and Leisure Centre) for district heating were then explored in more detail, with particular attention paid to:

- Existing buildings and future developments, and which of these would be eligible for connection to a district heating network (DHN);
- Suitable heat generation technologies;
- Existing or planned heat sources and supplies in the vicinity;
- Viable energy centre locations; and
- Key infrastructure in the area such as road, railways, rivers and utilities (i.e. gas and electricity).

Transport for London (TfL) confirmed that there are ventilation shafts for the London Underground located in South Wimbledon/Colliers Wood on the Northern Line. However, in the interests of security, TfL did not confirm their exact location. High level calculations showed a potential heat source capacity of around 850kW might be recoverable from such a shaft. A new ultra-low temperature network could serve the High Path Estate, a large new development (see red shaded area in Figure 0-1) which is close to the indicative shaft location range (which runs between South Wimbledon and Colliers Wood in line with the A238). Utilising an ultra-low temperature network would enhance the efficiency of the heat recovery system on the ventilation shaft, whilst also reducing the heat losses experienced on the network.

Also in close proximity to the High Path Estate is the River Wandle, with a suggested heating capacity of 3.6MW, according to the Department for Business Energy and Industrial Strategy's (BEIS) map of water source potential in the UK. With the use of a heat pump, this energy could also be fed into an ultra-low temperature network in the development. This quoted heat capacity is subject to further scrutiny, since a visual survey of the 'river' showed it to be of very low flow rate.

Additional heat sources in the Borough that were assessed include the Beddington Energy Recovery Facility (ERF) in the neighbouring borough of Sutton; a large electrical substation on Plough Lane (from which heat could be recovered); and planned Combined Heat and Power (CHP) installations in the area. These technologies were analysed quantitatively and were not currently found to be either technically viable or economically attractive for incorporation into a DHN in Merton.

Other heat generation technologies were appraised in terms of their financial, environmental, deliverability and technical performance to establish which would be the most applicable for use in Merton. It was found that gas CHP was currently the best performing technology but that this should be reassessed against the prevailing regulatory, market and carbon emissions conditions when the first generation plant reaches the end of its useful life.

A range of gas CHP fed district heating network scenarios were proposed and modelled for each of the two areas, in order to assess their technical, financial and environmental performance.

Colliers Wood and South Wimbledon (CWSW) area

Figure 0-1 and Table 0-1 show the network scenarios for the CWSW area, where each scenario is made up of different network sections as denoted in the figure. Council owned areas were assessed for their viability as locations for the network Energy Centre (EC). The most preferable location was within the High Path Estate development (see red shaded area in Figure), but further engagement with the developers is necessary to determine whether this would be acceptable. Network routing is indicative at this stage.

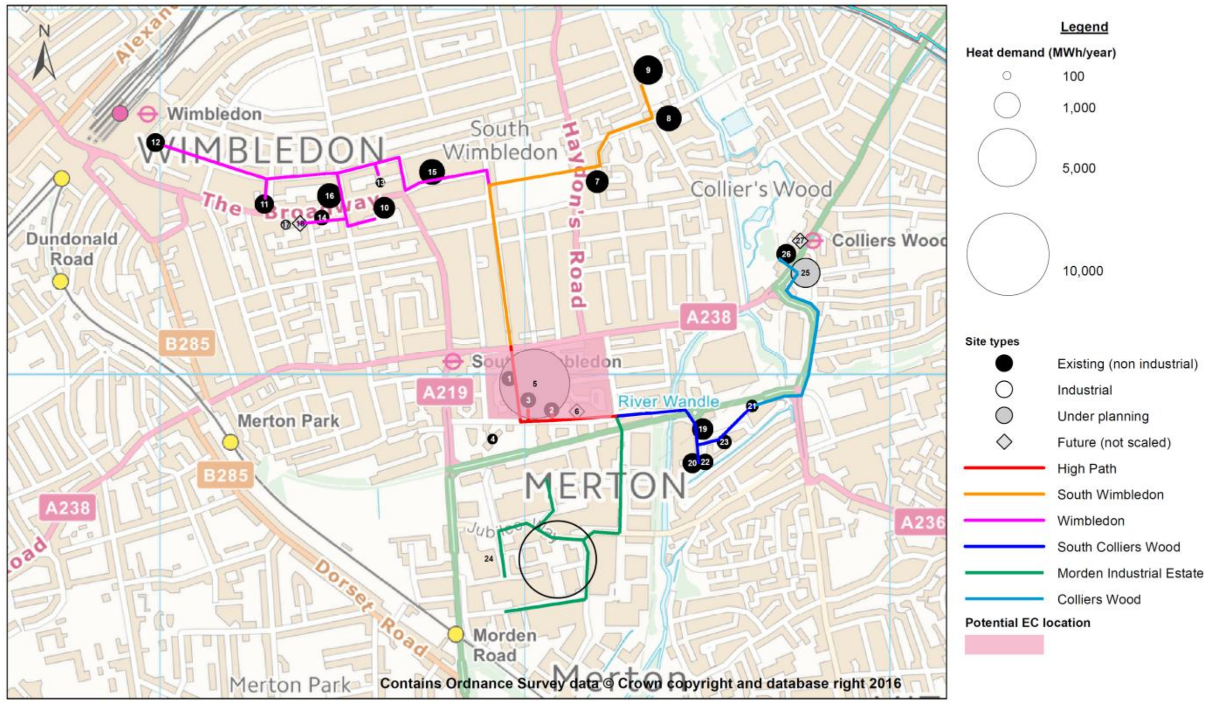

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Figure 0-1: CWSW Network Options (building numbers provided in Table 7-1)

Table 0-1: Summary of CWSW network scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
CWSW	Hyde Path and South Colliers Wood	Hyde Path, South Colliers Wood and Central Colliers Wood	Hyde Path, South Colliers Wood, South Wimbledon and Wimbledon	Hyde Path, South Colliers Wood, Central Colliers Wood, South Wimbledon and Wimbledon	Hyde Path, South Colliers Wood, Central Colliers Wood, South Wimbledon, Wimbledon and Morden Industrial Estate

A summary of the resultant technical and financial results for each network scenario in the CWSW area is provided in Table 0-2. Scenario 1 performs best financially, due to the heating loads being in close proximity to one another, hence reducing pipework requirements.

Table 0-2: Summary of CWSW network scenario results

CWSW key findings (40 year period)	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Total network thermal load (MWh_{th} p.a.)	11,300	13,600	18,900	21,200	31,800
Total EC Capacity (kWth)	2,700	3,500	7,300	8,100	22,400
New External Energy Centre size (m^2)	269	352	725	809	2,244
Total CAPEX (£'000s)	£4,320	£5,805	£9,312	£10,881	£21,365
IRR (%)	9.2%	8.0%	7.0%	6.5%	4.6%
NPV (£'000s)	£4,137	£4,330	£5,228	£5,235	£3,539
Av. annual CO_{2e} savings (tCO_{2e})	77	81	226	230	484
Average annual CO_{2e} reduction (% on counterfactual)	4.4%	3.7%	6.0%	5.5%	7.7%
Total customer savings	**8.9%**	**8.8%**	**13.3%**	**12.8%**	**18.4%**

The addition of the Morden Industrial estate in Scenario 5 has a negative impact on the network financial performance due to the large pipework requirements to serve the load. It is AECOM's view that the council pursues Scenario 1 in the CWSW area in the first instance, with a view to extending the network out towards Central Colliers Wood. Future phases of this study will seek to further assess the viability of an ultra-low temperature network specifically for the High Path Estate, using the River Wandle and London Underground vent shafts as low grade heat sources.

Morden Town Centre and Morden Leisure Centre (MTCML) area

Figure 0-2 and Table 0-3 show the network scenarios for the MTCML area. Morden Town Centre is undergoing significant refurbishment and includes a number of new developments such as the large Morden Station development and Abbotsbury Triangle development which are due to include hotels, residential, commercial and office buildings. Furthermore, road infrastructure improvements are being proposed in the area around Morden Station, which may help the installation of buried pipework.

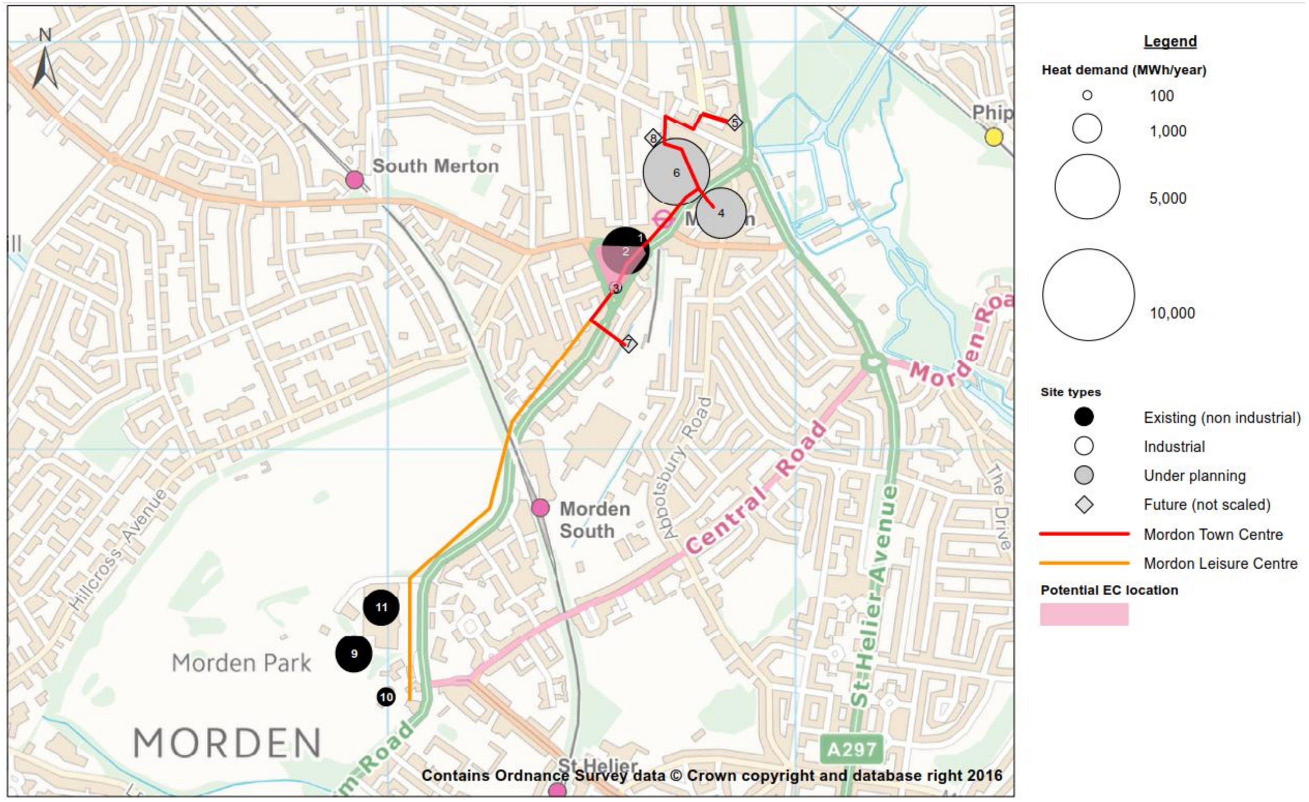

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Figure 0-2: MTCML Network Options (building numbers provided in Table 7-2)

It is proposed that the energy centre for the MTCML network would be located next to, or inside the Merton Civic Centre (see Figure 0-2). This is particularly advantageous to the development of a network in the area as the council already has access to the land and the existing building on site is tall, aiding flue arrangements and helping ensure air quality regulations can be met, assuming planning consent is granted.

Table 0-3: Summary of CWSW network scenarios

	Scenario 1	Scenario 2	Scenario 3
MTCML	Morden Town Centre	Morden Leisure Centre	Morden Town Centre and Morden Leisure Centre

Table 0-4 provides an overview of results for the three modelled network scenarios in the MTCML area. Scenario 1, which includes the civic centre and the new developments around Morden Station, performs best over the 40 year assessment period. It offers higher customer savings than the CWSW network scenarios, suggesting that financial performance could be improved by increasing parameters such as the price of heat, connection costs and standing charges, whilst still offering benefits to customers.

Table 0-4: Summary of CWSW network scenarios

MTCML network key findings (40 year period)	Scenario 1	Scenario 2	Scenario 3
Total network thermal load (MWh_{th} p.a.)	13,100	4,300	17,400
Total EC Capacity (kWth)	7,400	4,000	11,300
New External Energy Centre size (m^2)	739	395	1,135
Total CAPEX (£'000s)	£6,512	£4,682	£10,500
IRR (%)	5.71%	0.38%	4.35%
NPV (£'000s)	£2,462	-£2,034	£1,474
Av. annual CO_{2e} savings (tCO_{2e})	43	85	127
Average annual CO_{2e} reduction (% on counterfactual)	0.3%	1.8%	0.7%
Total customer savings	18.0%	30.3%	21.4%

AECOM recommends that the Council takes forward Scenario 1 of the MTCML options, with a view to extending the network to the south in the future. The difficulties and costs associated with laying pipework along the London Road dual carriageway and under the railway in order to serve the Morden Leisure Centre and nearby buildings should be further investigated if this area is to be included.

Key findings and next steps

Due to the predicted future decarbonisation of the UK's electricity grid, gas CHP is only expected to provide carbon emissions savings up to c.2032. CHP is therefore considered a viable low-carbon technology for use at inception, and provides the Council with a proven and reliable source of heat that is able to generate significant revenue streams over the course of its operating life and thereby provide a return on the original investment. However, CHP engines are generally expected to have an operating life of 80,000 – 100,000 hours; thereafter, a replacement primary heat source will need to be found.

Based on future carbon emission factors published by the Government, CHP is predicted to become less carbon efficient than the equivalent 'do-nothing' base case (e.g. gas boiler) by 2032. As such, the network operator must keep abreast of developments in terms of carbon emissions associated with grid electricity consumption, and periodically assess the low-carbon performance of different heat generation technologies, especially when the first generation CHP engines reach the end of their useful life after 12-15 years of operation.

The findings of the financial and technical modelling are particularly sensitive to the amount of generated electricity which is sold to private customers in the area, as opposed to exported back into the grid. Maximising private sales is paramount, as revenues generated from private sales are much higher than those generated through export to the electricity grid. This is because sales to 3rd parties can be negotiated on the basis that they will be comparing any agreed electrical unit price (£/kWh) against the price they currently pay on the retail market (typically between 8-13p/kWh. Sales direct to the grid can only be done at wholesale prices (typically 4p/kWh). Whilst unit rates to 3rd parties are typically offered at a discount of 5-20% below their existing unit rates, this is still significantly greater than the prices that can be achieved by selling directly to the grid.

Finding relevant and willing private wire customers is therefore an essential part of district heating network development, and a key element of the next stages of work. Initial conversations with TfL suggested that in general they are open to opportunities for purchasing electricity from CHP schemes. This will be a key point to engage with in future phases of this study.

The Phase 2 aspects of this study will seek to refine the findings of Phase 1, initially concentrating on stakeholder engagement and site surveys, before moving into design development and detailed financial modelling.

1. Introduction

AECOM has been commissioned by the London Borough of Merton (LBM) to investigate the potential for a decentralised energy network in the heat network opportunity areas of Colliers Wood and South Wimbledon (CWSW) and Morden Town Centre and Leisure Centre (MTCML). As part of this work, the Merton heat map will be updated across the borough, and network opportunities will be technically and commercially assessed with a view to identifying the most viable solution.

1.1 Background to Study

The London Borough of Merton (Figure 1-1) has a population of approximately 200,000. This makes it one of the smaller boroughs in London, in part due to the fact that 18% of Merton is open space. It is a key area for housing, employment, retail and community services and supports opportunities for further sustainable development and economic growth.

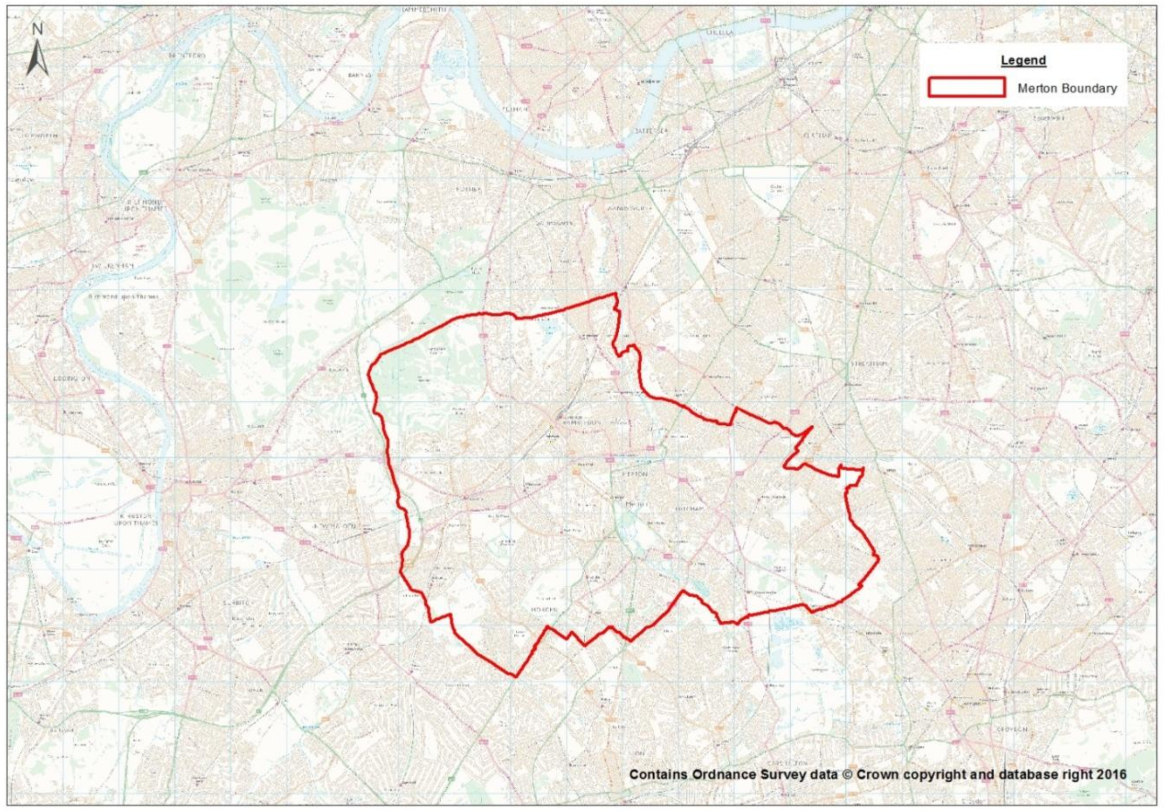

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Figure 1-1: Map of Merton

LBM has commissioned this study to investigate the feasibility of developing a decentralised energy network in and around Merton (the area shown by the red line in Figure 1-1) with the objective of delivering lower energy costs and increased energy security to residents and businesses in the area and wider environmental benefits through the use of low carbon technologies.

1.2 The Study

This report has been prepared for the LBM for the purposes of assessing the technical and commercial feasibility of a district energy network in Merton. The project has been split into three distinct phases as shown in Figure 1-2; the work described in this report makes up the first in this series.

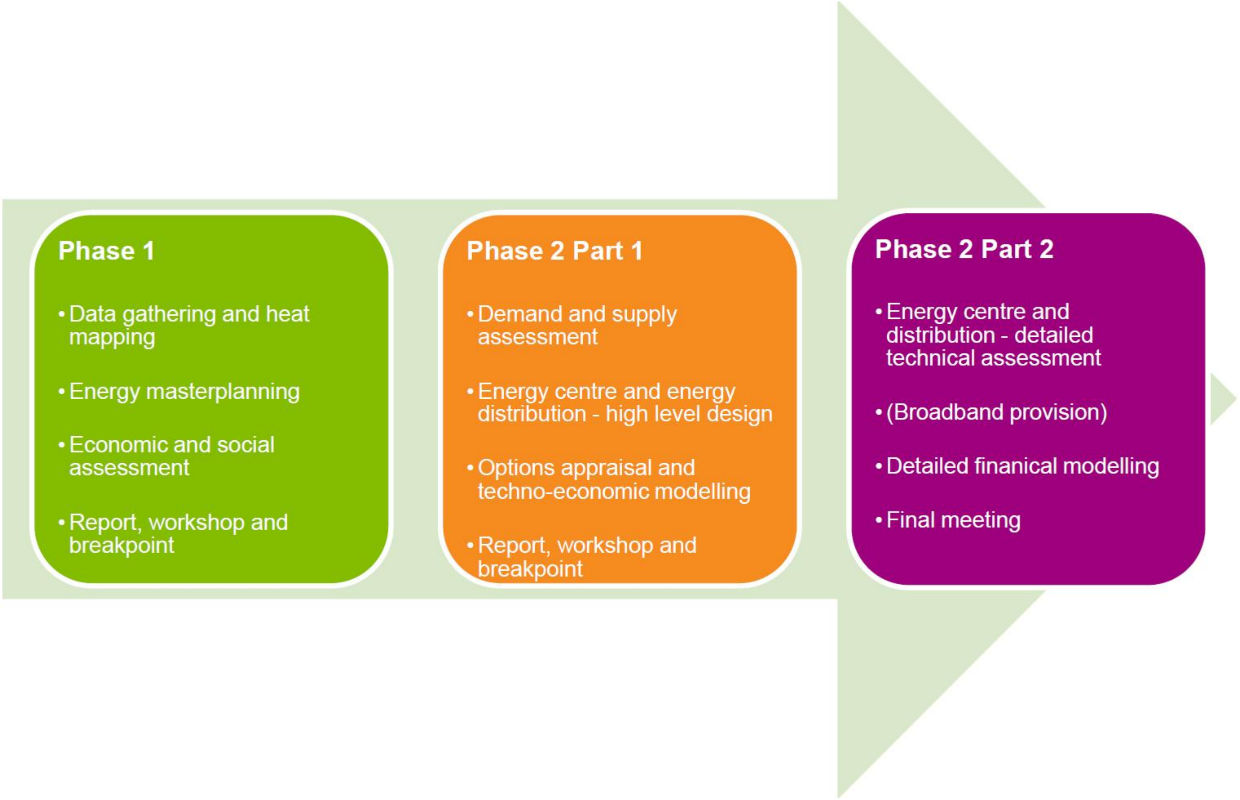


Figure 1-2: Scope of study

1.3 Phase 1 Methodology Summary

The following summarises the methodology developed to undertake Phase 1 of the study. Detailed methodology will be presented in the relevant sections of this report.

1. A high level review of potential low carbon technologies was carried out by assessing their suitability for use against deliverability, environmental, financial and technical criteria.
2. Research was undertaken to identify suitable developments (existing and future buildings) within Merton to connect to a potential decentralised energy network (DEN) in the area. Buildings were shortlisted based on criteria such as location, building use, and floor area. Such information was collected through an information request process and desktop study. It should be noted that site visits were not carried out at this stage.
3. An annual load analysis was undertaken to support the next stages of the project. This analysis used a number of sources to establish load quanta, including collecting energy consumption by fuel, based either on industry recognised benchmarks or record data provided by LBM. 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.
4. Using this annual load analysis, energy maps were produced, illustrating the size and location of the key heating, cooling and power loads within Merton.
5. Heat maps enabled the buildings and the associated areas deemed to be particularly suitable for an energy network to be identified, by considering a number of criteria (e.g. heat demand density, annual heat consumption, the presence of anchor loads, physical constraints, etc.).
6. Having established and prioritised suitable areas for district heating networks, load profiling and peak load analysis was undertaken to establish Energy Centre plant requirements.
7. Optioneering of potential network opportunities was carried out, taking into account the main barriers and load priorities, in addition to considering coordination with existing energy utilities.
8. 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.
9. 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.
10. Recommendations for the most technically and commercially viable network options were made.

2. Policy Context

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

2.1 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 for Communities and Local Government (DCLG)'s 'Building A Greener Future - Towards Zero Carbon Development', 2006 demonstrates the step change required in the Building Regulations to achieve zero carbon housing. District heating is recognised as a means to provide low or zero carbon energy to a development.

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.

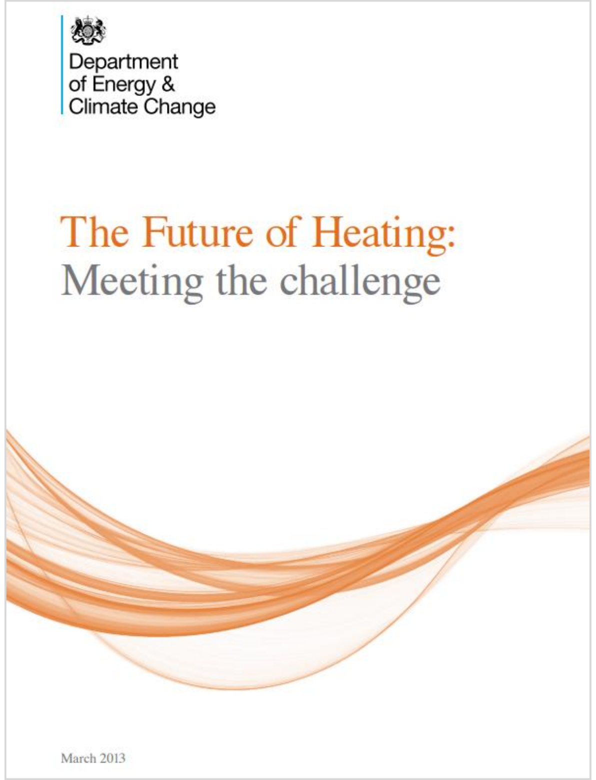
The Planning and Energy Act, 2008 enables local planning authorities to set requirements and targets for energy use and energy efficiency in local plans.

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 National Planning Policy Framework (NPPF), 2012 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.

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)[1] 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).



Department
of Energy &
Climate Change

The Future of Heating:
Meeting the challenge

March 2013

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[1] 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. At the time of writing, this legislation had not yet been enacted.

The Productivity Plan, Fixing the Foundations: Creating a More Prosperous Nation, 2015 indicates that the Government does not intend to proceed 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.

2.2 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:

2.2.1. Merton Local (Core) Strategy (2011)

Policy CS15 requires b) all minor or major developments, including major refurbishment, minimises CO_2 emissions following energy hierarchy; f) all non-domestic development over 500 m^2 to achieve BREEAM Very Good standard, and in line with the requirements of the London Plan or national policy, whichever is the greater. Furthermore, the council requires new non-residential developments over 1,000 m^2 to generate at least 10% of their energy demand from on-site renewable energy equipment.

2.2.2. Merton Climate Change Strategy & Action Plan 2014-2017

This strategy sets out Merton's climate change programme over the period of 2014 – 2017, providing a clear framework of action to tackle climate change.

2.3 Summary of Policy Considerations

At a national level, Government policies have set targets and pathways for the transition to a low-carbon heat supply. These include a legal commitment to reducing greenhouse gas emissions by 34% over the 1990s baseline by 2020, with 80% reductions targeted by 2050. District heating is expected to form an important part of the least cost technologies mix for achieving these goals, with gas-fired CHP dominating heat networks until approximately 2030.

Whilst there are no specific requirements to provide DH schemes, regional and local policies have been developed to support these goals; the Merton Core Strategy (2011) requires 10% of energy needs for new non-residential developments over 1,000 m^2 to come from on-site renewable technologies. Further policy requirements, such as the Climate Change Strategy & Action Plan 2014-2017, sets out action plans for carbon emissions reductions and the roll-out of low-carbon sources of energy. Compliance with these requirements supports the development of alternative energy supplies in the Merton area, including the development of DH networks, which will be discussed in the following section.

3. Stakeholder Engagement

Stakeholder engagement was undertaken to obtain information where available for the development of a District Heating scheme in Merton. The following hierarchy of communication was used:

1. Meetings (where applicable)
2. Phone calls
3. Emails

Merton Council is currently developing a future communication strategy to ensure successful and timely engagement with stakeholders during the next phase of this project. Proper engagement is essential to ensure stakeholders:

- are aware of the project the council is running
- understand the implications of having a district energy network in the area
- understand the benefits a district energy network can bring to the environment and to customers
- are made aware of construction and phasing implications in their area

Table 3-1 gives a summary of the engagement and outcome of various discussions held with stakeholders in Merton.

Table 3-1: Summary of stakeholder engagement

Stakeholder	Summary of engagement
Merton Council	Approach: Meetings, phone calls and email. Summary: As a key stakeholder, and also the client, the London Borough of Merton Council were engaged to provide: · Energy demand information · Details of future developments in the area · GIS files, land ownership and areas of specific interest/constraints · Results of previous heat mapping studies · Any other useful details Next steps: LB Merton will continue to be engaged in this project, playing a key enabling role in the implementation of a DEN in Merton.
Department for Business, Energy and Industrial Strategy (BEIS)	Approach: Meetings, phone calls and email. Summary: This is a HNDU funded project, and as such engagement with BEIS and in particular the HNDU, is vital to ensure that the work is being carried out effectively and with the most up-to-date policy and BEIS guidance. Next Steps: Engagement with BEIS will continue throughout the project
Morden Industrial Estate	Approach: Email via South Wimbledon Business Area Ltd (SWBA) Summary: Contact details sought for key contacts in the estate A questionnaire was drafted for occupants of the estate to ask them about their potential for involvement in a district energy scheme. Questionnaire and covering letter drafted by AECOM for issue by SWBA Ltd when LB Merton has formalised the communications strategy. Next Steps: Due to its location, the Morden industrial estate is considered a key opportunity in Merton – future engagement with the residents of this estate is therefore vital, including a site survey to check viability of connection to a wet district heating network. Further information on the heating systems used in the estate is necessary. The Morden Industrial Estate will be a key target of the Merton Council engagement plan.
Circle, Mace Group, PRP Architects development group	Approach: Meeting (26 May 2016), phone calls and email. Summary: The development team listed here are involved with three key developments in the London Borough of Merton: · High Path Estate · Eastfields Estate · Ravensbury Estate The High Path Estate is a key opportunity anchor load in the CWSW area, with

Stakeholder	Summary of engagement
	construction due to start on site in early 2017. Early discussions suggest that this may be a potential location for an Energy Centre Next Steps: Due to apparent willingness to host the energy centre on site and the relative size of the high path estate to others around it, this stakeholder may be key for the development of a network in the CWSW area.
Couchperrywilkes: Brown and Root tower development	Approach: Phone calls and email. Summary: This new development, situated adjacent to the existing Brown and Root Tower in Colliers Wood, presents a significant opportunity for connection to a DEN. Initial engagement suggests the building would be eligible for connection and that the developers would be keen to pursue such an opportunity. Next Steps: If this particular development is included in any recommended DEN as a result of this study, further engagement is required throughout the design process.
TfL	Approach: Phone calls and email. Summary: Engagement to date has been regarding heat recovery and private wire electricity sales. Vent shafts located in the South Wimbledon/Colliers Wood area, exact location unknown. Next Steps: AECOM will seek to arrange a meeting to discuss both topics with TfL representatives during Phase 2 of the study.
Crossrail 2	Approach: Meeting (1 July 2016), phone calls and email Summary: The Crossrail 2 project will see a number of significant new developments being built in Wimbledon. Construction is due to take place over 8 years; developments may serve to promote future expansion of a proposed network in Wimbledon. A new train depot is proposed to be installed which may represent an opportunity for private wire electricity sales. Next Steps: Although there is limited information currently on the usage of new developments and construction phasing is only indicative, the developments built as part of the Crossrail 2 project should be considered for future network expansion.
UKPN	Approach: Emails Summary: UKPN operate the substations and electrical distribution infrastructure in Merton. A G59 application form will need to be submitted at a future date if it is a project outcome that electricity is to be exported back to the grid. Communication with the company had the prime objective of investigating whether there were substations in the area that would be eligible for heat recovery. No constructive discussions were held with anyone from the company. Next Steps: If it is found that heat recovery from substations is a viable technical solution for integration with a DEN in Merton, further engagement and communications strategy work is required to find the correct contact at UKPN.
Sutton District Energy Network (SDEN)	Approach: Emails Summary: Information was sought on the network and routing to interrogate the possibility of extension into Merton. Next Steps: Operators were receptive to the suggestion but further work is required to investigate the technical and commercial viability of such a solution.
SITA	Approach: Emails Summary: Plans have been made for an anaerobic digestion facility in Merton. The operating company SITA were engaged to investigate whether there was any waste heat available on site. Next Steps: AECOM understands that this facility will not currently be built.

4. 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, also producing 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 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.

4.1 District Heating

District heating 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 secondary side distribution systems are necessary; the existing boiler could be removed or decommissioned and replaced with a heat interface unit (HIU) which transfers heat from the DH network to the local building distribution system. Compatible temperatures and operating regimes however do need to be established.

The following heat generation technologies have been assessed herein, further detailed in Appendix A:

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

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 7.

4.2 District Cooling

District cooling (DC) is distributed in the form of chilled water through a network of insulated pipes to different buildings to supply demand for cooling. Chilled water (typically 6°C flow/12°C return) is used in central cooling units such as air handling units, or in local units such as fan coil units or chilled beams. Chilled water can be generated in different ways: through conventional electrically-driven vapour compression chillers; or via absorption (i.e. heat-driven) chillers. Both of these could be utilised in providing DC services. These technologies are further detailed in Appendix A.

5. Energy Mapping

5.1 Identification of Buildings

Initially, a high level analysis was undertaken to determine the key existing and future buildings in LBM 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 assumptions made have been briefly described in the sections to follow.

5.1.1. Existing Developments

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

- A list of existing buildings provided by London Borough of Merton (LBM) based on the Local Land and Property Gazetteer (LLPG), an address database including all buildings in the borough.
- SystemLink, an online portal which includes metered and fiscal energy data for a number of properties, was used to identify buildings with annual gas consumption over 100 MWh.
- The Employment Land Survey 2014 list, which offers a description of current employers and the building premises of current large industrial sites.
- The London Heat Map, an interactive tool providing information on major energy consumers, energy supply plants and heat density.

A list of sites was compiled including all developments identified from the above sources. The list was narrowed down to only include buildings with a thermal demand higher than 100MWh, since AECOM experience shows that only larger developments are eligible for connection to DE networks. These buildings typically fall in the following categories:

- Large residential schemes
- Offices
- Hospitals
- Hotels
- Schools and universities
- Industrial sites
- Community centre
- Leisure centre/Health clubs
- Libraries
- Museums

Industrial buildings have been grouped into 15 strategic/significant industrial sites, based on the Employment Land Survey 2014. Where applicable, additional information (such as gross internal area (GIA), land use and land area) was gathered from numerous other sources, such as published Display Energy Certificates (DEC), Energy Performance Certificates (EPC), Google Maps and the Valuation Office Agency (VOA).

5.1.2. Developments in Planning

A thorough investigation was carried out in order to identify developments currently in planning offering over 100MWh of heat consumption annually. Three separate lists from Merton Council were provided, (Development Sites, Housing estates and Housing pipeline over 100 units).

Additional research was carried out on the developments contained in these lists, focussing on the Merton Council planning application online portal as well as the Greater London Authority's (GLA) referable applications (for large scale schemes). Major developments currently at the pre-planning or planning application stage and approved proposals were all studied and considered for inclusion.

5.1.3. Future Opportunities

Future development opportunities were investigated using the three lists provided from Merton Council (see above). In addition, the Merton Council local policy documents were used to identify the strategic development opportunity areas. The “Potential Sites for new uses within Merton” and “Sites and Policies DPD – Future Sites” documents were reviewed in order to collect information on the sites' areas and the Council's preferred future use.

Where no information on building use and GIA existed, developments are only mapped to show their location, as appropriate assumptions on scale, usage type and timescales cannot be realistically made.

5.2 Energy Data Analysis

Heating, cooling and electrical energy loads were estimated using the following source hierarchy:

- Actual metered energy data for existing sites (half hourly, monthly, annually);
- Fiscal data for existing sites (monthly, quarterly, annually);
- Display Energy Certificates (DEC) (annual data);
- Benchmarks:
  - CIBSE TM46 'Energy Benchmarking' (October 2008);
  - CIBSE Guide F 'Energy Efficiency in Buildings' (Third Edition, May 2012); 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; an overview of the source data used for buildings identified is provided in Section 0.

5.2.1. Existing Developments

For a number of the existing buildings, gas and electricity consumption data is available through the SystemLink which includes actual metered and fiscal data. However, for existing buildings where such data is not available, published data was used. CIBSE TM46 benchmarking was used in all other cases.

CIBSE Guide TM46[2] 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 to significantly overestimate energy consumption in new buildings, they still form the most extensively accepted benchmarks in the industry.

Cooling consumption was estimated from CIBSE Guide F[3] benchmarks, a widely recognised industry standard providing information on how to improve energy efficiency in buildings. Following the review of a wide range of industry standards including Energy Consumption Guides, CIBSE TM22[4] and BSRIA Rules of Thumb[5], it was found that cooling benchmarks only exist for Offices and Retail building types.

Cooling consumption estimations for other building types require detailed end-use energy consumption analysis, beyond the scope of this study. As such, cooling demand has only been shown for Offices and Retail building types.

5.2.2. Developments in Planning / Future Developments

For new developments in Planning, it is expected that the use of CIBSE Guide TM46 is unlikely to be representative of the energy requirements, due to the significant improvements to energy efficiency in buildings made in 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) 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.

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

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

5.3 Energy mapping

The energy consumption analysis described above is used to produce maps illustrating the annual heat demand, cooling demand and total electricity demand for the most appropriate buildings in Merton (Figure 5-1, Figure 5-2 and Figure 5-3). These maps form the backbone to the energy masterplanning phase of the study.

In all cases, buildings are represented by coloured circles, where the colour represents the building usage, and the size of the circle is scaled to the amount of energy consumed by the building. Future developments for which no energy consumption data was known or derived (due to a lack of information about the development) are shown with diamonds but are not scaled.

Note that the scale of the heat and electricity consumption circles are the same, whilst the cooling consumption circles are shown with a different scale, such that the smaller scale cooling loads are visible. The heating and cooling maps show buildings with thermal energy consumption of greater than 100MWh only.

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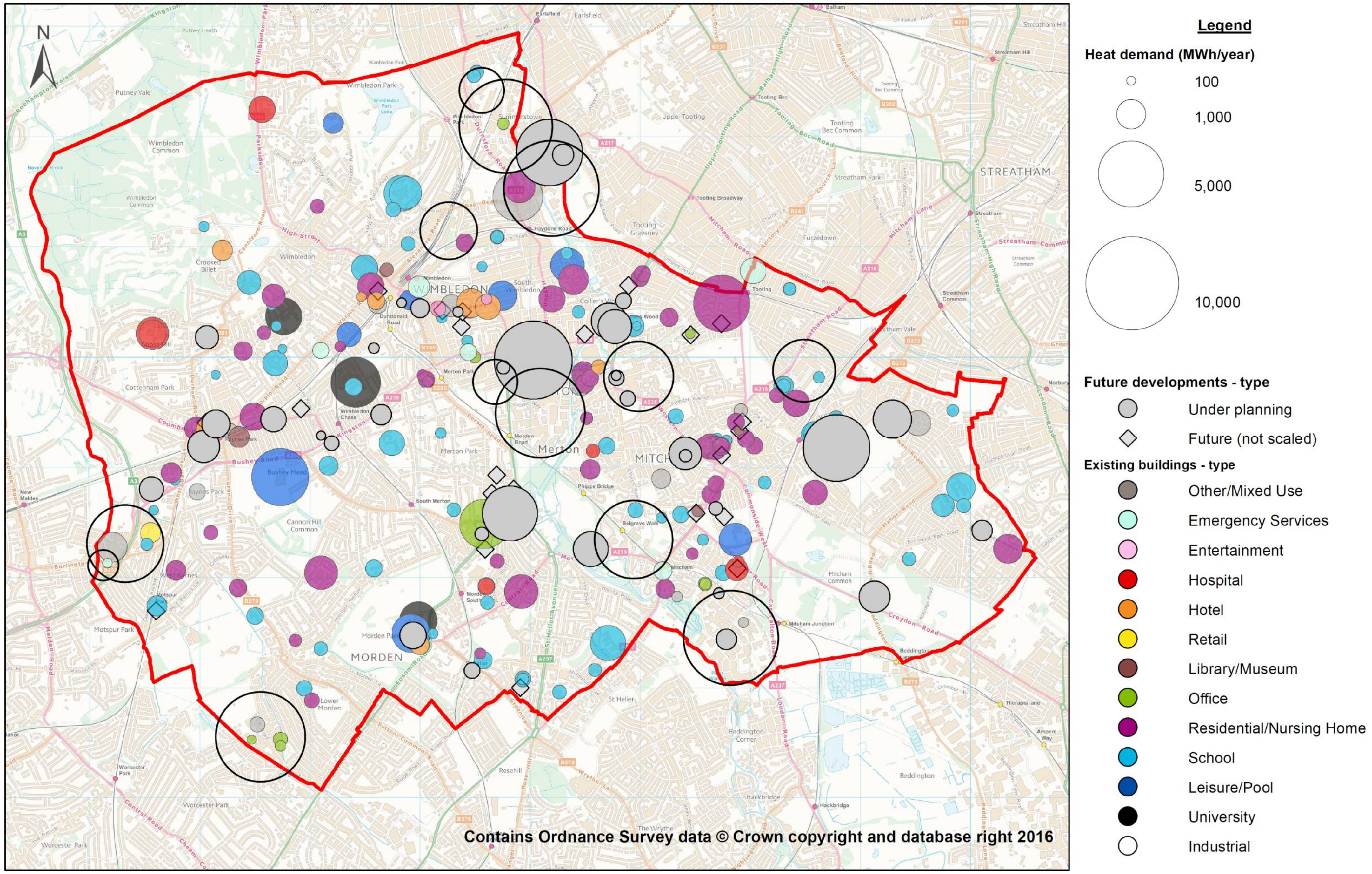
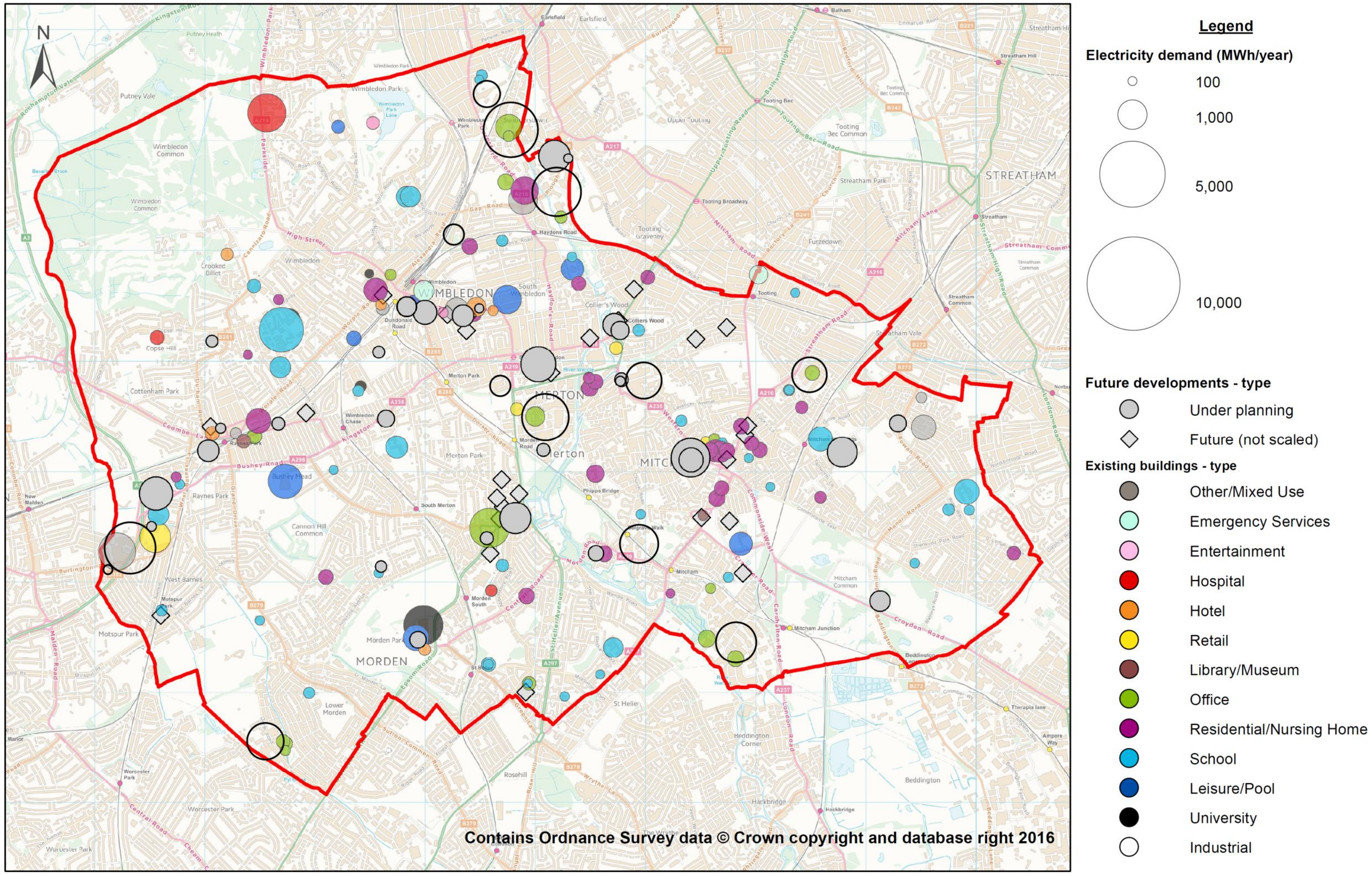
[2] http://www.cibse.org/Knowledge/knowledge-items/detail?id=a0q20000008I7evAAC
[3] http://www.cibse.org/Knowledge/knowledge-items/detail?id=a0q20000008I7oTAAS
[4] http://www.cibse.org/Knowledge/knowledge-items/detail?id=a0q20000008I7eWAAS
[5] https://www.bsria.co.uk/download/product/?file=zxrulZgWBrY%3D



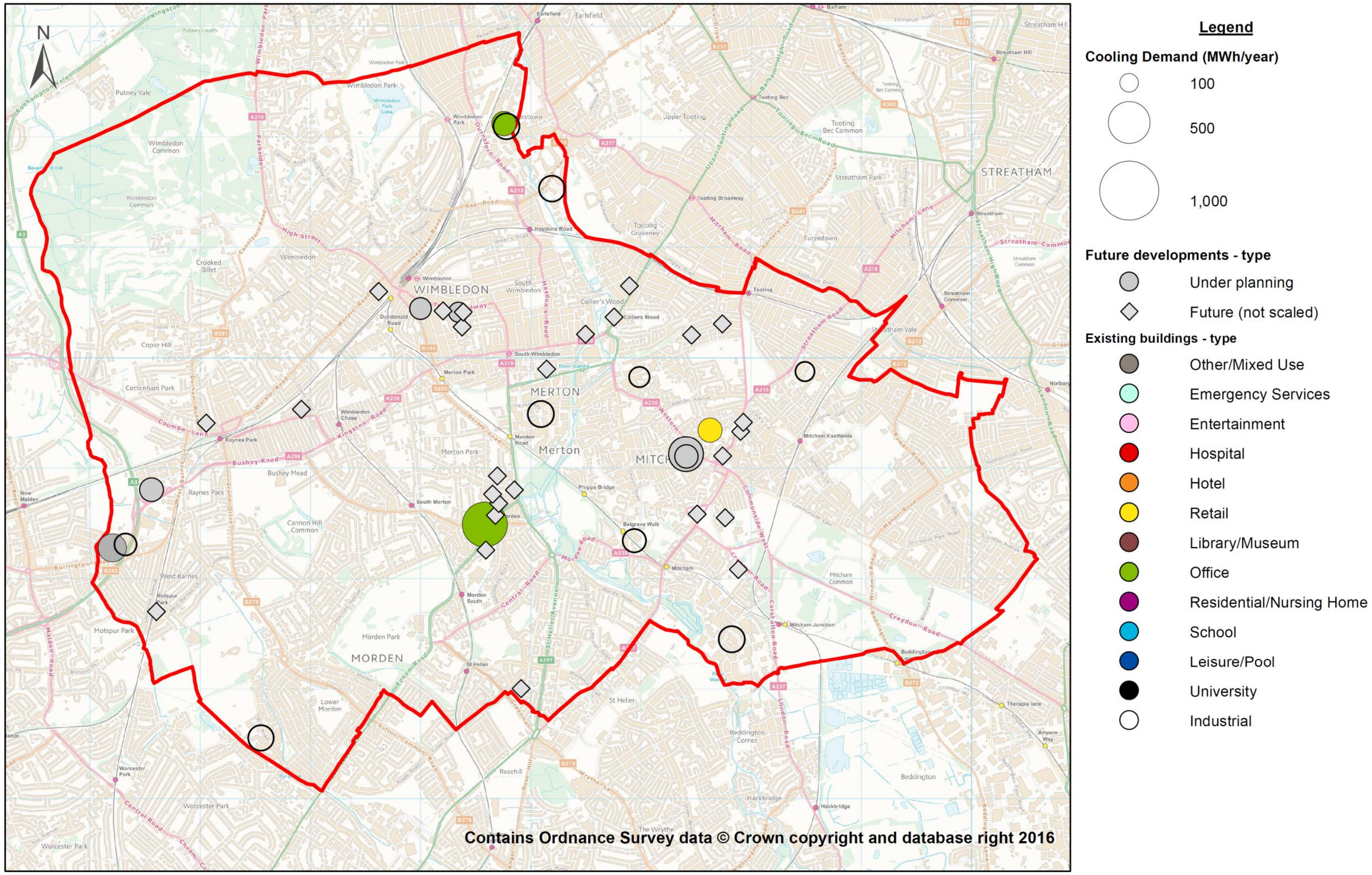
Contains Ordnance Survey data © Crown copyright and database right 2016

Figure 5-1: Merton heat demand map



Contains Ordnance Survey data © Crown copyright and database right 2016

Figure 5-2: Merton electricity demand map



Contains Ordnance Survey data © Crown copyright and database right 2016

Figure 5-3: Merton cooling demand map

5.3.1. District heating potential

Figure 5-1 presents the findings of the heat mapping study for Merton. 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 such as distance from energy centre, physical barriers on required pipework routes and the building heat distribution system. See Section 6 for more details.

Figure 5-4 shows the total heat requirement of the buildings included in the study, separated by building usage class. There is an estimated heat demand of approximately 105 GWh p.a. for the existing buildings included, and circa 40 GWh p.a. for the proposed developments across Merton.

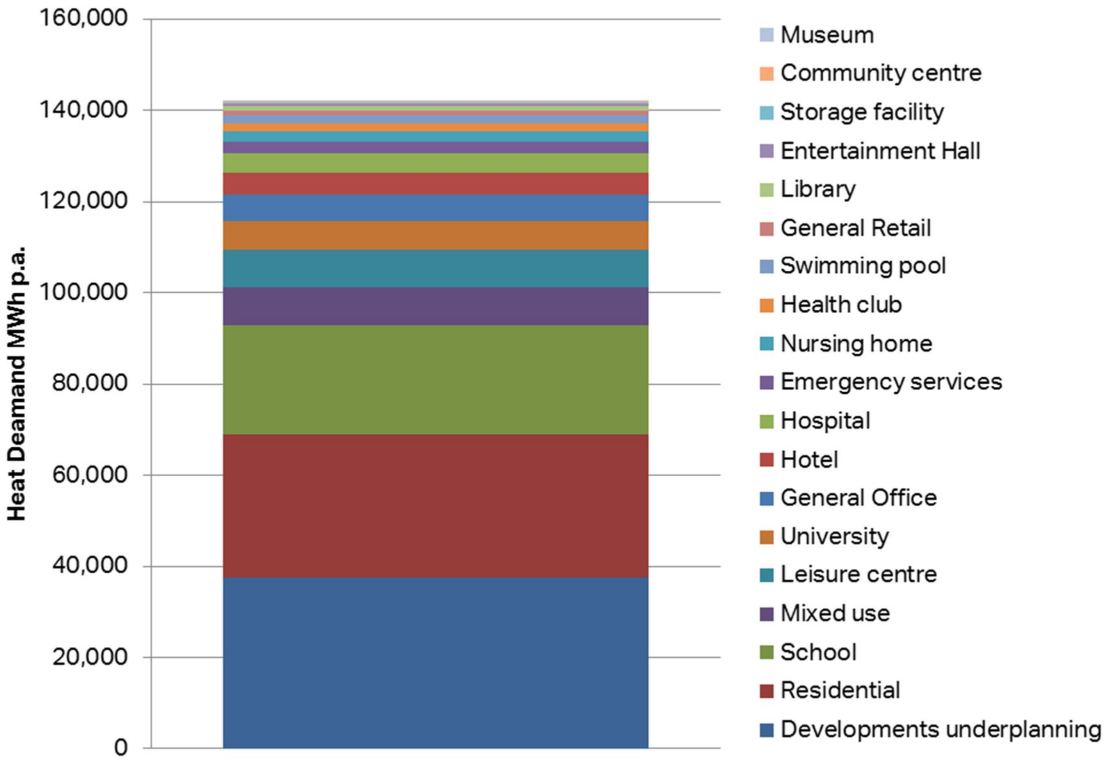


Figure 5-4: Heat demand breakdown

5.3.2. Electricity Supply Potential

The annual electricity consumption for each of the buildings investigated is illustrated in Figure 5-2. This is important in co-generation schemes, since commercial viability often hinges on the ability for the network operators to sell the generated electricity immediately to local users via a private wire, without having to export any power back to the grid: electricity revenue when sold via a Power Purchase Agreement (PPA) is typically much higher than would be achievable if exported to the national grid.

Serving a private wire requires the end customer to have a large and consistent electrical demand to enable the CHP to run consistently and at the capacity required to serve thermal loads. Figure 5-5 shows the total annual electricity consumption for building types with relative consistent electrical demand, which show a larger potential to connect to a low carbon network to increase energy security. Residential, emergency services, nursing homes, entertainment halls, storage facilities and school building types have been excluded due to the inconsistent nature of their demand throughout the day/month/year:

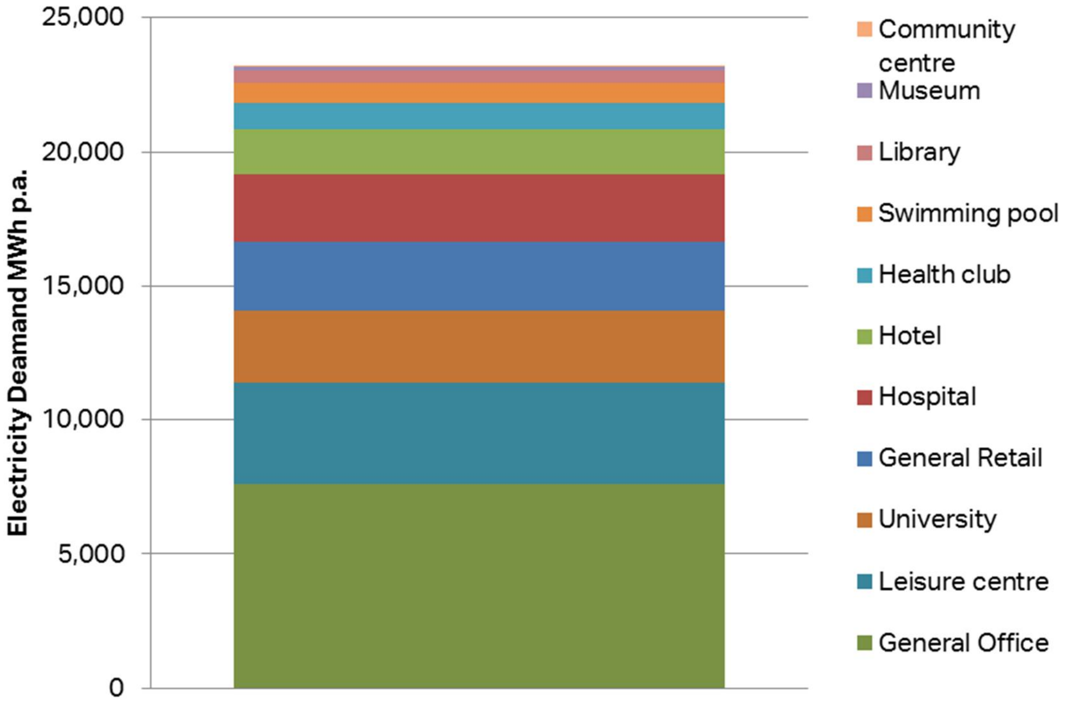


Figure 5-5: Electricity demand breakdown

As it can be seen in the figures, the heat demand in Merton is much larger than the amount of electricity that is eligible for export to the surveyed buildings. As such, any co-generation scheme such as gas CHP would likely be required to export electricity to other consumers in the area not shown here, such as to TfL for use in a local underground station. This is an item for future investigation.

5.3.3. District Cooling Potential

Figure 5-3 shows that cooling is mainly predominant in non-domestic buildings (i.e. retail, offices etc.). Comparison of annual heating and cooling demand in Figure 5-6 further demonstrates that cooling requirements are much lower than heating: cooling consumption represents 3% of the annual heating consumption requirement. Furthermore, the limitations in terms of potential compatible customer systems (many cooling systems use refrigerant based distribution systems that are not compatible with chilled water systems typically deployed by district cooling systems), together with the limited operational effectiveness and cost savings that can be achieved through the deployment of District Cooling (DC), means that DC is not considered advantageous when compared to the potential benefits that can be realised through DH.

For these reasons, the potential to establish a viable DC network is not considered high enough to warrant further investigation. This report will therefore concentrate only on the potential for district heating provision. The provision of DC in Merton will not be further investigated.

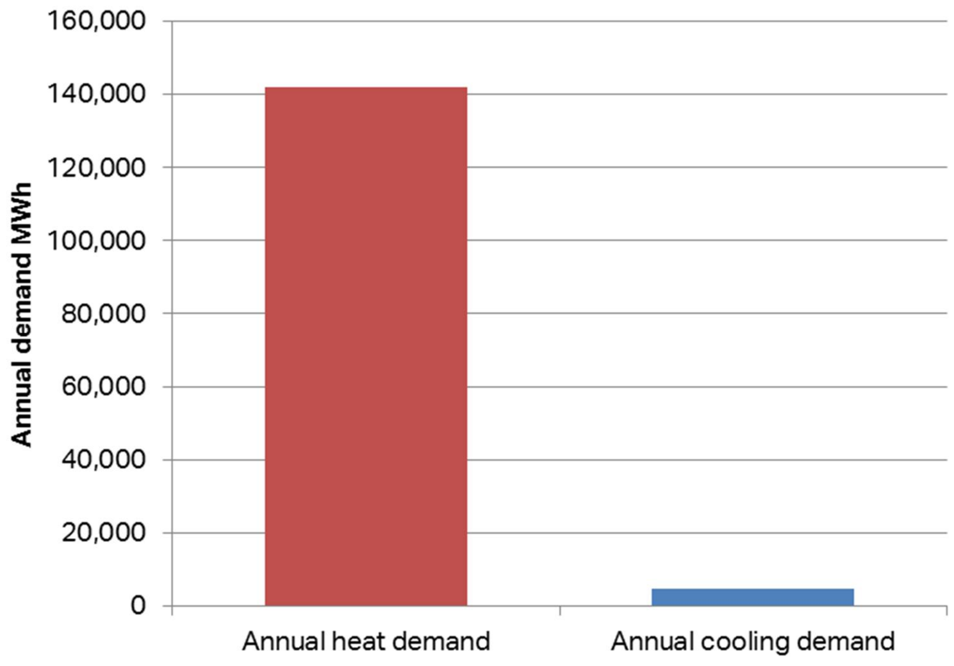


Figure 5-6: Comparison of heating & cooling demand identified in Merton

6. Heat Generation Technologies Appraisal

This section assesses the technical feasibility of various heat generation technologies available to the CWSW and MTCML network opportunities in Merton. The analysis is undertaken for the low carbon heating technologies discussed in Section 4.1 and the following appraisal forms the justification for the chosen heat generation technologies that are taken forward into the commercial evaluation phases of this study. Appendix A gives a broad overview of each of the technologies discussed in this section.

6.1 Methodology for the Feasibility Assessment

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 demand 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 the deliverability such as reliance on third parties together with implications on space requirement and energy centre size/design. Technologies were further evaluated based on their suitability on a local level.

Each technology was then scored between 1 and 5 against each criterion and shown in a matrix to determine the most viable technology for the DHN. Using each criterion's weighting importance, the weighted totals have been calculated for each technology and the technologies were ranked. The methodology was conducted for two scenarios; 0-15 years of DHN operation and 15+ years of DHN operation.

Table 6-1 details each criterion and their given 'Importance', a score between zero and five to reflect its impact on the overall assessment. Please note that zero 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 6-1: Criteria for the feasibility assessment

Category	Criterion	Relative Importance 1 - 5	Weighting %
Technical	Technology maturity and availability	5	10.0
Technical	Suitability for scale and profile of heat demand	2	4.0
Technical	Security of supply	3	6.0
Technical	Suitability for required supply temperatures	4	8.0
Technical	Proximity to heat demands	2	4.0
Environmental	Level of CO_2 emission savings	5	10.0
Environmental	Air quality implications	5	10.0
Environmental	Wider environmental impacts	2	4.0
Financial	Technology cost	3	6.0
Financial	Impact on scheme financial viability	5	10.0
Financial	Long term financial risks	3	6.0
Deliverability	Suitability to London Borough of Merton	4	8.0
Deliverability	Implications for energy centre size/design	3	6.0
Deliverability	Implications for additional space requirements	2	4.0
Deliverability	Reliance on third parties	2	4.0
Total			100.0

6.2 Technology Appraisal Results

Table 6-2 and Table 6-3 present the results of the technology appraisal for both operational timescale scenarios, with rank 1 representing the most viable technology. The assessment presented here seeks to identify constraints and advantages associated with the use of different technologies in Merton, providing a first indication as to which might be suitable. Their specific potential for use in Merton is further discussed later in this section (and also Section 7.4) taking into consideration their proximity to the site, their heat capacity to serve the heat requirements of the network and any potential risks associated with their use.

Table 6-2: Technology appraisal matrix (0-15 years)

Category	Name Ref	Option 1 Gas Fired CHP	Option 2 Biomass Fired CHP	Option 3 Biofuel Fired CHP	Option 4 Energy From Waste	Option 5 Biomass Boiler	Option 6 Biofuel Boiler	Option 7 Geothermal	Option 8 Anaerobic digestion	Option 9 Air Source Heat Pumps	Option 10 Water Source Heat Pump	Option 11 Ground Source Heat Pump	Option 12 Heat recovery from the underground	Option 13 Heat recovery from substations	Option 14 Solar Thermal
Technical	Technology maturity and availability	5	4	4	4	4	4	1	4	4	4	4	2	2	3
Technical	Suitability for scale and profile of heat demand	4	4	4	2	4	4	3	2	3	2	4	2	2	1
Technical	Security of supply	4	2	2	4	2	2	3	4	5	4	4	4	4	3
Technical	Suitability for required supply temperatures	5	5	5	5	5	5	3	5	2	2	2	3	3	3
Technical	Proximity to heat demands	5	5	5	1	3	3	1	1	3	3	3	1	1	3
Environmental	Level of CO_2 emission savings	4	4	4	5	4	4	5	5	3	3	3	3	5	5
Environmental	Air quality implications	2	1	1	4	1	1	5	4	5	5	5	5	5	5
Environmental	Wider environmental impacts	3	3	3	4	3	3	3	4	3	3	3	3	4	3
Financial	Technology cost	4	3	3	4	4	4	1	4	4	4	3	4	2	3
Financial	Impact on scheme financial viability	4	3	3	3	3	3	1	3	3	3	3	3	3	3
Financial	Long term financial risks	3	3	3	2	3	3	2	2	3	3	3	3	3	4
Deliverability	Suitability to Merton	5	5	5	3	4	4	1	2	2	1	2	3	3	1
Deliverability	Implications for energy centre size/design	4	3	3	4	3	3	5	4	4	4	4	4	5	4
Deliverability	Implications for additional space requirements	5	3	3	5	3	3	5	5	1	4	1	5	5	2
Deliverability	Reliance on third parties	5	2	2	1	3	3	5	1	5	5	5	1	1	4
	Total score (%)	81.60	66.80	66.80	72.00	65.60	65.60	57.20	70.40	67.60	66.40	66.00	63.20	66.80	65.60
	Rank	1	5	5	2	10	10	14	3	7	10	8	11	9	10

Table 6-3: Technology appraisal matrix (15+ years)

Category	Name Ref	Option 1 Gas Fired CHP	Option 2 Biomass Fired CHP	Option 3 Biofuel Fired CHP	Option 4 Energy From Waste	Option 5 Biomass Boiler	Option 6 Biofuel Boiler	Option 7 Geothermal	Option 8 Anaerobic digestion	Option 9 Air Source Heat Pumps	Option 10 Water Source Heat Pump	Option 11 Ground Source Heat Pump	Option 12 Heat recovery from the underground	Option 13 Heat recovery from substations	Option 14 Solar Thermal
Technical	Technology maturity and availability	5	5	5	4	4	4	2	4	4	4	4	3	3	4
Technical	Suitability for scale and profile of heat demand	4	4	4	2	4	4	3	2	3	2	4	1	2	1
Technical	Security of supply	4	3	3	4	2	2	3	4	5	4	4	4	4	3
Technical	Suitability for required supply temperatures	5	5	5	5	5	5	3	5	3	3	3	3	3	3
Other	Proximity to heat demands	5	5	5	1	3	3	1	1	3	3	3	1	1	3
Environmental	Level of CO2 emission savings	2	4	4	5	3	3	5	5	5	5	5	3	5	5
Environmental	Air quality implications	1	1	1	4	1	1	5	4	5	5	5	5	5	5
Environmental	Wider environmental impacts	2	2	2	4	2	2	3	4	3	3	3	3	4	3
Financial	Technology cost	4	4	4	4	4	4	2	4	4	4	3	4	2	3
Financial	Impact on scheme financial viability	4	3	3	3	3	3	1	3	3	3	3	3	3	3
Financial	Long term financial risks	3	3	3	2	3	3	2	2	3	3	3	3	3	4
Deliverability	Suitability to Merton	5	5	5	4	4	4	1	2	2	1	2	3	3	1
Deliverability	Implications for energy centre size/design	4	3	3	4	3	3	5	4	4	4	4	4	5	4
Deliverability	Implications for additional space requirements	5	3	3	5	3	3	5	5	1	4	1	5	5	2
Deliverability	Reliance on third parties	5	2	2	1	3	3	5	1	5	5	5	2	1	4
	Total score (%)	74.80	70.40	70.40	73.60	62.80	62.80	60.40	70.40	73.20	72.00	71.60	70.00	73.60	67.60
	Rank	1	7	7	2	12	12	14	7	4	5	6	10	2	11

6.3 Technology Appraisal Discussion

6.3.1. Current assessment

The analysis shows that among the low carbon technologies tested, gas-fired CHP is considered to be the most viable current option for serving a DH network in Merton. The expected size and profiles of the heat demands that have been identified for a DHN in Merton will be well suited for the use of a gas-CHP system, enabling the delivery of significant run hours of gas-CHP engines at a scale that will generate significant quantities of electricity, providing both carbon savings (in the short to medium term) and financial returns. CHP is a mature technology that has been used successfully in other similar projects; it does not usually involve a requirement for additional space, nor any reliance on third parties. Some practical issues, including the air quality implications will need to be addressed but early investigations suggest that there are no major barriers that would prevent the use of this technology.

Biomass or biofuel CHP engines and boilers are considered to be good substitute technologies for gas CHP, with good applicability to heat networks and technology maturity levels. The reliance on third parties (for fuel security), high fuel costs (relative to gas) and air quality implications (high levels of NOx and particulate emissions) are particular risks however.

Due to the exceptionally high costs of drilling to the required depths, deep geothermal heat recovery is not considered viable. There were no existing deep wells identified in the area.

Similarly, no anaerobic digestion plants exist in the vicinity of either of the network opportunity areas so this technology is not deemed a viable solution for heat generation in Merton. See Section 7.4.3 for further details.

Due to the buildings under consideration consisting of older, existing building stock as well as new developments, heat pump technologies did not score highly. Older buildings require higher heating supply temperatures which significantly reduce the efficiencies of heat pumps. As such, the operating costs and CO_2 emissions savings of such systems are not as favourable as other technologies. Whilst building secondary side systems could be changed for lower temperature heat emitters, this would entail significant site disruption and associated costs that would not likely be favoured by customers. Large new developments lend themselves well to heat pump technologies, as the design of their heating distribution systems can allow for lower heating supply temperatures, giving higher efficiencies.

Both Air and Ground Source Heat Pumps require additional areas for plant that is not considered achievable in the vicinity of the two considered areas. The River Wandle and the River Graveney that run through Merton present a significant enough body of water to mean that Water Source Heat Pumps could be used in Merton. The use of WSHP in Merton is explored further in Section 7.4.6. Supplementing a wider network with heat from heat pumps is difficult as it requires either that the whole network is operated at a low heating supply temperature (i.e. older, existing building stock cannot be connected without significant building upgrade works) or that the heat pump runs inefficiently in order to supply higher temperatures.

Heat recovery from the Transport for London Underground network is feasible but would not represent a significantly large enough proportion of the heat required for the network opportunities identified in Merton. Furthermore, the requirement for heat pumps to increase the temperature of the heat recovered from vent shafts limits the technology to low heating supply temperatures, which are likely to be suited to new developments only. Please refer to section 7.4.1 for further discussion on the potential of this opportunity in Merton.

Heat recovery from substations is not currently a widely used/understood technology, with high reliance on third parties and high financial risks. However, due to the fact that the heat recovered would otherwise be rejected to atmosphere, the technology performs well with regards to environmental factors and is assessed to improve generally in the future. See Section 7.4.3 for further detail on the application of this technology in Merton.

Energy from Waste scores well in the appraisal: it is a well understood technology with low emissions, lower plant room and additional space requirements, and is supported through local and regional policy. However, it is reliant on third parties and as such represents a high level of risk. Research identified an Energy Recovery Facility (ERF) at the existing Beddington landfill and recycling site. Its potential to supply heat to a DH in Merton is further investigated in Section 7.4.2.

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.

6.3.2. Future assessment

In light of the decarbonisation of the grid, it is expected that gas-led technologies will not be as favourable as other options in the future (see 15+ years technology appraisal, Table 6-3). Predicting future grid decarbonisation as well as future fuel prices is inherently difficult. If the council are to pursue a gas-fired CHP network in Merton, reassessing the heat generation technology throughout the project will be vital if it is to continue to deliver carbon savings cost effectively beyond the lifetime of the first engines (typically after 10-15 years).

Whilst currently less feasible, technologies like heat pumps, heat recovery from substations, heat recovery from the London Underground and Energy from Waste facilities will become more important considerations in the future. Equally, gas CHP is expected to continue to offer financial benefits beyond the first replacement cycle.

The most likely outcome is that future district energy networks will incorporate a number of different technologies, and be controlled in a way that ensure heat or cooling is delivered with delivering focus on optimising both the carbon savings and financial benefits for the network operators. Merton contains a number of interesting heat sources that could form part of this technology mix (see Section 0) and, if the project goes forward, these should be continuously monitored and formally reviewed in advance of plant replacement.

6.4 Technology Appraisal Conclusion

Overall, taking into account the criteria listed above, gas-fired CHP was identified as currently the most viable low-carbon technology to provide heat for a DEN in Merton. This would be topped-up by gas boilers, enabling the CHP engines to be reduced in size so that they pick up a significant proportion of the heat demands while also ensuring long running hours to generate the electricity that will deliver the required financial returns and carbon savings to make the networks viable.

Energy from waste, water source heat pumps and heat recovery from substations and the London Underground will also be brought forward into the masterplanning phases of the project, to assess whether they would be a viable technology for the borough to implement. Please refer to Section 7.4 for further assessment of these technologies.

In the future, it is uncertain which technology (or combination of technologies) would be most suitable for replacing the gas-CHP plant, and therefore further investigation, accounting for the prevailing technical, regulatory and commercial climates, will be necessary. There are inherent risks involved with recommending what is appropriate in the future and it is important that LB Merton remains flexible in the future to allow for change.

7. Energy Masterplanning

7.1 Heat Network Strategic Development Areas

Areas with large concentrated heat loads present significant opportunities for the installation of a District Heating Network. 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 that comply with one or more of the following criteria:

- Buildings with a high level of heat consumption (e.g. schools 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 the connection to a DHN (e.g. Council Civic Centre), since it is often easier to secure customers for a DHN if there is consent from related institutions.

An initial heat mapping exercises and various feasibility studies have been carried out since 2005, in which dense areas of heat demand were identified as heat network strategic development areas. These are shown in Figure 7-1 which also illustrates that the updated heating loads largely align with the previously identified strategic development areas. Of these, the two that are under consideration as part of this study are:

- Colliers Wood and South Wimbledon (CWSW)
- Morden Town Centre and Morden Leisure Centre (MTCML)

The energy masterplanning phase of the study, as described in this section, focusses on proposing a network in each of these two key areas.

7.2 Building Prioritisation

Of the areas identified, only a proportion of the buildings within each area 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 buildings such as residential developments, leisure centres and hospitals that were deemed to present high and stable heat loads over the year, typically with wet heating distribution systems already installed. Buildings situated in close proximity to each other were also prioritised.

Buildings have been scored 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 3,500kWh of heating demand per meter of necessary pipework was used to ascertain whether a building would be commercially viable for connection.
- 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. Figure 7-2 displays the existing Infrastructure & environmental/urban barriers.
- 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. Figure 7-3 shows the council owned land.
- 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. AECOM understands that a group of new developments in and around Morden Town Centre and Leisure Centre (MTCML) are currently going through the planning system now. However, their compatibility with connection to a DHN can often be made a condition of planning consent.
- 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.

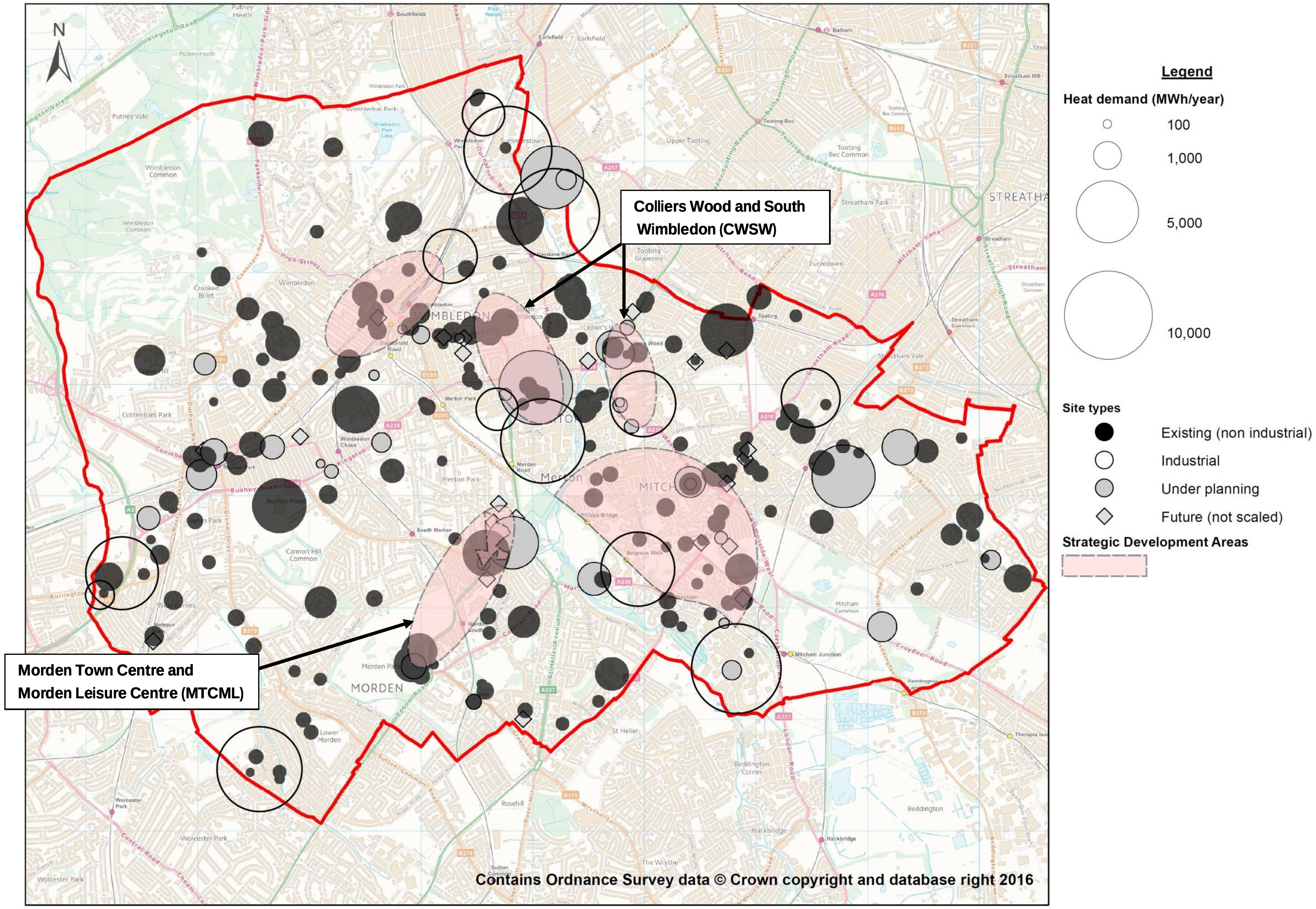


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Figure 7-1: Heat network strategic development areas

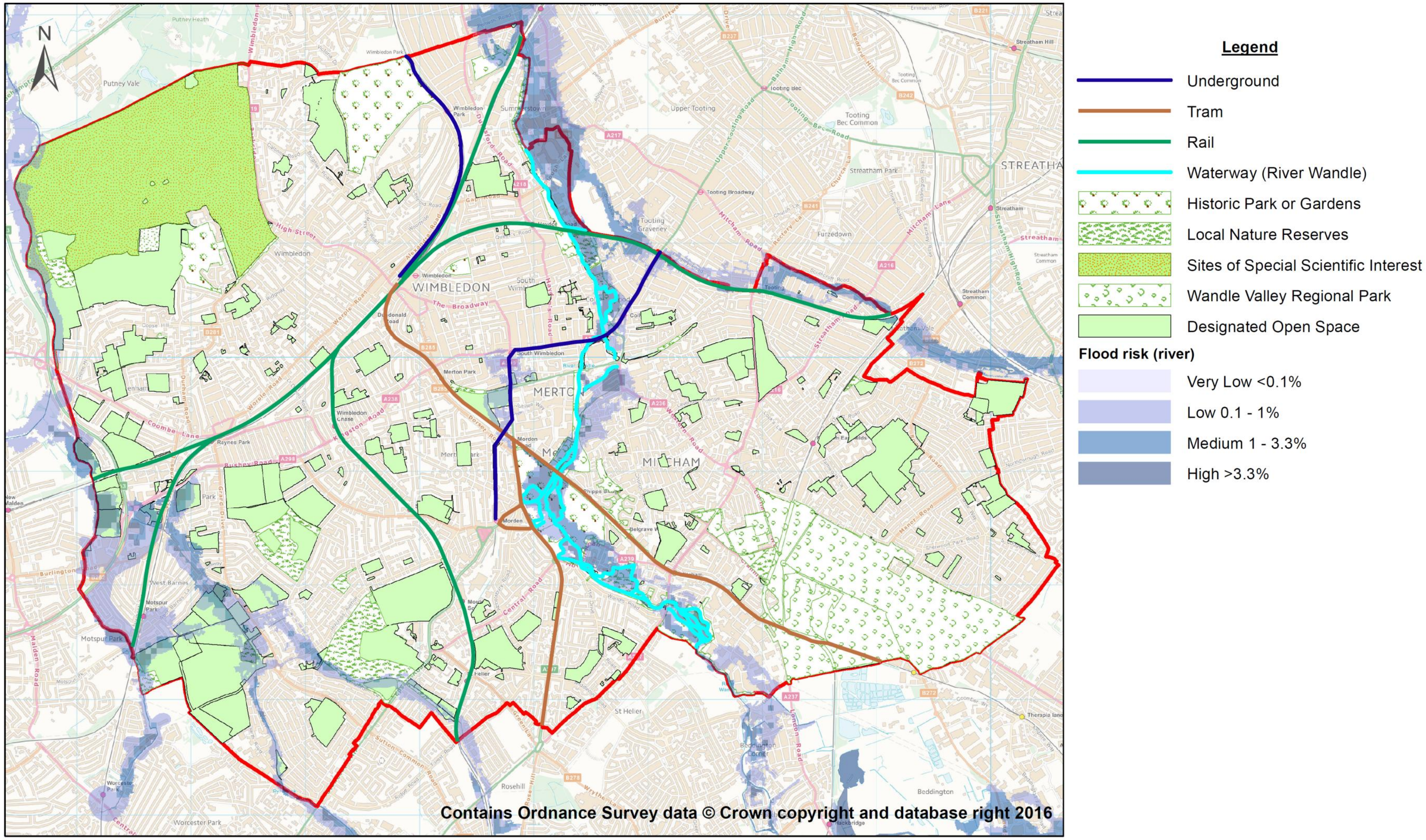

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Figure 7-2: Existing Infrastructure & environmental/urban barriers in Merton

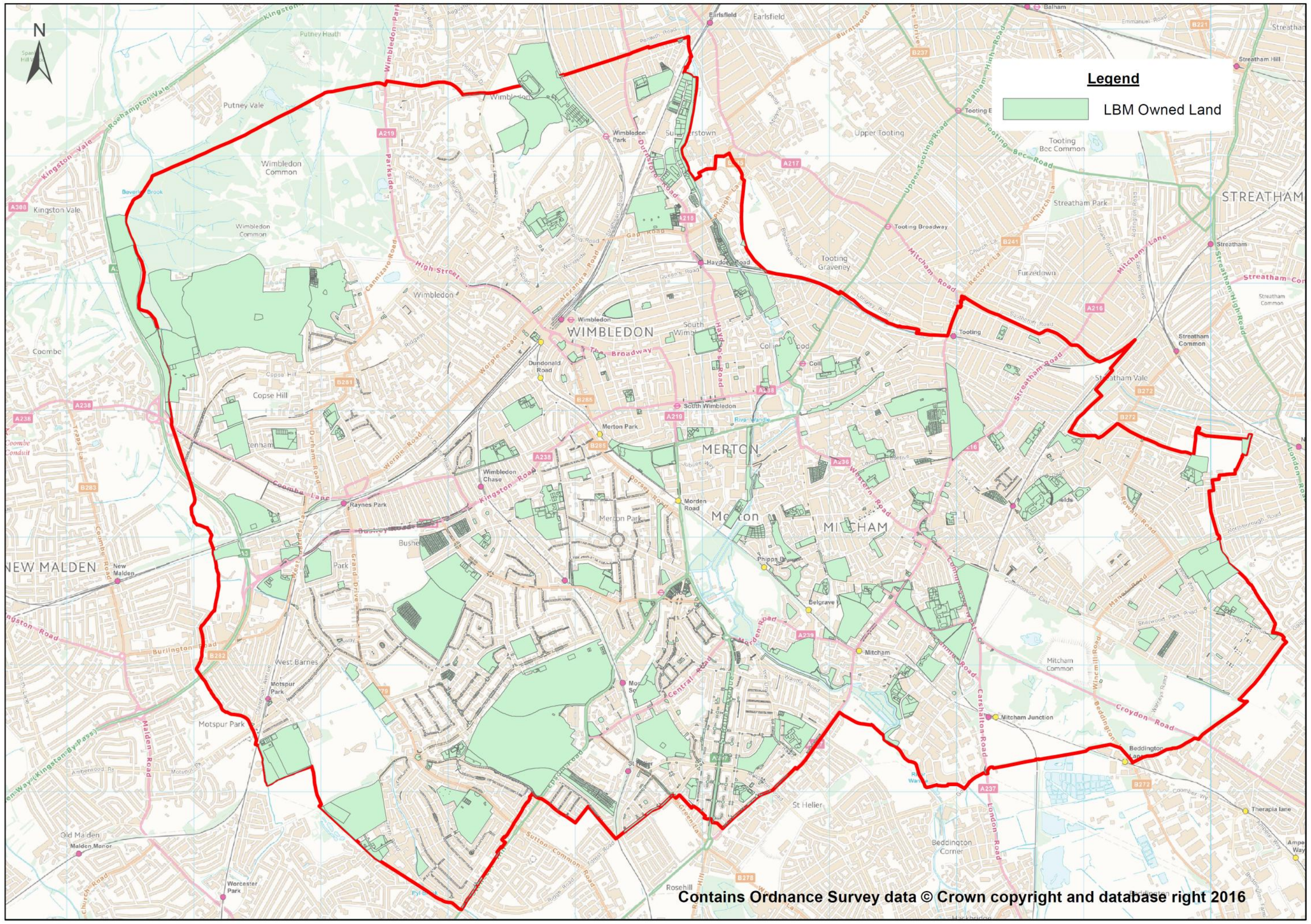

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Figure 7-3: LBM owned land

7.3 Identified feasible loads

Buildings have been identified based on their proximity to the 'anchor loads' and the presence of physical barriers (e.g. major road systems, waterways and railways) within each network. Not all the buildings shown in each network will necessarily be included – further technical and financial assessment is required.

7.3.1. Colliers Wood and South Wimbledon (CWSW)

The CWSW network includes buildings in Wimbledon, South Wimbledon, Colliers Wood and Merton as well as the Merton Industrial Estate.

The High Path Estate, with 1,000 residential units and located centrally within the cluster of other identified buildings, is considered to be the anchor load of this network due to its large size and associated high energy consumption. Buildings North-West of Wimbledon station have been excluded due to the significant rail infrastructure that would make pipework installation very costly.

It should be noted that the Northern line at South Wimbledon area is under ground and not considered as a physical barrier at this stage. Loads in Colliers Wood require the crossing of the River Wandle.

Table 7-1 and Figure 7–4 show the loads included in the CWSW network, as well as key infrastructure barriers in the area.

7.3.2. Morden Town Centre and Leisure Centre (MTCML)

LBM would like to investigate developing a DEN between Morden Town Centre and Morden Leisure Centre: There are a number of relevant notes regarding the local area, including:

- A group of new developments in and around Morden Town Centre are currently under planning. However, very little is known about them (usage, area etc), making technical and commercial modelling of the network difficult;
- Road improvement works are under planning around Morden Town Centre (as shown in Figure 7-5)
- A railway exists between the town centre and the leisure centre which will add cost to the installation.
- Figure 7–5 and Table 7-2 show the loads included in the MTCML network. As well as key infrastructure and physical barriers and constraints in the area.

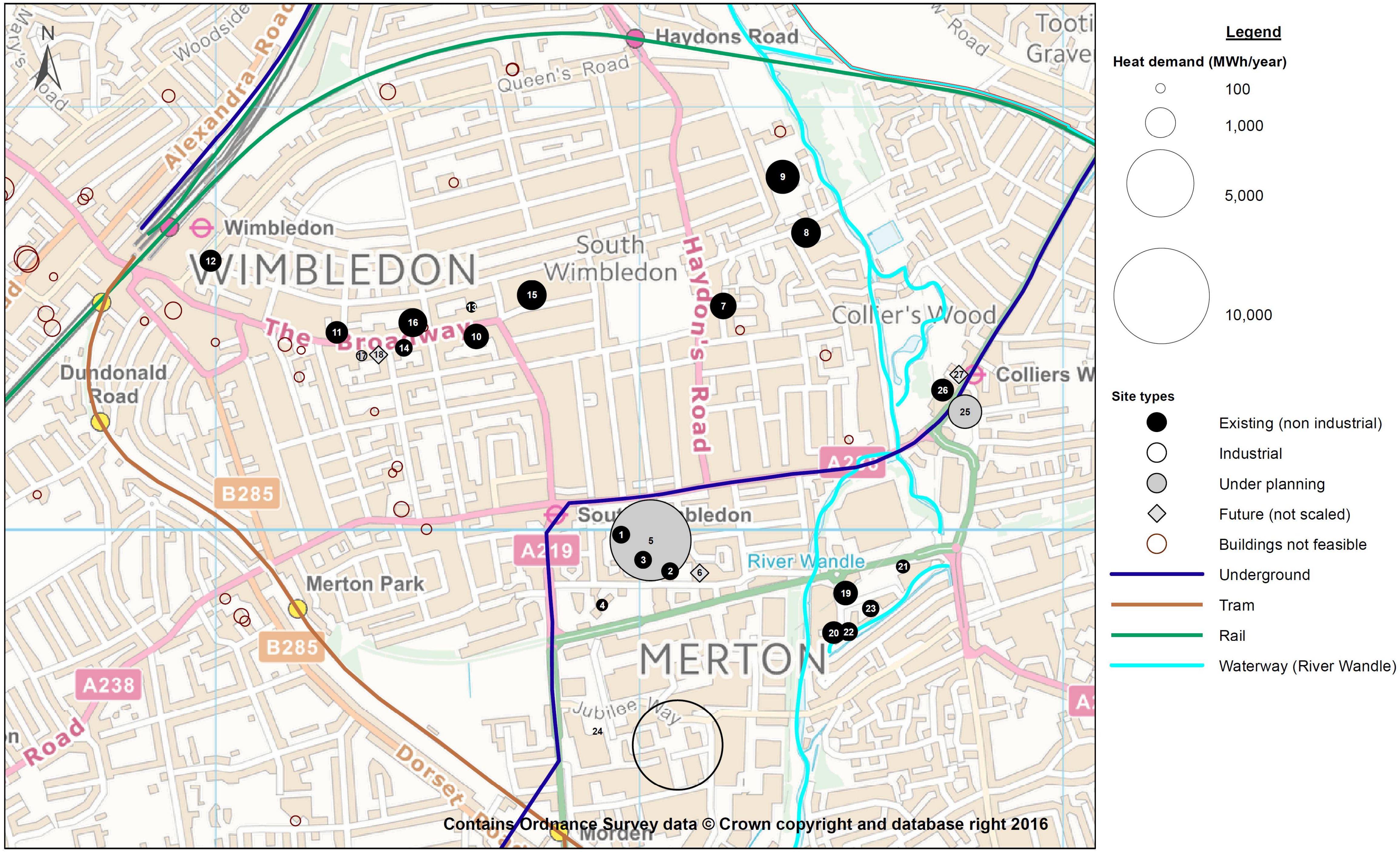

Figure 7-4: CWSW feasible loads (see Table 8-3 for building number identifications)

Table 7-1: Identified feasible buildings for the CWSW network

No.	Building	Postcode	Building Class	Stage	Electricity consumption, MWh/annum	Gas consumption, MWh/annum	Heating consumption, MWh/annum	Data Source
1	Hudson Court	SW19 2LF	Residential	Existing	322	514	411	TM46
2	Marsh Court	SW19 2LD	Residential	Existing	322	514	411	TM46
3	May Court	SW19 2LE	Residential	Existing	322	514	411	TM46
4	Merton Abbey Primary School	SW192JY	School	Existing	50	229	183	TM46
5	High Path Estate	TBC	Residential	Under Planning	1,414	-	7,007	AECOM model
6	The Old Lamp Works	TBC	TBC	Future	-	-	-	-
7	All Saints Boiler Houses: Tintern Close/Woburn Close	SW19 1DP	Residential	Existing	-	1,008	806	TM46
8	Connolly Leather Works	SW19 1AJ	Residential	Existing	237	1,306	1,045	TM46
9	Virgin Active, Health Club, Battle Close	SW19 1AQ	Health club	Existing	603	1,658	1,326	TM46
10	Antoinette Hotel	SW19 1SD	Hotel	Existing	126	924	739	TM46
11	Broadway House, The Broadway & 2-14 Stanley Road	SW19 8RF	Mixed use	Existing	625	642	578	TM46
12	Police Station, 15-23 Queen's Road	SW19 8NN	Emergency services	Existing	479	678	543	TM46
13	Polka Theatre, 238-244 The Broadway	SW19 1SB	Entertainment Hall	Existing	60	168	134	TM46
14	Viscount Point	SW19 1NL	Residential	Existing	278	444	355	TM46
15	Wimbledon Leisure Centre, Latimer Road	SW19 1EW	Leisure centre	Existing	918	1,254	1,003	TM46
16	YMCA, 200 The Broadway	SW19 1RY	Hotel	Existing	433	1,190	952	TM46
17	153-161 The Broadway	TBC	General office	Under Planning	527	-	132	AECOM model
18	165-171 The Broadway	TBC	TBC	Future	-	-	-	-
19	Merton Abbey Mills	SW19 2RE	Residential	Existing	160	881	704	TM46
20	Merton Abbey Mills, Watermill Way, Colliers Wood	SW19 2RF	Mixed use	Existing	127	676	609	TM46
21	Premier Inn	SW19 2RF	Hotel	Existing	95	297	238	TM46
22	Flat 1 2 Chapter Way London	SW19 2RY	Residential	Existing	317	507	405	TM46
23	Flat 1 4 chapter way London	SW19 2RZ	Residential	Existing	268	429	343	TM46
24	Morden Industrial Area (SWBA)	Various	Industrial	Existing	182	734	587	TM46
25	Brown & Root House	SW19 2JG	Mixed use	Under Planning	396	-	1,315	AECOM model/ Guide F
26	Holiday Inn Express	SW19 2BH	Hotel	Existing	182	734	587	TM46
27	Land at Corner of Baltic Close & High Street	TBC	TBC	Future	-	-	-	-

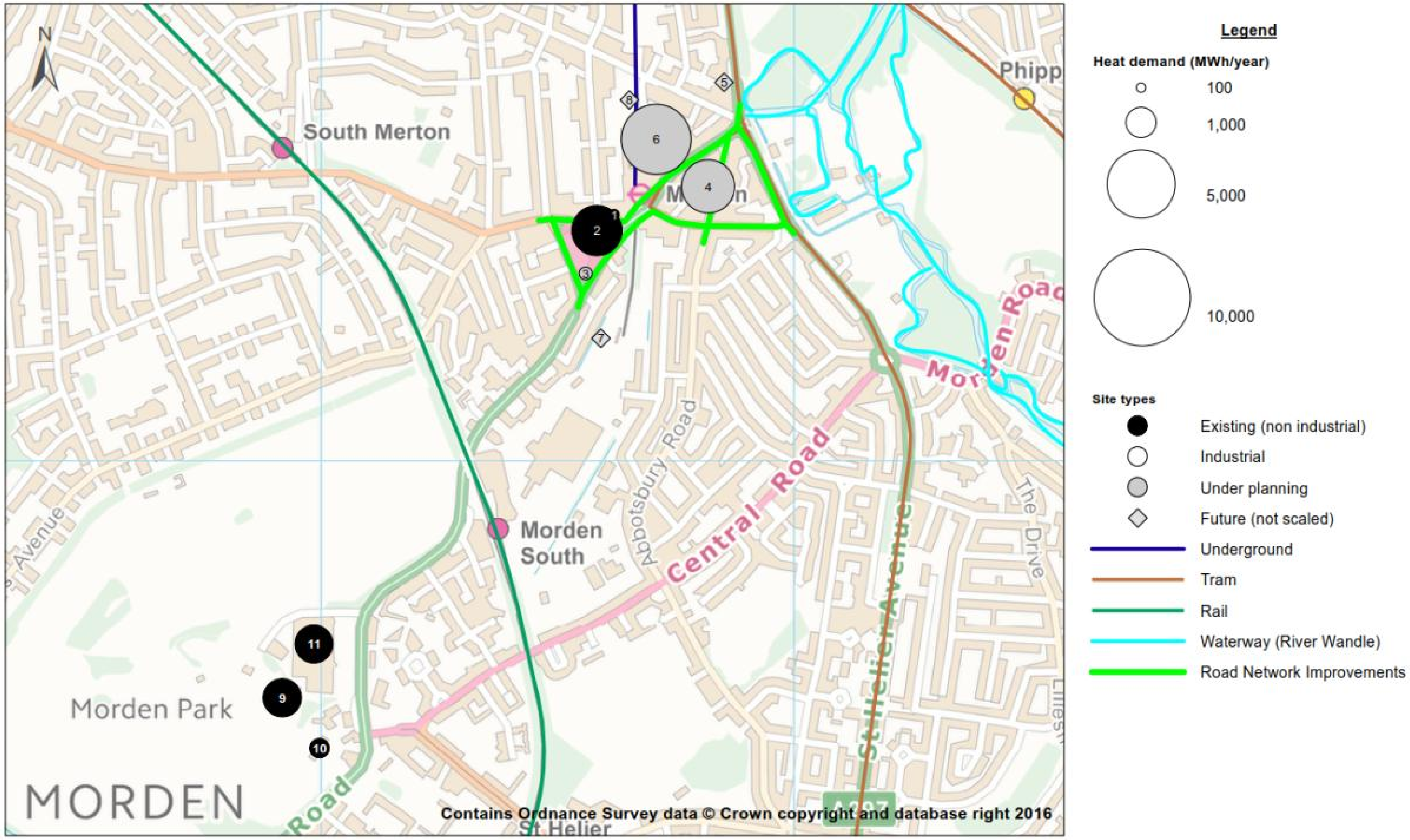

Figure 7-5: MTCML feasible loads (see Table 7-2 for building number identifications)

Table 7-2: Identified feasible buildings for the MTCML network

No.	Building	Postcode	Building Class	Stage	Electricity consumption, MWh/annum	Gas consumption, MWh/annum	Heating consumption, MWh/annum	Data Source
1	Crown Lane Studio	SM4 5BL	Entertainment Hall	Existing	60	168	134	TM46
2	Merton Civic Centre	SM4 5DX	General Office	Existing	1,816	3,556	2,845	TM46
3	The Crown	TBC	Mixed use	Under Planning	205	238	214	AECOM model/ CIBSE Guide F
4	Abbotsbury Triangle site	TBC	Mixed use	Under Planning	1,031	3,335	3,001	AECOM model/ CIBSE Guide F
5	Morden Road Clinic	TBC	TBC	Future	-	-	-	
6	Morden Station Offices and retail units (Morden Station)	TBC	Mixed use	Future	1,267	5,794	5,214	AECOM model/ CIBSE Guide F
7	York Close Car Park	TBC	TBC	Future	-	-	-	-
8	Morden Station staff car park (Morden Station)	TBC	TBC	Future	-	-	-	-
9	Morden Park Swimming Pool	SM4 5HE	Swimming pool	Existing	762	2,109	1,688	TM46
10	Travelodge	SM4 5PH	Hotel	Existing	168	528	423	TM46
11	Merton campus of South Thames College	SM4 5QX	University	Existing	1,780	2,036	1,629	TM46

7.4 Energy sources

A number of heat sources have been identified in Merton that could be used to supply a heat network. This section identifies the location of these heat sources and assesses their viability for use in Merton. Figure 7-6 illustrates the location of the energy sources listed here, alongside the key physical barriers in the area.

7.4.1.London Underground

The motion of trains running through the London Underground network moves significant amounts of air, pushed out of the tunnel in front of the train and pulled in behind it. As the air leaving the tunnel is usually warmer than the air entering it, this represents a source of energy for a DEN.

In order to recover some of this heat, air leaving the ventilation shafts is passed through a heat exchanger. The heat exchanger forms the evaporator of a heat pump that then raises the temperature of the heat to the required heating supply temperature of the network.

TfL have indicated that there are ventilation shafts in the South Wimbledon and Colliers Wood area; the exact location was not provided for security reasons. An indicative location range is shown in Figure 7-6.

The amount of heat that could be recovered from a vent shaft is not constant, and its temperature fluctuates seasonally. If the flow rate of air through the shaft is equal to the amount of air displaced by a train moving at an average speed of 33km/h, an approximate heat capacity can be calculated:

- Diameter of tunnel/train: 3.5m
- Heat Pump COP: 3
- Temperature change of vented air: 5K
- Approximate heating capacity: 810kW

This heating capacity is sufficient to warrant further investigation, as the heat pump could be used to provide the base load heating of a network in South Wimbledon and Colliers Wood area, assuming:

- The vent shaft location is in close proximity to the proposed network
- The network operating temperature is sufficiently low to ensure good heat pump COPs.

Attention would need to be paid to the network supply temperature, as heat pumps become less efficient at higher supply temperatures/lower source temperatures. As such, this technology would be particularly suited to a network serving new developments, where the council could ensure that lower heating supply temperatures are designed for, enabling the future use of heat pumps on site.

Of particular importance is the proximity of the shaft location range to the High Path Estate development, which could be designed to employ a lower temperature network. This would enable the use of the heat recovered from the shafts, if they are found be close enough to the development.

7.4.2.Beddington Energy Recovery Facility

Viridor commenced the work for Energy Recovery Facility (ERF) at the existing Beddington landfill and recycling site in 2015. The ERF was designed to process circa 275,000 tonnes of non-hazardous residual waste a year.[6] The London Borough of Sutton has formed a wholly owned Energy Services Company called Sutton Decentralised Energy Network Limited (SDEN) to develop a heat network across South London using Viridor's ERF. These facilities comprise Energy from Waste (EfW) plant which will be operational in around 3 years, and existing landfill gas fuelled CHP engines.

The EfW facility led district heat network could operate at a temperature regime of 95°C/60°C, where the peak EfW heat capacity is 15MW. A high level analysis estimates that the EfW facility could provide 45GWh of heat per year (i.e. assuming average output of 6MW with 15% losses. Any demand requirements above the EfW capacity could then be met by back up boilers and thermal storage.

As shown in Figure 7-6, the Beddington ERF is located to the south of Merton Borough approximately 3.8km from Morden town Centre and 4.5km from South Wimbledon station, representing significant cost implications for the pipework alone (c. £5m[7] for a 4km pipeline). Consideration should be also given to major infrastructure between these areas and the EfW facility that may add further significant costs and technical difficulty.

It would be necessary to establish an agreement with the ERF to purchase heat at a cost much less than it is possible to generate at on site. If agreements are made such that heat is purchased at £0.01/kWh less than the usual costs of production (i.e. from gas boilers or gas CHP), then purchasing 10GWh of heat from the facility would enable a £5m additional investment for the 4km pipework from the ERF facility to pay back in 50 years. Purchasing 20GWh would pay back in 25 years. This assessment makes no allowance for other associated costs such as the wider network pipework costs, connection costs and heat generation systems etc, and assumes the network is already in place when the connection goes live.

Given the high payback period anticipated, this option does not currently represent a viable solution for district energy in Merton. However, the integration of the SDEN and a Merton district network may be viable in future if both undergo expansion and the required pipework length to join them is reduced. Therefore, it is recommended to investigate this option again in the future in order to capture any further developments.

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[6] https://viridor.co.uk/our-developments/beddington-erf/
[7] Based on the assumption that pipework costs are approximately £1200/m

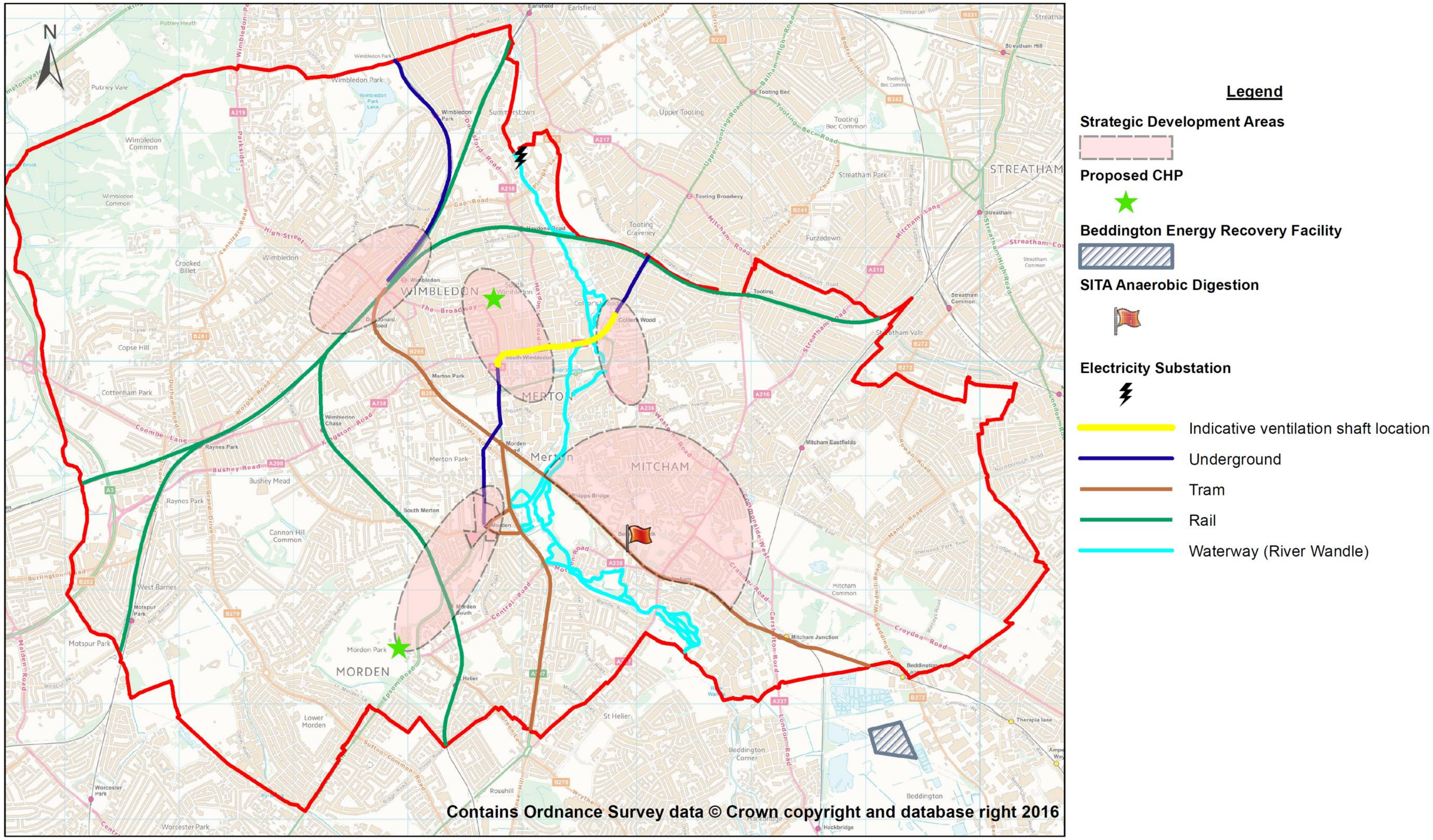

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Figure 7-6: Existing energy sources in Merton

7.4.3. SITA Anaerobic digestion plant

SITA has in the past proposed the development of an Anaerobic Digestion (AD) plant in Mitcham, with an outline district heat network. The scheme was granted planning permission in 2011 but it is understood that the scheme is not currently going forward. Unless the scheme is brought back online, this energy source will no longer be considered as part of this study.

7.4.4. Electrical substations

Electrical substations represent a potential source of heat, as their continued operation produces low temperature heat. There are a number of electricity substations in Merton. Most contain smaller step down transformers which do not emit sufficient heat to warrant heat recovery. An electricity substation of 1320MVA capacity has been identified in North East Merton on Plough Lane next to Wimbledon Stadium (see Figure 7–5).

The substation is operated by UKPN, and whilst no details on the substation were confirmed by them, AECOM initial investigations suggested that there are:

- 4no. 240MVA 275/133kV transformers
- 2no. 180MVA 275/133kV transformers

With very few projects in existence that utilise waste heat from substations, it is hard to accurately estimate the amount of heat that might be available from this site. Some high level assumptions and calculations have been made to test the economic feasibility of installing the necessary pipework and equipment to serve a network in CWSW.

Assumptions:

1. Transformers are on average 25% loaded throughout the year
2. Of the six transformers on site totalling 1360MVA, UKPN only agree to allow heat recovery from three of them for resilience purposes, i.e. 680MVA is available for heat recovery
3. Transformers are 98% efficient at stepping down the voltage of the electrical power, i.e. 2% of the energy handled on site is wasted.
4. Of this wasted energy, only 60% of it is heat of an appropriate temperature for input to a DEN and possible to capture with heat recovery systems.
5. 15% of recovered heat is lost during distribution
6. Heat is recovered at 50°C[8], and raised to 95°C with a heat pump operating at a COP of 4.
7. Electricity is purchased at 10p/kWh to run the heat pump
8. 1.6km of pipework is necessary, installed at a cost of £1,200/m.
9. A further c. £1m is required for plant and works on the substation
10. Low grade heat is purchased from UKPN cheaper than it is sold on the network, such that the profit margin on 1kWh of heat is £0.02 (two pence per kWh).

Working through these assumptions results in the following high level results (all numbers approximate):

Energy supplied: 6.7GWh (27% of the total heat requirement of the proposed CWSW network)

CAPEX: £3m

Heat sales revenue: £810k p.a.

Cost of electricity for heat pumps: £1.2m p.a.

This high level estimation suggests that due to the difference in price between the cost of electricity and the revenues from heat sales, the cost of operating the system could be higher than the amount of revenue generated, i.e. it runs at a loss. This is due to the requirement for a heat pump to increase the temperature of the low grade recovered heat to the network temperature of 95°C and the fact that, unlike typical air, water or ground sourced heat pumps, the low grade heat is not free. Were it possible to reduce the network temperature to 50°C, then there would be no requirement for heat pumps and the scheme could run at a profit and further high level calculations suggest a payback of around 20 years.

Whilst this option could still present an opportunity in Merton, significant works to the secondary side systems of buildings connected would be necessary to reduce supply temperatures and ensure that the scheme runs at a profit.

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[8] London's Zero Carbon Energy Resource Report, July 2013
https://www.london.gov.uk/sites/default/files/gla_migrate_files_destination/031250%20GLA%20Secondary%20Heat%20-%20Summary%20Report_0.pdf

7.4.5. Planned CHPs

There are two proposed CHPs that have been granted planning permission and are currently under construction at the following locations:

- Wimbledon Leisure Centre
- Morden Park Swimming Pool

An investigation of the plant capacity of these units will be necessary in the next phase of this study, to investigate whether there is any spare capacity to enable them to export heat into a wider Merton DEN, extending their operational hours and increasing the revenue associated with their generation of electricity.

7.4.6. Water Source Heat Pumps (WSHP)

The River Wandle and the River Graveney run through Merton, joining near Haydons Road in North Wimbledon. The BEIS national heat map[9] suggests that the heating capacity of this river is 3.6MW, but it is unclear whether this figure is attributed to both rivers, or only after they join together (see Figure 7-7).

Whilst 3.6MW is of sufficient scale to represent the heat requirement of a small network, all buildings on this network would be required to have low heating supply temperatures if the heat pumps are to operate efficiently and the network is to be financially viable.

The BEIS heat map states that the river is at an average temperature of around 9°C. Assuming a 5K temperature difference on the heat pump evaporator, then the evaporating temperature will be 4°C. Using the following assumptions, the efficiency of a WSHP on the River Wandle can be estimated for two potential heating supply temperatures:

- 5K temperature difference on the condensing side of the heat pump
- Carnot efficiency (ηCarnot) of 50%[10]
- Where:

$$\mathrm{COP_{Carnot}} = \frac{T_{hot}}{T_{hot} - T_{cold}}$$

- And:

$$\mathrm{COP_{Actual}} = \eta_{Carnot} \times \mathrm{COP_{Carnot}}$$

This methodology results in average COP estimations of 3.8 and 2.6 for heating supply temperatures of 50 and 80°C. Considering the current spark gap and the above estimated COPs, a WSHP would only be viable in Merton if ultra-low supply temperatures were achievable. Either all buildings would need to be new developments, or existing buildings would require significant upgrades to their secondary side distribution systems – a costly and disruptive exercise.

The proximity of the River Wandle to the High Path Estate suggests that there may be scope for utilising the heat capacity of the river to serve an ultra-low temperature network in this development, perhaps in conjunction with heat recovery from the London Underground. The council would have to work closely with the developers, Circle, to enable this.

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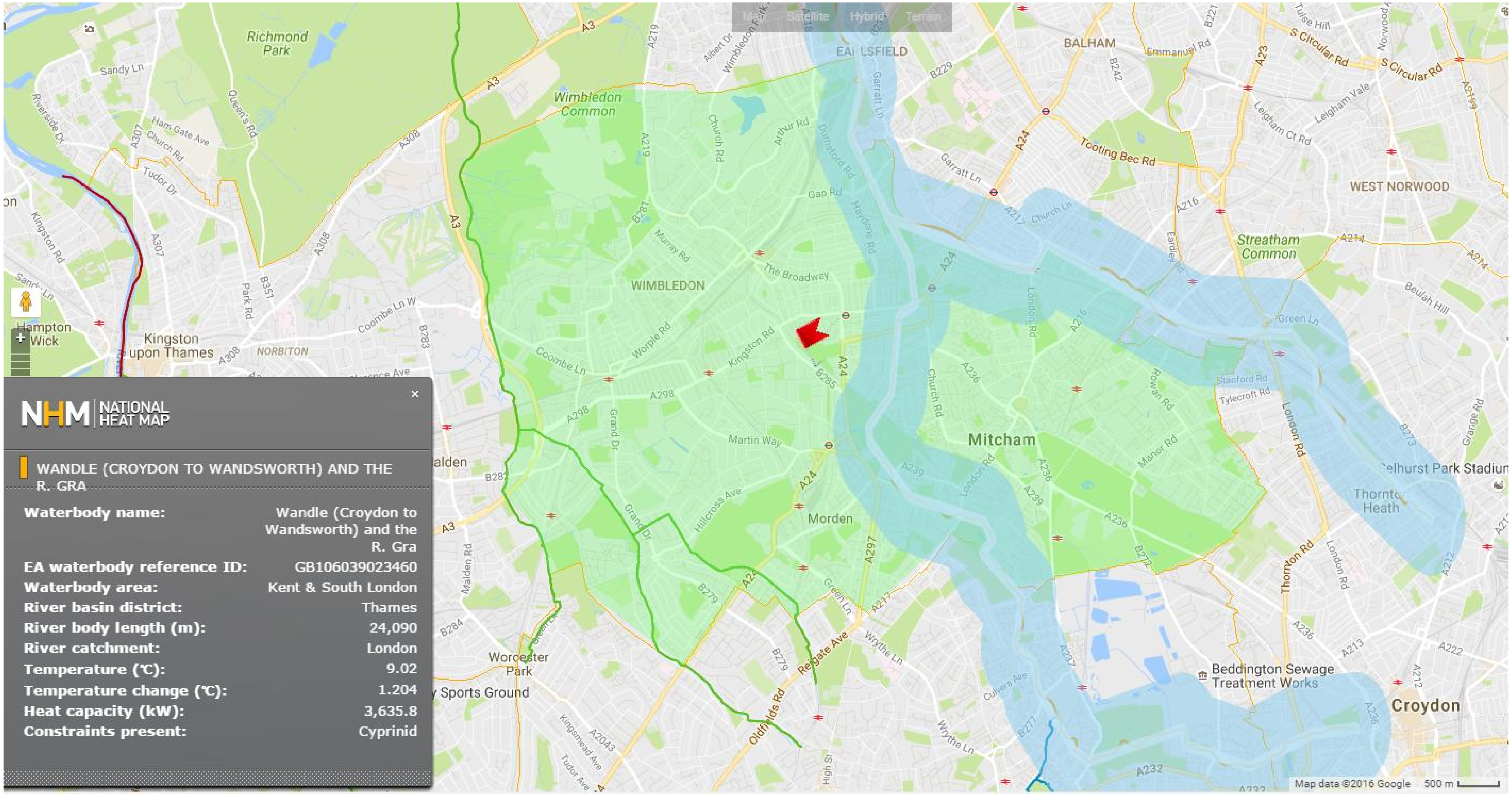
[9] Information taken from the BEIS National Heat Map http://tools.decc.gov.uk/nationalheatmap/#

[10] The Carnot COP is the theoretical maximum efficiency of a heat pump operating between two temperatures. The Carnot efficiency is a measure of how the heat pump actually performs in comparison to this theoretical maximum. For air, water and ground source heat pumps supplying heating to buildings, Carnot efficiencies of 50-60% can be expected.



WANDLE (CROYDON TO WANDSWORTH) AND THE R. GRA

Waterbody name: Wandle (Croydon to Wandsworth) and the R. Gra

EA waterbody reference ID: GB106039023460

Waterbody area: Kent & South London

River basin district: Thames

River body length (m): 24,090

River catchment: London

Temperature (℃): 9.02

Temperature change (℃): 1.204

Heat capacity (kW): 3,635.8

Constraints present: Cyprinid

Figure 7-7: Water source heat pump potential in Merton

8. Energy Centre Considerations

The delivery of district heating to buildings in Merton would be through the centralised generation of heat. Heat generation plant 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.

Based on the technology review summarised in Sections 6 & 7, it is proposed that the Energy Centre will operate gas-fired combustion plant (including boiler systems and CHP engines) at inception. The proposed EC 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.

8.1 Peak Heating Demand

The peak network demand for heat is a key factor in calculating thermal generation plant sizes and 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:

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

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 diversity factor may be less than 0.1 (Danish Standard DS 439) and can be as low as 0.05. On networks whose buildings are largely commercial, diversity factors are typically much higher, to reflect the similar operation of these buildings that require pre-heating of the space prior to opening times. For the purposes of this study, a diversity factor of 0.1 has been applied to residential dwellings, and 0.85 applied to commercial properties.

Analysis was undertaken for each considered building with an AECOM in-house tool which uses degree day analysis and suitable occupancy patterns per building type to estimate the peak demand from an annual total consumption. The tool allows for peak demand to be calculated separately for space heating and DHW on the basis that they experience different demand profiles. To do so, annual total space heating consumption and annual total DHW consumption are estimated making use of the split assumptions outlined in Table 8-1.

Table 8-1: Space Heating/DHW Split for different building types

Use	Data Source	Space Heating	Domestic Hot Water (DHW)
Retail	Modelling Experience	90%	10%
Clinic	CIBSE Guide F	70%	30%
Swimming Pool Centre	CIBSE Guide F	50%	50%
Fitness Centre-no pool	CIBSE Guide F	80%	20%
Offices	Modelling Experience	90%	10%
School	Modelling Experience	80%	20%
University Campus	Modelling Experience	80%	20%
Prison	Modelling Experience	70%	30%
Cinema	Modelling Experience	80%	20%
Hotel	CIBSE Guide F	70%	30%
Café	Modelling Experience	20%	80%
Residential	Modelling Experience	40%	60%
Community Area	Modelling Experience	90%	10%

8.2 Energy Centre Capacity

Having analysed the peak annual heating demands and diversity of loads required in both network options, together with other key considerations such as required boiler resilience and CHP heat provision, the appropriate composition of EC plant has been identified for each of the investigated heat networks as presented in Table 8-2. The numbers given represent the requirements for the whole network; further granularity on various network options is provided in Sections 11 and 12.

Based on the anticipated loads for the schemes identified, the CHP and boiler plant capacity required to service the different heat networks have been sized. High level CHP sizing is made from assumed CHP run hours of 6,500, with a good quality benchmark of 75% of all heat supplied via CHP. The high level CHP sizing does not account for multiple units being installed, as hourly heat profiling has not been undertaken at this stage.

The remaining 25% heat consumption would be met by boilers. For the purposes of this high level EC appraisal, it is assumed that 6 boilers with N+1 resilience are installed.

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.

Note that, at this stage, there has been no assessment of whether the space requirements for these proposed Energy Centres align with the space availability in the locations discussed in Section 8.3.1. This assessment must undergo further analysis in future stages of this study order to ascertain whether the locations identified can accommodate the required Energy Centre.

Table 8-2: Technical parameters of proposed networks

	CWSW	MTCML
Thermal Energy Balance		
Total end user thermal consumption (MWh$_{th}$ p.a.)	27,600	10,400
Total network thermal load at EC (MWh$_{th}$ p.a.)	31,800	12,000
CHP heat provision (MWh$_{th}$ p.a.)	22,300	8,400
Heat network top up boiler heat provision (MWh$_{th}$ p.a.)	9,500	3,600
Plant Installation		
CHP system size (kWth)	3,400	1,300
HN Gas boiler capacity (kWth)	18,800	8,300
Total EC Capacity (kWth)	22,200	9,600
New External Energy Centre size (m^2)	2,200	960
Fuel and Carbon Balance		
Total gas demand (MWh/year)	66,200	24,100
CHP electricity output (MWh/year)	22,300	7,600
40 year cumulative carbon emission savings (tonnes CO2e)	17,000	4,900

8.3 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 a DHN in Merton and will require the following consideration in future phases of this study:

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

A shape file of council owned land in Merton was provided, as shown in Figure 7-3. This map was assessed with regards to the proposed network routes and possible EC locations were identified, as shown in Figure 8-1. The numbers shown in the diagram correspond to those in Table 8-3 and Table 8-4, where the advantages and disadvantages of using each of the proposed locations are explored.

(a)

(b)

Figure 8-1: Potential energy centre locations in (a) the CWSW opportunity area and (b) the MTCML opportunity area (see Table 8-3 and Table 8-4)

Table 8-3: EC Locations (CWSW)

Map ID / Location	Total area (m^2)	Commentary and Conclusions	Map ID / Location	Total area (m^2)	Commentary and Conclusions
1. Wimbledon Theatre, 93 The Broadway	1,550	Advantages: · There is good access to the building via the outside carpark. Disadvantages: · Not located centrally or in close proximity to the wider network · Unlikely to be sufficient space in the building to serve the whole network. · The construction would be likely to disturb the operations of the building. Conclusion: Unviable location for the EC as it is likely there is not sufficient space available.	4. Hartfield Road Shopping Centre	3,120	Advantages: · There is a large amount of potential space. · The building is tall which would aid the installation of flues to a height higher than surrounding buildings. Disadvantages: · Possible poor accessibility due to the location being a busy shopping area. This could also cause losses for retailers. · Not in close proximity to loads – additional pipework implications Conclusion: Unlikely location for an EC due to location and current land use
2. Car Park, 111-127 The Broadway	2,090	Advantages: · Good access for installation, maintenance and removal of plant. · Offers a clear area for the construction of an EC. Disadvantages: · Not in close proximity to loads – additional pipework and thermal losses implications · Car parking spaces would be lost; cost of this would have to be included in financial modelling of network. · Potentially no existing sufficient gas/elec infrastructure. Conclusion: This is a potential location for the EC. A cost benefit analysis would be required to see the impact of the revenue lost from the car park.	5. Wimbledon Leisure Centre	3,900	Advantages: · A CHP is already located on site · Large onsite heat load and in close proximity to other heat loads · There is good access into the leisure centre through its car park. · The building is 2 stories high which will aid the installation of the plant equipment. Disadvantages: · The CHP which will have been proposed will be undersized for the network. Thus the work gone towards sizing the initial CHP will have to be adjusted. Conclusion: This site offers an ideal location for an EC as it is council owned, has a CHP unit already and has a large heat load. There are cost implications with replacing and resizing existing CHP.
3. Hartfield Road Car Park	4,080	Advantages: · There is good access for installation, maintenance and removal of plant · There is a lot of available space in this location. · There will be an open area of land on which to construct the EC. Disadvantages: · Not in close proximity to loads – additional pipework and thermal losses implications · There is no existing gas/elec infrastructure. Conclusion: Low priority location for the EC due to the distance from the network.	6. South Wimbledon Community Centre	3,920	Advantages: · Near the centre of the load cluster. Disadvantages: · Unlikely that there will be much available space on site for a new building Conclusion: Though the building is located centrally, the available space is small – not recommended

Map ID / Location	Total area (m^2)	Commentary and Conclusions	Map ID / Location	Total area (m^2)	Commentary and Conclusions
7. Haydons Road Recreational Centre	35,180	Advantages: · Large area of available space. · Close to identified heat loads Disadvantages: · No existing gas/elec infrastructure. · Potential planning permission issues due to current land use as recreational area · No heat load on site. Conclusion: Despite the good location and the large amount of potential space this is a low priority location due to potential planning issues.	**9. High Path Park**	3,710	Advantages: · Large amount of open space Disadvantages: · The park is located approximately 80m from the cluster loads. · Potential planning permission issues due to current land use as public amenity space · There is no existing infrastructure. Conclusion: This is not a viable location for an EC.
8. Merton Abbey Primary School	10,730	Advantages: · Has a small on-site heat load and is located close to other loads · Good access from two main roads to allow for installation, maintenance and removal of plant equipment. Disadvantages: · Construction would likely be preferred during school holidays. · Although the total area is large, it is unlikely that the site will have the required available space. Conclusion: This location is worthy of future investigation	**10. High Path Estate**	~100,000	Advantages: · Located in the area of highest heat demand in South Wimbledon. · New development site, thus the opportunity to incorporate EC design as part of the building. · Located near the central network. · Has one of the largest heat loads in the area Disadvantages: · Dependency on developer for approval. Conclusion: The site is in a potentially ideal location for the EC but its availability is dependent on the developer.

Table 8-4: EC Locations (MTCML)

Map ID / Location	Total area (m^2)	Commentary and Conclusions	Map ID / Location	Total area (m^2)	Commentary and Conclusions
1. Morden Park Swimming Pool	2,500	Advantages: · There is good access to the building via a car park nearby which is just off the main road (London Road). · Close proximity to heat loads · A CHP unit is already in use on site. Disadvantages: · The swimming pool is located approximately 1km from the wider cluster of heat loads in Morden Town Centre. · Unclear whether there is sufficient space available on site · Cost implication association with resizing and replacement of existing CHP Conclusion: This location is low priority due to the distance of the location from the wider network in Morden town centre	3. Abbotsbury Primary School	26,060	Advantages: · There is a large amount of potential space. Disadvantages: · Potentially poor access · Construction will likely be preferred to be phased with school holidays · Not in close proximity to heat loads Conclusion: This location is low priority due to the large distance from the network route which would require significant additional pipework and associated cost
2. Morden Primary School	8,190	Advantages: · Close proximity to heat loads to the south of the opportunity area (Morden Leisure Centre) Disadvantages: · Construction will likely be preferred to be phased with school holidays · Unlikely that there will be sufficient available space on site for the EC · It is approximately 1km away from the wider network in Morden town centre. Conclusion: This location is low priority due to the distance of the location from the wider network in Morden town centre	4. York Close Car Park	6,110	Advantages: · The car park is positioned at the centre of the heat load cluster · There is a large amount of available open space. Disadvantages: · Reallocating space for the EC would result in a loss of car parking spaces Conclusion: This represents a high priority location for EC.

Map ID / Location	Total area (m²)	Commentary and Conclusions	Map ID / Location	Total area (m²)	Commentary and Conclusions
5. Merton Civic Centre	8,080	Advantages: · The site contains the largest heat load in the cluster and there is a high density of heat loads nearby. · The building is easy to access as the main road forms a perimeter around the Civic Centre and there is a car park which is accessible from the A24. · The building is tall which will aid with flue arrangements required to disperse above nearby buildings. · It is itself a large heat load on the network, so will require minimal additional pipework · There is currently a site under planning, thus the plant room could be incorporated into this project. · There is potential for the Council to operate this as it is located in their headquarters. Disadvantages: · Unclear whether there is sufficient available area on site Conclusion: The Merton Civic Centre offers a potential location for the EC, if there is sufficient space available. .	7. Kenley Road Car Park	3,580	Advantages: · There is a large amount of open space available to construct the EC. · It is located next to the pipeline with heat loads located nearby. Disadvantages: · Revenue would be lost from the car spaces which would be removed due to the EC. · There is no existing gas/elec infrastructure. Conclusion: This is a viable location for an EC as it offers a large clear space in close proximity to the heat loads.
6. Sainsbury's Car Park	4,900	Advantages: · There is a large amount of open space on site · Proximity to a number of heating loads, reducing distribution heat losses and pipework costs · Located adjacent to the proposed heat cluster Disadvantages: · Revenue would be lost from the car spaces which would be removed due to the EC. This cost must be factored into the financial model · The area is shown to be council owned but the lease agreement terms with Sainsbury's (who operate the car park) are unknown. Sainsbury's will not be in favour of losing car park spaces. Conclusion: Low priority location for the EC due to the risks around the ownership/lease agreement of the existing car park			

8.3.1.EC Location Appraisal Conclusion

Based on the findings of the location appraisal detailed in Table 8-3 and Table 8-4 the following EC locations are to be investigated for the purposes of modelling the two masterplan options:

CWSW masterplan:

On the basis of the high level assessment described above, the High Path Estate (Location 10 on map a) in Figure 8-1) has been selected as the most appropriate location for the following reasons:

- Located centrally to the heat network cluster
- The development is still undergoing design, giving the council an opportunity to influence planning requirements
- There is a large amount of available space

Whilst early engagement has been undertaken with the developer as part of this study, further investigation of whether this is a viable option is necessary. This will be carried out at the beginning of Phase 2 of this study.

The assumption that the Energy Centre could be located in the High Path Estate development is a high risk item that must be mitigated at the earliest opportunity (see Appendix B). If it found that this location is not viable, the council must seek to identify alternative locations in the vicinity.

MTCML masterplan:

On the basis of the high level assessment described above, Merton Civic Centre (Location 5 on map b) in Figure 8-1) has been selected as the most appropriate location for the following reasons:

- The building is located close to the large heat loads in the cluster, and also to a number of new developments that would be sought for connection at a later stage
- There may be existing plant room area availability
- Existing electrical infrastructure on site
- The building is tall, aiding necessary flue arrangements
- The building itself has high heat consumption, meaning that the losses associated with servicing that load are minimised.

Despite these above recommendations for EC location, further investigation is required in the future phases of this study to better assess the viability of the locations.

8.4 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.

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

8.5 Electricity Generation

Utilising the electrical output from the CHP 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 CHP 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.

8.5.1.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 to ensure continued operation of the CHP, 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 CHP 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 (often between £0.08-0.13/kWh, depending on the customer’s scale of usage and tariff) 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. In London, large industrial customers are not so prevalent. However, the transport network, in particular the London underground and the national rail network, is a large user of electricity, with stations located both in Morden and South Wimbledon. The baseload of the TfL network alone is around 26MWe, showing significant capacity for electricity sales from CHP generated electricity. Initial discussions held with TfL indicate that they would welcome opportunities for purchasing cheaper electricity.

In CWSW, other eligible customers for private wire agreements would include certain commercial/industrial users in the Morden Industrial Estate and the Hyde Path development.

For the MTCML network it is suggested that electricity is also used on site in the Merton Civic Building, i.e. where the EC is proposed to be located. This will reduce the need for other private wire arrangements, and will be the most cost effective solution for the council.

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 affecting the operation of the CHP, since surplus electrical generation can spill over into the grid for direct grid export 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 (similar to the 20% suggested above) would likely need to be offered in order to secure agreement.

8.5.1.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/kWh at present rates).

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 at a later design stage.

8.6 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 – London'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.
- Flue Arrangements - Exhaust gases from the combustion plant will need to be expelled to atmosphere. This is typically done through flue chimneys that are sufficiently high to disperse the exhaust. Typically this requires the flue to be at least higher than surrounding buildings.
- 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.

9. Heat Distribution Network

The design of DH networks must consider local conditions, existing or planned infrastructure, physical or regulatory barriers and the potential for future expansion of the proposed network. This section describes the key considerations for designing a network in Merton and determines potential routes for the CWSW and MTCML network options.

9.1 Existing Infrastructure & Environmental/Urban Barriers

Information on the existing infrastructure barriers within Merton, including main roads, railways and waterways was collected and is presented in Figure 7-2

In addition, an investigation of the protected areas (i.e. conservation areas; AQMAs; areas of high grade agricultural land, etc.) and flood risk areas was undertaken to identify any potential environmental and/or urban considerations that should be taken into account in the development of an energy network.

9.2 Network Routing

Based on the physical barriers identified, indicative pipework routes for each option are shown in Figure 9-1 and Figure 9-2. Crossing main barriers such as major road systems, waterways and railways was avoided where possible. Where crossing of the River Wandle was necessary, existing crossings (i.e. road bridges or underpasses) were used to limit additional costs. The Northern line running across the areas is under ground and not considered as a physical barrier at this stage. See Section 9.5 for a summary of each network's physical constraints.

These routes should be subject to further scrutiny and detailed planning, should a network option be chosen for further development. For the purposes of this study, the network routing is used to estimate pipework lengths required for each identified network. This allows for approximate network costs to be developed, using a typical installed pipework cost assumption of £1,200/m of trench run.

Networks have been nominally split into areas (represented by different pipework colours on the maps), to allow easy comparison between different aspects of the proposed networks.

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.

9.3 Coordination with Existing Utilities

Coordination of pipework routing and 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:

- Gas, water and sewage mains
- Electrical cabling (HV and LV)
- Telecommunications (e.g. broadband)

Many of these services cannot be routed immediately adjacent to one another and may require certain distances to be maintained between them and the proposed DH pipework. It is recommended that a review of these services is undertaken at an early design stage in order to confirm the proposed pipework route.

9.4 Pipework

Detailed pipework sizing and specification should be undertaken at a later design stage. It is important that good quality pipework, with high levels of insulation and manufacture is specified. Additionally, installation of the pipework should be undertaken by experienced contractors in order to reduce the potential for damage during installation. Damaged or defected pipework is likely to increase heat losses while in operation and has a higher risk of developing a leakage.

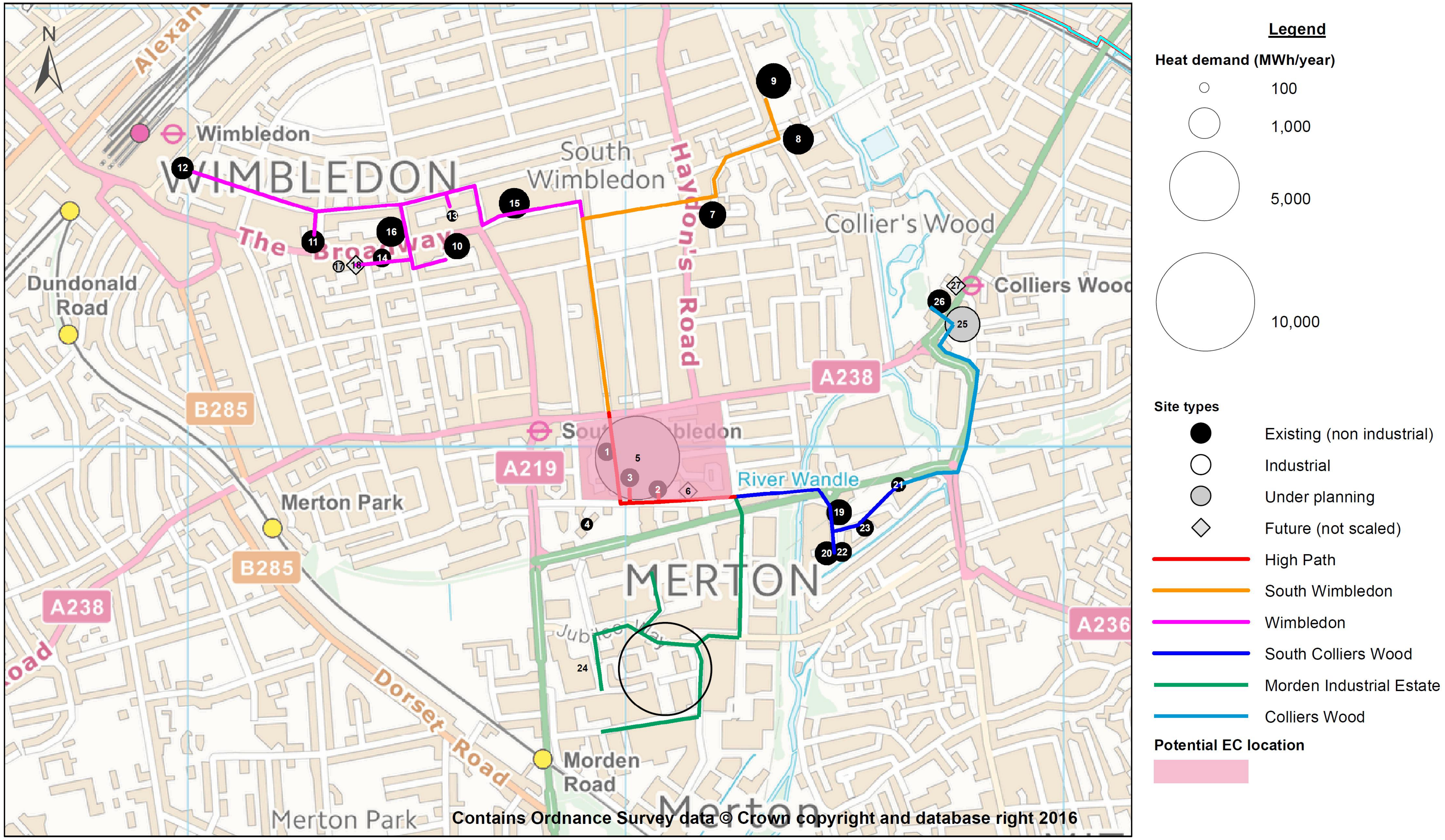


Figure 9-1: Indicative CWSW network routing and EC location (see Table 7-1 for building references)

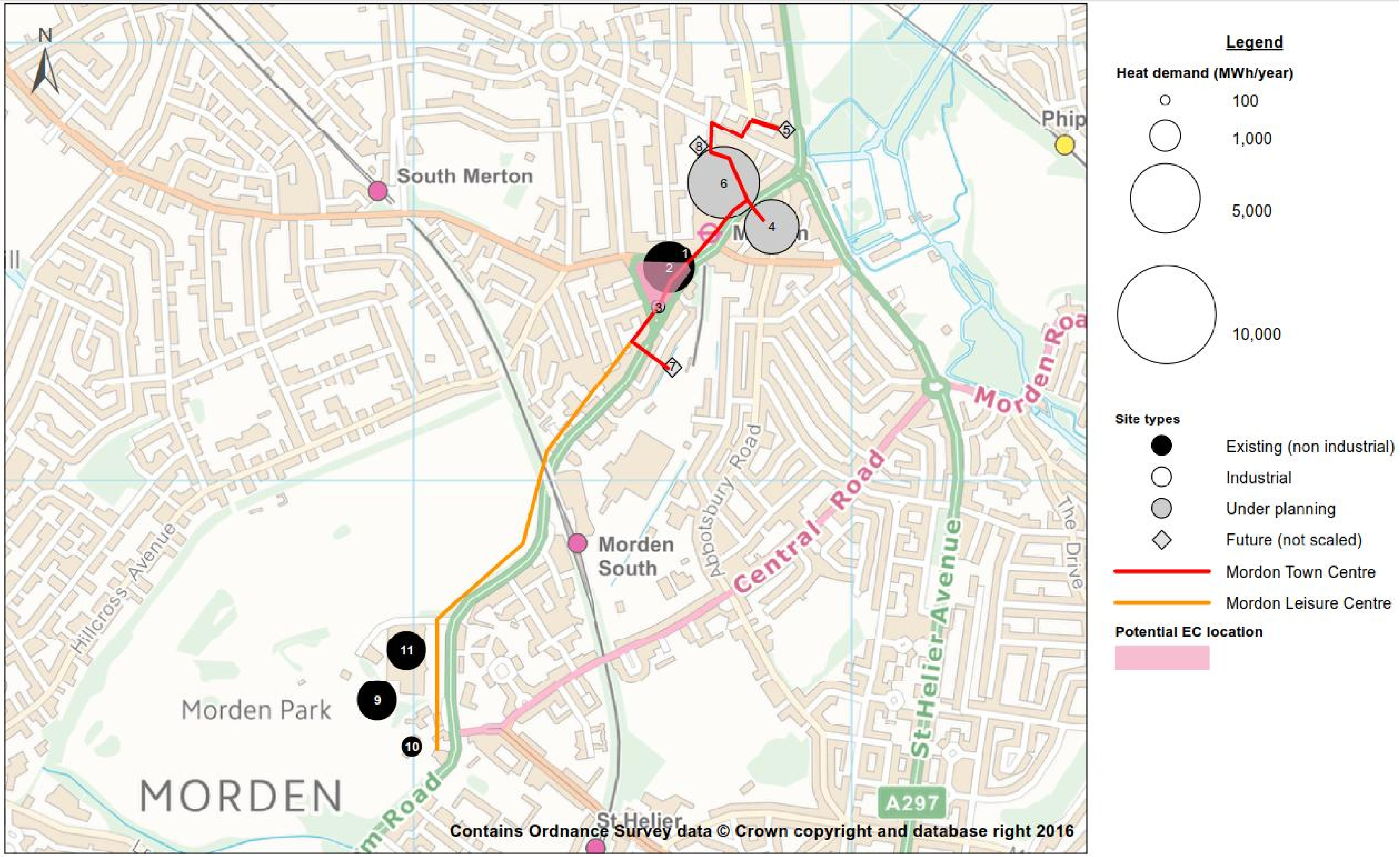


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Figure 9-2: Indicative MTCML network routing and EC location (see Table 7-2 for building references)

9.5 Key Network Constraints/Considerations

Physical constraints and key infrastructure considerations in the investigated opportunity areas were highlighted in Section 7.3. Those that will be encountered by the proposed pipework routing detailed in Section 9.2 are summarised in Table 9-1.

Table 9-1: Key network constraints

	Constraint/infrastructure consideration	Notes
CWSW	Northern Line Underground Line crossing, Merton High Street	Since the Northern Line is underground at this location, it is assumed that it does not present a significant constraint to pipework routing
	River Wandle	The proposed routing follows the A24 as it crosses the River Wandle. Reviewing the technical viability of using this routing is necessary.
MTCML	Northern Line Underground Line crossing, London Road, A24	Since the Northern Line is underground at this location, it is assumed that it does not present a significant constraint to pipework routing
	Railway line crossing, London Road (adjacent to Morden South Station)	It is proposed that pipework is routed under the railway, through the existing tunnel of the A24. Due to the disruption that this will cause, increased pipework costs are expected to overcome this constraint. Alternative pipework routes such as along Hillcross Road and through Morden Park should be investigated.
	Road network improvements, London Road	The proposed road network improvements as shown in Figure 7-5 may help installation of pipework in that area, i.e. for serving the Abbotsbury Triangle and Morden Station developments.

9.6 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 can achieve heat losses as low as 10% or less, 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. Therefore, for this particular study, heat losses have been assumed to be in the order of 15%[11].

9.7 Operating Temperatures

Conventionally, temperatures of 82/71°C flow/return are used to serve radiators and other water based-heat emitters for space heating in existing buildings. However, in recent years there has been a drive to reduce network and service temperatures, both through the use of lower mean flow temperatures and achieving lower return temperatures, in an effort to both reduce distribution losses and to increase the efficiency of heat generating plant.

Ultra-low temperature (<70°C flow) networks are more efficient and potentially offer a more viable network for using heat pumps, since the efficiency of heat pumps reduces as operating temperatures increase.

The operating temperature of any district heating network will depend on the buildings that are connected to it. The network temperature should be reduced as much as possible whilst still being able to serve the heating loads on the network.

Where networks are serving predominantly older buildings with more conventional heating supply temperatures (~82/71°C flow/return), reducing network temperatures below this requires careful consideration. Many older radiators are oversized and are therefore capable of meeting heating demands with lower temperatures, but this requires detailed assessment. Where this is not possible, secondary heating supply networks can be changed to accommodate lower temperatures, but this entails significant and potentially prohibitive costs for the network.

For networks serving significant new developments (e.g. the Hyde Path Estate, Morden Station and Abbotsbury Triangle developments), ultra-low temperature DH networks operating in the region of 60-70°C flow (as opposed to conventional 90°C flow networks) may be more applicable.

The implementation of an ultra-low temperature district heating network is probably particularly suited to Scenario 1 of the MTCML network options, since both the Abbotsbury Triangle and the Morden Station developments, alongside other proposed future developments; represent a significant proportion of the heating loads. In this case it would be recommended that Merton Council engage with developers and impose requirements for them to design to lower heating supply temperatures, such that the developments would be compatible. In this case, it would also be necessary to assess whether the Merton Civic building would be capable of having lower heating supply temperatures.

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[11] Chartered Institute of Building Services Engineers (CIBSE) (2015) *Heat Networks: Code of Practise for the UK*. London: CIBSE and the Association for Decentralised Energy (ADE)

9.8 Potential for Expansion

The heat footprint and future development plans in Merton support the potential to expand any potential DHN 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.

9.9 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 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 connection).

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 design of plantrooms within customer buildings for the heat substations should provide sufficient space for maintenance access and for future plant replacement.

10. Techno-Economic Modelling Assumptions

10.1 Introduction

This section details the assumptions made during the assessment of technical and economic feasibility of different network scenarios within the CWSW and MTCML areas. A full techno-economic model has been developed from first principles to allow for the comparison of the two network options, where heat generation technologies are assumed to be Gas CHP, with like-for-like replacement throughout the network lifespan.

The purpose of the model is to give an indication of the financial viability of the project under the assumed capital and operational costs, and associated energy sales revenues. A number of sensitivity scenarios on key assumptions have been investigated within the model to help understand the economic robustness of the projects and to identify risks to economic performance. The modelling process also gives an indication of the financial returns of the project. The key assumptions made and the outcomes of scenario and sensitivity testing are given below. The model allows for key sensitivities to be assessed, interrogating the effects of key parameters on the network viability.

10.2 Scenarios and timing

Each network has undergone modelling of potential scenarios, made up of the different network areas as identified in Section 9 (see Figure 9-1 and Figure 9-2). The scenarios are given in Table 10-1.

The model assumes that each network is constructed as a single unphased installation, with operation starting in 2018. In reality, a more likely strategy would be to phase the installation of different aspects of the network over the course of a few years. Such an approach would allow an initial network operation to be established, its operation and cash flow to be demonstrated, and to provide revenue streams to reduce financial risk. It is recommended that further detailed investigation, accounting for network phasing is undertaken in subsequent stages.

Table 10-1: Modelled network scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
CWSW	Hyde Path and South Colliers Wood	Hyde Path, South Colliers Wood and Central Colliers Wood	Hyde Path, South Colliers Wood, South Wimbledon and Wimbledon	Hyde Path, South Colliers Wood, Central Colliers Wood, South Wimbledon and Wimbledon	Hyde Path, South Colliers Wood, Central Colliers Wood, South Wimbledon, Wimbledon and Morden Industrial Estate
MTCML	Morden Town Centre	Morden Leisure Centre	Morden Town Centre and Morden Leisure Centre	-	-

10.3 CAPEX Assumptions

Values are derived from AECOM experience and suitable industry standards (such as SPONS), which have been back checked with contractors during the tender stages of other DH projects to ensure that values are up to date and accurate.

The key assumptions made in the estimation of the capital costs (CAPEX) of each network scenario are given below. The model updates the CAPEX values to reflect the user-selected parameters, i.e. which clusters are to be modelled and of these, which buildings within each cluster are included in the calculations.

Table 10-2: CAPEX metric assumptions

CAPEX item	Metric	Based on
Energy Centre:		
EC Construction (new)	£1,500/m^2	Applied to any additional EC area requirements over the existing suitable plant room area. This value reflects a basic EC building. For a higher aesthetic/architectural finish a value of £2,000/m^2 should be used.
Heat Generation Systems:		
Gas CHP engines	£950/kWth below 1MWth, £650/kW above 2MW. Linear relationship between	Thermal output capacity of large CHP engines
Thermal storage systems	£1,000/m^3	Total volume of required thermal storage vessels, assumed at 60m^3
Selective Catalytic Reduction units and urea storage tank	£100/kWth	Thermal output capacity of CHP engines
Boilers	£30/kW	Additional boiler thermal capacity
Other mechanical plant (incl. heat rejection, ventilation and noise attenuation)	£200/kW	Additional boiler thermal capacity
Water Systems:		
Water Systems	£5/kW	Energy centre total heat output capacity
Electrical Ancillaries:		
Sub-station including private HV transformers, HV switch room, LV switch gear, connection cost	£100,000	One off cost, subject to G59 application of local HV infrastructure upgrade requirements. Significant risk item – see Risk Register in Appendix B
Buried HV cable	£200/m	Required trench length of 55m
Gas Systems:		
Budget allowance for gas connection including pressure increasing equipment	£30,000	One off cost
Extension of buried low pressure gas main (<180mm dia.)	£120/m	Required trench length of 55m (subject to full gas network capacity study)
BMS/Controls:		
Budget allowance for BMS/Controls	£20/kWth	Energy centre total heat output capacity
External works:		
DH pipework	£1,200/m	Pipework length for each network option (average, to account for a mixture of hard dig and soft dig trenching)
Heat exchanger	£32/kW	Undiversified heat load, kW
Railway/tube crossing	£50,000	Cost per item, scenario specific
Other Costs/Fees:		
Professional fees	2.5%	Of sub-total
Legal fees	5.0%	Of sub-total
Contingency	15.0%	Of sub-total

10.3.1. Asset replacement cycles

The following assumptions have been made on the required replacement cycles of plant and equipment. All other plant and equipment is assumed to either last beyond the project lifetime or replacement costs are included in annual maintenance costs estimates. The table assumes that gas CHP is used as the replacement technology throughout the lifetime of the scheme. As discussed in Section 6.3, it is important that the council maintains continual reassessment of the heat generation replacement technologies for use in Merton, against the prevailing cost of fuel and the progression of grid decarbonisation.

Table 10-3: Asset replacement assumptions

Technology/asset	Replacement cycle	Replacement year (install 2018)
Gas CHP	Every 70,000 hours operation	2028 and 2039 (assuming 6,500 run hours per year)
EC boilers and thermal substations	Every 25 years	2042

10.4 OPEX Assumptions

10.4.1. Fuel costs

DECC published future fuel price projections from the Green Book Guidance Tables[12] were used:

- Electricity prices: Table 4, Commercial customers
- Gas prices: Table 5, Commercial customers

Within the Green Book tables, three bands of prices are given: High, Medium and Low. For the purposes of the model, it is assumed that customers are currently paying the High price for gas and electricity. The model allows comparison to be drawn between what price the network operator will pay for gas: either Medium or Low. This is because it is likely that the network operator will be able to buy fuel at a lower cost than customers in the area are currently paying due to buying fuel in larger quantities.

Figure 10-1 shows the HM Treasury Green Book future fuel price projections, showing the High scenario for electricity, and all three scenarios for gas. Fuel costs used in the model do not account for any uplift due to VAT or other fixed costs. Whilst these projections have been used in the model, it is important to note that the cost of fuel highly affects the network financial viability and that the projections made in the Green Book do not show any change to price beyond c. 2027, an unlikely scenario.

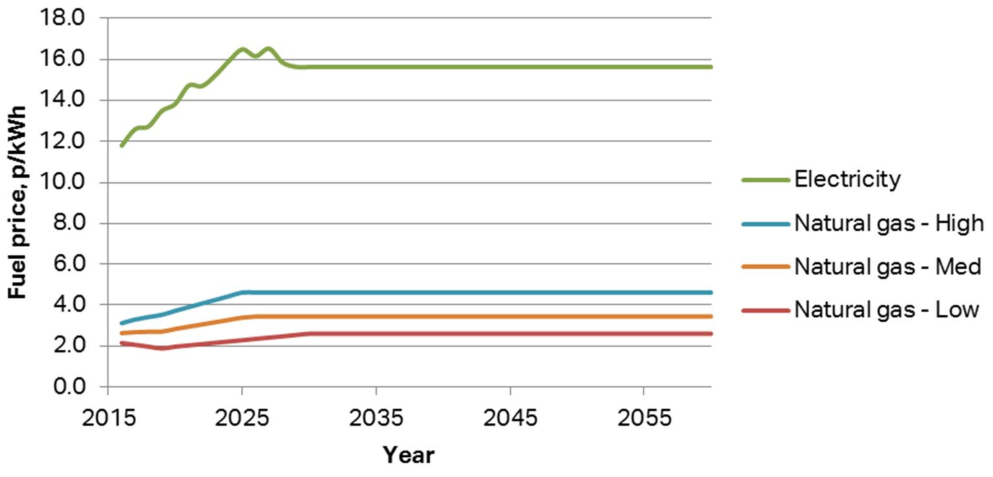

Figure 10-1: Bespoke emission factors for electricity displaced by gas CHP (gCO2/kWh) (BEIS, 2014)

10.4.2. Maintenance and staffing costs

Maintenance and staffing costs are assumed to be constant over the lifespan of the project. The figures given in Table 10-4 are based on AECOM experience and recent quotes from contractors and developers.

Table 10-4: OPEX assumptions

OPEX item	Metric	Based on
Maintenance:		
Gas CHP	£0.015/kWh$_{th}$ p.a.	CHP thermal energy output
Energy centre boilers	£2.25/kW p.a.	Boiler thermal output capacity
Thermal substations	£1.00/kW p.a.	Energy centre total thermal output capacity
Pipework	2%	Pipework CAPEX, spread over 50 year lifespan
Staffing costs:		
Heat meter reading and billing	0.15p/kWh$_{th}$	Site heat consumption
Staffing and management	0.25p/kWh$_{th}$	Site heat consumption

10.5 Revenue

Revenue will come from a number of sources, including direct charges for heat, fixed charges for operation (comparable to standing charges on conventional utility services), as well as any electricity income which may be available through sales 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. Additionally, in the case of energy recovery or biomass technologies, there may be revenue generated from the UK Government's RHI scheme.

10.5.1. 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

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[12] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/483282/Data_tables_1-20_supporting_the_toolkit_and_the_guidance.xlsx

- 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

The Client 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 scheme may be willing to pay a connection charge.

For the purposes of the model, connection charges have been assumed to be linked to the cost of replacing boiler plant in each building, less a user-specified discount rate. The default values chosen for the results of the model are that plant is assumed to be replaced once over the 40 year lifespan of the network, and that the cost of this replacement is equal to £100/kW of the building's peak heating demand. A discount of 50% is then applied thereafter.

10.5.2. Heat sales

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.

It has been assumed that heat demand does not fluctuate from year to year over the assessment period, i.e. no allowance is made for future developments, or redevelopment of existing buildings, beyond those captured by the energy mapping study herein.

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.

For the purposes of the model, the Fixed Charge is calculated against the estimated costs of maintaining their current system, with an applied discount. Boiler maintenance costs are estimated at £2.25/kW p.a. as shown in Table 10-4.

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.

For the purposes of the model, the variable charge for heat is linked to the DECC predictions for the price of gas, less a nominal assumed boiler efficiency of 85% and a user selected discount beyond this such that customers are offered savings on their heat bills.

Proposed Charges

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.

The model details IRR, NPV and customer savings over the lifetime of the network. Users can alter the discount rates used to calculate the variable and fixed charges for customers to explore the limitations of what can be charged to customers in order to offer them a saving whilst also delivering an attractively high IRR.

10.5.3. Electricity revenue

The electricity generated by the CHP (which is not already being used by the energy centre itself) can either be sold privately or exported to the grid. Current electricity prices are between 13-17p/kWh retail[13] and 3-6p/kWh wholesale[14].

Revenue generated through exporting energy to National Grid will be at wholesale (rather than retail) prices. However, there are a number of opportunities available to exploit peak demand periods and gain access to availability payments for generation capacity being available, as described below:

- TRIAD refers to the three half-hour periods of highest electricity demand between November and February. If exporting to the network during these periods, the local network operator will recompense the generator for reducing fees payable to National Grid. The amount paid depends on the local electricity network operator, and the contract with whomever buys the electricity, but it can be worth in the region of £25,000 - 30,000 each year per MW of electricity generation capacity.

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[13] Average variable unit costs and fixed costs for electricity for selected towns and cities in the UK (QEP 2.2.4)

[14] http://www.energybrokers.co.uk/electricity/historic-price-data-graph.htm

The TRIAD periods are determined in retrospect so it is not possible to know for certain when these periods will occur. It is therefore difficult to be certain that TRIAD income will be receivable and so we have not included this income in the modelling.

- STOR (Short Term Operating Reserve) - At certain times of the day National Grid needs reserve power in the form of either generation or demand reduction to be able to deal with actual demand being greater than forecast demand and/or plant unavailability. National Grid will procure part of this requirement ahead of time through STOR. A STOR provider must be able to offer a minimum of 3MW capacity. The amount of revenue available depends on the location of the capacity and the season during which it is available, however, such contracts can be worth in the region of £10,000 – 15,000 each year per MW of electricity generation capacity. Given the generating capacity of this project, it is unlikely that the required capacity can be made available to the grid and therefore we have not included this income in the modelling.

Revenue generated through the sale of electricity via private wire or a sleeving arrangement 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 what they would pay otherwise. The rate that electricity is sold at via private wire is adjustable in the model. See Section 10.6 for details on the default values used in this report.

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 or sleeving arrangement to that which is exported at whole sale rates affects the commercial viability of the network significantly. As such, this is highlighted as a key risk item that should be subject to further investigation in subsequent studies. Whilst it is preferable to sell all generated electricity privately, AECOM recognises that this may not be technically feasible. Instead, a conservative assumption is made, that only 75% of generated electricity is sold privately, with the remainder exported.

The model allows the user to select the proportion of electricity sold privately to that exported to the grid. Given the likely constraints regarding the potential to export to the grid, default values for the purposes of the results given in this report are that all electricity is sold privately at a discount rate of 10% against the HMT Green Book retail price.

10.6 Default Parameters

The default values chosen for the results given in this section are listed below. Electricity revenues are calculated based on a reduction from the predicted future retail prices as given in Figure 10-1.

Table 10-5: Default parameters used within the model for analysis

Parameter	Value	Report section reference
First year of scheme operation	2018	10.2
CHP run hours	6,500	8.2
CHP heat provision, % of total	75%	8.2
Network distribution heat losses	20%	9.5
Proportion of electricity sold via private wire	75%	8.5
Private wire electricity discount rate against retail price	10%	10.5.3
Exported electricity discount rate against retail price (i.e. wholesale)	50%	10.5.3
Exported heat discount rate against self-generation (heat)	10%	10.5.2
Connection charge discount against customer boiler replacement costs	50%	10.5.2
Standing charge discount rate against customer boiler maintenance costs	50%	10.5.2
Discount rate	3.5%	10.10

10.7 Carbon

Scheme carbon savings depend on the input fuel and the associated carbon factors of the grid electricity which is being offset by the CHP electricity. Emissions associated with the combustion of gas are assumed to be constant over the lifetime of the project, where the emission factor used is 0.184kgCO$_2$e/kWh, based on UK Government GHG Conversion Factors 2016[15]. Electricity carbon factors are taken from the DECC (now BEIS) bespoke CHP emissions factors[16] spreadsheet for electricity exported and used on site (Figure 10-2). This analysis accounts for the decarbonisation of the grid, where emissions are calculated based on the amount of electricity generated by the CHP that is used on site, as opposed to that which is exported. The model calculates the CO$_2$ emissions savings for each year of operation, based on the forecast carbon factors. Full project life savings will also be reported.

Gas CHP currently delivers carbon savings 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.

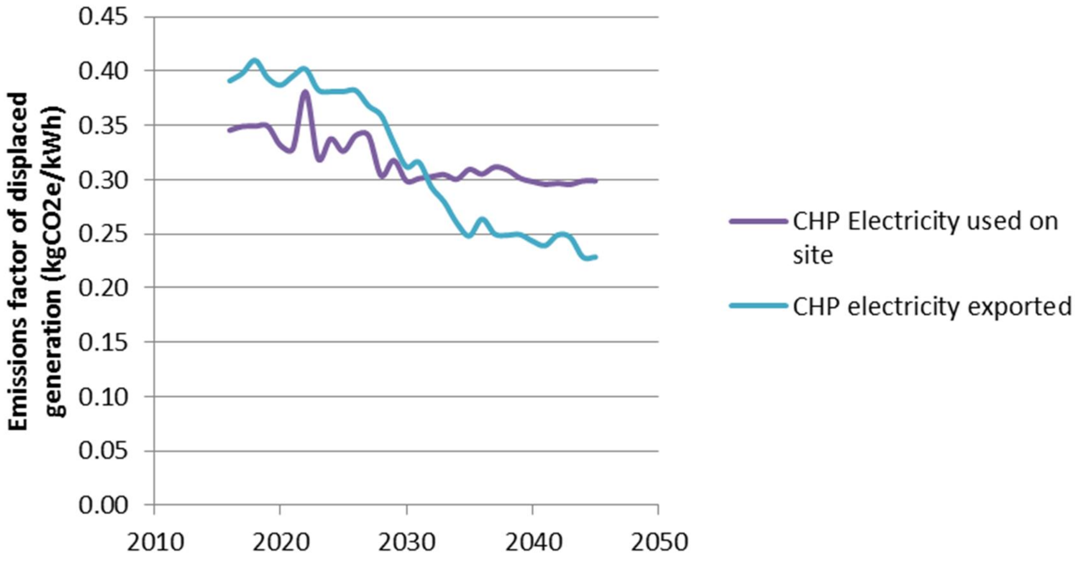

Figure 10-2: Bespoke emission factors for electricity displaced by gas CHP (gCO2/kWh) (BEIS, 2014)

10.8 Tax

We have not modelled VAT in the model as it only has a small impact on the cashflow due to the short construction period. Since this overlaps with operation it is therefore not be expected to impact the feasibility of the project.

10.9 Scheme Ownership

The model assumes the network is operated by a separate entity, referred to as the ‘ESCo’, or Energy Supply Company. Costs are borne by the new company, and if the network includes Merton Council buildings, then they are treated as any other customer on the network. In this scenario, LB Merton would experience the same costs and savings as the other customers.

10.10 Discount Rates

Discount rates are used to represent the future value of money spent now. In the UK, the government makes decisions based on ‘discounted Net Present Value (NPV)’, which is a calculation that helps inform whether a capital outlay made today will be worthwhile in the future. The model assumes a constant discount rate over the life of the network of 3.5%[17].

10.11 Financing Options

The model does not consider at this stage the impact of financing (e.g. the cost of raising finance, servicing debt, debt limits, types of credit etc.). The next stage of this study will advance the modelling of a chosen network option, accounting for these elements.

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[15] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/526958/ghg-conversion-factors-2016update_MASTER__links_removed__v2.xls accessed 20th July 2016

[16] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/446512/Emissions_Factors_for_Electricity_Displaced_by_Gas_CHP.xlsx accessed 20th July 2016

[17] Based on values taken from https://data.gov.uk/sib_knowledge_box/discount-rates-and-net-present-value, accessed 1st August 2016

11. Techno-Economic Modelling Results: CWSW

This section details the results outputs from the techno-economic model for the key network scenarios identified in Section 10.2 and shown again in Table 11-1 and Figure 11-1 for the CWSW network. Due to the high number of user-variable parameters throughout the model, not all results can be presented in this report. Instead, sensible parameters for each variable have been chosen (as given in section 10.6) and the resultant outputs detailed in this section. Thereafter, a sensitivity analysis is carried out around some of the key parameters to identify the effects of various parameters on system feasibility.

Where results are shown against a 'counterfactual', this refers to the 'do-nothing' base case, i.e. where buildings are assumed to have their own individual boiler plant.

Table 11-1: CWSW modelled network scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
CWSW	Hyde Path and South Colliers Wood	Hyde Path, South Colliers Wood and Central Colliers Wood	Hyde Path, South Colliers Wood, South Wimbledon and Wimbledon	Hyde Path, South Colliers Wood, Central Colliers Wood, South Wimbledon and Wimbledon	Hyde Path, South Colliers Wood, Central Colliers Wood, South Wimbledon, Wimbledon and Morden Industrial Estate

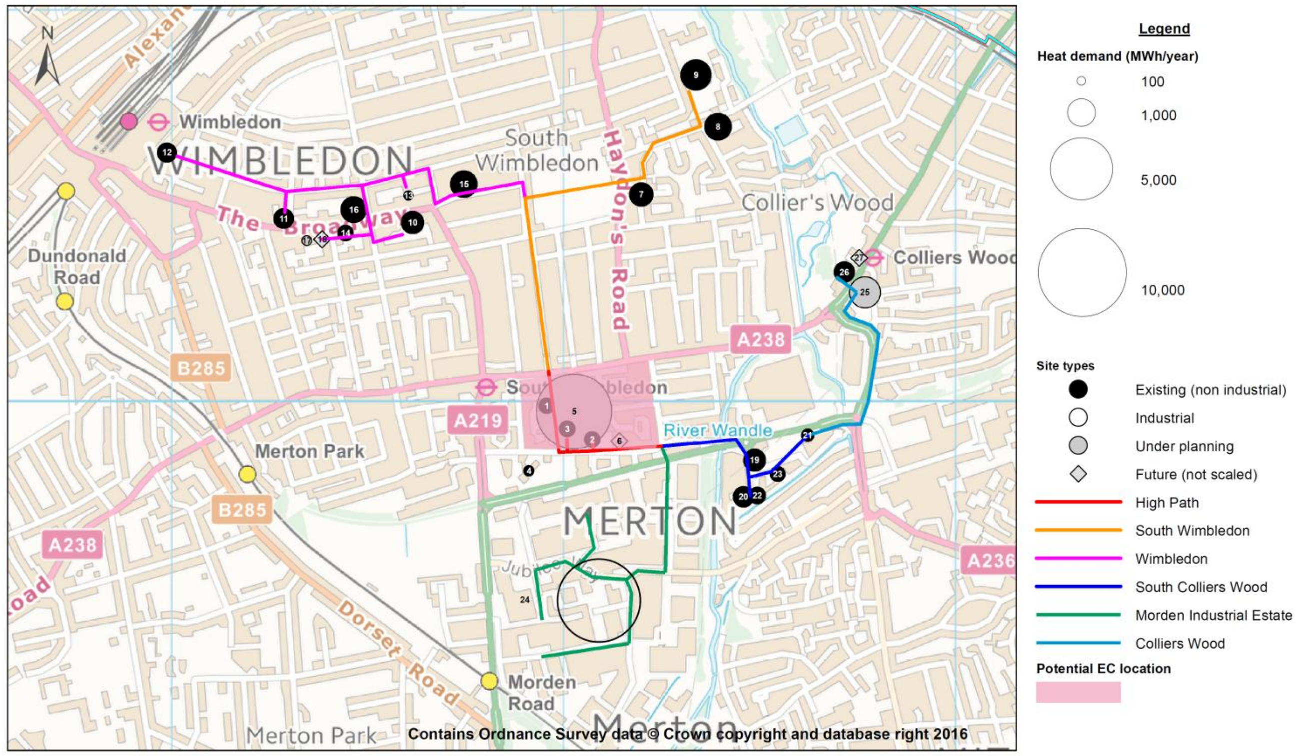

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Figure 11-1: Indicative CWSW network routing and EC location

11.1 Technical Evaluation

The primary parameters that affect the resultant CAPEX values for each network option are summarised in Table 11-2, this includes plant room sizing, network pipework lengths and key carbon parameters.

Table 11-2: Technical evaluation: CWSW

Thermal Energy Balance	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Total thermal consumption (MWh_{th} p.a.)	9,800	11,800	16,500	18,400	27,600
Total network thermal load (MWh_{th} p.a.)	11,300	13,600	18,900	21,200	31,800
CHP heat generation (MWh_{th} p.a.)	8,500	10,200	14,200	15,900	23,900
Heat network top up boiler heat generation (MWh_{th} p.a.)	2,800	3,400	4,700	5,300	7,900
Plant Installation					
CHP system size (kWth)	1,300	1,600	2,200	2,400	3,700
HN Gas boiler capacity (kWth)	1,400	2,000	5,100	5,600	18,800
Total EC Capacity (kWth)	2,700	3,500	7,300	8,100	22,400
New External Energy Centre size (m^2)	269	352	725	809	2,244
Network pipework length, (m)	890	1,497	2,423	3,030	4,380
Total gas demand (MWh/year)	24,300	29,200	40,700	45,600	68,400
CHP electricity output (MWh/year)	8,500	10,200	14,200	15,900	23,800
40 year cumulative carbon emission savings (tonnes CO2e)	3,100	3,200	9,100	9,200	19,400

11.2 Economic Evaluation

CAPEX breakdowns for each scenario are provided in

Table 11-3. Key economic outputs of the model are shown in Table 11-4, including the IRR, NPV and carbon saving results for 25, 30 and 40 year network operation lifetimes, as well as carbon saving projections. All results shown in Table 11-4 account for the 'medium' fuel costs given in the DECC Green Book. For an interrogation of the effects of fuel cost on scheme financial viability, see Section 11.5.1.

Table 11-3: CWSW Scenarios CAPEX breakdown

CAPEX breakdown, £'000s	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Energy Centre:					
EC Construction	£404	£529	£1,088	£1,213	£3,366
Heat Generation Systems:					
Gas CHP engines	£1,120	£1,222	£1,420	£1,590	£2,384
Thermal storage systems	£150	£150	£150	£150	£150
Selective Catalytic Reduction units and urea storage tank	£131	£157	£218	£245	£367
Boilers	£42	£59	£152	£169	£563
Other mechanical plant	£277	£391	£1,014	£1,128	£3,754
Water Systems:					
Water Systems	£13	£18	£36	£40	£112
Electrical Ancillaries:					
Sub-station costs	£100	£100	£100	£100	£100
Buried HV cable	£20	£20	£20	£20	£20
Gas Systems:					
Budget allowance for gas connection	£30	£30	£30	£30	£30
Extension of buried low pressure gas main	£12	£12	£12	£12	£12

CAPEX breakdown, £'000s	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
BMS/Controls:					
Budget allowance for BMS/Controls	£54	£70	£145	£162	£449
External works:					
DH pipework	£1,068	£1,796	£2,908	£3,636	£5,256
Heat exchanger	£44	£61	£159	£177	£589
Railway/tube crossing	£50	£100	£100	£150	£150
Other Costs/Fees:					
Professional fees	£88	£118	£189	£221	£433
Legal fees	£176	£236	£378	£441	£865
Contingency	£567	£760	£1,218	£1,423	£2,790
Total	£4,345	£5,830	£9,336	£10,906	£21,390

Table 11-4: CWSW economic evaluation results summary (Medium fuel costs)

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Year Zero Cost Balance					
Total CAPEX (000's)	£4,345	£5,830	£9,336	£10,906	£21,390
Total Connection Charge Revenue (000's)	£94	£136	£379	£422	£1,452
Year One Cost Balance					
Maintenance, management, staffing and billing (000's)	-£233	-£290	-£416	-£473	-£721
Fuel Costs (000's)	-£656	-£787	-£1,097	-£1,229	-£1,843
Heat sales (000's)	£356	£427	£595	£667	£1,000
Electricity sales (000's)	£864	£1,037	£1,446	£1,619	£2,428
Balance (000's)	-£3,878	-£5,261	-£8,369	-£9,837	-£18,970
25 Year Assessment					
IRR (%)	8.1%	6.7%	5.5%	4.9%	2.5%
NPV (000's)	£2,202	£2,016	£1,947	£1,597	-£1,953
Av. annual CO_{2e} savings (tCO_{2e})	310	361	617	668	1140
Average annual CO_{2e} reduction (% on counterfactual)	17.6%	16.6%	16.3%	16.0%	18.1%
30 Year Assessment					
IRR (%)	8.8%	7.5%	6.4%	5.9%	3.7%
NPV (000's)	£3,102	£3,077	£3,412	£3,224	£501
Av. annual CO_{2e} savings (tCO_{2e})	209	240	447	478	855
Average annual CO_{2e} reduction (% on counterfactual)	11.8%	11.0%	11.9%	11.4%	13.6%
40 Year Assessment					
IRR (%)	9.2%	8.0%	7.0%	6.5%	4.6%
NPV (000's)	£4,137	£4,330	£5,228	£5,235	£3,539
Av. annual CO_{2e} savings (tCO_{2e})	77	81	226	230	484
Average annual CO_{2e} reduction (% on counterfactual)	4.4%	3.7%	6.0%	5.5%	7.7%

Figure 11-2 and Figure 11-3 show the IRR and NPV results for the CWSW network options graphically. As the figures and above table shows, the most attractive network scenarios are the smaller networks encompassing the Hyde Path Estate, as well as South and Central Colliers Wood and South and Central Wimbledon (i.e. scenarios 1, 2, and 3).

Approximately a third of all revenue is attributed to the sale of electricity. The network assumes that three quarters of the electricity generated is sold privately via a private or 'sleeving' arrangement, with the remainder sold on the wholesale market to the grid. This assumption for electricity sales is high risk and must undergo further scrutiny during the later stages of this project.

In each scenario, the model assumes that all related buildings will join the network. As this is unlikely, building selections within each network scenario can be changed within the model, allowing for more detailed analysis depending on each enterprise's likely desire to be included on any scheme, in addition to the technical and economic effects of their inclusion. The model will, however, always assume that all buildings included on the network will be active on the network from the commencement of the scheme. This again is potentially unrealistic, and a phased installation of the network and related energy centre plant could result in improved cash flows, although this requires further assessment in later stages.

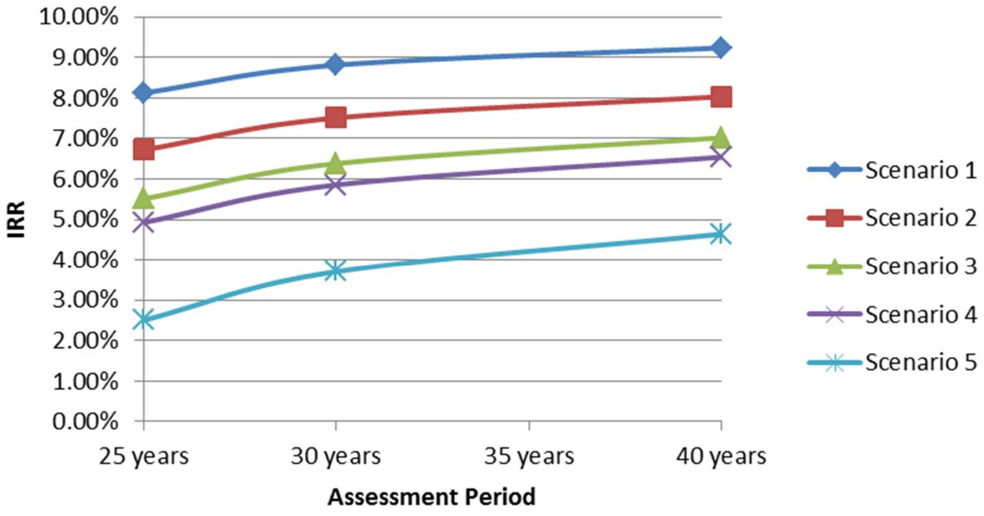

Figure 11-2: Comparative long term IRR assessments of all scenarios (CWSW, medium fuel costs)

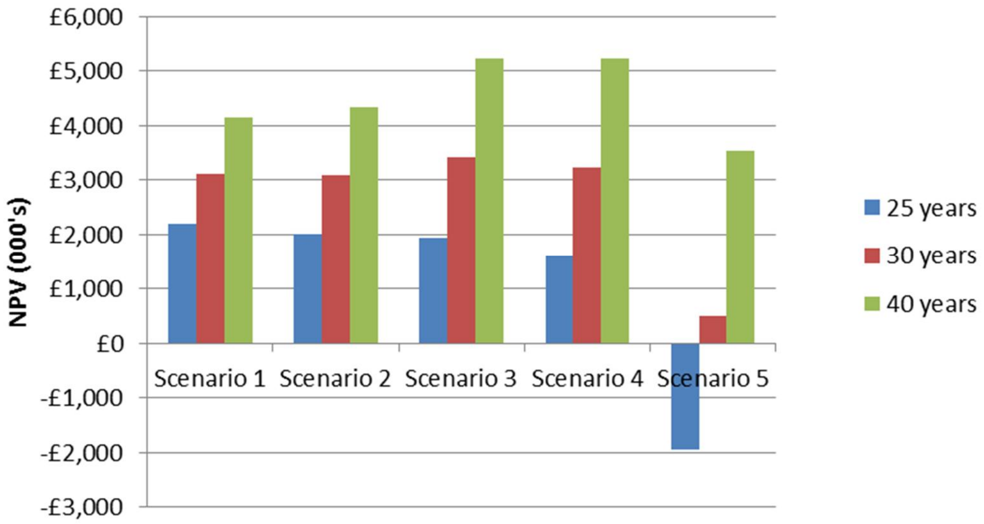

Figure 11-3: Comparative long term NPV assessments of all scenarios (CWSW, medium fuel costs)

11.3 Customers' financial case

The viability of any scheme is reliant on the presence of sufficient heat demand in order to generate the revenue streams required to provide a suitable rate of return seen on CAPEX investment. In order to encourage the participation of all proposed customers, it is important that they also see a reasonable savings from joining a heat network in comparison to the costs they are currently paying to generate heat. Ideally, at a minimum, customers should not experience an increase in running costs. For the purposes of the model, the counterfactual customer fuel costs are assumed to be as per the high values from Table 5 of the DECC Green Book[18].

Table 11-5: Percentage long term saving seen by the proposed customers, CWSW

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Total customer savings over 40 year period	8.9%	8.8%	13.3%	12.8%	18.4%

Table 11-5 shows the total percentage savings over a 40 year period from the total counterfactual costs (fuel costs, boiler maintenance and a one-off boiler plant replacement cost) to the total proposed DH network costs (connection charge, standing charge and heat costs). The customers of the scheme, experience a range of savings across scenarios.

Typically, network operators would seek to provide customers savings in the region of 5-10%, adapting the various heat charges in order to provide savings within this range. However, offering less savings to customers clearly improves the financial viability of the scheme from the operator's perspective, i.e. reduced customer savings gives improved IRRs and NPVs.

Table 11-5 shows that customer savings are greater for Scenarios 3, 4 and 5. These network scenarios have been previously shown to be the poorest performing financially from the operator's perspective. For the purposes of this report, each network has been modelled with equal parameters as listed at the beginning of this chapter. However, offering the customers on these networks reduced savings (within the range of 5-10%) will improve the financial feasibility of such networks (from the operator's perspective) and will bring the IRR and NPV performance of Scenarios 3,4 and 5 in line with 1 and 2.

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[18] DECC Green Book, Table 5 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/483282/Data_tables_1-20_supporting_the_toolkit_and_the_guidance.xlsx

11.4 Carbon Emissions Savings

As illustrated by Figure 11-4, it can be seen that gas CHP led schemes typically only achieve carbon savings (indicated by a positive gradient to the line) until 2030 – 2033, after which the scheme begins to generate more carbon than the counterfactual case (which relies on gas fired boilers generating heat and grid electricity providing power). This is indicated by a negative gradient to the carbon savings.

This is due to the carbon factors associated with the de-carbonisation of the electric grid as a whole (see Section 10.7). It is for this reason that the technology chosen to replace gas-fired CHP circa 10-15 years after the initial CHP installation (after which carbon savings start to turn negative) is a key consideration in terms of how to ensure long-term carbon emissions savings for the scheme. The technology with which the gas CHP engine is replaced with at each replacement phase should therefore be carefully considered to maximise any potential carbon benefit without adversely affecting the commercial case for the network.

Although all scenarios are shown to give net carbon savings over their projected lifespan, it is recommended that alternative replacement technologies such as energy from waste, heat recovery from substations and biomass CHP are considered for use in the scheme after the first engines reach the end of their useful lives. Further analysis is recommended in future stages of the study.

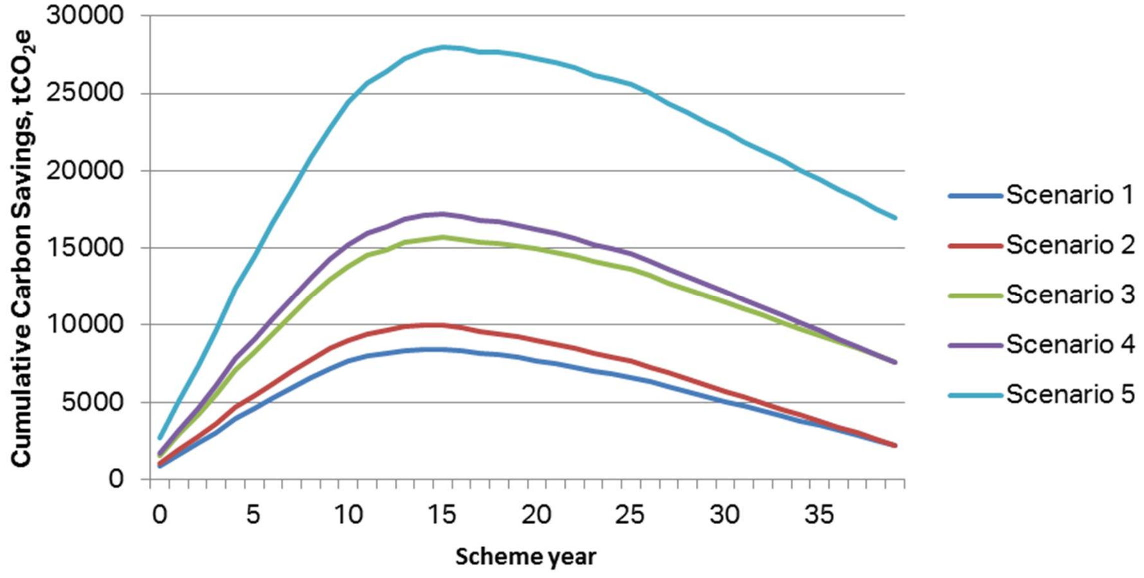

Figure 11-4: The cumulative carbon savings curve for all CWSW scenarios, showing the typical projected carbon savings against the counterfactual case over the proposed scheme lifetime

11.5 Sensitivity analysis

11.5.1. Fuel costs

The financial viability of any DH scheme is particularly dependent on the costs of the input fuel, in this case gas. The future cost of gas is uncertain and difficult to predict. The DECC Green Book[19] gives some projections for the future price of gas for three price bands: low, medium and high.

Which band a purchaser of gas will fall into is dependent on a number of factors, but is largely due to the amount of gas the purchaser is buying; smaller customers will experience higher fuel costs, whereas larger purchasers such as DH network operators will be charged less.

Table 11-6: CWSW IRR and NPV results summary (Medium and Low fuel costs)

Metric	Network operator fuel costs	IRR Assessment Period	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
IRR (%)	Medium	25 years	8.1%	6.7%	5.5%	4.9%	2.5%
		30 years	8.8%	7.5%	6.4%	5.9%	3.7%
		40 years	9.2%	8.0%	7.0%	6.5%	4.6%
	Low	25 years	14.3%	12.5%	10.8%	10.1%	7.2%
		30 years	14.6%	12.9%	11.3%	10.6%	7.9%
		40 years	14.8%	13.1%	11.6%	11.0%	8.4%
NPV (£'000s)	Medium	25 years	£2,202	£2,016	£1,947	£1,597	-£1,953
		30 years	£3,102	£3,077	£3,412	£3,224	£501
		40 years	£4,137	£4,330	£5,228	£5,235	£3,539
	Low	25 years	£5,824	£6,366	£8,009	£8,386	£8,228
		30 years	£7,117	£7,899	£10,131	£10,749	£11,785
		40 years	£8,761	£9,883	£12,966	£13,901	£16,534

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[19] DECC Green Book https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/483282/Data_tables_1-20_supporting_the_toolkit_and_the_guidance.xlsx

The results detailed in this report thus far have assumed that the network operator will pay the 'Medium' costs for gas, whilst customers are currently paying the 'High' gas prices. Table 11-6 illustrates the dependence of financial viability on the cost of fuel, showing the increase in IRR and NPV across all network scenarios if the network operator is able to purchase gas at lower cost.

11.5.1. Other sensitivities

A number of different sensitivity scenarios have been investigated in order to determine their effect on the IRR (over a 25 year period).

Table 11-7: IRR sensitivity analysis for Scenario 1, showing the response to driving parameters

IRR Sensitivity	90.0%	95.0%	100.0%	105.0%	110.0%
Total CAPEX	9.5%	8.8%	8.1%	7.5%	7.0%
Annual heat demand	7.1%	7.6%	8.1%	8.6%	9.1%
Gas price	10.4%	9.3%	8.1%	6.9%	5.5%
Connection costs	8.1%	8.1%	8.1%	8.1%	8.2%
Exported heat price	6.7%	7.4%	8.1%	8.8%	9.5%
Private wire & exported electricity price	4.7%	6.5%	8.1%	9.7%	11.1%
Network distribution heat losses	8.2%	8.1%	8.1%	8.1%	8.1%
Adjustment of electricity private wire sales against grid export sales	6.9%	7.5%	8.1%	8.7%	9.3%

As can be seen by the curve in Figure 11-5 and Table 11-7, the project is particularly sensitive to the gas price, initial CAPEX costs, variation in overall heat demand and the price at which electricity is sold. For example, by reducing the overall CAPEX by 10%, the 25 year IRR rises from 6.5% to 7.8%. Further value engineering, from consideration of such options as plastic pipework, optimized routes and exclusion of certain buildings from the network, could yield such improvements.

The sensitivity analysis shown here is only illustrated for Scenario 1. However, the general trend regarding sensitivity is consistent for all scenarios.

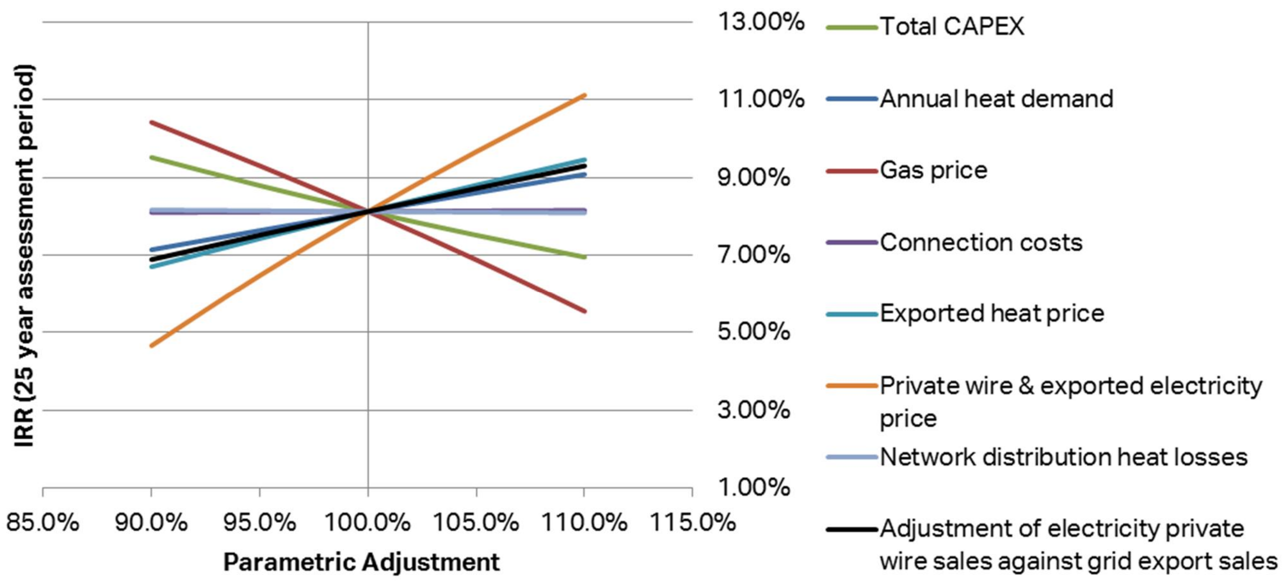

Figure 11-5: IRR sensitivity analysis for Scenario 1, showing the typical response to driving parameters.

12. Techno-Economic Modelling Results: MTCML

Key results of the techno-economic modelling exercise for the three MTCML network scenarios detailed in Table 12-1 (using the notation shown in Figure 12-1) are given in this section. The prevalence of developments under planning in the Morden Town Centre area, for which there were no floor area or energy usage information, means that results shown here are conservative estimates of what a network in the area could achieve. The addition of these loads would only further improve the financial performance of network scenarios.

Table 12-1: MTCML modelled network scenarios

	Scenario 1	Scenario 2	Scenario 3
MTCML	Morden Town Centre	Morden Leisure Centre	Morden Town Centre and Morden Leisure Centre

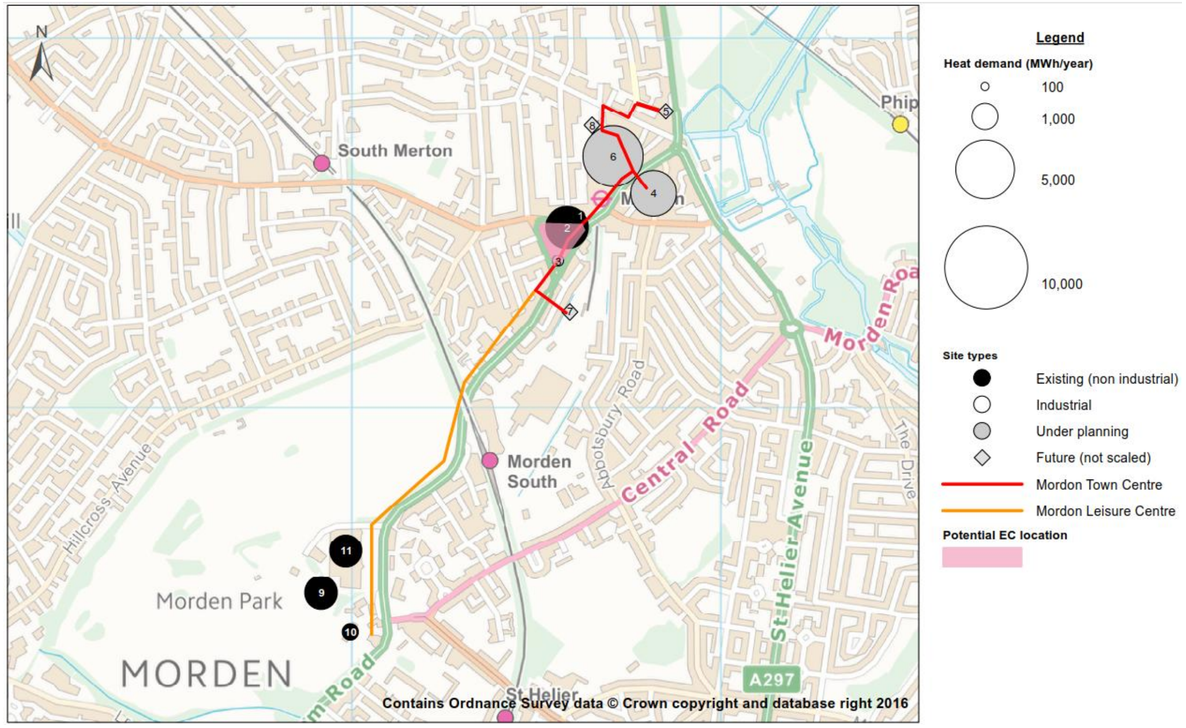

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Figure 12-1: Indicative MTCML network routing and EC location

12.2 Technical Evaluation

An overview of the key technical parameters for the three MTCML network scenarios is given in Table 12-2. As further information on new developments in the area materialises, the values given in this table will be affected and subject to change.

Table 12-2: Technical evaluation: MTCML

Thermal Energy Balance	Scenario 1	Scenario 2	Scenario 3
Total thermal consumption (MWh$_{th}$ p.a.)	11,400	3,700	15,100
Total network thermal load (MWh$_{th}$ p.a.)	13,100	4,300	17,400
CHP heat generation (MWh$_{th}$ p.a.)	9,825	3,225	13,050
Heat network top up boiler heat generation (MWh$_{th}$ p.a.)	3,275	1,075	4,350
Plant Installation			
CHP system size (kWth)	1,500	500	2,000
HN Gas boiler capacity (kWth)	5,900	3,500	9,300
Total EC Capacity (kWth)	7,400	4,000	11,300
New External Energy Centre size (m^2)	739	395	1,135
Network pipework length, (m)	741	1,190	1,931
Fuel and Carbon Balance			
Total gas demand (MWh/year)	27,100	8,900	36,000
CHP electricity output (MWh/year)	8,900	2,900	11,900
40 year cumulative carbon emission savings (tonnes CO2e)	1,700	3,400	5,100

12.3 Economic Evaluation

The CAPEX breakdown for each MTCML network scenario is provided in Table 12-3. The IRR, NPV and carbon saving results for 25, 30 and 40 year network operation lifetimes, as well as carbon saving projections are given for the network scenarios in Table 12-4. As for the CWSW network modelled and described in Section 11, all results shown account for the 'medium' fuel costs given in the DECC Green Book. Fuel cost sensitivity is given in Section 12.6.1.

Table 12-3: CWSW Scenarios CAPEX breakdown

CAPEX breakdown, £'000s	Scenario 1	Scenario 2	Scenario 3
Energy Centre:			
EC Construction	£1,109	£593	£1,702
Heat generation systems			
Gas CHP engines	£1,205	£471	£1,306
Thermal storage systems	£50	£50	£50
Selective Catalytic Reduction units and urea storage tank	£151	£50	£201
Boilers	£176	£104	£280
Other mechanical plant	£1,175,823	£691,703	£1,868
Water systems			
Water Systems	£37	£20	£57
Electrical Ancillaries			
Sub-station costs	£100	£100	£100
Buried HV cable	£20	£20	£20
Gas systems			
Budget allowance for gas connection	£30	£30	£30
Extension of buried low pressure gas main (<180mm dia.)	£12	£12	£12
BMS/Controls			
Budget allowance for BMS/Controls	£148	£79	£227

CAPEX breakdown, £'000s	Scenario 1	Scenario 2	Scenario 3
External Works			
DH pipework	£889	£1,428	£2,317
Heat exchanger	£184	£109	£293
Railway/tube crossing	£0	£50	£50
Professional fees	£132	£95	£213
Legal fees	£264	£190	£426
Contingency	£853	£614	£1,373
Total	£6,537	£4,706	£10,524

Table 12-4: MTCML economic evaluation results (Medium fuel costs)

Year Zero Cost Balance	Scenario 1	Scenario 2	Scenario 3
Total CAPEX (000's)	£6,537	£4,706	£10,524
Total Connection Costs (000's)	£450	£271	£721
Year One Cost Balance			
Total OPEX (000's)	£242	£84	£326
Fuel Costs (000's)	-£730	-£239	-£970
Heat sales (000's)	£413	£135	£548
Electricity sales (when all via private wire, 000's)	£911	£298	£1,209
Balance (000's)	-£6,592	-£4,834	-£10,731
25 Year Assessment			
IRR (%)	4.1%	-2.9%	2.4%
NPV (000's)	£440	-£2,654	-£1,300
Av. annual CO_{2e} savings (tCO_{2e})	289	165	454
Average annual CO_{2e} reduction (% on counterfactual)	2.2%	3.5%	2.6%
30 Year Assessment			
IRR (%)	4.7%	-2.0%	3.1%
NPV (000's)	£972	-£2,513	-£495
Av. annual CO_{2e} savings (tCO_{2e})	182	130	312
Average annual CO_{2e} reduction (% on counterfactual)	1.4%	2.8%	1.8%
40 Year Assessment			
IRR (%)	5.7%	0.4%	4.4%
NPV (000's)	£2,462	-£2,034	£1,474
Av. annual CO_{2e} savings (tCO_{2e})	43	85	127
Average annual CO_{2e} reduction (% on counterfactual)	0.3%	1.8%	0.7%

Figure 12-2 and Figure 12-3 show the IRR and NPV results for the MTCML network scenarios modelled over the 25, 30 and 40 year assessment periods.

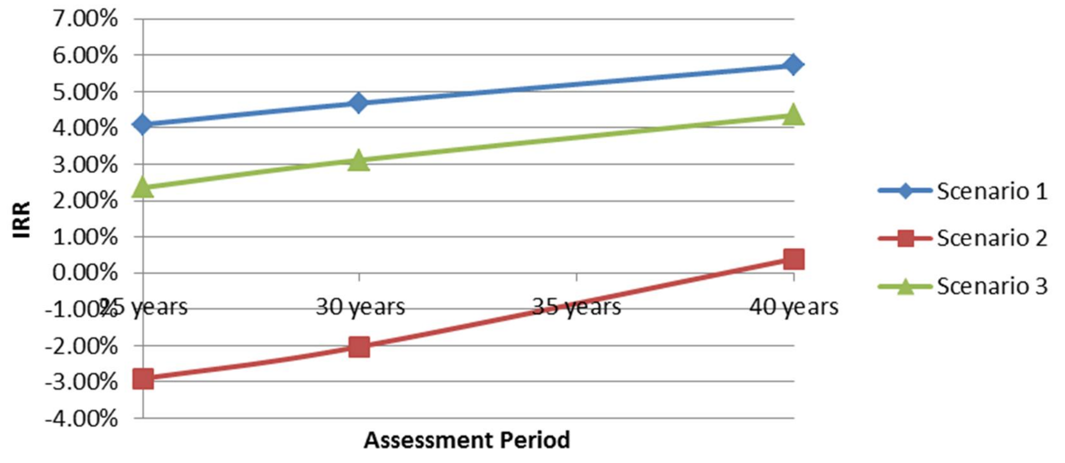

Figure 12-2: Comparative long term IRR assessments of all scenarios (MTCML, medium fuel costs)

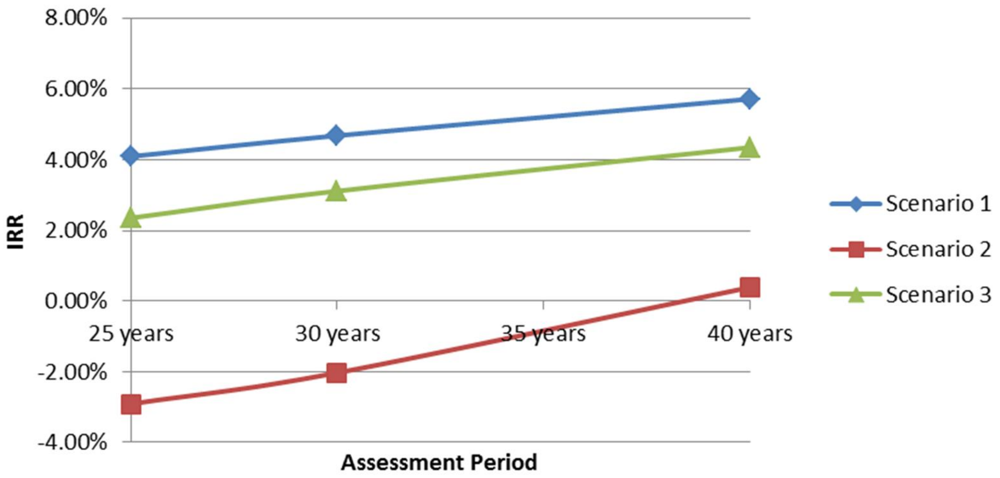

Figure 12-3: Comparative long term NPV assessments of all scenarios (MTCML, medium fuel costs)

The results show the financial performance of all three network scenarios in the MTCML to be lower than that of the modelled networks in the CWSW area. This is due to the lack of modelled energy data for certain planned developments in the area. The network is costed to supply energy to the new developments, i.e. pipework is costed, but the revenue stream is zero, as no energy use data is available. However, the addition of these revenue streams would only serve to improve the financial performance.

Scenarios that contain the Merton Civic Centre and the Morden Station and Abbotsbury Triangle developments perform best, due to the high density of heat loads in the area, and relatively lower pipework requirements than the Morden Leisure Centre scenario.

12.4 Customers' financial case

The same default parameters for the modelling as given in Section 10.2 were used for both network areas and all scenarios. The resultant customer savings offered by each scenario are given in Table 12-5.

Table 12-5: Percentage long term saving seen by the proposed customers, MTCML

	Scenario 1	Scenario 2	Scenario 3
Total customer savings over 40 year period	18.0%	30.3%	21.4%

Since network operators would typically seek to provide customers savings in the region of 5-10%, the savings shown here are above what would be expected of a scheme like this.

In this case, parameters could be altered to reduce customer savings and improve the financial case for the network operator.

12.5 Carbon Emissions Savings

As shown in the CWSW modelling results, gas CHP schemes only offer carbon savings for the initial 10 – 15 years of their operation (see Section 10.7).

The carbon savings of the network scenarios for the MTCML opportunity area are shown in Figure 12-4.

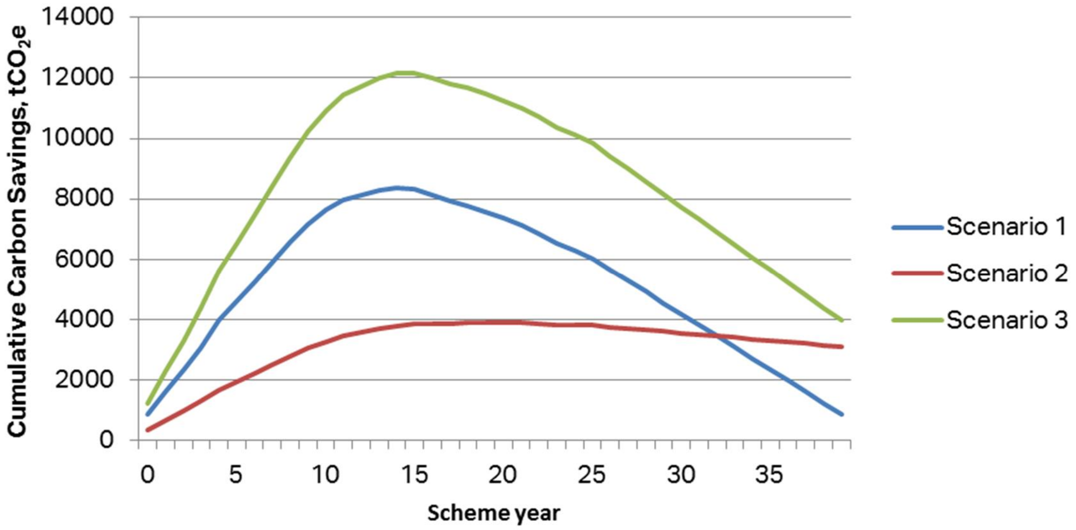

Figure 12-4: The cumulative carbon savings curve for all MTCML scenarios, showing the typical projected carbon savings against the counterfactual case over the proposed scheme lifetime

12.6 Sensitivity analysis

12.6.1. Fuel costs

Table 12-6 shows the dependence of the network financial viability on the cost of fuel, comparing the medium and low DECC Green Book future projections for the cost of gas. The table shows that the scheme performs significantly better financially if the network operator is able to secure the purchase of gas at the lowest predicted rate.

Table 12-6: MTCML IRR and NPV results summary (Medium and Low fuel costs)

Metric	Network operator fuel costs	IRR Assessment Period	Scenario 1	Scenario 2	Scenario 3
IRR (%)	Medium	25 years	4.1%	-2.9%	2.4%
		30 years	4.7%	-2.0%	3.1%
		40 years	5.7%	0.4%	4.3%
	Low	25 years	8.9%	0.7%	6.7%
		30 years	9.3%	1.5%	7.2%
		40 years	9.8%	3.0%	7.9%
NPV (£'000s)	Medium	25 years	£440	-£2,654	-£1,300
		30 years	£972	-£2,513	-£495
		40 years	£2,462	-£2,034	£1,474
	Low	25 years	£4,475	-£1,331	£4,058
		30 years	£5,445	-£1,047	£5,443
		40 years	£7,613	-£347	£8,313

12.6.2. Other sensitivities

Sensitivity analysis has been carried out to illustrate the effects of varying CAPEX, heat demand, fuel costs, connection costs, heat and electricity prices, heat losses and the proportion of electricity that is sold privately has on the IRR offered by each scheme scenario.

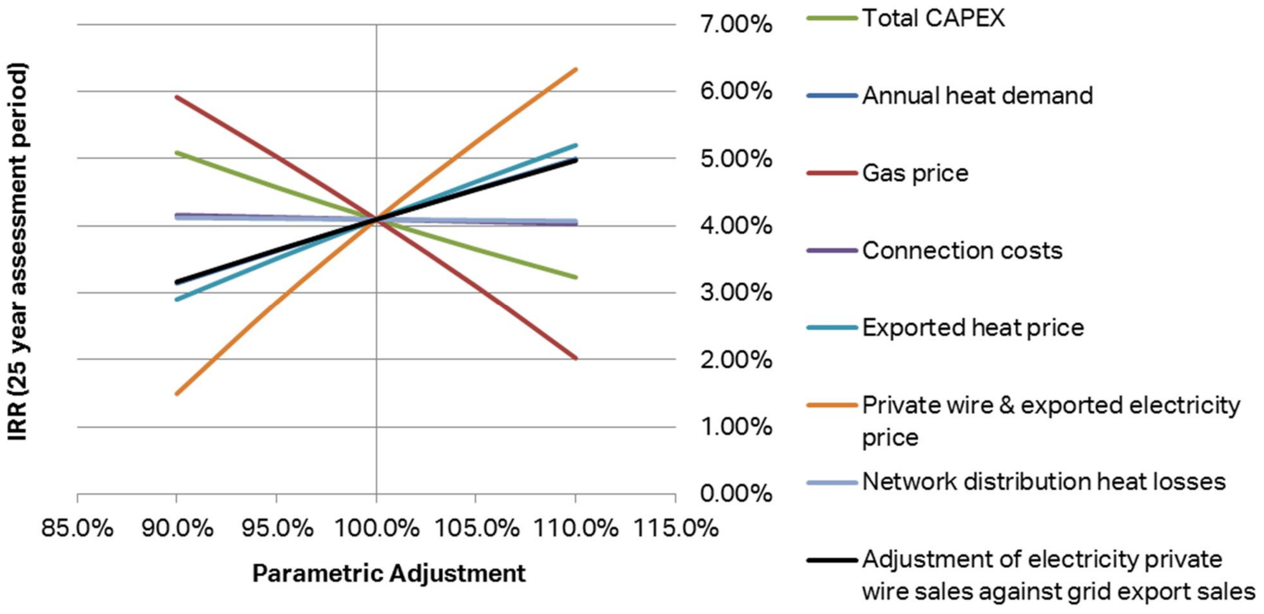

Figure 12-5: IRR sensitivity analysis for Scenario 1, showing the response to driving parameters.

As can be seen in Figure 12-5 above and Table 12-7 below, the scheme is particularly sensitive to fuel costs, CAPEX and the revenue generated through the export of electricity.

Table 12-7: IRR sensitivity analysis for Scenario 1, showing the response to driving parameters.

IRR Sensitivity	90.0%	95.0%	100.0%	105.0%	110.0%
Total CAPEX	5.1%	4.6%	4.1%	3.7%	3.2%
Annual heat demand	3.2%	3.6%	4.1%	4.6%	5.0%
Gas price	5.9%	5.0%	4.1%	3.1%	2.0%
Connection costs	4.2%	4.1%	4.1%	4.1%	4.0%
Exported heat price	2.9%	3.5%	4.1%	4.7%	5.2%
Private wire & exported electricity price	1.5%	2.9%	4.1%	5.3%	6.3%
Network distribution heat losses	4.1%	4.1%	4.1%	4.1%	4.1%
Adjustment of electricity private wire sales against grid export sales	3.2%	3.6%	4.1%	4.5%	5.0%

13. Conclusions

This section summarises the findings of the energy mapping and masterplanning study carried out for the London Borough of Merton.

13.1 Energy Mapping

Key commercial buildings in the area were identified and their energy requirements assessed through various means. Where actual data for gas and electricity consumption was not available, energy use was deduced from Energy Performance Certificates and Display Energy Certificates if applicable or appropriate industry standard benchmarks based on building type.

Heating, cooling and electricity demands were mapped out in GIS to illustrate the energy use in the borough by location.

13.2 District Energy Masterplanning

Network opportunities in two key strategic development areas were investigated:

- Colliers Wood and South Wimbledon (CWSW)
- Morden Town Centre and Morden Leisure Centre (MTCML)

Identified buildings in each area were subject to a selection procedure which determined whether they were likely to be connected to a future network and as such included in the technical and commercial evaluation phase of this study. Criterion against which buildings were judged for inclusion included:

- Expected thermal energy demand/requirement
- Physical barriers such as railways or rivers separating buildings from each other
- Secondary side system type and eligibility for connection to a wet district energy network
- Whether buildings could be considered as ‘anchor loads’
- Distance of buildings from anchor loads

Once the initial building list was condensed and loads prioritised, the area was investigated for suitable heat sources. The existing local heat sources included London Underground network ventilation shafts, energy from waste facilities, anaerobic digestion plants, electrical substations and CHP units within existing buildings. No anaerobic digestion facilities currently exist or are under consideration in Merton, rendering this technology an unlikely candidate for supplying heat to a potential network in Merton.

London Underground vent shafts were reported to be present in the area (exact locations were not provided by TfL for security reasons) and it was shown that they could provide approximately 850kW of heating capacity with the use of an air source heat pump to recover heat. This may be a viable solution for the High Path Estate, which is close to the indicative shaft location range provided.

The heating capacity of the River Wandle, that runs through the borough, was investigated and found to be sufficiently high to warrant further investigation. A Water Source Heat Pump could be used to supply an ultra-low temperature DH network such as that which could be employed in the High Path Estate development. The 3.6MW heating capacity of the river as indicated by the BEIS WSHP map needs more detailed assessment.

The Beddington energy from waste facility exists in the neighbouring borough of Sutton, with plans for the Sutton District Energy Network underway. The facility is approximately 4km away from MTCML area (and further to the CWSW area), and was shown not to offer much potential for supplying heat cost effectively to the proposed networks (with paybacks of around 25-50 years).

A high capacity electrical substation was identified in north east Merton on Plough Lane. A high level assessment found that such a scheme could take up to 60 years to pay back, due to the c. 1.6km required pipework and its associated cost.

A total of 12 heat generation technologies were appraised both generally and in their relation to Merton. The appraisal recommended that gas CHP was the most applicable heat generation technology currently. When the initial CHP engines reach the end of their useful life (10-12 years depending on use) it is recommended that other technologies are re-evaluated to ensure that the most effective and best available technology is adopted.

The co-generation of heat and electricity will provide the network operator with revenue streams for the sale of both. Electricity could be sold to local users via ‘sleeving’ or a private wire (see section 10.5.3) or exported back to the grid for wider use elsewhere. Securing local users can be difficult, but often vital for the commercial and technical viability of the network. This is because electricity can be sold privately for around 80-90% of the retail price, whilst electricity exported to the grid sells at the wholesale price, which is typically around 40-50% of the retail price. TfL and National Rail were identified as key target customers for private wire electricity sales: initial conversations with TfL suggested that they would be keen to explore opportunities for purchasing cheaper electricity.

The two opportunity areas were investigated for suitable energy centre locations, based on LBM owned land in the vicinity. It was found that the High Path Estate presents the best EC location for the CWSW network, whilst the Merton Civic Centre is the most suitable for the MTCML network.

Using these locations, and the list of prioritised buildings, high level network routes were planned, accounting for local infrastructure and physical barriers and constraints in the areas.

13.3 Key Techno-Economic Model Findings

Network scenarios were identified and assessed in a techno-economic mode to test their level of viability and inform LBM's decision on which could warrant further investigation. The bespoke model was built from first principles and allows the user to select various key parameters in the operation and installation of a network, such as:

- Buildings to be connected
- Plant sizing
- Heat and electricity sale prices
- Proportion of electricity sold via private wire (as opposed to exported back to the grid)
- Customer network connection costs and standing charges
- Discount rate
- Network distribution losses

In order for a network to be commercially viable, it must present the operator/investor with a good rate of return on their investment, whilst also offering the customers a saving when compared to the base case.

Five possible scenarios of the CWSW network were modelled, accounting for different combinations of pre-determined network areas. The network options with the least pipework were shown to perform best, with a 40 year IRR of 9.2% and NPV of £4.1m for the High Path Estate and South Colliers Wood scenario. Expanding the High Path/South Colliers Wood network into Wimbledon instead of up to Central Colliers Wood sees a reduction in IRR and NPV due to increased pipework lengths necessary to service the loads in that area. Inclusion of the Morden Industrial Estate presents the lowest opportunity scenario. Findings are based on the assumption that the EC can be located in the High Path Estate – a high risk item that needs verification through further engagement with the developers.

The analysis indicates that the MTCML network opportunity area does not perform as well as the CWSW area financially. This is because the area includes a number of future planned developments for which no energy consumption information is currently available. However, if these loads connect in the future, the financial performance of the proposed network will significantly improve. The inclusion of the Merton Civic Centre in the MTCML network would be beneficial for Merton Council. The fact that the energy centre could be located there and that flueing arrangements would be aided by the existing height of the building, make the network attractive. The MTCML Scenario that includes the Merton Civic Centre and the significant Abbotsbury Triangle and Morden Station developments performs best with a 40 year IRR of 5.7% and NPV of £2.5m. Customer savings are also higher for the MTCML Scenarios, suggesting that finances could be further improved by imposing higher charges on customers.

13.4 Carbon Emission Savings

Gas CHP was shown to provide carbon emissions savings for the first 16 years of the scheme's operation. Thereafter, if gas CHP is retained as the heat generation technology, the scheme becomes less carbon efficient than the equivalent 'do-nothing' base case option. This is due to DECC predicted carbon offset factors for electricity and the fact that the grid is expected to become less carbon intensive with time as the penetration of low carbon and renewable technologies increases..

It is recommended that if a gas fired CHP scheme is pursued, that the council pay close attention to the trends in district heating over the coming years and continually reassess the heat generation replacement technology, with carbon savings at the top of their agenda. Future heat networks are expected to incorporate more than one heat generation technology; in Merton a future network may include a number of low temperature technologies like water source heat pumps and heat recovery from the London underground network and local electrical substations.

13.5 Next steps

Based on the information resented in this report a decision needs to be taken on which of the network opportunities identified are to be taken into Phase 2 of the study.

Phase 2 will primarily focus on:

- Detailed profiling of network energy demands
- Surveys of buildings and existing heating systems
- Further engagement with stakeholders, in particular:
    - High Path estate developers: Energy centre location
    - TfL: vent shaft locations and private wire electricity sales
- Confirmation of EC locations, with identification of local utilities infrastructure
- Concept EC designs
- Detailed financial modelling (to be carried out by Grant Thornton)

A workshop will be held at the end of Phase 2 to talk through the findings of the study, identify the key risks and discuss the implications of the project as a whole. This meeting will also be an opportunity to present the final results of the studies to wider stakeholders.

APPENDIX A – Heat Generation Technologies Overview

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 Merton) 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 CO_2 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[20], the CO_2 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 NO_x 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.

Biomass Combined Heat and Power (CHP)

The use of biomass as fuel is considered renewable and low-carbon, since the CO_2 that is released during combustion is offset by the CO_2 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)[21] 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.

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[20] DECC (2015) *Bespoke natural gas CHP analysis*, https://www.gov.uk/government/publications/bespoke-natural-gas-chp-analysis [Assessed July 2016]

[21] 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 [Assessed July 2016].

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 NO_x 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.

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. Biofuels are currently eligible for financial incentives such as Renewable Obligation (RO)[22].

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 NO_x and particulate emissions that contribute to air quality problems.

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.

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.

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. CO_2 savings can also be realised through the displacement of natural gas consumption by AD biomethane production.

AD is significantly wide spread, with over 100 AD[23] 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.

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.

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[22] Renewables Obligation is a government programme that supports large-scale renewable electricity projects in the UK. UK electricity suppliers are required to provide an increasing proportion of electricity from renewable sources. Suppliers can purchase Renewable Obligation Certificate (ROC) by an accredited generator for renewable electricity generated. In the case that the required renewable electricity level is not achieved, a penalty is required. The scheme is due to close to all new entrants in April 2017. Further information is provided by Ofgem (n.d.) *Environmental Programmes*, https://www.ofgem.gov.uk/environmental-programmes [Assessed July 2016].

[23] Please refer to WRAP (n.d.) *Operational AD Sites*, http://www.wrap.org.uk/content/operational-ad-sites [Assessed July 2016] for map showing operational anaerobic digestion plants in the UK.

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. Currently there are 5 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.

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).

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 -15°C, and can provide heat at temperatures suitable for LTHW heating circuits. However, 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.

While the low efficiencies achievable for high-temperature heat pump systems mean their operating costs and CO_2 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, heating 1200 homes, reducing the schemes carbon emissions by an additional 500 tonnes a year[24]. 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[25]. It is worth noting that due to the high capital costs

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[24] http://www.districtenergy.org/blog/2013/11/18/waste-heat-from-the-tube-to-heat-london-homes/
[25] http://www.britishgas.co.uk/business/blog/how-is-londons-tate-modern-planning-to-reduce-1400-tonnes-of-carbon-emissions/

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 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.

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 m^2 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.

Electrically-driven Vapour 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.

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 B – Risk Register

Risk	Commentary	Risk			Typical Risk Mitigation
		Probability	Impact	Severity	
Customer satisfaction	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.	Low	High	Med.	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
Heat Tariff	Heat tariff may require change due to external influences, in order to remain attractive or compliant with future guidance	Low	High	Med.	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
Customer bad debt	The customer fails to pay on submitted bills and falls into Debt.	Med.	High	High	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.

Risk	Commentary	Risk			Typical Risk Mitigation
Assessment of thermal loads	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.	High	Med.	High	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. 5. For existing residential buildings, the heat network provider will need to estimate peak and annual demands based on modelling or experience from supplying buildings of similar size and type, or where block boilers are used from fuel consumption data.
Connection of thermal loads	The projected peak and annual thermal loads do not occur due to; development not progressing or customers do not connect	Med.	Low	Med.	1. Engage with responsible representative/stakeholder/customer at an early stage of the project 2. Maintain dialogue until connection is made 3. Identify heat sale agreements with commercial information being made available 4. Ensure that the heat network offering is competitive with the counter factual
Realisation of thermal load	The projected thermal loads of connected customers fail to be realised.	High	Med.	High	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
Change of connected thermal loads	Connected thermal loads change due to alteration of building usage, improvement in energy performance or connection termination	Low	High	Med.	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
Unsuitable operating temperatures	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 lower operating temperatures will result in higher efficiencies with some types of heat sources, e.g. heat pumps and steam turbine extraction.	Med.	High	High	An optimisation study shall be carried out to determine the operating temperatures for peak design conditions and how they vary with any given scheme as it will be impacted by the type of heat supply plant and the characteristics of the heat network. The designer has also to consider constraints such as the temperatures used for existing heating systems and the degree that these can be varied. Hence the requirements given below may not be valid in all cases and may be over-ruled by the conclusions of a detailed study for an individual scheme.
Heat losses	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.	Med.	Med.	Med.	Detailed assessment of below ground and above ground losses. Review of insulation applied, pipework diameter, length of pipe and operating temperatures.

Risk	Commentary	Risk			Typical Risk Mitigation
Combustion plant size	It is common for combustion plant to be oversized to meet peak thermal demand, in order to be cautious. However, this may be further compounded in combination with a plant resilience strategy and how the thermal capacity of any low carbon thermal plant is considered. The impact of this is increased plant costs, increased space requirements (cost and loss of development revenue), possible lower thermal efficiency and increased maintenance costs. Oversizing a CHP is normally driven by overestimating annual thermal consumption. Oversizing a CHP will result in increased plant costs, increased space requirements (cost and loss of development revenue), increased maintenance costs and lower operational performance due to lack of operation.	Low	Med.	Med.	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
Heat controls	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.	Med.	Low	Med.	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
Inefficient heat network routes, pipe sizes and reliability	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.	Med.	High	High	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
Inappropriate building interface connection	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.	Low	High	Med.	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 retained 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.

Risk	Commentary	Risk			Typical Risk Mitigation
Assessment of Environmental Impacts	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.	Med.	Med.	Med.	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.
Air quality requirements	Optimism that emissions standards can be met with ease, without any flue scrubbing and emissions reduction technologies (which are costly)	Low	Med.	Med.	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
Health and safety issues in construction, operation and maintenance	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.	High	High	High	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
Poor performance of central plant	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, energy from waste). The economic case for the heat network will depend on achieving the cost and environmental benefits at the central plant.	Med.	High	High	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
Inadequate thermal energy supply	Failure to deliver the required amount of heat to each customer, critically at the times of peak demand.	Low	High	Med.	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
Thermal Connection Arrangements	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	Med.	High	High	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

Risk	Commentary	Risk			Typical Risk Mitigation
Future fuel price variation	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.	High	High	High	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.
Change of regulation	Financial incentives and various funding scheme have significant impact on the case financial model.	Med.	High	High	Financial analysis based on both current regulations and potential policies under consultation.
Industry Regulation	The heat industry is not regulated by an external third party. Formation of external regulatory body will incur additional management costs	Med.	High	High	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 may still occur 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
Professional experience	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.	Med.	High	High	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.
Fuel incomer requirement	Risk that gas main infrastructure near chosen scheme site is of sufficient pressures and kW capacity to service energy centre.	High	Med.	High	Energy centres often require significant gas main peak capacity and pressure which cannot always be readily provided locally from the existing in situ pipework. Early investigation of gas mains infrastructure recommended.
Fuel incomers costs	Assumed that connection of gas network to Energy Centre is straightforward when it can be onerous and costly	Med.	Low	Med.	Early investigation of gas mains infrastructure recommended.
Water quality	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.	Low	Med.	Med.	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.

Risk	Commentary	Risk			Typical Risk Mitigation
DNO electrical connection	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.	High	High	High	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
Electric export market	Electrical energy generated on-site, not evaluated suitability based on the perceived inability to connect to suitable loads, resulting in 100% export	Med.	Low	Med.	Local grid constraints to be assessed at Feasibility Stage. Identify opportunities to sell electricity to higher value connections. Conduct sensitivity analysis based on assumed average unit price per kWhe. As the project progresses, further mitigate risk and sensitivity by proving viability of connections and entering commercial negotiations with potential customers
Electrical load available for sleeving/private wire	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	Low	High	Med.	Early engagement with potential customers is required to establish the real electrical load available. Discussion around potential costs and willingness to enter contractor to be commenced at an early stage to de-risk item.
Sleeving/Private wire arrangements	Assumption of sleeving to end customers is assumed to be technically easy, requiring little or no upgrade to electrical infrastructure. Cost can directly impact maximum sale price per MWh.	Low	High	Med.	Capital costs to be identified, based on the level of design information available. Risk of price increased to be considered and appropriate contingency value put in place until risk designed out.
Electrical export	Parasitic loads, transmission losses and transformer inefficiency often under-estimated/ignored.	Med.	Med.	Med.	Assess potential parasitic loads and losses that could impact the quantity of electrical energy available for sale. Can reduce saleable electricity by up to 10%.
Electric revenue	Achievable sale price of electric often assumed to be too high (retail/wholesale).	Med.	High	High	Consider value of electricity used to generate heat and evaluate cost benefit of making loads parasitic Identify suitable electrical customers. Assess mid-point sale price per kWh for each point of sale. Agree a lower price and a higher price to sensitivity analysis
Heat meters	Heat meters either not present, not installed properly or unable to transmit recorded information	Low	Low	Low	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.

Risk	Commentary	Risk			Typical Risk Mitigation
Energy Centre size and cost metrics	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 (£/m^2).	Med.	Med.	Med.	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.
Connection to external heat sources	Potential current/future requirements to connect to other external heat sources e.g. Energy from Waste plants. External heat sources will impact both peak and base load generation requirements for the heat network.	Low	High	Med.	1. Assess potential for current/future connections to external heat sources and their technical compatibility 2. Identify drivers that would lead to connection and the cost impact of the connection 3. Establish possible timescale in which a connection would be made 4. Review impact on peak thermal generation plant (possible redundancy) 5. Review impact on LZC plant due to reduced run hours 6. Review impact on plant area required
Connection to other DH networks	Potential current/future requirements to connect to other heat networks. External heat network will impact both peak and base load generation requirements for the heat network.	Med.	High	High	1. Assess potential for current/future connections to external heat networks and their technical compatibility 2. Identify drivers that would lead to connection and the cost impact of the connection 3. Establish possible timescale in which a connection would be made 4. Review impact on peak thermal generation plant (possible redundancy) 5. Review impact on LZC plant due to reduced run hours 6. Review impact on plant area required
DH pipework design	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	Med.	High	High	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.
DH pipework costs	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.	Med.	High	High	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.
DH pipework maintenance	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.	Low	Med.	Med.	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

Risk	Commentary	Risk			Typical Risk Mitigation
Secondary/Tertiary system compatibility (existing buildings)	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.	High	High	High	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°C/71°C to 80°C/60°C flow and return temperatures.
Secondary/Tertiary system compatibility (new buildings)	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.	High	High	High	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.
Secondary/Tertiary systems operation	Poor secondary/teritiary side operation can result in high return temperatures, corridor overheating and poor system performance	Med.	Low	Med.	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.
Secondary/Tertiary systems commissioning	Poor secondary/tertiary side commissioning can result in high return temperatures, corridor overheating and poor system performance	Med.	Med.	Med.	Potentially significant risk. Impact can be reduced by incentivising down streamsystem 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.
Planning consent and Way leave agreements	Planning process often not considered, or are assumed to be straightforward. Energy Centre building planning performance requirements often not considered. Assumption that wayleave 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.	Med.	High	High	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. Way leaves agreement may take considerably longer than anticipated.
Carbon content of fuels	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.	Med.	Med.	Med.	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.

Risk	Commentary	Risk			Typical Risk Mitigation
Technology costs with maturity	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.	Med.	Med.	Med.	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.
Technology availability	Expectation that future technologies that replace CHP as the prime mover become available at scale, and are compatible with designed and installed network.	Med.	Low	Med.	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.
Energy centre location	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).	Med.	Med.	Med.	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.