Hounslow District Heating Feasibility

Project number: 60708989

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London Borough of Hounslow

Delivering a better world

Quality information

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Definitions

Term	Definition
Counterfactual	The alternative technology that a heat customer would employ looking forward, should they not connect to a heat network. The counterfactual technology for each customer is used to determine a suitable heat tariff which would be charged by the network. In this study, to align with the GHNF, the counterfactual for domestic customers is gas boilers and for non-domestic customers is air source heat pumps.
Business as Usual (BaU) Case	The current assumed technology that is employed by each building, in the 'Do-Nothing' scenario where heating systems are not decarbonised. The BaU technology for each customer is used to evaluate carbon savings of the network. In this study, the BaU heating technology is assumed to be gas boilers for all existing and under-construction buildings, and air source heat pumps for all planned future developments.
Heat Tariff	The cost to customers for heat from the network. In this study, this tariff is based on the customers avoided cost of the counterfactual and is inclusive of both standing and variable charge.
Base Case	Techno-economic analysis based on initial stated parameters.
Scenario	Technoeconomic analysis with stated adjustments to specific Base Case parameters. All parameters not mentioned remain as per the Base Case.
Levelised Cost of Heat (LCoH)	Levelised Cost of Heat is a metric that allows for the comparison between schemes/projects considering of all component costs required to deliver heat to customers. In this study, it is assessed over a 40-year lifespan and an annual discount is applied to 'levelise' the future cost to today's value. The LCoH of a network can be compared to the counterfactual, or to other networks, to demonstrate its value in terms of heat delivered
Internal Rate of Return (IRR)	In this context the IRR is a measure of the underlying return the district energy network owner expects to achieve by investing in the project excluding cost of financing. Fundamentally, the IRR is the constant interest rate at which a given series of cash outflows must be invested for an investor to earn a given series of cash inflows as income. All IRRs in this report are 40-year pre-tax values.

Executive Summary

As part of the London Borough of Hounslow's (LBH) commitment to reduce scope 1 and 2 carbon emissions from council assets to net zero by 2030 and use its influence to reduce emissions from elsewhere in the borough as quickly as possible, AECOM have been commissioned to undertake a Feasibility Study to assess the opportunities for low carbon district heating networks in the borough. District heating can offer a low carbon alternative to natural gas combustion for heating, which as of 2023, represents 71% of LBH council's scope 1 and 2 emissions[1]. This feasibility report, building upon the previous Heat Mapping and Masterplanning stage, sets out detailed techno-economic modelling findings and establishes a recommended Technical Solution for progression to Detailed Project Development (DPD).

AECOM have identified viable heat network opportunities in all three of the study boundaries, 'Brentford', 'East of Borough' and 'Borough-wide' that achieve the Environmental, Economic and Social Key Performance Metrics for the project. AECOM's recommendation from the feasibility study undertaken is for LBH to progress Technical Solution 13 (see below) to the DPD stage of the Heat Network Delivery Unit (HNDU) plan of work, using the development/funding option 'Full DPD'. It is likely that the recommended solution would be considered as a 'Large' network, however it is recommended that this is confirmed with HNDU prior to application.

Technical Solution 13 is a heating-only, conventional high temperature heat network, serving the 'Borough-wide' extent of Hounslow in addition to Heathrow Airport. This solution uses waste heat rejected from Thames Water's 'Mogden' Sewage Treatment Works as primary source for heat pumping, supported by gas boilers, for peak load and resilience purposes. The proposed network extent and phased growth strategy is demonstrated in Figure 1 below. Delivery will require close cooperation with Thames Water who control the heat source, one of the energy centre sites and potentially a strategic route to electrical supply. Thames Water have expressed a preference for any role they play in the network as being more than a seller of heat.

[redacted]

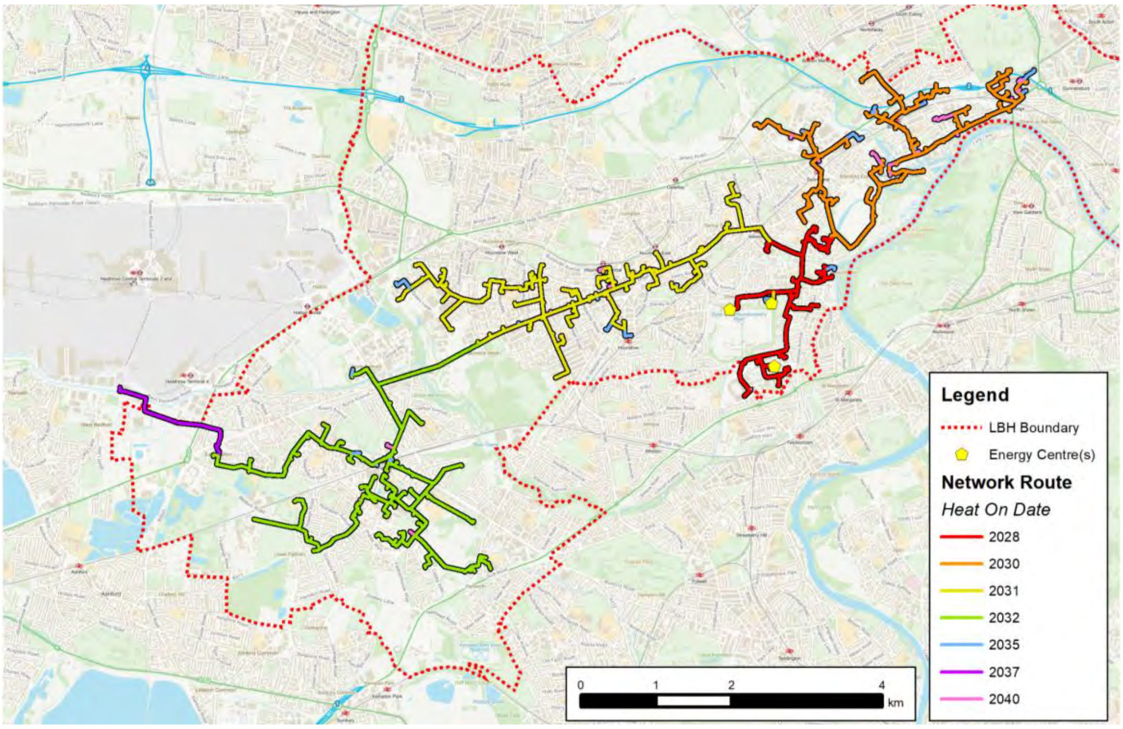


Figure 1 - Network Extent and Phasing Plan for the Recommended Solution.

[1] Climate Emergency Annual Update Report - Third Edition

This solution has been Techno Economically Modelled to offer a lower cost heat tariff (aligned to a gas boiler counterfactual) to domestic and microbusiness customers, with a higher cost tariff to all other customers which is calculated to be equivalent to the appropriate alternative small-scale low carbon solution. Through this, the heat network can offer protection against the risk of fuel poverty associated with low carbon heating / renewables for 'At Risk' customers, while remaining commercially viable by offering low carbon heat at a competitive cost to the non 'At Risk' customers. This is considered to be the correct approach to tariff setting by DESNZ. In addition, the network has the ability to act as a 'buffer' to protect against customers against any rises in fuel price caused by geopolitical factors by controlling, in so far as is contractually possible, how much, if any, said rises impact the customer heat tariff.

The key metrics for Technical Solution 13 are detailed in Table 1. The solution offers significant carbon savings over a 40-year lifespan (over the assumed comparator / business as usual), assisting LBH to achieving its net zero targets whilst achieving an Internal Rate of Return (IRR) that would be attractive to investment, subject to receipt of funding support. The capital investment, whilst considerable, offers a cost per unit of carbon saved that is significantly lower than LBH's alternative options, such as double glazing (typically 10-15x) and solar photovoltaic retrofit cost (typically 4-5x). Additionally, the capital expenditure is planned to be spread over a 12-year construction programme, from 2028 – 2040, aligned to the growth of the network and anticipated customer 'heat on' date requirements.

Metric	Value
Estimated Capital Cost	[redacted]
Pre-Grant Pre-Tax 40-year Project IRR	[redacted]
Estimated Level of Government Grant Support Required	[redacted]
Pre-Tax 40-year Project IRR with Above Grant	[redacted]
Estimated Number of Building Connections	266
Total Heat Delivered	484 GWh/year
Total Trench Length for Pipework	68.5 km
Lifetime Carbon Savings compared to Gas Boilers	[redacted]
Capital Cost per unit of Lifetime Carbon Saved	[redacted]
40-Year Average Annual Carbon Savings[2]	60.9 $ktCO_2e$/year
40-Year Average Annual Carbon Savings[2] for Hounslow Borough only (excludes Heathrow)	38.9 $ktCO_2e$/year
Above as a Percentage of Hounslow Borough's 2021 Total Emissions (includes emissions from Council and non-Council sources)	3.8%
40-Year Average Annual Carbon Savings[2] from Council Scope 1 Properties Only	8.1 $ktCO_2e$/year
Above as a Percentage of Council 22/23 Scope 1 Emissions	45%
40-Year Average Annual Carbon Savings[2] from Council Scope 3 Properties Only (social housing)	9.0 $ktCO_2e$/year
Above as a Percentage of Council 22/23 Social Housing Emissions	35%
40-Year Average Annual Carbon Savings[2] from all Council Properties as a Percentage of Total Council 22/23 Emissions	26.2%

Table 1: Proposed Solution Metrics.

Additional unquantified benefits of the project are its ability to improve local air quality in Hounslow as well as to potentially mitigate the grid constraints which would otherwise be experienced by widespread electrification within the borough, when compared to alternative decentralised energy technologies.

The scale of the network would make it larger than any existing in the UK today (although similar are currently in design stages) but smaller than many examples elsewhere in Europe, such as Berlin and Copenhagen, as well as in North America and Asia. Additionally, the technical solution for low carbon heat capture is similar in nature and scale to that employed recently by E.ON in Malmö. Therefore, whilst ambitious, the solution is proven, and

[2] Compared to 'Business as Usual' which is assumed to be gas boilers for all existing and under-construction buildings, and air source heat pumps for all planned future developments.

has been matched to the level of potential that exists within Hounslow, considering the magnitude and accessibility of low carbon heat in Mogden, the net-zero aspirations of the local public and private sector (e.g., Heathrow Airport) and financial and strategic support for the sector by central government. The technology is proven over the long term and has an extensive list of case studies from which to build.

It is anticipated that an application to the Green Heat Network Fund (GHNF) for the full [redacted] of 'Government Grant Support Required' (as shown in Table 1) at the outset of the project would not be feasible. Given the scale of the network and time taken to complete to the final solution, it is anticipated that grant support for an initial network would be applied for and over time the network would expand from this. Based on evidence from previous GHNF funding rounds, a grant value of [redacted] is considered feasible and assuming a similar grant support rate as the final modelled solution [redacted] would allow construction of a 'starter network' with an approximate CapEx of [redacted]. The suggested Phase 1 starter network is shown in Figure 2 and includes one of the energy centres and the pipe network for Isleworth.

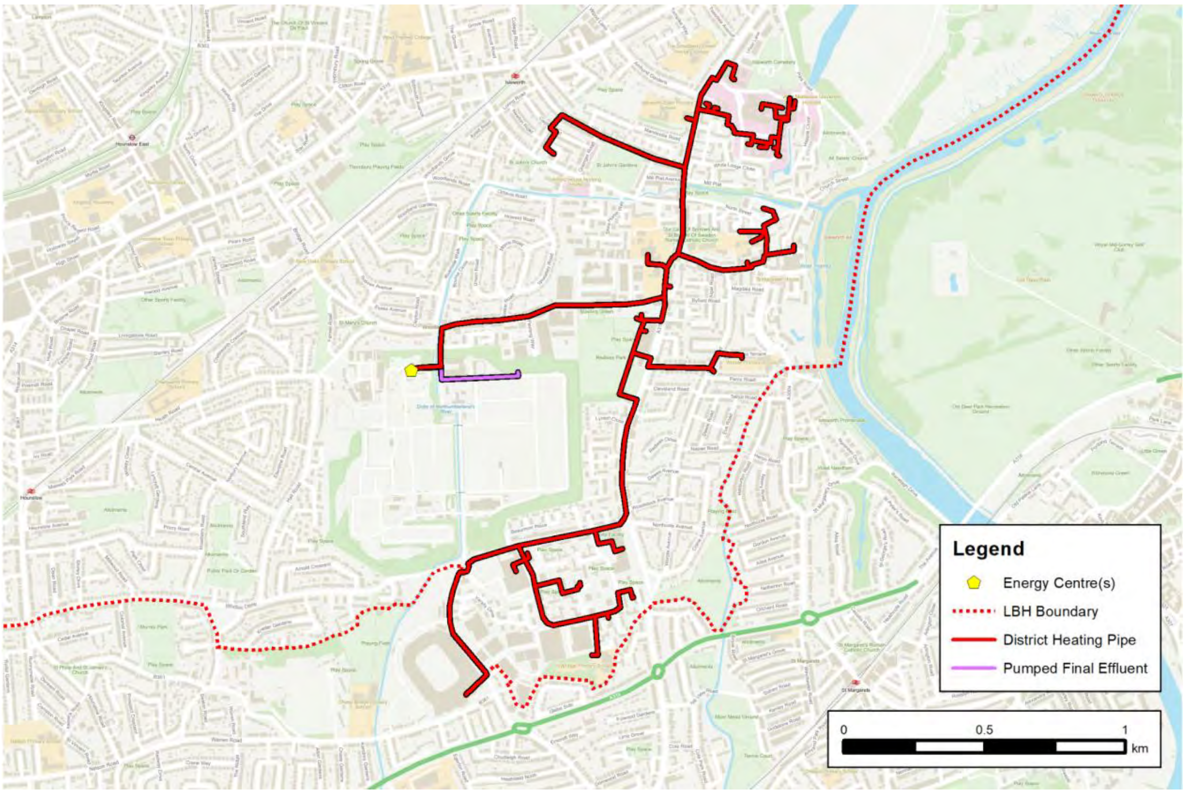


Figure 2 - Proposed Phase 1 / 'Starter' Network Route Extent and Infrastructure.

A starter network has not been modelled as part of feasibility stage; however, it is anticipated that expansion beyond Phase 1 would be required for the network to be economically viable over its 40-year assessed lifespan. The difference between the [redacted]unding required for the full network solution and the anticipated [redacted] GHNF grant may be funded through the HM Treasury-backed UK Infrastructure Bank (UKIB), which has so far allocated [redacted] of finance to support green infrastructure development in the UK. [redacted]

1. Introduction

1.1 Project Drivers

On 18th June 2019, the London Borough of Hounslow (LBH) declared a Climate Emergency, committing the Council to reducing its Scope 1 and 2 emissions to net zero by 2030, alongside using its powers and influence to reduce wider emissions from across the Borough as quickly as possible.

As of the Council's third Climate Emergency Annual Update Report, published September 2023, emissions resulting from heating-related gas consumption in Council-operated buildings amounted to 16.7 $ktCO_2e$ for the 2022/23 period. This figure equates to 25.6% of Hounslow Council's overall carbon footprint, and 71% of its Scope 1 and 2 emissions. A further 25.9 $ktCO_2e$ of emissions were attributed to Social Housing energy consumption (classified as Scope 3 emissions) for the same period (39.7% of total Council emissions).

Across the wider borough, the latest statistics[3] published by the Department of Energy and Net Zero (DESNZ) attribute 325 $ktCO_2e$ of emissions to domestic, commercial, and public sector gas consumption (32% of total Borough emissions) for the year 2021.

In recent years, through the significant growth in renewable generation capacity, the UK electricity grid has significantly decarbonised and is predicted to continue reducing in carbon intensity. It could, therefore, reasonably be concluded that emissions from electricity will eventually reduce without LBH intervention. However, demand reduction and local generation is critical to this being achieved.

Conversely, the natural gas grid is predicted to remain consistently high in carbon intensity, and so should be considered the higher priority target of the two with regards to reducing emissions. For Hounslow Council, this fact is particularly relevant in pursuit of achieving net-zero by 2030 – gas consumption represents the overwhelming majority of Council Scope 1 & 2 emissions.

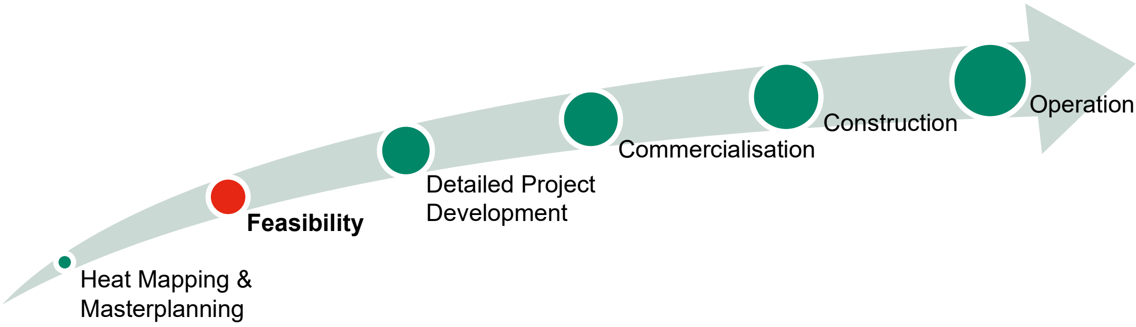
Heat Networks can offer a low carbon alternative to natural gas combustion for the provision of heat[4]. Crucially, utilisation of waste heat sources and heat pump technology allow the bulk generation of heat to be less reliant on electricity. Consequently, a district heating scheme in Hounslow would help mitigate the local grid constraints that would otherwise be faced by widespread electrification (the alternative heat decarbonisation approach). This electrification would likely comprise individual air source heat pumps, but direct electric heating may also be used in specific instances.

In addition to carbon reductions, Hounslow also seeks to improve local air quality by reducing NOx and Particulate Matter (PM) pollutant levels within the borough, as part of the Air Quality Action Plan, approved in 2018. Through replacing local gas combustion with electrically fuelled heat generation, district heating can contribute towards these ambitions, and is currently a key component of the planned measures[5].

[3] UK local authority and regional greenhouse gas emissions, 2021, Department for Energy Security and Net Zero.
[4] Some industrial uses – e.g., heat for manufacturing purposes – are an exception to this.
[5] London Borough of Hounslow Air Quality Annual Status Report for 2020

1.2 Objectives

This study is undertaken as part of *Programme One - Energy Efficiency* of Hounslow's *Climate Emergency Action Plan* and is the second stage – Feasibility – of the Government's Heat Network Delivery Unit (HNDU) plan of work, shown below.



The primary objective of this study is to recommend a preferred solution for any viable district heating opportunities identified within Hounslow, which is intended for progression to the subsequent stage of the HNDU development timeline: Detailed Project Development. The preferred solution will have been designed to meet the gated metrics of the Green Heat Network Fund (GHNF) and be compliant with CIBSE CP1 (2020) – *Heat Networks: Code of Practice for the UK*.

The Key Performance Indicators (KPIs) of the project, generated in collaboration between the AECOM and LBH project teams, are set out in Table 1-1.

Category	Criterion
Environmental	Network carbon intensity averaging 45 gCO2e/kWh of heat delivered over 40 years.
Economic	[redacted]
Social	Heat tariffs for all customers equal to, or less than, the equivalent cost for a counterfactual technology.

Table 1-1: Project Key Performance Indicators.

The carbon intensity target (environmental KPI) differs from that previously used at Heat Mapping stage, i.e., the GHNF-aligned 100 gCO_2e/kWh maximum 'carbon gate'. An average target has been preferred to a maximum, in order to decouple the various modelled scenarios from the electrical grid's Year 1 carbon intensity, and consequently better reflect the lifetime carbon savings of the chosen scheme. The ambitious 45 gCO_2e/kWh figure has been chosen to represent an improvement against the blended counterfactual carbon intensity in all Study Boundaries, and more effectively exploits the significant potential of Mogden Sewage Treatment Works as a low-carbon heat source.

The economic KPI of a [redacted] IRR ensures that the preferred solution is commercially attractive to private sector investment, in case the preferred delivery structure chosen at the next stage is not fully council led. Even if it was to be council led, it is assumed that an IRR greater than [redacted] will be expected.

The social KPI refers to a 'counterfactual technology' to determine the heat tariffs for each customer. These have once again been aligned with GHNF guidance, and are defined as:

i. Gas boilers (high carbon), for 'at-risk' customers (existing domestic buildings and micro-businesses).

ii. Air source heat pumps (low carbon), for all other customers.

The result is a two-tier tariff structure with a lower rate, equivalent to the cost of an individual gas boiler, for customers most at risk of fuel poverty. This approach enables the heat network operator to offer protections against fuel cost increases for low carbon heat by controlling the customer heat tariff. This would be more difficult to achieve with alternative low carbon solutions, for example, air source heat pumps, where the fuel tariff (in this case electricity) is set by the electrical utility provider for individual customers.

It should be highlighted that LBH's ability to control the tariff structure will depend on the commercial structure of the network, which is explored at high level in Section 9, and in more depth during the DPD stage of design.

1.3 Study Methodology

Following the recommendations of the Heat Mapping and Masterplanning study (summarised in Appendix A), this feasibility study has explored the district heating and cooling opportunities for the following areas:

1. Borough-wide, with the addition of Heathrow Airport as a sensitivity.
2. Isleworth, Brentford, and Hounslow Town Centre – referred to as 'East of Borough'.
3. Brentford.

The boundaries for these areas are shown in Figure 1-1.

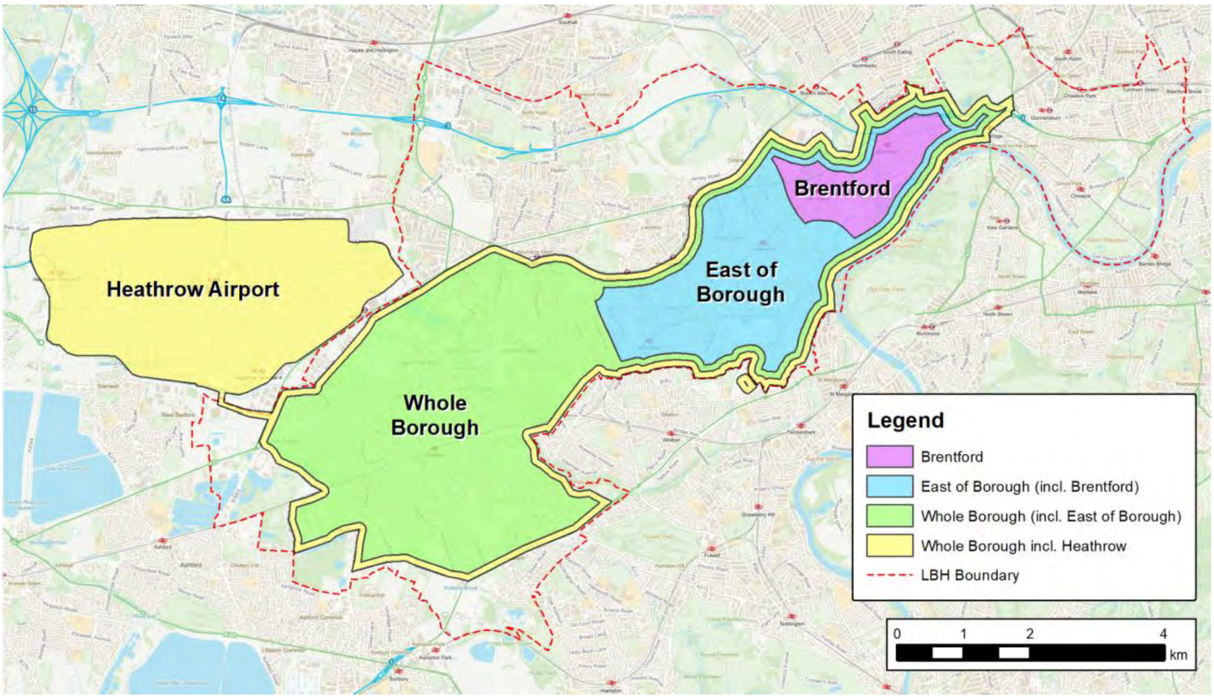


Figure 1-1: Hounslow Feasibility Study Boundaries.

The methodology for the study has been displayed in Figure 1-2. Note that a precursor to this methodology was a refreshed heat mapping exercise undertaken as part of Work Package 1 (summarised in Appendix A).

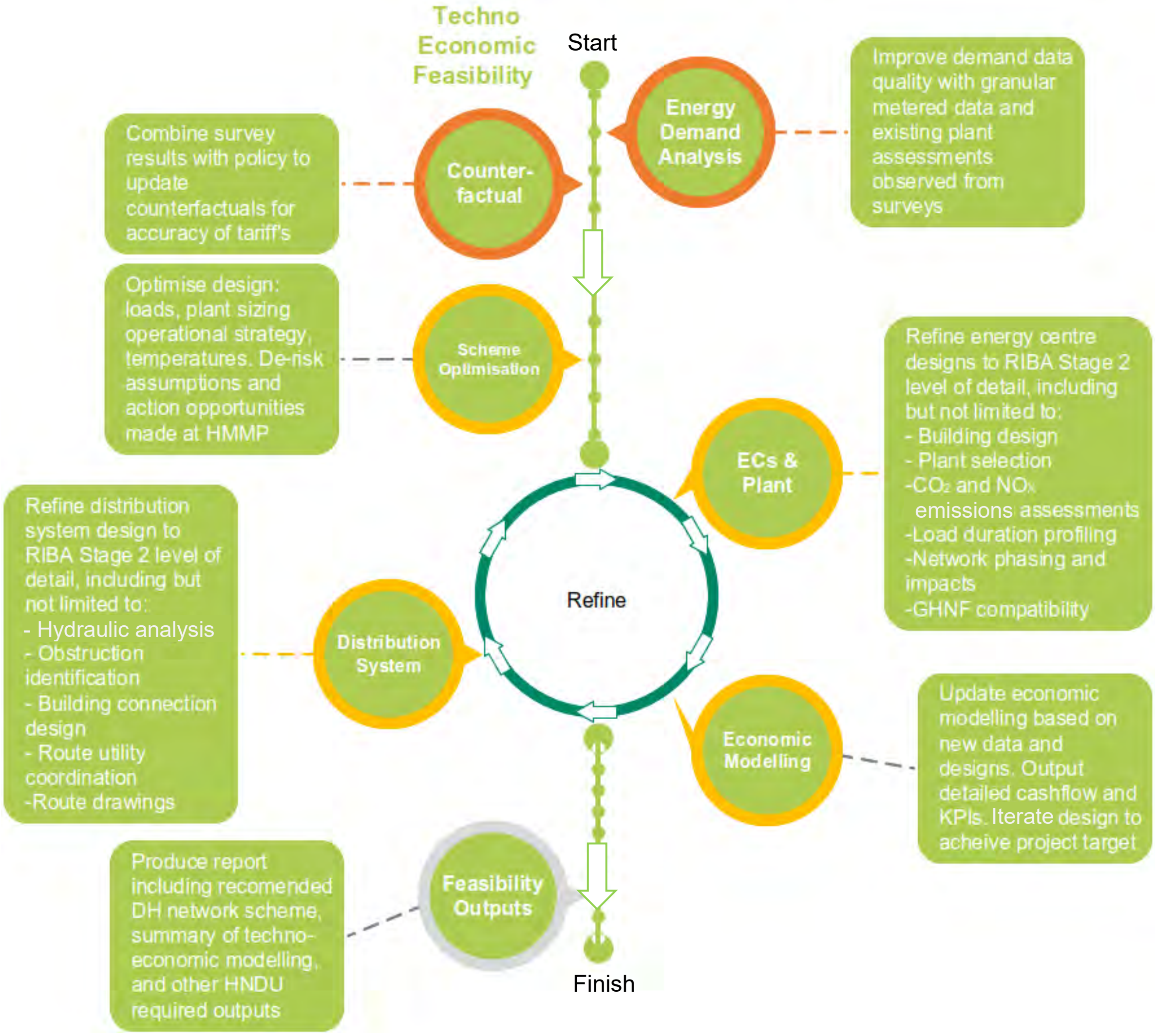


Figure 1-2: Hounslow Feasibility Study Methodology.

1.4 Heat Network Code of Practice for the UK CP1 Statement

CIBSE CP1 (2020) – *Heat Networks: Code of Practice for the UK* is the industry standard design guidance for heat networks. Demonstration of compliance with its process is a requirement of the Green Heat Network Fund. Future regulation of heat networks by Ofgem, due in 2024/25, will be underpinned by the Heat Network Technical Assurance Scheme[6] (HNTAS), drawing heavily from the principles of CP1.

AECOM have undertaken this feasibility study in accordance with the principles defined in CP1. In continuation of the works conducted at HMMP, a CP1 Stage 2 tracker has been attached at Appendix S. It is critical that this is reviewed and approved by LBH to maintain continuity of the process. A recommended CP1 Statement of Applicability has also been submitted in Appendix T.

AECOM fully support the use of CP1 on all heat network projects. Should additional information be required on the impact, benefit, and use of CP1 for a heat network project, this can be provided outside of this report.

[6] Assuring the technical performance of heat networks - CIBSE Journal

2. Energy Demand

2.1 Breakdown of Demand

A summary of the refreshed energy data for the Study Boundaries is shown in Figure 2-1.

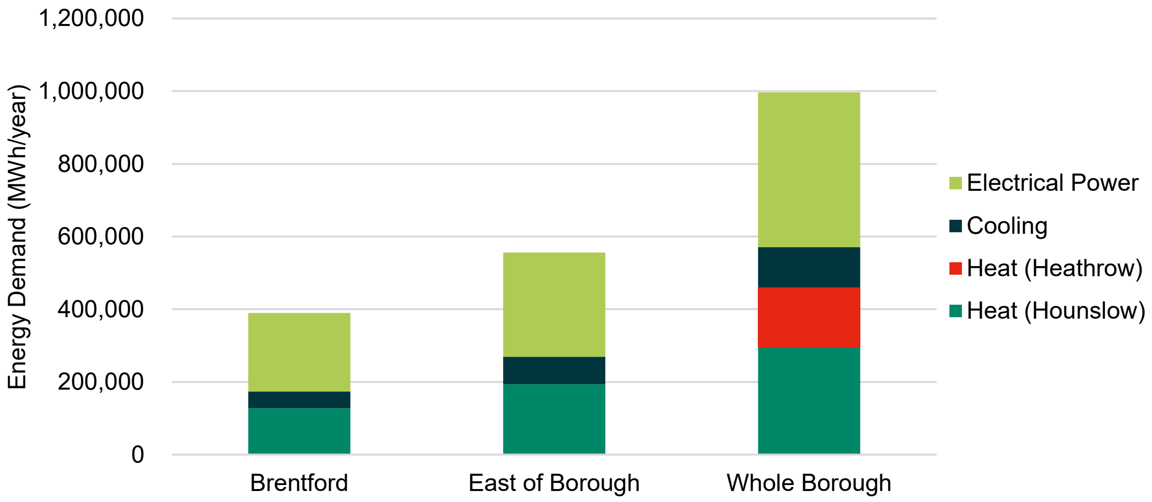


Figure 2-1: Breakdown of Energy Demands for each Study Boundary.

Note that the chart shown represents the current cooling demand in the borough as it currently stands. In the long-term, increased cooling demand can be expected due to the rise in global temperatures as a result of climate change. This has been explored in more detail in Appendix C. At the time of writing, the cooling demand of Heathrow is not known and so is excluded from Figure 2-1, however, it has anecdotally been described as of a similar scale to heating and should be investigated in future.

2.2 'Business as Usual' Emissions

In recent years, through the significant growth in renewable generation capacity, the UK electricity grid has significantly decarbonised and is predicted to continue to do so. Conversely, the natural gas grid is predicted to remain consistently high carbon. Figure 2-2 demonstrates how the carbon emissions associated with energy use in the assessed buildings is predicted to change over time for the 'Borough-wide' study boundary. This assumes a 'Do-Nothing' scenario where existing technologies and usage habits do not change.

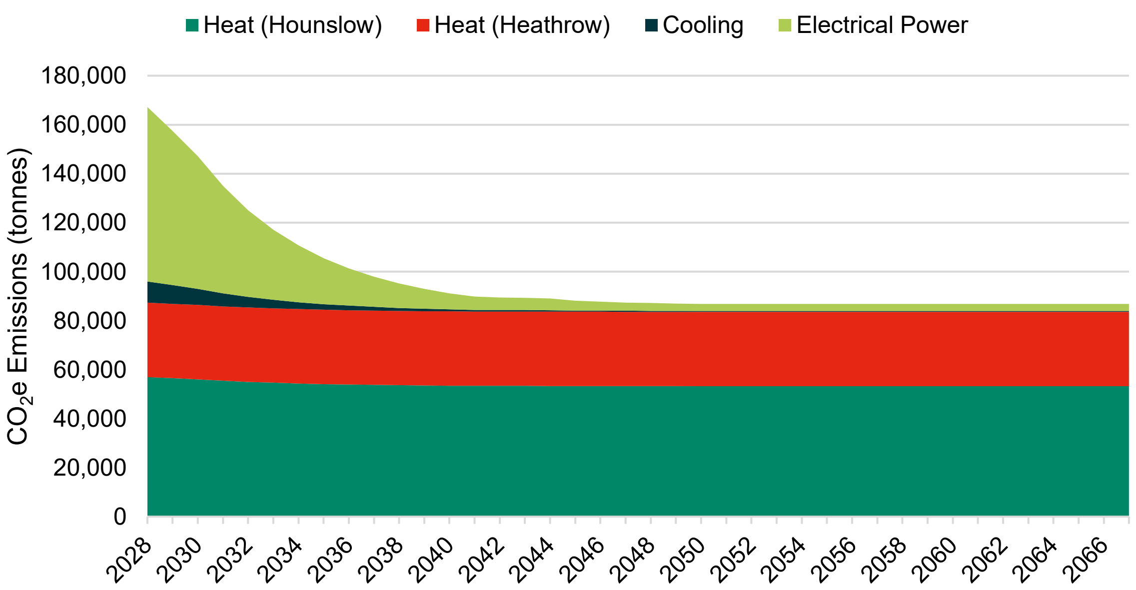


Figure 2-2: Breakdown of Projected 'Business as Usual' / 'Do-Nothing' Emissions by Energy Type7.

2.3 Heating – Network Extents

The district heating network extents to be modelled are directly aligned with the Study Boundaries set out in Section 1.3. The scale and distribution of heat demand across the borough is demonstrated in Figure 2-3.

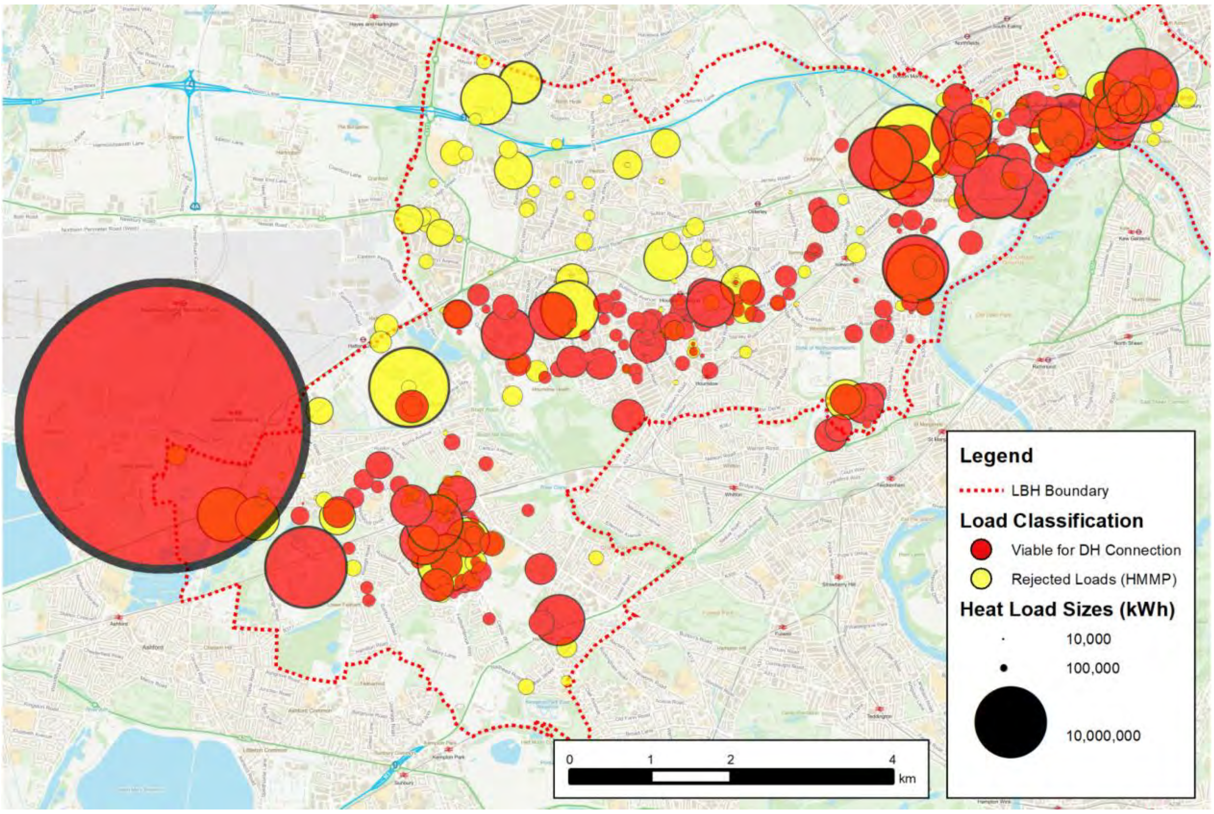


Figure 2-3: Distribution of Heating Demand across LBH (with Heathrow).

The total heat demand of each network extent is shown in Figure 2-4.

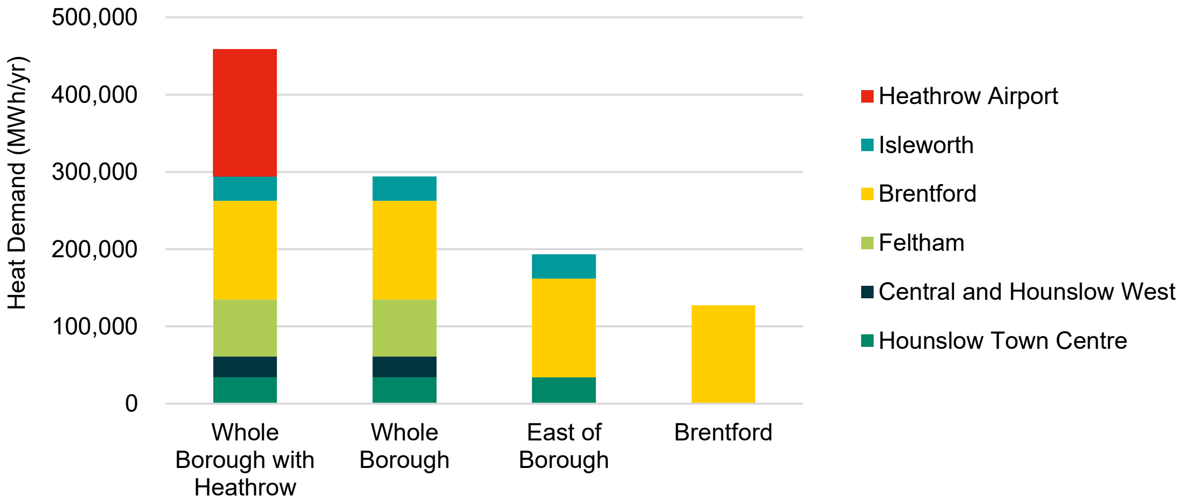


Figure 2-4: Breakdown of Heat Demand for Each District Heating Network Extent.

[7] The Business as Usual technology is assumed to be gas boilers for all existing and under-construction buildings, and air source heat pumps for all planned future developments.

2.4 Cooling – Network Extents

The scale and distribution of cooling demand across the borough is demonstrated in Figure 2-5.

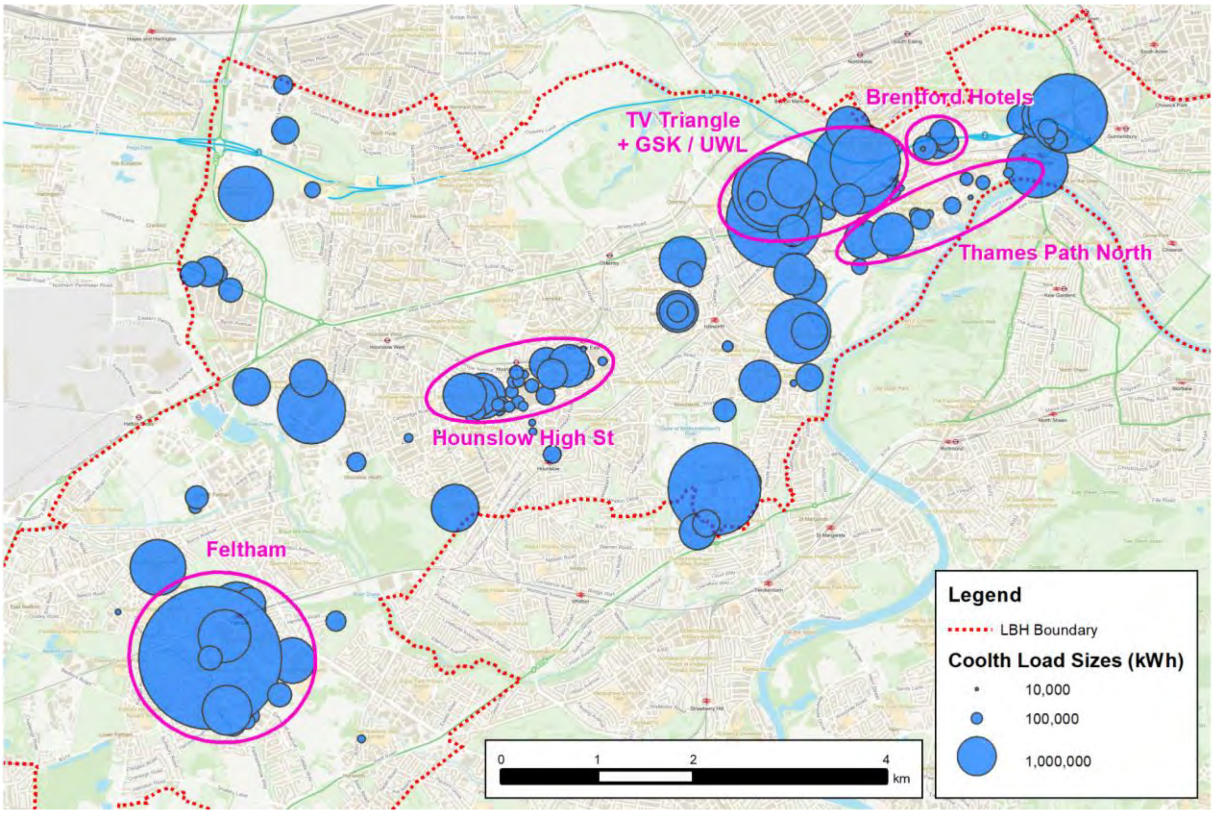


Figure 2-5: Distribution of Cooling Demand across LBH.

Dense regions of cooling demand were identified in the Brentford, Feltham, and Hounslow Town Centre areas. However, due to these areas' dispersion from each other, it would not be financially or technically viable to interconnect them[8]. As a result, a number of distinct cooling networks have been proposed, with dedicated cooling centres capable of interfacing with the district heating scheme (detailed in Appendix C). The proposed routes for each cooling network, established in Work Package 1, can be found in Appendix J.2.

The total cooling demand for each cooling network extent is shown in Figure 2-6.

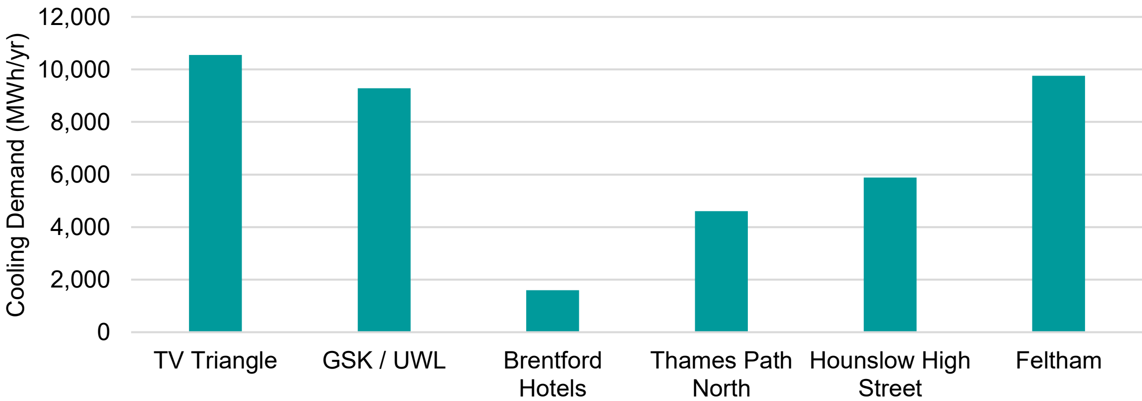


Figure 2-6: Cooling Demand for Each District Cooling Network Extent.

[8] Likewise, Heathrow Airport's cooling demand has not been considered in this study due to its remote location from Hounslow's main areas of demand, making it less suitable for inclusion within a cooling network. The capital cost and coolth losses associated with bridging this distance would be unlikely to offer financial or carbon benefits over Heathrow's existing (electrified) cooling systems.

2.5 Electrical Power

The scale and distribution of electrical power demand across the borough is demonstrated in Figure 2-7.

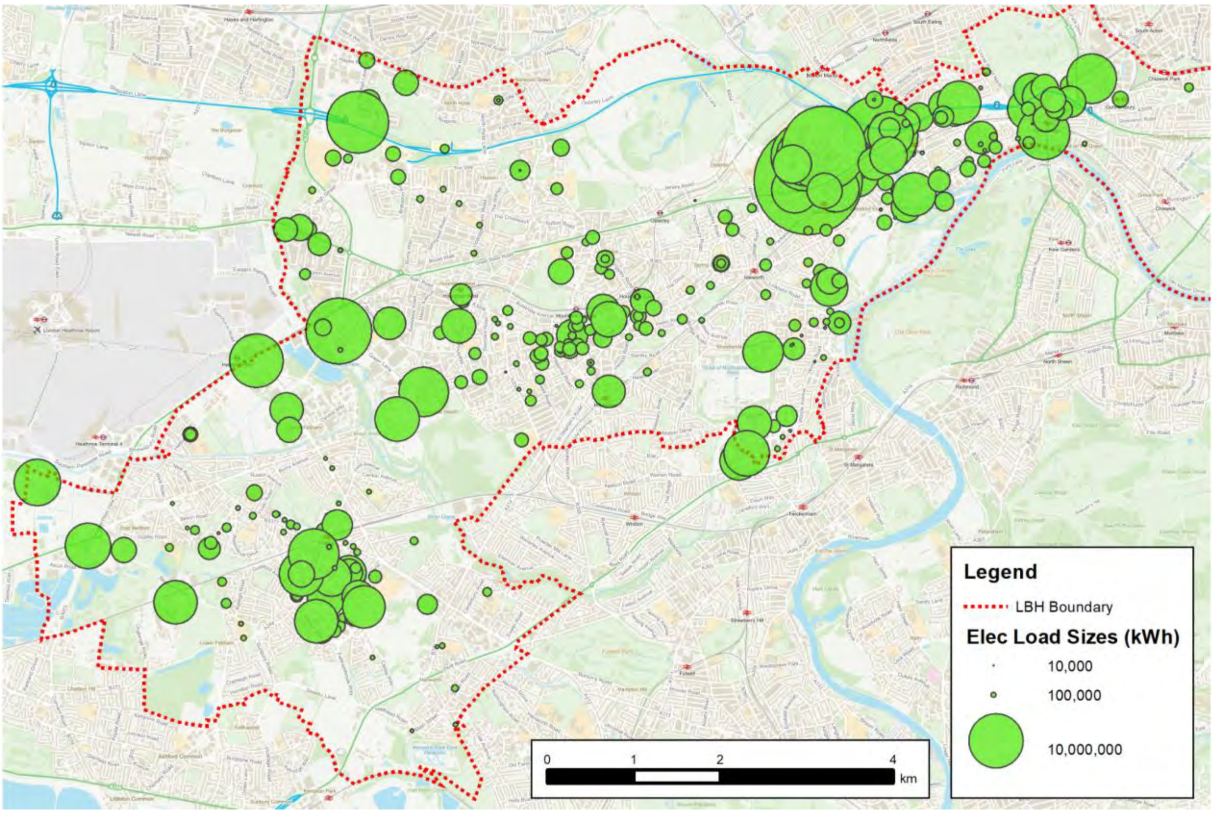


Figure 2-7: Distribution of Electrical Power Demand across LBH.

Similar to Heating and Cooling demand, Figure 2-7 includes sites which are likely to have a large enough demand to be connected to a decentralised energy network, based on floor area of a single load. This therefore does not demonstrate the full extent of power demand across the borough, as smaller loads, such as individual homes, are excluded from the analysis.

Installation of a private wire network alongside a district energy scheme would reduce the local strains on the electricity grid and could provide carbon savings, if supplied from a renewable generation source. It would also serve as an additional revenue source for the network. However, as set out in Section 3.1.3, no promising low-carbon electricity source could be identified within the borough.

A study was undertaken by LBH to determine the viability of installing solar photovoltaics panels on the rooftop of LBH owned properties throughout the borough. In total, this study concludes that 4.3MW of generation could be installed, however the points of generation are dispersed throughout the borough which does not lend itself to the establishment of a decentralised power network due to the length of private cables required to connect the various points of generation. However, this study estimated that approx. 50% (1.8GWh/year) of the generated electricity would not be consumed on site and would instead be exported to the grid. Rather than exporting to grid, it may be beneficial for LBH to explore selling the excess power to the heat network via a sleeved power purchase agreement (PPA) with the electrical DNO. If the resultant tariff is greater than the grid export tariff from PV and less than the grid import tariff from the heat network, then it would be beneficial for both projects.

3. Technical Optioneering

Initial techno-economic modelling (Section 5.1) was undertaken for a longlist of 'Technical Solutions', each consisting of:

1. Heat / cooling source(s), as well as peaking / resilient plant.
2. Heating / cooling energy centre location(s)
3. District heating / cooling network extent(s).

The opportunities for each of these categories have been assessed and appraised, as summarised in this section, in order to develop a number of technical solutions for each study boundary.

3.1 Low-Carbon Energy Sources

A technical appraisal and qualitative scoring assessment of the available low and zero carbon (LZC) energy sources was undertaken as part of Work Package 1. This process considered a number of factors in four categories:

- **Technical –** technology maturity, availability, security, and viability.
- **Environmental –** decarbonisation potential, air quality, and wider environmental impacts.
- **Financial –** envisaged capital and operational costs, as well as financial risks.
- **Deliverability –** envisaged implications from Planning and third parties.

The technologies required to exploit each energy source have been described in Appendix D. Detailed information of the appraisal process and a complete list of the options scored are contained in Appendix E.

3.1.1 Heating

The highest-scoring heat sources which were used as a basis to develop the network technical solutions longlist (detailed in Section 5.1) are shown in Table 3-1.

Waste heat recovery from the treated sewage outfall at Mogden remains the preferred heat source for the study boundaries encompassing Isleworth[9]. However, heat from on-site combustion of the biogas produced at Mogden is also shown to score highly and has been considered in the technical solutions. This biogas heat could be generated by either CHP as a byproduct of electricity generation or by boilers as heat only. Please see Appendix D.5 for further information.

The highest-scoring heat source for the Brentford study area was deemed to be ground source heat pumps. GSHPs are typically preferred due to their superior seasonal efficiency; however, the limited aquifer yield in the local area necessitates that air source heat pumps (ASHPs) also be employed in order to reach the defined environmental KPI.

Study Boundary	Technology	Location	Appraisal Score
East of Borough & Borough-wide	Waste Heat Recovery SSHP	Mogden Sewage Treatment Works	81%
East of Borough & Borough-wide	Biogas Combustion Excess Heat	Mogden Sewage Treatment Works	80%
Brentford	Open-loop GSHP	Boston Manor Park	80%
Brentford	ASHP	On Energy Centre site	78%

Table 3-1: Highest Scoring LZC Heating Energy Sources

3.1.2 Cooling

The preferred cooling solution in all cases would utilise water-to-water heat pumps as an interface to the district heating scheme, as listed in Table 3-2. This exchange of energy between the cooling networks and the main heat

[9] The acronym SSHP is used throughout the remainder of this report to describe this technology, which is covered in more detail in Appendix D.4 and differs from direct sewer heat recovery, covered in Appendix D.3.

network (termed 'prosuming') would be beneficial to the overall efficiency of the systems. Dry air coolers are included to ensure coolth can be generated even in the absence of heat demand from the network. In this scenario, waste heat from the cooling system would be discharged to atmosphere rather than captured as usable heat.

Study Boundary	Technology	Location	Appraisal Score
All	Heat Prosuming WSHP with Dry Air Cooler	On Energy Centre site	85%

Table 3-2: Highest Scoring LZC Cooling Energy Source.

3.1.3 Electrical Power

It was concluded that the only feasible low-carbon electrical power opportunity would be to offtake excess electricity from Mogden's existing CHP (Combined Heat and Power) engines, as shown in Table 3-3. However, this was not developed into one of the technical solutions (Section 5.1) after it was indicated that a significant number of CHP units were to be decommissioned.

Study Boundary	Technology	Location	Appraisal Score
East of Borough & Borough-wide	Mogden Biogas CHP	Mogden Sewage Treatment Works (STW)	77%
Brentford	None viable	None viable	-

Table 3-3: Highest Scoring LZC Electrical Power Energy Sources

3.2 Energy Centre Location

A technical appraisal and qualitative scoring assessment of potential energy centre (EC) sites was undertaken as part of Work Package 1, considering factors such as:

- Proximity to low / zero carbon energy sources.
- Proximity to energy offtakers.
- Space availability.
- Land ownership / usage / deliverability.

Detailed information of the appraisal process, as well as a complete list of the options scored, is contained in Appendix F.

3.2.1 Proposed Sites – Heating

The two energy centre locations at the council-owned Ivybridge Estate in Isleworth (Boxing Gym and Langdale Centre), along with the privately-owned site at Capital Vehicle Maintenance, were developed into the longlisted technical solutions for the East of Borough / Borough-wide study boundaries (Section 5.1). An on-site EC at Mogden (which would be located on land owned by Thames Water) was later incorporated into Stage 2 modelling (Section 7) following the establishment of the detailed phasing strategy.

For the Brentford cluster, two energy centre locations were modelled that were suitable for the proposed GSHP solution at Boston Manor Park.

Study Boundary	Heating Energy Centre Location	Appraisal Score
East of Borough / Borough-wide	Ivybridge Estate (Boxing Gym)	84%
East of Borough / Borough-wide	Ivybridge Estate (Langdale Centre)	83%
East of Borough / Borough-wide	On site at Mogden	81%
East of Borough / Borough-wide	Capital Vehicle Maintenance	79%
Brentford	Profile West Car Park (Site Allocation)	82%
Brentford	Boston Manor Park (Land beneath Chiswick Flyover)	78%

Table 3-4: Highest Scoring Heating Energy Centre Locations

3.2.2 Proposed Sites – Cooling

The preferred local cooling energy centre locations serving each cooling network extent are listed in Table 3-5.

District Cooling Network Extent	Cooling Energy Centre Location	Appraisal Score
TV Triangle	Harlequin Avenue Former Substation	91%
GSK / UWL	Boston Manor Park (Land beneath Chiswick Flyover)	91%
Brentford Hotels	Layton Road Car Park	96%
Thames Path North	Brentford Towers	91%
Hounslow High St	Hounslow House (Car park at rear of building)	97%
Feltham	Feltham Assembly Hall Car Park	86%

Table 3-5: Highest Scoring Cooling EC locations

3.3 Peaking and Resilient Plant

Supplementary heat generation is required in addition to the technologies in Table 3-1 for the following purposes:

- To supply the entire demand of the network in the event of unavailability of the main LZC heat source, i.e., ‘Resilience’.
- To supply the network during brief periods of peak demand, when LZC capacity is already maximised, and thermal storage has been depleted. ‘Peaking’ plant as such will only supply a small fraction of the total annual heat generated.

Typically, a single supplementary technology is used to serve both the purposes above. Three options are considered viable, listed below, and have been compared in Table 3-6.

1. Gas boilers (for heating)
    - Biogas, produced during the sewage treatment process, see Figure D-5, at Mogden, has also been considered as a potential fuel for boilers. Use of natural gas has been assumed in this section due to uncertainty regarding the resilience of the biogas supply – however, this is an option which should be further explored at the next stages of the project. Further information is included in Appendix D.5.
2. Electric boilers (for heating)
3. Air source heat pumps (ASHPs) (for both heating and cooling)

Technology	Pros	Cons
Gas boilers	- Low capital cost. - Low operational / fuel cost.	- High carbon emissions. - Flue required for gas discharge.
Electric boilers	- Low capital cost. - Low carbon emissions (long-term). - No flue required.	- High operational / fuel cost. - Large grid supply required[10].
ASHPs	- Low carbon emissions. - Medium operational /fuel cost.	- High capital cost. - External area required for evaporators.

Table 3-6: Comparison of Peaking/Resilient Plant Technology Options.

Gas boilers are the preferred short-to-medium term peaking and resilient plant technology due to their low cost and negligible impact on the electrical grid. However, over time the heat produced by gas boilers will represent a significant portion of the scheme’s lifetime carbon content. It is therefore envisaged that in the long-term it would be preferable to transition the peaking / resilient plant from gas boilers to electric, and subsequently to ASHPs, when economically viable.

Consequently, 13 of the 15 longlisted technical solutions in Section 5.1 have been modelled with gas boilers with an assumed efficiency of 90% as the peaking / resilient plant. The remaining two solutions have been modelled with electric boilers, due to anticipated difficulty with installing gas boiler flues next to the Chiswick flyover.

[10] This factor is exacerbated by the electrical grid constraints in West London: West London Electrical Capacity Constraints

4. Techno-Economic Modelling Strategy

This section outlines the key assumptions used in AECOM's in-house techno-economic model (TEM). For a more detailed list of TEM assumptions, refer to Appendix N.

All modelled scenarios have been compared against the project Key Performance Indicators (KPIs), as set out in Section 1.2. A solution will only be considered feasible if it achieves all three project KPIs.

4.1 Counterfactual Technologies

To assess the techno-economic viability of a district energy project, considering the counterfactual heating/cooling solution is crucial. It determines the maximum heating/cooling tariff that can be applied, preventing any customer from paying more for heating than they would otherwise pay, thus preventing customer detriment.

As agreed with LBH and aligned with GHNF requirements, it has been assumed that the counterfactual cases presented in Table 4-1 will be used to derive the tariffs that off-takers can pay without financial detriment.

Table 4-1: Counterfactual Technologies Considered in the Techno-economic Model.

Network Relevance	Counterfactual Technology	Applicable Customers	Notes
District Heating	Gas Boilers	Existing residential customers and micro-businesses[11].	For the purposes of GHNF, existing domestic customers and micro-businesses are considered "at risk" and must not be offered a price of heat greater than a gas counterfactual[12].
District Heating	ASHPs	All other customers including existing and future private and public sector buildings.	Regarding public buildings, it is assumed that each building would need to transition to a low carbon heat source, even if the District Heating Network (DHN) project does not proceed, in order to meet net zero ambitions. The current business-as-usual (BAU) solution of gas boilers in some buildings would not be suitable in the long term, as it does not align with the council's decarbonisation plans or those of other public sector bodies. Additionally, it is assumed that all future developments will require a low carbon heating solution to comply with Building Regulations Part L and comply with the Future Buildings Standard (currently anticipated to come into effect from 2025).
District Cooling	Air-cooled chillers	All customers with a cooling load.	This is the most common cooling generation technology for large commercial buildings and so is considered to be most representative of the loads which are identified as potential connections.

4.2 Key Assumptions

4.2.1 Heat Purchase/Sale Tariffs

4.2.1.1 Gas and Electricity Purchase Tariffs

At the time of writing, fuel prices are highly volatile due to the impact of geopolitical factors. For this analysis, projected fuel unit prices for gas and electricity are based on energy price analysis published by the Department for Business, Energy, and Industrial Strategy (BEIS) published in April 2023[13].

Within the Treasury Green Book tables, three bands of electricity prices are given: High, Central and Low for three scales of consumption: large scale (Industrial), medium scale (Public Sector/Commercial) and small scale (Domestic). Gas prices are also provided in the tables, under four different scenarios: A (low prices), B (average

[11] Guidance for Microbusinesses | Ofgem
[12] Green Heat Network Fund: guidance for applicants, Round 6 (publishing.service.gov.uk)
[13] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

prices), C (high prices) and D (high long term fuel prices) for large, medium, and small-scale use. These projections are illustrated in Figure 4-1.

For the purposes of the model, it is assumed that the customers are currently paying the Central and scenario B prices within the relevant consumption category for electricity and gas, respectively.

The heat network is assumed to purchase utilities at the 'Industrial' price, whereas for the counterfactual scenarios, 'Domestic' prices are used.

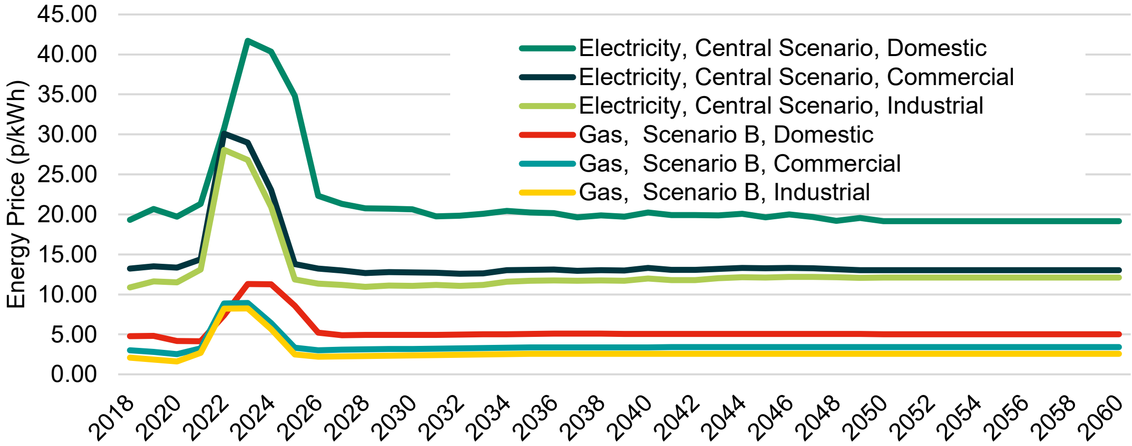


Figure 4-1: HM Treasury Green Book Future Fuel Price.

4.2.1.2 Mogden STW Purchase Tariffs

The variable price paid for offtaking waste heat from Mogden Sewage Treatment Works has been derived as follows:

- Sewage Outfall Waste Heat Recovery – [redacted]
- Biogas Combustion Excess Heat Recovery – [redacted]

4.2.1.3 Heating/Cooling Sales Tariffs

To calculate the heat tariff for each customer, counterfactual costs of heating and cooling were initially calculated for each site, following the approach outlined in Section 4.1. This process yielded a pence per kilowatt-hour value for every year throughout the project's lifespan. This value takes into account, for each customer, the purchase of replacement counterfactual heating/cooling plant, maintenance, and fuel costs, as expressed below.

Fixed portion of the tariff (typically)

Variable portion of the tariff (typically)

$$T = \frac{\overbrace{\frac{C}{L} + M}^{\text{fixed}} + \overbrace{F}^{\text{variable}}}{H}$$

Where:

T = Counterfactual Heat Tariff (p/kWh)
C = Capital Cost of the Counterfactual Plant (£)
L = Lifespan of Counterfactual Plant (years)
M = Maintenance Cost of Counterfactual Plant (£/year)
F = Fuel Cost of Counterfactual Plant (£/year)
H = Annual Heat Consumption (kWh/year)

C/L can also be referred to as Replacement Expenditure (RepEx). It is modelled as an annual sinking fund which accumulates to the capital cost of the counterfactual over the lifespan of the counterfactual.

The resulting tariffs are contingent on the peak demand for each customer and the size of the counterfactual plant. As much of the cost associated with the counterfactual plant is linked to its capacity (kW), the greater the ratio of peak (kW) to annual (kWh) demand, the higher the tariff.

Heat tariffs based on gas counterfactuals are lower than those based on heat pump counterfactuals. Despite the higher efficiency of heat pumps compared to gas boilers, the elevated cost of electricity and the higher plant costs contribute to an overall higher heat cost.

Table 4-2 below outlines the network's 40-year weighted average heating and cooling sales tariffs. These are the weighted[14] average across all customers within the Customer Category.

Energy Type	Customer Category	40-Year Average Weighted Tariff
Heating	Existing residential customers and micro-businesses (GHNF "at risk")	[redacted]
	All other customers including existing and future private and public sector buildings.	
Cooling	All customers with a cooling load.	

Table 4-2: Network's 40-Year Average Heating/Cooling Sales Tariffs – Borough-wide Plus Heathrow

4.2.2 Connection Charges

Connection charges have been modelled as upfront costs for connection to both the heating and cooling networks (if a cooling offtaker). This charge typically covers the cost of constructing the connection to each building / site and is aligned to the upfront capital cost of the counterfactual. This differs from "C" in the tariff equation in 4.2.1.3 in that it is the capital cost associated with initial construction of the counterfactual, whereas C is the cost of replacing the counterfactual at the end of its lifespan, spread evenly over the duration of its lifespan.

These have been calculated at a rate of [redacted] of peak demand for heating and at a rate derived from counterfactual system costs (i.e., air-cooled chillers) for cooling. The connection charge for heating has been selected to correspond to typical market rates from other low carbon heat networks, but must also offer value against the counterfactual system. The final value will be subject to agreement between the network operator and the customers through a process of negotiation. The total heating connection charge [redacted] for all customers equates to approximately [redacted] of the estimated total cost of the counterfactual ([redacted]), so there is potential for the average rate to be increased whilst still offering value, subject to the network developers pricing strategy.

It is important to highlight that a uniform connection charge structure is implemented across all customers as opposed to the two-tiered tariff structure discussed in previous section. Table 4-3 below provides a summary of the total connection charges modelled in this study.

Network Type	Rate	Property Type	Total Connection Charge
Heating	[redacted]	LBH Buildings Excluding Social Housing	[redacted]
		LBH Social Housing	
		Other Public and Private Buildings	
		Total	
Cooling	[redacted]	LBH Buildings	
		Other Public and Private Buildings	
		Total	

Table 4-3: Heating and Cooling Networks Total Connection Charges.

4.2.3 Carbon Emission Assumptions

Scheme carbon savings depend on the input fuel and the associated carbon factors of the fuel which is being offset by the heat generation technology. Emission factors associated with the combustion of gas are assumed to be

[14] Accounting for the different volume of heat sale to the customers

constant over the lifetime of the project, where the emission factor used is 0.184kgCO_2e/kWh of gas consumed, based on UK Government GHG Conversion Factors. Emission factors associated with electricity are assumed to decarbonise over time and are taken from the grid average emission factors from the HM Treasury Green Book (Data Table 1), as illustrated in Figure 4-2.

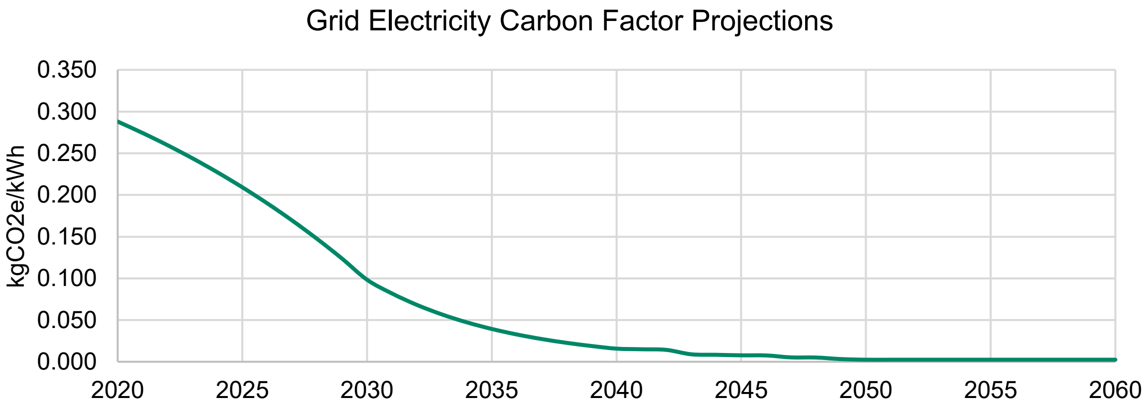


Figure 4-2: BEIS Green Book Supplementary Guidance: Grid Electricity Emission Factors[15].

Biogas has been modelled as a zero-carbon source, aligned with SAP 10.1 guidance. This is under the assumption that residual carbon emissions are associated with transport, which is not applicable at the point of generation, i.e., Mogden STW.

[15] BEIS Green Book Supplementary Guidance (Nov 2022) Long-run marginal, Commercial/ Public sector, include transmission and distribution losses.
https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

5. Techno-Economic Modelling – Stage 1

5.1 Longlisted Technical Solutions

In collaboration with LBH, 16 technical solutions were developed using the highest scoring low carbon energy sources and energy centres that were cross compatible. The solutions taken forward for assessment are set out in Table 5-1. In some solutions, more than one low carbon energy source is proposed. The number indicates the priority of the source. Note that solutions 4 and 5 are fully electric, due to anticipated difficulty with installing gas boiler flues next to the Chiswick flyover at Boston Manor Park energy centre site.

In solutions 9, 10, 15 and 16, within the modelling excess biogas heat was prioritised over waste heat recovery only to assist in assessing whether inclusion of the former had a positive or negative impact on the project.

Ref No.	Study Boundary	Low/Zero Carbon Heat Source(s)	Peaking / Resilience Plant	Heating Energy Centre Location	Cooling Networks Included
1	Brentford	1. Open-loop GSHP	Gas Boilers	Profile West Car Park	No
2	Brentford	1. Open-loop GSHP 2. ASHP	Gas Boilers	Profile West Car Park	No
3	Brentford	1. Open-loop GSHP 2. ASHP	Gas Boilers	Profile West Car Park	Yes
4	Brentford	1. Open-loop GSHP 2. ASHP	Electric Boilers	Boston Manor Park	No
5	Brentford	1. Open-loop GSHP 2. ASHP	Electric Boilers	Boston Manor Park	Yes
6	East of Borough	1. Open-loop GSHP 2. ASHP	Gas Boilers	Capital Vehicle Maintenance	No
7	East of Borough	1. Waste Heat Recovery SSHP	Gas Boilers	Ivybridge Estate (Boxing Gym)	No
8	East of Borough	1. Waste Heat Recovery SSHP	Gas Boilers	Ivybridge Estate (Boxing Gym)	Yes
9	East of Borough	1. Biogas Combustion Excess Heat 2. Waste Heat Recovery SSHP	Gas Boilers	Ivybridge Estate (Boxing Gym)	No
10	East of Borough	1. Biogas Combustion Excess Heat 2. Waste Heat Recovery SSHP	Gas Boilers	Ivybridge Estate (Boxing Gym)	Yes
11	Borough-wide	1. Open-loop GSHP 2. ASHP	Gas Boilers	Capital Vehicle Maintenance	No
12	Borough-wide	1. Waste Heat Recovery SSHP	Gas Boilers	Ivybridge Estate (Boxing Gym)	No
13	Borough-wide + Heathrow	1. Waste Heat Recovery SSHP	Gas Boilers	Ivybridge Estate (Boxing Gym)	No
14	Borough-wide	1. Waste Heat Recovery SSHP	Gas Boilers	Ivybridge Estate (Boxing Gym)	Yes
15	Borough-wide	1. Biogas Combustion Excess Heat 2. Waste Heat Recovery SSHP	Gas Boilers	Ivybridge Estate (Boxing Gym)	No
16	Borough-wide	1. Biogas Combustion Excess Heat 2. Waste Heat Recovery SSHP	Gas Boilers	Ivybridge Estate (Boxing Gym)	Yes

Table 5-1: Modelled Technical Solutions (TS).

5.2 Stage 1 Modelling Results

5.2.1 Environmental

The performance of the technical solutions against the Environmental KPI is demonstrated in Table 5-2.

A 'fail' indicates that the solution is unable to achieve the target KPI (45gCO_2e per kWh heat delivered) with the capacity that is available for that solution's LZC technology. Note that in the case of solutions 4 and 5, the target KPI has been significantly surpassed as these are fully electrified solutions.

Ref. No.	Study Boundary	40-Year Average Carbon Intensity (gCO_2e/kWh)	KPI Pass / Fail	Lifetime Carbon Savings compared to Gas Boilers (ktCO_2e)
1	Brentford	171	Fail	200
2	Brentford	45	Pass	786
3	Brentford	45	Pass	743
4	Brentford	15	Pass	924
5	Brentford	13	Pass	927
6	East of Borough	45	Pass	1,219
7	East of Borough	45	Pass	1,216
8	East of Borough	45	Pass	1,171
9	East of Borough	45	Pass	1,215
10	East of Borough	45	Pass	1,169
11	Borough-wide	45	Pass	1,888
12	Borough-wide	45	Pass	1,877
13	Borough-wide + Heathrow	45	Pass	2,947
14	Borough-wide	45	Pass	1,816
15	Borough-wide	45	Pass	1,873
16	Borough-wide	45	Pass	1,814

Table 5-2: Environmental Performance of Technical Solutions.

5.2.2 Economic

The performance of the technical solutions against the Economic KPI is demonstrated in [redacted] Table 5-3. For any solution to achieve an IRR of [redacted] would almost certainly rely on Government capital grant support, such as the Green Heat Network Fund. Modelled scenarios have therefore been evaluated against their capacity to reach this [redacted] figure with the *maximum estimated grant required* (under GHNF guidance). In the event that this quantity of grant funding is not available[16], then UK Investment Bank (UKIB) funding may also be required.

A 'fail' indicates that the amount of grant support required to achieve the KPI is greater than is allowable with state aid limits, which is less than or equal to 50% of the capital expenditure.

[redacted]

Ref No.	Solution Description (Network Extent | LZC Source | Peaking & Resilient Plant | Cooling Included)	40-Year Pre -Grant IRR	40-Year IRR with Maximum GHNF	Grant Support Required to Achieve 10% IRR (% of CapEx)	KPI Pass / Fail	Project CapEx (£m)
1	Brentford | GSHP | Gas Boilers | No Cooling	[redacted]	[redacted]	[redacted]	Fail	[redacted]
2	Brentford | GSHP + ASHP | Gas Boilers | No Cooling	[redacted]	[redacted]	[redacted]	Pass	[redacted]
3	Brentford | GSHP + ASHP | Gas Boilers | Cooling	[redacted]	[redacted]	[redacted]	Pass	[redacted]
4	Brentford | GSHP + ASHP | Electric Boilers | No Cooling	[redacted]	[redacted]	[redacted]	Fail	[redacted]
5	Brentford | GSHP + ASHP | Electric Boilers | Cooling	[redacted]	[redacted]	[redacted]	Fail	[redacted]
6	East of Borough | GSHP + ASHP | Gas Boilers | No Cooling	[redacted]	[redacted]	[redacted]	Pass	[redacted]
7	East of Borough | Final Effluent SSHP | Gas Boilers | No Cooling	[redacted]	[redacted]	[redacted]	Pass	[redacted]
8	East of Borough | Final Effluent SSHP | Gas Boilers | Cooling	[redacted]	[redacted]	[redacted]	Fail	[redacted]
9	East of Borough | Biogas Heat + Final Effluent SSHP | Gas Boilers | No Cooling	[redacted]	[redacted]	[redacted]	Pass	[redacted]
10	East of Borough | Biogas Heat + Final Effluent SSHP | Gas Boilers | Cooling	[redacted]	[redacted]	[redacted]	Fail	[redacted]
11	Borough-wide | GSHP + ASHP | Gas Boilers | No Cooling	[redacted]	[redacted]	[redacted]	Fail	[redacted]
12	Borough-wide | Final Effluent SSHP | Gas Boilers | No Cooling	[redacted]	[redacted]	[redacted]	Pass	[redacted]
13	Borough-wide + Heathrow | Final Effluent SSHP | Gas Boilers | No Cooling	[redacted]	[redacted]	[redacted]	Pass	[redacted]
14	Borough-wide | Final Effluent SSHP | Gas Boilers | Cooling	[redacted]	[redacted]	[redacted]	Fail	[redacted]
15	Borough-wide | Biogas Heat + Final Effluent SSHP | Gas Boilers | No Cooling	[redacted]	[redacted]	[redacted]	Pass	[redacted]
16	Borough-wide | Biogas Heat + Final Effluent SSHP | Gas Boilers | Cooling	[redacted]	[redacted]	[redacted]	Fail	[redacted]

Table 5-3: Economic Performance of Technical Solutions

The pre- and post-grant IRRs for each scenario have also been presented graphically in Figure 5-1.

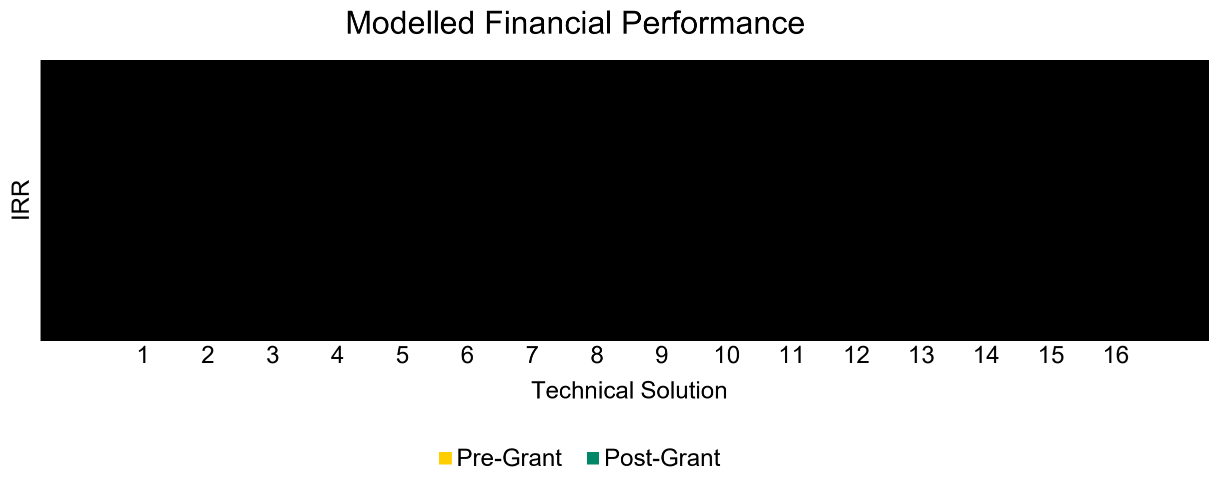


Figure 5-1: Impact of Grant Funding on IRR for Each Modelled Technical Solution.

It should be highlighted that through design refinement and sensitivity analysis, it may be possible for solutions which come close to achieving the target IRR of [redacted] to achieve a pass; an example of a borderline case being solution 8.

5.3 Stage 1 Results Summary

Out of the 16 modelled technical solutions (TS), only one (TS1) failed to achieve the Environmental KPI, while two (TS4 and TS5) exceeded it due to a technical requirement to use only electrical generation plant, thereby eliminating natural gas from the heat mix.

A total of eight technical solutions met both the Environmental KPI and Economic KPI. These were TS2 and TS3 in Brentford, TS6, TS7, and TS9 in the East of the Borough, and TS12, TS13, and TS15 in the Borough-wide. These are discussed further below.

5.3.1 Brentford

Within Brentford, TS2 demonstrated the highest carbon savings, the highest Internal Rate of Return (IRR), and the lowest Capital Expenditure (CapEx). Additionally, it featured reduced complexity due to the omission of the cooling network. Moreover, if a cooling network becomes desirable in the future, it can be retrofitted to TS2. Hence, TS2 is considered the most promising solution for the Brentford boundary.

5.3.2 East of the Borough

The performance of the three viable solutions (TS6, TS7, and TS9) within the East of the Borough is closely aligned, with TS9 demonstrating marginally greater carbon savings and TS7 having the highest Internal Rate of Return (IRR). Strategically, TS7 and TS9 are preferred due to their higher potential for growth owing to the scale of the low carbon heat source and the opportunity to utilise council-owned land for the energy centre. However, it is essential to note that they are dependent on a third party (Thames Water) for the low carbon heat source, unlike TS6, which is not reliant on external partners. TS7 is considered the most promising solution for the East of Borough boundary.

5.3.3 Borough-wide

Among the three viable solutions (TS12, TS13, and TS15) for the Borough-wide, TS12 and TS13 differ only in the inclusion of Heathrow Airport as a customer (which is seen in TS13). Both carbon savings and IRR are improved with the addition of Heathrow Airport. TS15 differs from TS12 with its inclusion of excess heat from biogas combustion as an LZC source and performs worse economically. The primary reason for this is that each kWh of heat from biogas combustion is approximately [redacted] more expensive than each unit of heat from the sewer source heat pump – approximately [redacted] vs [redacted]

Given that TS13 has the highest IRR and carbon savings among the three options, it is considered the most promising solution. However, in future stages, if Heathrow Airport chooses not to connect for technical or commercial reasons, the resulting TS12 still remains a highly viable option.

5.3.4 Summary

The preferred solutions for each study boundary are summarised in Table 5-4.

Ref. No.	Study Boundary	Scheme Details	40-Year Pre-Grant IRR	Lifetime Carbon Savings vs Gas Boilers (ktCO$_2$e)
2	Brentford	– LZC(s): Open-loop GSHP; ASHP – Peak / Resilience Plant: Gas Boilers – EC Location: Profile West Car Park – Cooling networks not included	[redacted]	786
7	East of Borough	– LZC(s): Waste Heat Recovery SSHP – Peak / Resilience Plant: Gas Boilers – EC Location: Ivybridge Estate (Boxing Gym) – Cooling networks not included		1,219
12	Borough-wide	– LZC(s): Waste Heat Recovery SSHP – Peak / Resilience Plant: Gas Boilers – EC Location: Ivybridge Estate (Boxing Gym) – Cooling networks not included		1,877
13	Borough-wide + Heathrow	– LZC(s): Waste Heat Recovery SSHP – Peak / Resilience Plant: Gas Boilers – EC Location: Ivybridge Estate (Boxing Gym) – Cooling networks not included		2,947

Table 5-4: Preferred Technical Solutions for Each Study Boundary Following Stage 1 Modelling.

TS7, TS12 and TS13 are highly similar in nature, with the same heat sources and energy centre location, differing primarily in scale of the network. Therefore, for all of these network solutions there remains flexibility about the final extent of the network through future design stages and even during construction of early phases.

Upon consultation with LBH, it was agreed to progress and analyse technical solutions 12 and 13 further as the overall preferred solutions for Stage 2 techno-economic modelling in this study. These networks are the most ambitious solutions, with the highest Capital Expenditure (CapEx) cost. However, they simultaneously save the greatest amount of carbon and have the highest Internal Rate of Return (IRR) among the solutions modelled.

6. Borough-wide Network Phasing Strategy

In recent years, the West London boroughs of Hillingdon, Ealing, and Hounslow have been particularly affected by electrical grid constraints at the DNO (Distribution Network Operator) level. New demand has been attributed to electric vehicles, electrified heating, and in particular, the opening of new data centres[17].

Following Stage 1 techno-economic modelling, a detailed phasing strategy has been established with input from the local DNOs, as set out in this section, with further detail in Appendix G. This ensures that the recommended solution is aligned with electrical capacity availability at grid level.

6.1 Ramped Electrical Connection

The proposed energy centre technical design for each district heating network extent, particularly the Borough-wide Solution, requires a significant electrical connection to the grid. This is required to power the water-to-water heat pumps, which are responsible for extracting waste heat from Mogden's sewage treatment outfall, as well as the main circulation pumps and other ancillaries. The estimated connection size for each network extent is shown in Table 6-1.

Network Extent (Heating Only)	Estimated Required Electrical Capacity (MVA)
Brentford	11.0
East of Borough	10.9
Borough-wide	16.9
Borough-wide + Heathrow	24.5

Table 6-1: Estimated Required Electrical Connection Sizes for Each Network Extent.

As shown above, an initial estimated connection size of ~25 MVA was calculated for a centralised energy centre capable of serving the Borough-wide including Heathrow Airport. From AECOM's correspondence with the two relevant electrical DNOs for the borough (SSEN and UKPN), it was established that it would not be possible to secure a connection of this size until 2037, due to the significant grid constraints in the West London area. A 'ramped' electrical connection, which could be applied for immediately, was suggested as an alternative, subject to the following conditions:

- Starting connection of 1 MVA, increasing every year by 1 MVA to a maximum of 10 MVA.
- Connection to be made to an 11 kV grid supply point.

The proposed phasing strategy has therefore modelled the Borough-wide network with three separate energy centres (described in the following section), in order to maximise the ramp rate and total connection size (3 MVA/year and 30 MVA, respectively).

In Appendix G, AECOM's Transmission & Distribution team have outlined the potential options for connection to grid supply points in the area, as well as the suggested next steps to be pursued with the DNOs.

6.2 Building Connections and Network Build-Out

The connection dates for each proposed customer of the heat network will be dictated by two factors:

1. The date by which the heat distribution pipe network has been built-out to reach their local area.
2. The predicted remaining life of existing heating plant installed.

The initial phase of the network will be for the loads in the immediate vicinity of Mogden STW: the Isleworth cluster. The remainder of the Borough-wide (including Heathrow) phasing strategy has been aligned with SSEN's ramped capacity scheme, as set out in the preceding section. This ensures that for any given stage of the project's build-out, there is sufficient electrical capacity to serve the customer heat demand (via heat pumps), without resorting to significant additional gas boiler utilisation.

All existing buildings with gas boilers currently installed have been assumed to connect to the network as soon as it arrives in their area and have been labelled as 'primary loads'. However, stakeholder engagement with key

[17] West London Electrical Capacity Constraints

customers (Section 9.1) revealed a number of buildings in which low-carbon heating had already been installed – for example, ASHPs at Hounslow House. It was therefore decided to delay these buildings' modelled connection dates until a point at which their existing plant would be end-of-economic-life (EOEL). As such, two 'infill load' phases, 2035 and 2040, have been proposed in the modelled phasing strategy, aligned with the installation dates and estimated lifespans of existing plant.

Figure 6-1 demonstrates how the proposed phasing strategy (Figure 6-2) has been designed to maximise the year-on-year increase in heat demand with the available ramped electrical connection. It should also be noted that network growth could potentially be accelerated if additional alternative capacity could be secured sooner (for example, using a private wire from the existing electrical supply at Mogden – detailed in Appendix G).

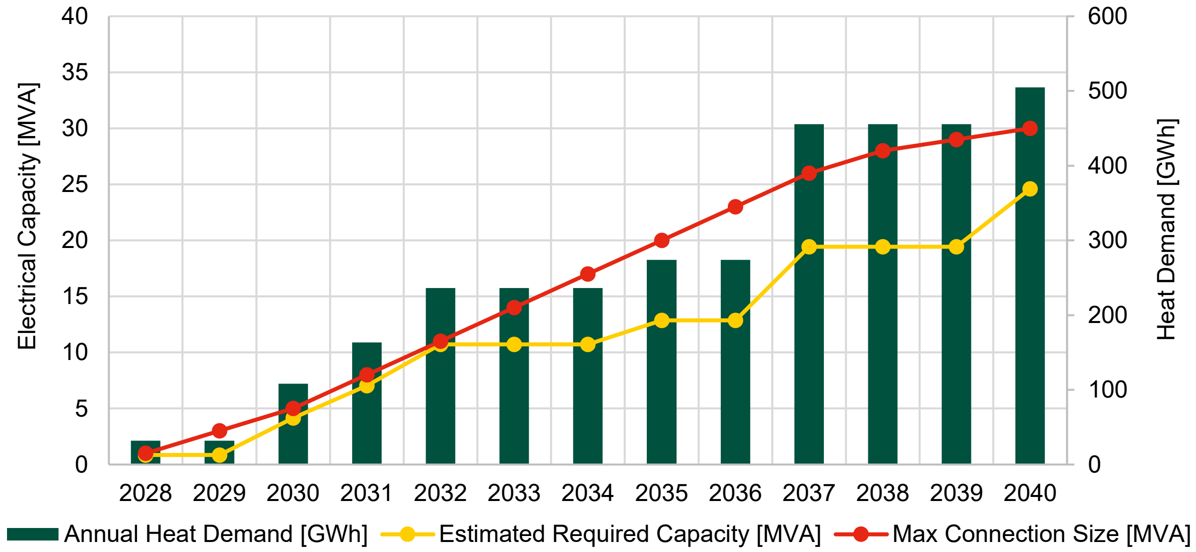


Figure 6-1: Phasing Strategy Heat Demand and Electrical Capacity.

6.3 Energy Centre Build-Out

The three energy centre locations proposed are listed in Table 6-2. A reduced footprint is possible at each site as a result of spreading the total installed plant across the locations. The highest-scoring locations from Section 3.2.1 were used, taking into account proximity to Mogden, usage[18], land ownership, and associated risk.

Ref	Name	What3words Location	Ownership	Proposed Construction Year
EC1	On Site at Mogden	///master.pocket.festivity	Thames Water	2028
EC2	Ivybridge Social Housing (Boxing Gym)	///wallet.index.sake	Hounslow Council	2029
EC3	Capital Vehicle Maintenance	///cure.asleep.famous	Private	2031

Table 6-2: Proposed Energy Centre Locations.

[18] Note that the Langdale Centre has not been selected as an EC, to allow for the Boxing Gym to be relocated to this site.

The proposed build-out timeline of the distribution network and energy centres is as shown in Figure 6-2.

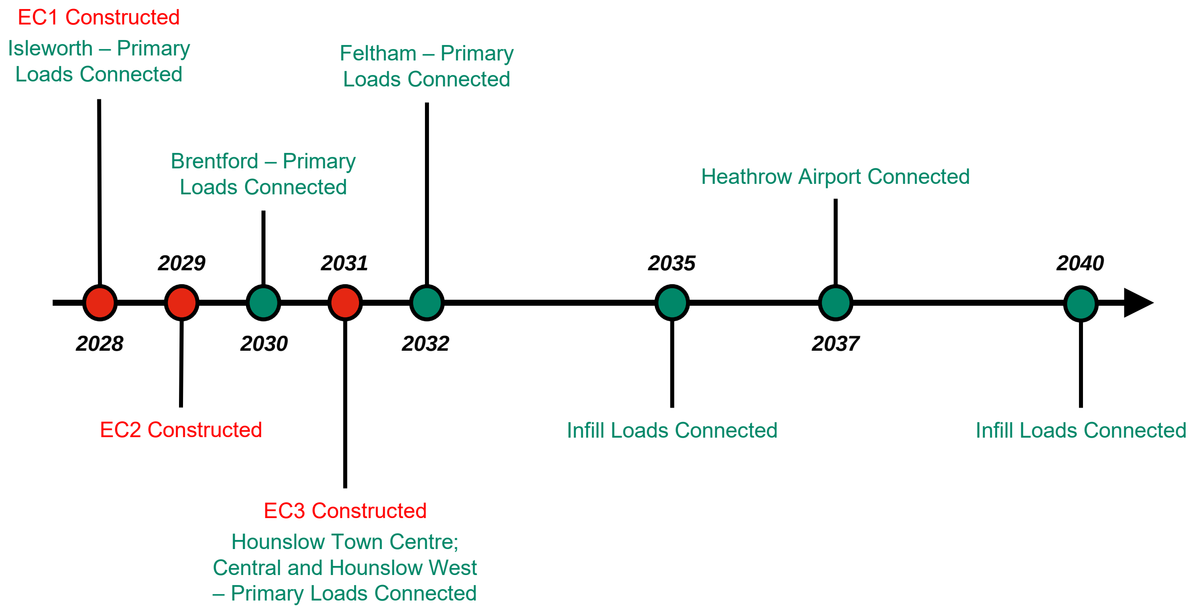


Figure 6-2: Proposed Borough-wide Network Phasing (including Heathrow).

This strategy proposes that the plant installed at each energy centre (primarily: heat pumps, gas boilers, and thermal stores) also be phased in accordance with customer heat demand and the connection available, shown for installed heat pump plant in Figure 6-3 (for details, refer to Appendix H). This allows for capital expenditure to be spread over a number of years, reducing the impact to IRR. Moreover, this approach offers strategic flexibility: there is a reduced risk of sunk capital if future phases' demand is not as predicted. For example, if Heathrow Airport were to choose not to connect, the network could viably continue with only two energy centres. The later construction of EC3 – which is currently proposed for location on currently a privately-owned site – also allows time for alternative sites to be considered.

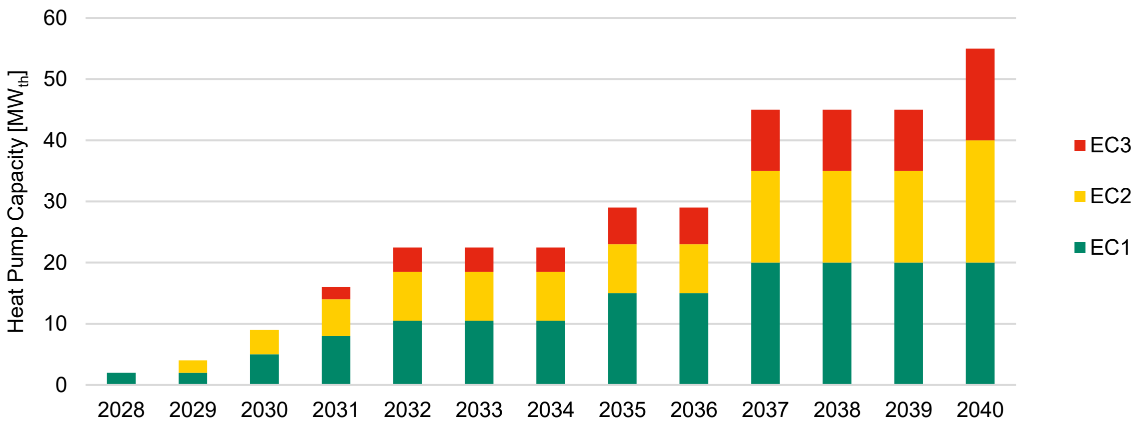


Figure 6-3: Phasing of installed Heat Pump Capacity by Energy Centre.

7. Techno-Economic Modelling – Stage 2

7.1 Developed Technical Solutions

As discussed in Section 5.3, technical solutions 12 and 13 were chosen as the overall preferred network solutions for subsequent modelling. Accordingly, the techno-economic models for these options have been updated to incorporate the bespoke phasing strategy set out in Figure 6-2 previous section. Table 7-1 shows the key parameters of the two phased Borough-wide solutions – with and without Heathrow.

Ref	Study Boundary	Low / Zero Carbon Heat Source(s)	Peak / Resilience Plant	Energy Centre Location(s) & Connection Year	Cooling Networks Included
12	Borough-wide	Mogden Waste Heat Recovery SSHP	Gas Boilers	EC1: Mogden – 2028 EC2: Ivybridge Boxing Gym – 2029	No
13	Borough-wide + Heathrow	Mogden Waste Heat Recovery SSHP	Gas Boilers	EC1: Mogden – 2028 EC2: Ivybridge Boxing Gym – 2029 EC3: Capital Vehicle Maintenance - 2031	No

Table 7-1: Overall Preferred Technical Solutions in Hounslow.

7.2 Stage 2 Modelling Results

Table 7-2 and Table 7-3 summarise the key network parameters for the scheme, and the economic and environmental performance for the developed solutions.

Parameter	Borough-wide	Borough-wide + Heathrow
Network Annual Heat Consumption (MWh/yr)	317,700	484,000
Peak Heat Demand at Full Build Out (MW)	126	162
SSHP Capacity (MW)	40	55
Gas Boiler Capacity (MW)	130	170
Thermal Store Capacity (m3)	2,000	2,750
%s of Annual Heat Demand met by SSHP & Thermal Stores over 40 years	86%	84%
% of Annual Heat Demand met by Gas Boilers over 40 years	[redacted]	[redacted]
Total Capital Cost	[redacted]	[redacted]
Total Connection Fees	[redacted]	[redacted]
Average Initial 5 Years CO2e Intensity (GHNF) (gCO2e/kWh)	95	86
Levelised Cost of Heat (p/kWh)	[redacted]	[redacted]
Levelised Cost of Counterfactual (ASHP & Gas Boilers) (p/kWh)	[redacted]	[redacted]
Levelised Cost of All ASHP Counterfactual (p/kWh)	[redacted]	[redacted]
Total Trench Length of Network Route (m)	66,476	68,510
Linear Heat Density (MWh/m)[19]	4.8	7.1

Table 7-2: Key Network Parameters for the Developed Options

Metric	Borough-wide	Borough-wide + Heathrow
40yr IRR without grant funding	[redacted]	[redacted]

19 [redacted]

Metric	Borough-wide	Borough-wide + Heathrow
40yr IRR with maximum grant funding[20]	[redacted]	[redacted]
40yr NPV without grant funding	[redacted]	[redacted]
40yr NPV with maximum grant funding[20]	[redacted]	[redacted]
40yr Social IRR (SIRR)[21] without grant funding	[redacted]	[redacted]
40yr Average scheme carbon factor (gCO_2e/kWh)	41.6	43.6
40yr CO_{2e} Savings vs ASHP Only BaU (tonnes)	[redacted]	[redacted]
40yr CO_{2e} Savings vs Gas Boiler Only BaU (tonnes)	[redacted]	[redacted]
40yr CO_{2e} Savings vs Project-Specific BaU (tonnes)	[redacted]	[redacted]
40yr NOx Savings vs Project-Specific BaU (tonnes)	[redacted]	[redacted]

Table 7-3: Key Economic and Environmental Performance Factors for the Developed Options

Borough-wide + Heathrow Option Projected Balance Sheet

Project Cumulative Cash Flow - '£'000

[redacted]

Figure 7-1: Projected Cumulative Cashflow for the Borough-wide Option Including Heathrow.

[20] [redacted]

[21] This includes the costed impact of carbon and air quality benefits, using BEIS valuation for these elements

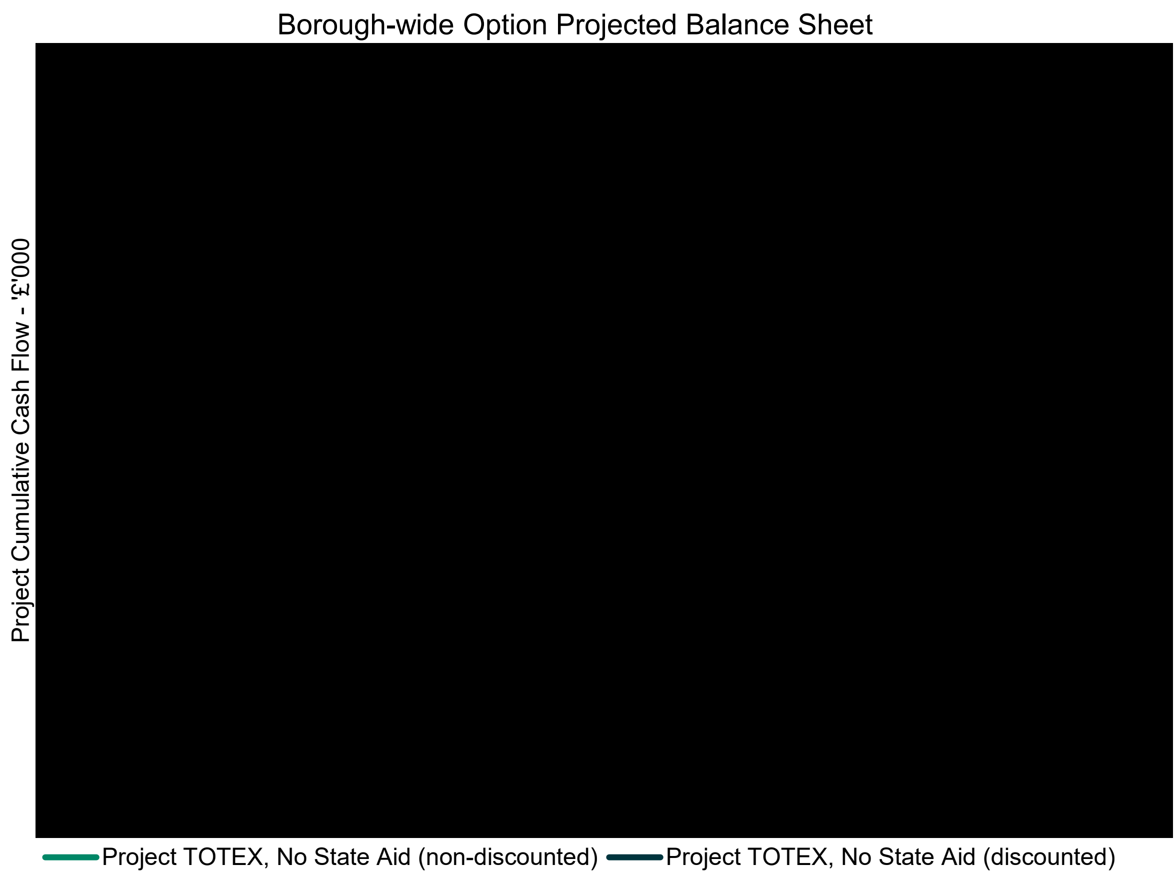


Figure 7-2: Projected Cumulative Cashflow for the Borough-wide

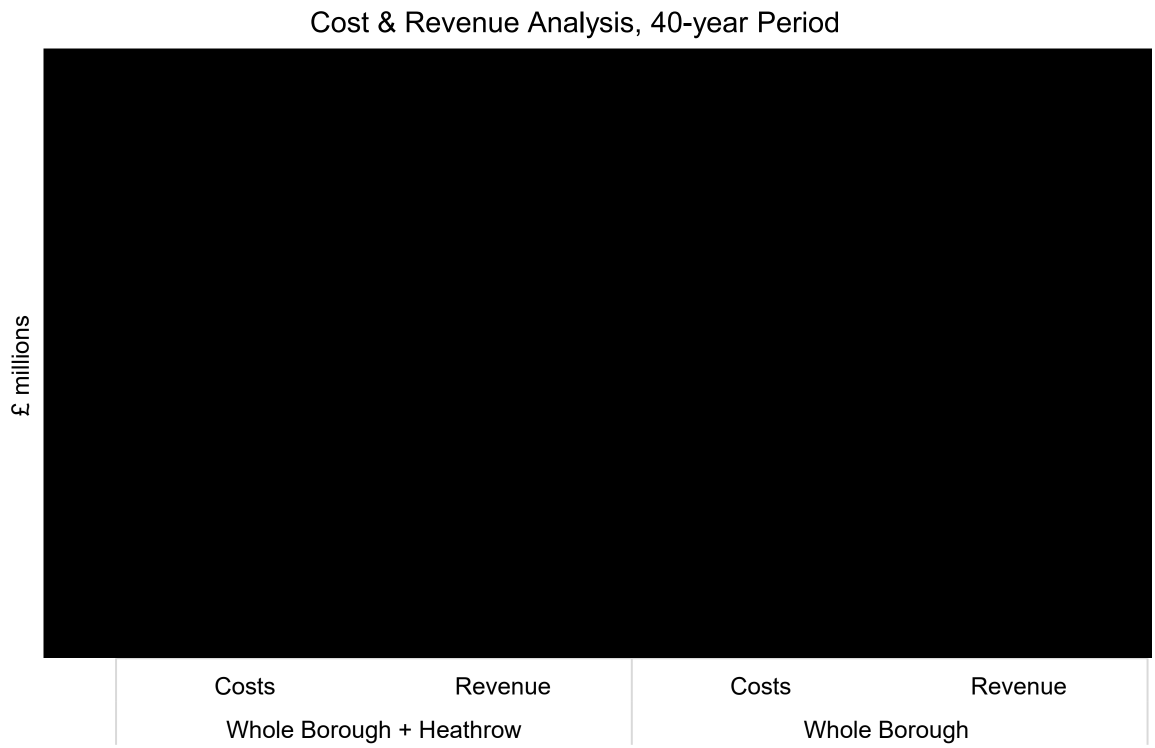


Figure 7-3: Networks' 40 Year Cost and Revenue Overview.

Environmental Performance:

- Both schemes achieve significant carbon savings when compared to the business-as-usual option of using gas boilers. However, including Heathrow within the network enables an additional 882 kilo tonnes of carbon savings over 40 years, equivalent to the CO_2 absorption of over 1 million mature trees[22].
- The results indicate that the carbon emission of the network is higher compared to the individual ASHP (Air Source Heat Pump) counterfactual. This discrepancy is attributed to the use of natural gas as a backup fuel. However, it is important to note that the Business-As-Usual (BAU) calculation does not consider the timeline for transitioning from existing fossil-based solutions to ASHP and assumes that ASHP installations occur immediately. In reality, many of the buildings are likely to continue to use gas boilers for several years until their systems are replaced with ASHP. Accounting for the longer timeframe to decarbonise heat across all buildings with individual ASHPs is likely to show a significant carbon saving for the heat network.
- The proposed scheme passes the Green Heat Network Fund (GHNF) carbon intensity requirements to be eligible for grant funding, as it is below the 100gCO_{2e}/kWh threshold.
- After implementing the phasing strategy, the 40-year average carbon intensity of heat for both networks has significantly improved. In the Borough-wide option, it decreased from 45 gCO_{2e}/kWh to 42 gCO_{2e}/kWh, and in the Borough-wide + Heathrow option, it reduced to 44 gCO_{2e}/kWh. These enhancements are attributed to the more efficient utilisation of heat pump capacity across various network phases and reduced reliance on gas boilers.
- Both network solution supply more than 80% of the heat demand via the LZC source, giving overall carbon emissions savings which will improve overall air quality. However, the localised effect of emissions from energy centres needs to be considered as a proportion of annual heat demand is met by gas boilers.

Economic Performance:

- The proposed networks demonstrate positive 40-year Internal Rate of Return (IRR), [redacted]
- The implementation of the phasing strategy and the incorporation of multiple energy centre locations have led to about [redacted] rise in the total costs of the networks. Specifically, [redacted] to [redacted] for the Borough-wide option and from [redacted] to [redacted] for the Borough-wide + Heathrow option. [redacted]
- The schemes easily pass the GHNF requirements to qualify for grant funding with a 40-year Social IRR (SIRR) greater than [redacted]. It should be noted that it is unlikely that GHNF will be able to provide a grant of the same quantity assumed in modelling (in excess of [redacted]). [redacted]
- These options demonstrate significant electricity savings when compared to an Air Source Heat Pump (ASHP) counterfactual, which is the most likely alternative Low and Zero Carbon (LZC) heat source for the buildings. Therefore, district heating results in the additional benefit of reducing demand on the local electrical grid. This reduces the potential need for grid reinforcement works and may liberate grid capacity to serve other end purposes like electric vehicles. This could have significant financial benefits by reducing future upgrade works.

[22] Trees help tackle climate change — European Environment Agency (europa.eu)

7.3 Sensitivity Analysis

At this stage of the assessment there are several inputs into the techno-economic model (TEM) that have some level of uncertainty. Further design, commercial negotiations and procurement activities will be required to confirm these inputs. To assess the impact of these uncertainties on the scheme, a sensitivity analysis has been undertaken, with each sensitivity tested in isolation to investigate its specific impact. The results of this sensitivity analysis are presented in Table 7-4. Note that these results exclude the potential benefit from grant funding.

#	Sensitivity	Variation	Borough-wide		Borough-wide + Heathrow	
			40-year IRR (%)	Scheme 40-Year CO_2e Emissions	40-year IRR (%)	Scheme 40-Year CO_2e Emissions
	Base case (SSHP)		[redacted]	**380 kt**	[redacted]	**592 kt**
1	Generation and supply CapEx	+ 15% from base case	[redacted]	380 kt	[redacted]	592 kt
		- 15% from base case	[redacted]	380 kt	[redacted]	592 kt
2	Distribution CapEx	+ 30% from base case	[redacted]	380 kt	[redacted]	592 kt
		- 30% from base case	[redacted]	380 kt	[redacted]	592 kt
3	Variable element of fuel input prices	+30% from base case	[redacted]	380 kt	[redacted]	592 kt
		-30% from base case	[redacted]	380 kt	[redacted]	592 kt
4	Variable element of energy sales tariffs for heat[23]	+ 30% from base case	[redacted]	380 kt	[redacted]	592 kt
		- 30% from base case	[redacted]	380 kt	[redacted]	592 kt
5	Customer discount against counterfactual heat price	5% discount	[redacted]	380 kt	[redacted]	592 kt
		10% discount	[redacted]	380 kt	[redacted]	592 kt
		15% discount	[redacted]	380 kt	[redacted]	592 kt
		20% discount	[redacted]	380 kt	[redacted]	592 kt
6	Energy demand usage (heat)	+ 15% from base case	[redacted]	434 kt	[redacted]	678 kt
		- 15% from base case	[redacted]	326 kt	[redacted]	507 kt
		- 30% from base case	[redacted]	272 kt	[redacted]	420 kt
7	Effect of a significant change in availability of LZC (SSHP)	- 25%	[redacted]	679 kt	[redacted]	1,071 kt
		- 50%	[redacted]	1,127 kt	[redacted]	1,758 kt
8	Reduction in connection fees	10% reduction	[redacted]	380 kt	[redacted]	592 kt
		20% reduction	[redacted]	380 kt	[redacted]	592 kt
		30% reduction	[redacted]	380 kt	[redacted]	592 kt
9	Heat network losses (primary/secondary)	+ 10% from base case	[redacted]	387 kt	[redacted]	601 kt
		+ 15% from base case	[redacted]	390 kt	[redacted]	605 kt
		+ 20% from base case	[redacted]	394 kt	[redacted]	610 kt
10	Cost of sewer heat from Thames Water	+ 50% (increase to 0.75p/kWh from 0.5p/kWh)	[redacted]	380 kt	[redacted]	592 kt
		- 50% (decrease to 0.25p/kWh from 0.5p/kWh)	[redacted]	380 kt	[redacted]	592 kt
11	Impact of capital grant support	Maximum grant funding (50% of total costs)	[redacted]	380 kt	[redacted]	592 kt
		Grant funding equivalent to 25% of total costs	[redacted]	380 kt	[redacted]	592 kt

Table 7-4: Sensitivity Analysis Showing the Variation in Key Parameters of the Developed Solutions.

[23] Concomitant with variable element of fuel purchase price

Some of the key indications from the sensitivity analysis for the developed options are as follows:

Economic Performance

- The economic viability of the scheme is highly sensitive to factors that impact the revenue generated by the network, particularly the heat sale price and connection fees. For instance, applying a [redacted] discount rate against the counterfactual heat price results [redacted] for Borough-wide and [redacted] for Borough-wide + Heathrow. As the network progresses and enters commercial discussions, it will be crucial to thoroughly verify and assess these factors. Ensuring accurate and appropriate pricing structures for heat sales and connection fees which are viewed by customers as offering value will be key in determining the overall economic viability of the scheme.

- The results reveal that variations in the distribution CapEx can notably impact the performance of the schemes. A [redacted] for the smaller network and [redacted] for the larger network. The values utilised in this study are based on AECOM's experience and industry standards, cross-verified with contractors during tender stages of other District Heating (DH) projects. It is advisable to continuously review and update these values as the project advances, ensuring they remain current and precise for accurate financial assessments.

- Furthermore, the study indicates that the schemes demonstrate resilience to fluctuations in gas prices but are notably sensitive to changes in electricity costs. In the scenario where fuel prices surge by [redacted] without a proportional increase in heat sales tariffs, the IRR drops below [redacted] for the smaller network. This emphasises the necessity of aligning pricing structures with market dynamics, particularly in response to counterfactual fuel price fluctuations, to maintain the economic viability of the project.

- A tariff of [redacted] has been proposed to Thames Water as a guide price for pricing the heat recovered from Mogden Sewage Treatment Works. The assessment results demonstrate the robustness of the schemes' economic performance, even when this tariff experiences a [redacted] increase. In this scenario, the IRRs for both options remain positive at [redacted] and [redacted] for Borough-wide and Borough-wide + Heathrow, respectively. Nevertheless, it is crucial for this tariff to be verified and agreed upon as commercial discussions commence to ensure the feasibility of the project. This should be treated as commercially sensitive until an agreement is reached with TW.

- Additionally, the analysis indicates that receiving a grant funding equivalent to [redacted] of the scheme's Capex results in IRRs [redacted]. These IRRs remain competitive and may still be considered attractive for a publicly funded scheme.

Environmental Performance

- The environmental performance of the preferred scheme is sensitive to variations in the heat demand of the connected buildings. If the heat demand increases without a corresponding increase in the installed heat pump or available low or zero-carbon (LZC) capacity, it diminishes the carbon savings. This is primarily due to the scheme relying more on gas boilers to meet the additional demand. This underscores the significance of carefully managing and balancing the heat demand and available low-carbon energy sources to optimise the environmental performance of the scheme.

- Data provided by Thames Water indicates an estimated 1.6 TWh of extractable heat, upgradeable to over 2 TWh. This capacity significantly exceeds the requirements to serve all identified compatible buildings in the borough, including Heathrow Airport (approximately 0.5 TWh in total). This surplus capacity offers an opportunity to harness more heat in the event of increased heat demand, providing a flexible and scalable solution for the future.

8. Technical Design

8.1 Generation

8.1.1 Mogden Sewage Treatment Works Interface

The conceptual transfer of heat from Mogden Sewage Treatment Works to customers across LBH has been illustrated in Figure 8-1. The heat recovered from the Effluent Treatment is taken from the final, treated outfall from the treatment works to the surface water course and so has been filtered and cleaned prior at the point of heat recovery. For more information, please refer to Appendix D.4.

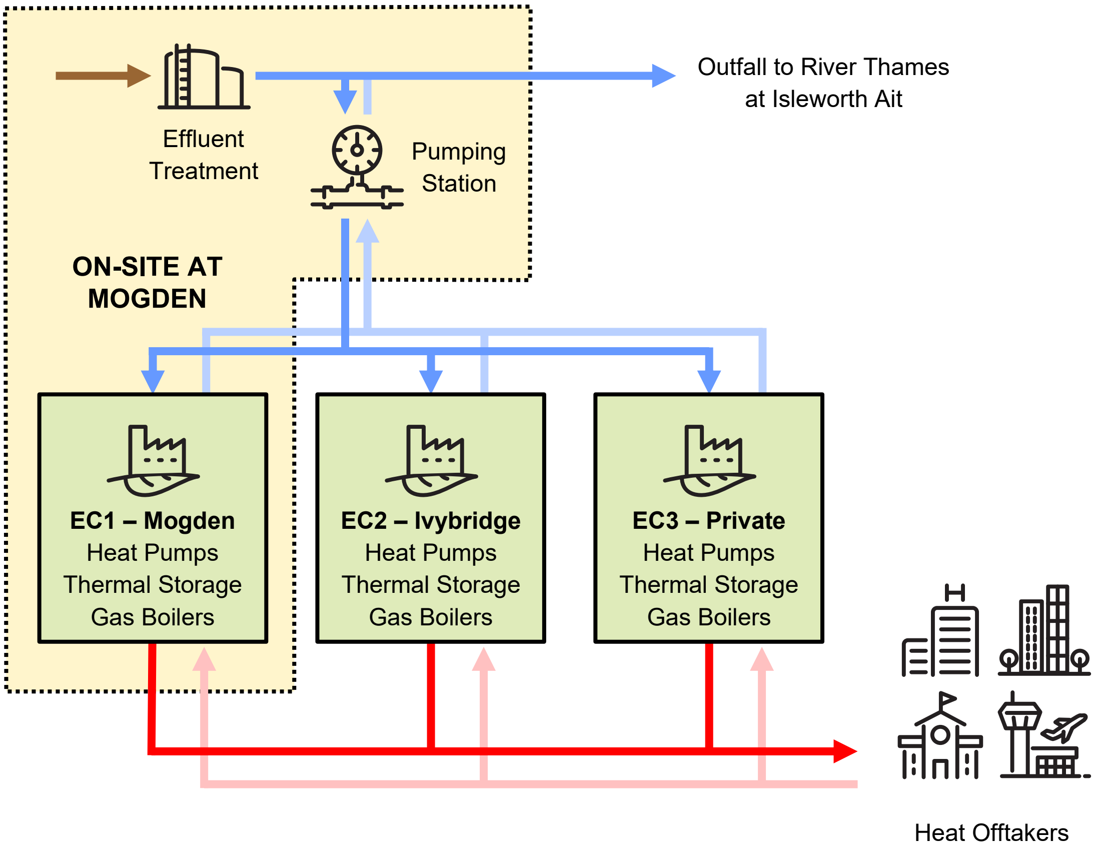


Figure 8-1: Conceptual Diagram of Proposed Heat Network.

The waste heat extraction opportunity at Mogden comes in the form of treated effluent, or 'Final Effluent' (FE) immediately prior to its discharge into the river Thames. As such, AECOM have assumed that no screening and filtration equipment will be required (as would be the case for direct sewer abstraction). Treated effluent is proposed to be pumped directly to the heat exchangers, equipped with self-cleaning functionality, at the energy centre. The proposed extraction point for this wastewater is at the northeast corner of the site, prior to where the flow is culverted to Isleworth Ait in the river Thames, but this is to be developed in collaboration with Thames Water in future.

A pumping station is required to distribute the outfall to the three energy centre locations. The currently assumed location is adjacent to a nearby existing final effluent sampling pit (what3words: ///prep.fairly.wipes), as shown in Figure 8-2. Uninsulated pipe is suggested for the routes between the extraction point / pumping station and energy centres, in order to reduce trench width and conserve cost.

Note that the locations and pipe routes shown have been determined via a desktop appraisal of the Mogden site. Further discussions with Thames Water will be required to determine a viable solution for wastewater extraction and situation of the on-site energy centre.

As above, the technical design of the pumping station will require considerable input from Thames Water to ensure compatibility with their existing infrastructure. In the absence of drawings / dimensions of the existing effluent pipelines and culvert, a pumping station design has not been generated as part of this feasibility study.

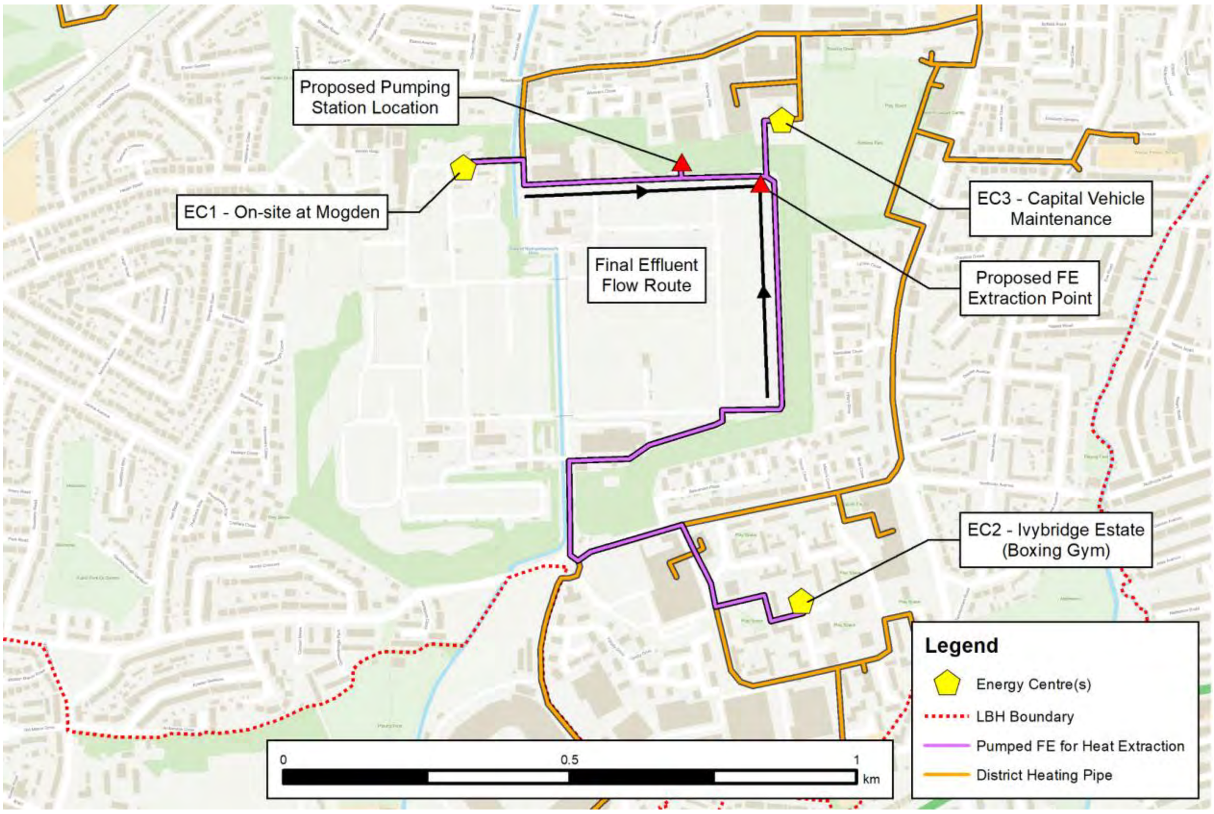


Figure 8-2: Proposed Locations for Pumping Station, Energy Centres, and New Pumped Final Effluent Pipe Route.

8.1.2 Energy Centre Design

When designing a heat network, it is typical to install a mix of low-carbon and (less expensive) higher-carbon heat generation technologies to strike a balance between carbon savings and acceptable commercial performance. The low-carbon heat source is often used in conjunction with thermal storage to meet c. 60-90% of the annual heat demands, with higher carbon sources installed to meet the remaining 10-40% (i.e., when heating demands are high, or the low carbon plant is unavailable due to maintenance).

Each of the three proposed energy centres will be supplied with treated effluent from Mogden Sewage Treatment Works, operating at a temperature difference of 7°C, as advised by Thames Water. Water-to-water heat pumps will be the primary energy generation source and have been sized to provide over 80% of the heat at each of the network. The remaining demand is supplied by gas boilers.

AECOM's techno-economic model has been used to ensure that heat pumps are sized appropriately to provide the proportion of low-carbon heat as specified. Thermal storage has been included within the energy centre, sized at 50 m^3 for each MW of installed heat pump capacity, aligned with typical industry guidance.

The major plant installed at each energy centre location has been listed in Table 8-1. Refer to Section 6 for information regarding the energy centre locations and plant phasing. General arrangements for each energy centre have been submitted in Appendix I.

EC / Plant Type	Unit Capacity	No. Units	Total Installed Capacity
EC1 – Mogden:			
Water Source Heat Pump	10 MW	2	20 MW
Gas Boilers	10 MW	7	70 MW
Thermal Stores	250 m^3	4	1,000 m^3

EC / Plant Type	Unit Capacity	No. Units	Total Installed Capacity
EC2 – Ivybridge:			
Water Source Heat Pump	10 MW	2	20 MW
Gas Boilers	10 MW	7	70 MW
Thermal Stores	250 m^3	4	1,000 m^3
EC3 – Capital Vehicle Maintenance:			
Water Source Heat Pump	5 MW 10 MW	1 1	15 MW
Gas Boilers	10 MW	4	40 MW
Thermal Stores	250 m^3	3	750 m^3

Table 8-1: Energy Centre Major Plant Schedule.

8.1.3 Futureproofing and Ongoing Decarbonisation

For the same reasons set out in Section 3.3, gas boilers are the preferred peaking and resilient plant technology for the district heating scheme. However, there are a number of options which should be revisited in future which could further reduce the year-on-year carbon emissions of the scheme:

- **Conversion of gas boilers** – potential alternative fuel options are:
  - **Hydrogen** – For this option to be viable, hydrogen would either need to be stored on site, made available through a piped network, or the UK gas grid would need to switch to hydrogen and supply it via their pipe network. There are concerns over the resource-efficiency of using hydrogen for energy uses which could be met more efficiently by heat pumps[24].
  - **Biogas / biomethane** – Biogas is currently produced on-site at Mogden via anaerobic digestion, one of the steps in the sewage treatment process. This is currently used to fuel several CHP engines, which provide heat and power for site processes. Plans have been released by Thames Water to 'upgrade' a proportion of this biogas to biomethane (a cleaner alternative, with higher calorific value) and export it to the gas grid[25], Mogden STW Biogas CHP Excess Heat, (further information has been included in Appendix D.5).

    One option could be for this biomethane supply to be consumed directly at the on-site energy centre, and potentially also be piped to EC2 (via a sleeving agreement) and EC3. This supply would effectively consist of carbon-free gas.

    Securing biomethane from Thames Water would rely on a cost-competitive purchase tariff that is mutually satisfactory. The assumptions made on this tariff have been outlined in Section 4.2.1.2.
- **Replacement with electric boilers** – This switch could be done when the gas boilers reached the end of their operational life. Electric boilers are virtually 100% efficient at converting electricity to heat but would significantly increase the required electrical capacity for the energy centre(s). In order to be technically and financially viable, this option would be reliant on less constrained local electrical grid infrastructure and a significant reduction in electricity prices compared to gas (the 'Spark Gap').
- **Installation of additional heat pumps** – It is possible to install additional heat pumps or combine technologies (e.g., SSHP and ASHPs) to deliver low carbon heat to the scheme However, the associated CapEx will be higher than using a gas boiler. This may become more feasible in future years as low carbon technology costs reduce, or if external funding becomes available.

It is important to note that electrically fuelled plant items will still generate carbon emissions unless provided with zero carbon electricity. However, the UK grid is decarbonising, and current government targets are for it to reach net zero carbon by 2035.

An option to reduce the carbon content of the electricity consumed by the scheme could be to introduce electricity generated by solar PV, either on-site or via a sleeved PPA (Power Purchase Agreement) from LBH assets. This

[24] https://www.leti.uk/hydrogen
[25] biomethane-installation-at-mogden-information-pack.pdf (thameswater.co.uk)

electricity supply would be 100% renewable (zero-carbon) and could be particularly impactful in the project's early years, whilst the electrical grid's carbon intensity remains high.

8.1.4 Refrigerants

While heat pump systems offer energy efficiency and environmental benefits, it is crucial to choose the right refrigerant, considering both performance and safety aspects. The specified heat pumps in this study utilize ammonia as the refrigerant, enabling the attainment of high temperatures required for the network.

In recent years, there has been a growing emphasis on using environmentally friendly refrigerants. Ammonia, for instance, is one such refrigerant that has gained attention due to its eco-friendly properties. Unlike some conventional refrigerants, ammonia leakage does not contribute to global warming – it is rated with a GWP (Global Warming Potential) of 0, whereas traditional refrigerants, typical to smaller heat pump systems that are suited to building level operation, range from GWPs of 1,100 (R401-A) to 2,600 (R402-A)[26].

- However, the benefits of using ammonia come with significant challenges. Firstly, ammonia is highly toxic. Exposure to even small amounts can be harmful and potentially fatal. Therefore, when designing and operating heat pump systems that use ammonia, strict safety protocols must be in place.
- Secondly, ammonia is flammable, posing fire hazards if not handled properly. Proper ventilation and stringent safety measures, including fire detection and suppression systems, are essential to mitigate these risks.

Additionally, the risk of leakage is a concern. Even small leaks can result in the release of ammonia into the environment, posing health risks to nearby occupants and potentially harming the ecosystem. Regular leak detection procedures, such as using ammonia sensors and routine inspections, are vital to identify and rectify leaks promptly. Therefore, companies and individuals involved in this project must strictly comply with the relevant regulations and safety protocols.

Ammonia heat pumps have been assumed at this stage of the project as high capacity, high-voltage units are required to comply with the DNO's phased electrical connection agreement (Section 6.1) – alternative lower-voltage units would require installation of a step-down transformer at considerable expense, and also introduce electrical losses. In addition, ammonia heat pumps operate at close to their highest efficiency at the proposed network temperatures. During the next design stage of the project, other refrigerants will be considered in more detail, with safety being a paramount factor.

8.2 Distribution

8.2.1 Temperature Regime

Operating temperatures are a key aspect of DHN design and will determine the capital cost, heat losses and pumping energy of the scheme. They can also have a significant impact on the efficiency of low carbon plant items, such as heat pumps. The proposed temperatures for the scheme are as listed in Table 8-2 below.

Heating / Cooling Network	Operation Type	Flow Temperature	Return Temperature
Heating Network	Normal operation	70°C	40°C
Heating Network	Coldest ambient conditions	80°C	50°C
Cooling Network	All operation	6°C	12°C

Table 8-2: Proposed District Heating and Cooling Network Design Temperatures.

The following points were considered when selecting the temperatures in the table above:

- The scheme should be capable of using a low temperature heat source (e.g., a heat pump) either now or in the future. Keeping the primary network flow temperature as low as possible will maximise the efficiency of heat pumps, thereby minimising the scheme OPEX and maximising economic performance.
- In continuity with the Heat Mapping stage, weather-compensated network temperatures have been modelled, which improve heat pump performance throughout the year, whilst ensuring compatibility with all customers' existing heating systems. As demonstrated in Figure 8-3, the network operates at ~70/40°C for

[26] Refrigerant GWP source: https://www.engineeringtoolbox.com/Refrigerants-Environment-Properties-d_1220.html

the majority of the year, resulting in an average annual flow temperature of 71.1°C. Note that due to conservative design assumptions a minimum flow temperature of 71°C has been used in modelling.

- Domestic hot water within customer buildings can be generated at a safe temperature with all of the possible existing generational plant options (instantaneous – stored).
- There will be a 5°C temperature drop across plate heat exchangers[27], meaning connected building heating systems will need to be capable of operating at 75°C flow in Winter.
- It is estimate that at full build out of the network, the index run (longest distance from energy centre to customer) will be approximately 10km, with a heat loss of approximately 200kW. The resultant temperature drop is estimated to vary from 0.2°C – 1.2°C, depending on the flow rate at the time (higher flow rate = lower temperature drop). This drop is not anticipated to have any significant impact on the performance of the network.

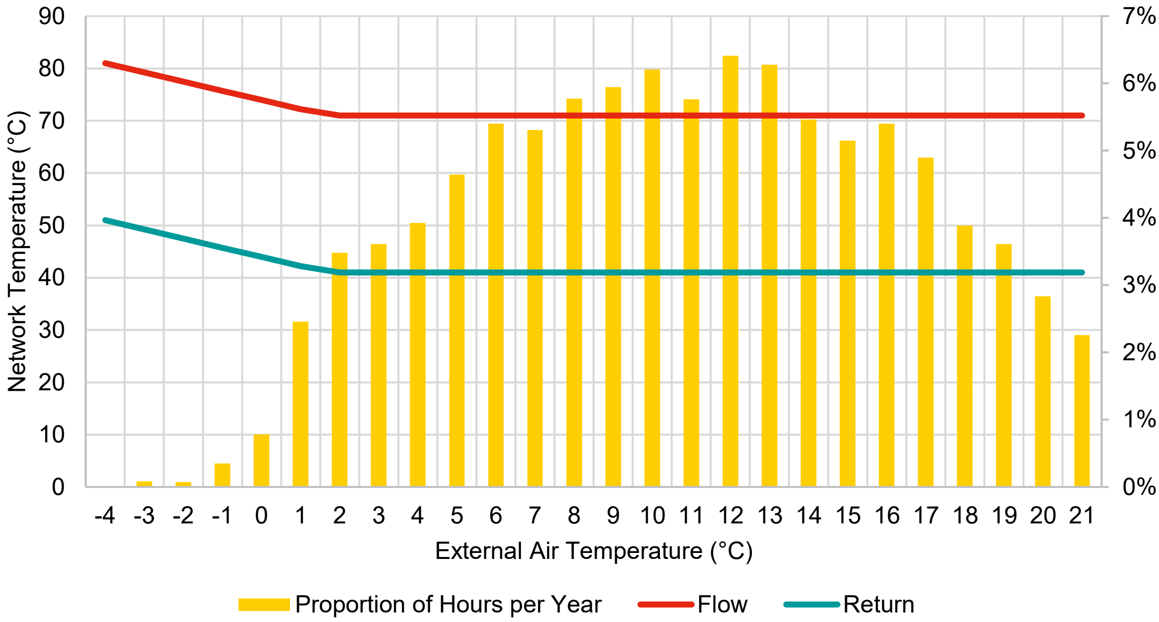


Figure 8-3: Modelled Network Temperature Regime Versus Ambient Conditions.

Surveys to proposed customer buildings which were undertaken during HMMP and Feasibility has found that the proposed temperature regime is suitable for existing systems, reducing the change of this incompatibility becoming a barrier to connection. However, over time it is recommended that network temperatures are reduced in line with upgrade works, such as fabric improvements and in-building infrastructure replacement.

8.2.2 Network Route(s)

The pipework routes for the modelled district heating and cooling networks have been included in Appendix J. The proposed routes have been designed to minimise both distance and cost, prioritising the following 'dig types' in order from lowest to highest cost:

1. Soft Dig / Closed Site

Works within an enclosed site where the majority of the making good civils works are not attributable to the project.

2. Urban Dig

Works in an urban environment (i.e. town centre), with additional allowance for making good of the ground. Possible to lay 6m per day (per team). Limited by the amount of road you can have open at once and the fact that it's hard dig.

[27] There is scope to reduce the temperature loss across plate heat exchangers to around 3°C, however this will increase CAPEX.

3. Extra Urban Dig

Works in an extra-urban environment (i.e. city centre) where utility congestion is known of or is highly likely, with additional allowance for making good of the ground. Possible to lay 5m per day (per team).

4. Specialist Crossing

Areas where special consideration is required, such as for the crossing of physical barriers / constraints such as main roads, railway lines, bridges, etc. Rate of install is highly subjective.

'Specialist' crossings, required for obstacles such as railways, major roads, canals, or rivers, have been avoided where possible. However, strategies have been developed for such crossings where they are necessary to access an area of high heating/cooling density. These can be found in Appendix K.

A large proportion of the heating route has been retained from Heat Mapping stage. However, a major modification has been made to the main spur connecting Isleworth and Brentford. This route is now proposed to go through Syon Park, rather than via London Road, allowing circa 1 km of 'extra-urban dig' pipework to be converted to 'soft dig'. This arrangement has been made possible following positive discussions with the Syon House Estate (who are now interested in connecting to the scheme).

A breakdown of dig types for each heating network extent is shown in Figure 8-4.

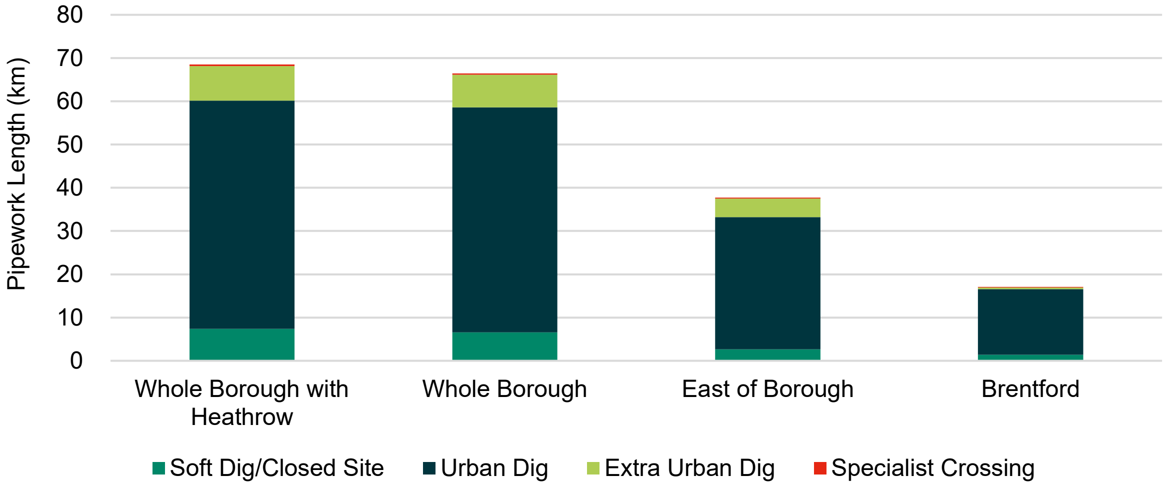


Figure 8-4: District Heating Pipework Length and Dig Type.

In addition to the main circulation pumps which will be housed in each energy centre, there is also a strong likelihood that one or several satellite pumping stations will be required along the network route, due to its extent across the entire borough[28]. It should be noted that such stations would be of a much lower scale and complexity compared to the energy centres.

8.2.3 Coordination of Works

Following discussion with LBH's Highways & Transport department (Section 9.1.3), the project team were made aware of several planned works which may overlap with the construction of the Borough-wide distribution network. These include:

- Construction of Cycleway 9 along London Road, 2024-27.
- Construction of the Priority Cycle Network (PCN) along Staines Road, 2027-28.
- Highways – general maintenance and upgrade works, undertaken on a case-by-case basis dependent on road condition. These works operate on a 24-month programme, with surveys undertaken annually.
- Traffic and Transport – 3-year forward-looking programme of works.

[28] Note that the capital costs associated with potential satellite pumping stations has not been allowed for in modelling.

Given the revised phasing strategy which has been proposed for the network's construction, there is no longer any overlap with the two cycle schemes listed above. However, efforts should be made to ensure that the proposed works will be compatible with the eventual installation of district heating pipework.

Maintenance works are typically only conducted due to deterioration, hence more information should be sought at the next stage on which areas may be due to deteriorate at a time closer to network construction (2028-2032).

One factor which has been highlighted by the project team is the role which the Highways Private Finance Initiatives (PFI) may have in the installation of pipework. The implications of this are to be explored in the next design stage.

The construction of the network and energy centre sites also creates the opportunity to install Sustainable Drainage Systems (SuDS) and Blue and Green Infrastructure (B&GI) and potentially achieving Biodiversity Net Gain. This should be explored in future design stages.

8.3 Building Connections

All building connections to the network are assumed to be communal supply, with each building either modifying existing plant rooms or allocating space for a dedicated room to accommodate a heat substation. A typical heat substation schematic is shown in Figure 8-5, with an example model shown in Figure 8-6.The costs of the substation will be covered by the network, and it is assumed that all future developments will be designed with spare room available for a district heating substation in their main plant room.

Stakeholder engagement has been conducted to ensure appropriate allowances are made for the network to connect to buildings/developments (Section 9.1.2). Site visits have been conducted for key anchor loads where possible, while virtual meetings have been deemed more appropriate for others. Building connection strategy '1-pagers' have been created for major anchor loads, contained in Appendix L. Guidance for LBH for ensuring planned capital works projects remain compatible with the heat network is provided in Appendix M.

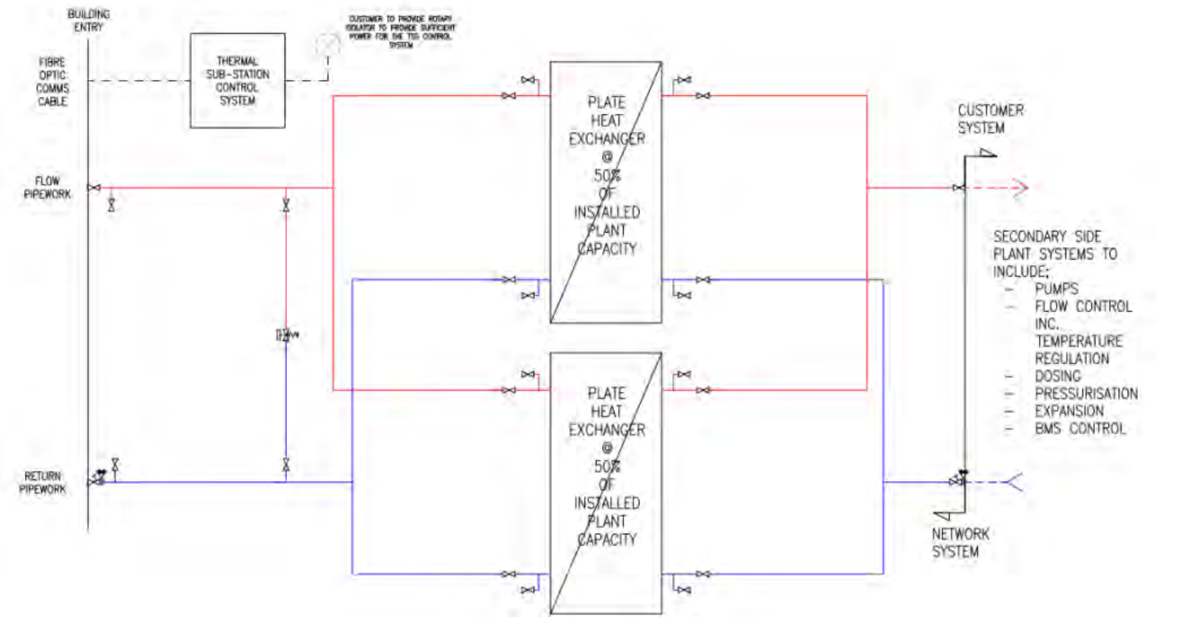


Figure 8-5: Typical Heating Substation Schematic.

The inclusion of a thermal substation is a conservative assumption made at this stage to allow for anticipated requirements for clear commercial demarcation between the heat network and building level heating systems. A thermal substation ensures there is no mixing of water between these respective systems. However, the omission of thermal substations and providing direct connections into building heating systems can offer efficiency improvements and should be considered as an improvement during detailed design.

Figure 8-6: DSE Flex Thermal Substation.

Source: Danfoss

9. Commercial Strategy

9.1 Stakeholder Engagement Summary

Developing a heat network can be a complex and lengthy process, and based on AECOM's experience, securing buy-in from stakeholders at the correct time is crucial. They need to be brought on the journey as partners rather than being excluded at the early stages. Therefore, significant stakeholder engagement has been undertaken, gathering information from the key new and existing anchor loads. Additionally, discussions have taken place with utility operators and Thames Water's 'Mogden' Sewage Treatment Works as the primary heat source and landowner of the energy centre site.

The following sections present the stakeholders, their influence level on the project, engagement activities, and confidence levels.

9.1.1 Heat Supply

Stakeholder	Priority	Engagement	Confidence	Notes
Thames Water	High	Initiated	Supportive	[redacted]

The project team has also been made aware of the proposed Teddington Direct River Abstraction scheme, which will involve the diversion of Mogden's treated effluent to the upstream location of Teddington. It is not anticipated that this scheme will impact the extraction (and return) of wastewater for heat extraction. It may, in fact, provide a strategic opportunity for the district heating project to improve environmental conditions at the Teddington outfall location, and for mutual benefits between both projects. Further information on the proposal and its impact is contained in Appendix Q.

9.1.2 Heat Offtakers (Existing and New Buildings)

Stakeholder	Priority	Engagement	Confidence	Notes
LBH owned buildings	[redacted]	Initiated	Supportive	[redacted]
West Middlesex University Hospital		Initiated	Supportive	
Syon House / Syon Estate		Initiated	Supportive	

Stakeholder	Priority	Engagement	Confidence	Notes
London Heathrow Airport (LHR)	[redacted]	Initiated	Supportive	[redacted]
Twickenham Stadium	[redacted]	Initiated	Neutral	[redacted]
Sky Campus	[redacted]	Initiated	Neutral	[redacted]
Gillette Building Studios	[redacted]	No response	N/a	[redacted]
University of West London Brentford	[redacted]	Initiated	Neutral	[redacted]
Aparthotel Adagio London Brentford	[redacted]	No response	N/a	[redacted]
GSK site	[redacted]	Initiated	Neutral	[redacted]
Blenheim Centre Hounslow	[redacted]	Not interested	N/a	[redacted]
Tesco Isleworth	[redacted]	No response	Neutral	[redacted]
Isleworth Crown Court	[redacted]	No response	Neutral	[redacted]
Heart of Hounslow Health Centre	[redacted]	No response	N/a	[redacted]
Greystar 14-746 London Road Charter Place	[redacted]	No response	N/a	[redacted]
Great West House	[redacted]	No response	N/a	[redacted]
Novotel London Brentford	[redacted]	No response	N/a	[redacted]

Stakeholder	Priority	Engagement	Confidence	Notes
St Marks School	[redacted]	No response	N/a	[redacted]
The Treaty Centre		Initiated	Neutral	
Brentford FC Community Stadium		Initiated	Supportive in principle	
Vantage West		Initiated	Supportive	
EMC Tower		No response	N/a	
Mille Building		No response	N/a	

9.1.3 Planning / Strategic Decision Making

Stakeholder	Priority	Engagement	Confidence	Notes
Hounslow Council - Asset & Investment Planning (Housing)	High	Initiated	Supportive in principle	[redacted]
Hounslow Council – Highways & Transport	High	Initiated	Supportive in principle	
Hounslow Council - Planning	High	Initiated	Supportive in principle	
Hounslow Council - Parks	High	Initiated	Supportive in principle	

[29] Site of Importance for Nature Conservation.

9.1.4 Utilities

Stakeholder	Priority	Engagement	Confidence	Notes
SSEN	High	Initiated	Supportive	[redacted]
UKPN	High	Initiated	Supportive	

9.2 Risk Management

AECOM has produced a risk register for the Hounslow Heat Network project, which lists the identified risks and mitigation measures based on what is known about the project so far (refer to Appendix U). The top 10 project risks, ranked by pre-mitigation score, are detailed in Table 9-1.

Risk Description	Impact	Likelihood	Rating	Mitigation & Action
[redacted]				

Risk Description	Impact	Likelihood	Rating	Mitigation & Action

[redacted]

Table 9-1: Current Top 10 Project Risks.

9.3 Commercial Delivery Options

As part of this study, Specialist Commercial Consultant Hermetica Black has prepared a paper that evaluates various delivery options from the perspective of Hounslow Council, the Project Sponsor (PS). The paper analyses the pros and cons of each option, focusing on aspects such as control, future exit strategies, and flexibility for potential expansion.

Additionally, the paper delves into the specifics of Special Purpose Vehicle (SPV) establishment and structure, tailoring the information to meet the project's specific requirements. A copy of the document is provided in Appendix R.

It should be noted that the preferred delivery structure will be determined through workshops in the next stage of project design development (DPD) between LBH and the Project Team. Therefore, at this stage no delivery options can been ruled out. However, of the five most commonly seen options, detailed in Figure 9-1, LBH may be able to consider some initial preferences based on key characteristics of the project.

These characteristics may include:

[redacted]

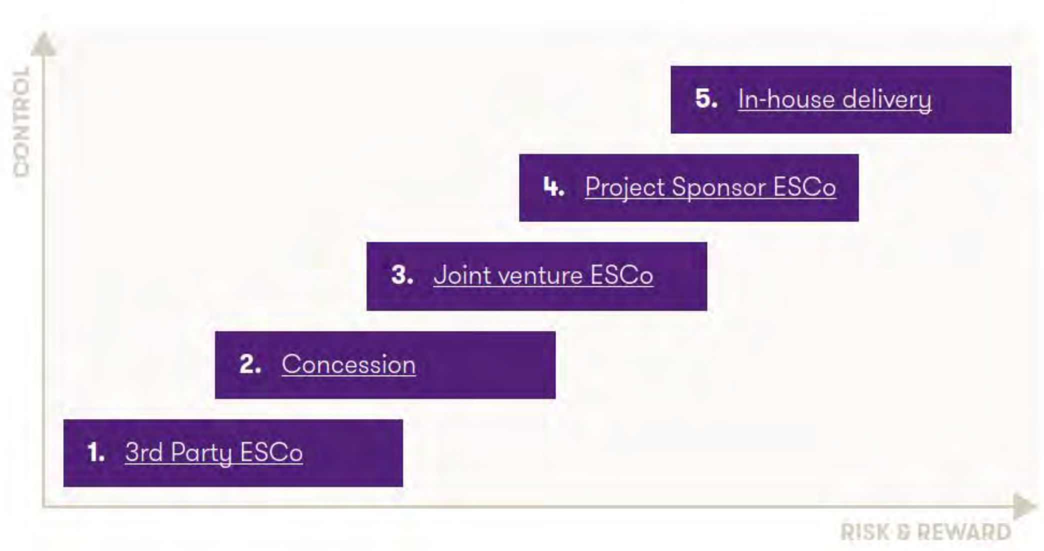


Figure 9-1: Typical Heat Network Commercial Delivery Structures.

Source: Financing Heat Networks in the UK, BEIS / Grant Thornton / HermeticaBlack (2018).

10. Conclusions

A total of eight technical solutions across the three network extents met the three project Key Performance Indicator (KPIs); Environmental, Economic and Social and are therefore considered viable. These viable solutions are summarised below:

Network Extent	Viable Technical Solutions (TS)
Brentford	TS2 & TS3
East of Borough	TS6, TS7 & TS9
Borough-wide	TS12 & TS13

Table 10-1: Technical Solutions Successful at Meeting All KPIs.

Technical Solution 13 is a heating-only, conventional high temperature heat network, serving the 'Borough-wide' extent of Hounslow in addition to Heathrow Airport. This option uses waste heat rejected from Thames Water's 'Mogden' Sewage Treatment Works as primary source for heat pumping, supported by gas boilers, for peak load and resilience purposes. [redacted]

Metric	Value
Estimated Capital Cost	[redacted]
Pre-Grant Pre-Tax 40-year IRR	[redacted]
Estimated Level of Grant Support Required	[redacted]
Pre-Tax 40-year IRR with Above Grant	[redacted]
Total Heat Delivered	484 GWh/year
Total Network Trench Length	68.5 km
Lifetime Carbon Savings compared to Gas Boilers	2,766 ktCO_2e

Table 10-2: Key Metrics for Technical Solution 13.

To meet the Economic KPI of [redacted]RR, an estimated grant support of approximately [redacted] is required, which constitutes a majority of the total allocated to the current Green Heat Network Fund (GHNF) ([redacted]). In the most recent funding round, the largest sum granted by GHNF was [redacted] to the Old Oak Park Royal Development Corporation (OPDC) Network, which is approximately [redacted] of the size of [redacted] However, construction of the network, comprising energy centres, pipeline, and building connections, is scheduled to be delivered over several phases from 2028 – 2040, meaning that applications can be made for individual, smaller scale phases to GHNF (or the equivalent funding scheme at the time of application). It is important to note that supporting the growth of heat networks aligns with the government's net-zero plan, making continued support likely.

An indicative Phase 1, or 'starter network', has been shown in Figure 10-1, with details shown in Table 10-3 below. A GHNF grant value of [redacted] (which is believed to be achievable) would allow construction of Phase 1 at a similar grant support rate as was assumed in modelling ([redacted] of [redacted] CapEx). A starter network has not been modelled as part of feasibility stage; however, it is anticipated that expansion beyond Phase 1 would be required for the network to be economically viable over its 40-year assessed lifespan. The difference between the [redacted] funding required for the full network solution and the anticipated [redacted] GHNF grant may be funded through the HM Treasury-backed UK Infrastructure Bank UKIB), which has thus far allocated [redacted] of finance to support green infrastructure development in the UK. The cost of finance through UKIB may have an impact on the financial performance of the network and will be explored in detail as part of the financial case during DPD stage along with opportunities to mitigate any resulting negative impact.

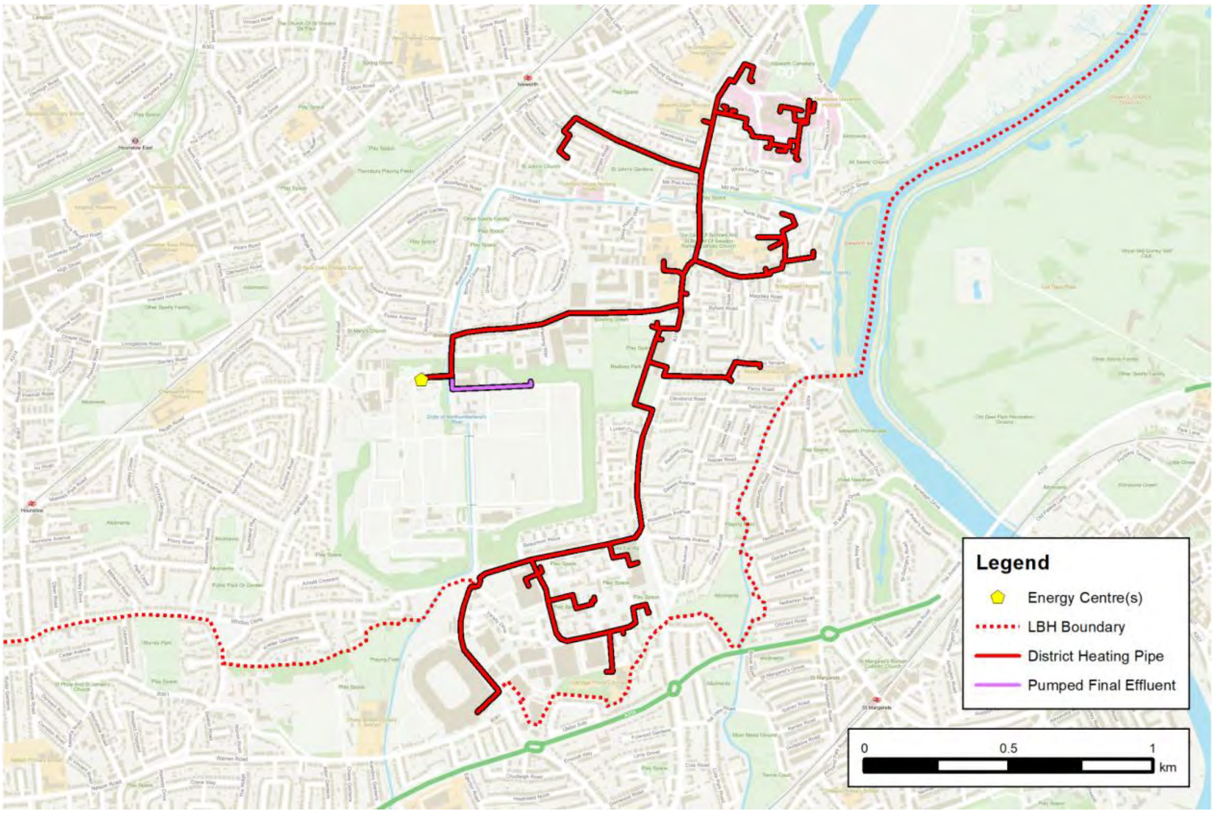


Figure 10-1: Proposed Phase 1 / 'Starter' Network Route Extent and Infrastructure.

Metric	Starter Network	TS13
Estimated Capital Expenditure	[redacted]	[redacted]
Assumed Capital Grant Support Value	[redacted]	[redacted]
Grant Value as % of CapEx	[redacted]	[redacted]
Annual Heat Demand	30 GWh	484 GWh
Network Trench Length	8.8 km	68.5 km

Table 10-3: Starter Network Metrics versus Technical Solution 13.

The wider network holds the potential to drive the decarbonisation of the existing built environment within and beyond Hounslow, improving local air quality in the process. The proposed network represents the lowest cost solution to customers to decarbonise their heating systems. This solution has been Techno Economically Modelled to offer a lower cost heat tariff (aligned to a gas boiler counterfactual) to domestic and microbusiness customers, with a higher cost tariff to all other customers which is calculated to be equivalent to the appropriate alternative small-scale low carbon solution. Through this, the heat network can offer protection against the risk of fuel poverty associated with low carbon heating / renewables for 'At Risk' customers, while remaining commercially viable by offering low carbon heat at a competitive cost to the non 'At Risk' customers. This is considered to be the correct approach to tariff setting by DESNZ and is covered in more detail in Appendix N.1. In addition, the network has the ability to act as a 'buffer' to protect against customers against any rises in fuel price caused by geopolitical factors by controlling, in so far as is contractually possible, how much, if any, said rises impact the customer heat tariff.

Furthermore, the network can offer a solution to the barrier that local grid constraints represent to the decarbonisation of heat and consequently mitigate the same barriers to housing growth and development plans and the deployment of electric vehicles. The electrical grid constraints mean the network may need to use a ramping up strategy, which will influence the rate of growth of the network, however there are potential opportunities through which these limitations could be mitigated through the use of existing electrical infrastructure that supplies the Thames Water Mogden site.

The largest single heat customer for TS13 is Heathrow Airport, representing approximately 35% of the total heat demand at full build out. However, should Heathrow choose not to connect to the network, the solution would revert to TS12, which remains a highly viable solution. [redacted]

[redacted]

The scale of the network would make it larger than any existing in the UK today (although similar are currently in design stages) but smaller than many examples elsewhere in Europe, such as Berlin and Copenhagen, as well as North America and Asia. Additionally, the technical solution for low carbon heat capture is similar in nature and scale to that employed recently by E.ON in Malmö. Therefore, whilst ambitious, the solution has been matched to the level of potential that exists within Hounslow, considering the magnitude and accessibility of low carbon heat in Mogden, the net-zero aspirations of the local public and private sector (e.g., Heathrow Airport) and financial and strategic support for the sector by central government. The technology is proven over the long term and has an extensive list of case studies from which to build from.

11. Recommendations and Next Steps

AECOM's recommendation would be for LBH to progress Technical Solution 13 to the Detailed Project Development (DPD) stage, culminating in the production of an Outline Business Case (OBC).

The image below shows the high-level development process for a district heating network (DHN) from feasibility to operation with indicative timescales for next steps. This report forms the key deliverable for the techno-economic feasibility study and should provide sufficient information to allow LBH to decide whether to progress the project to the next stage i.e., DPD.

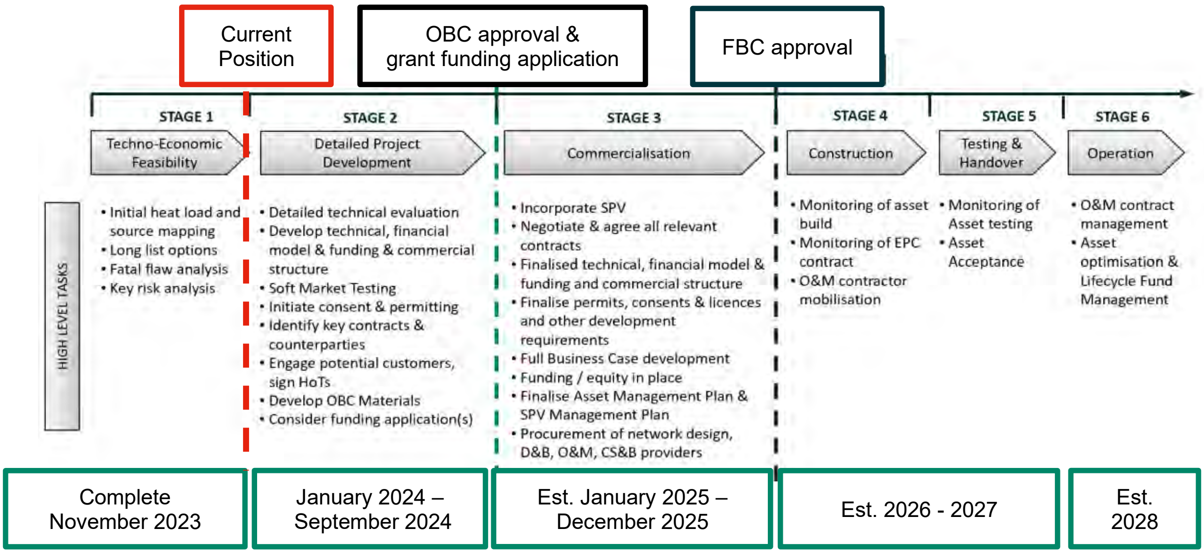


Figure 11-1: DHN Development Cycle via the Heat Network Delivery Unit

The following activities are recommended to be progressed by LBH in the interim between the feasibility and DPD stages. During the DPD stages these can be continued by the appointed consultant(s) and LBH:

[redacted]

[redacted]

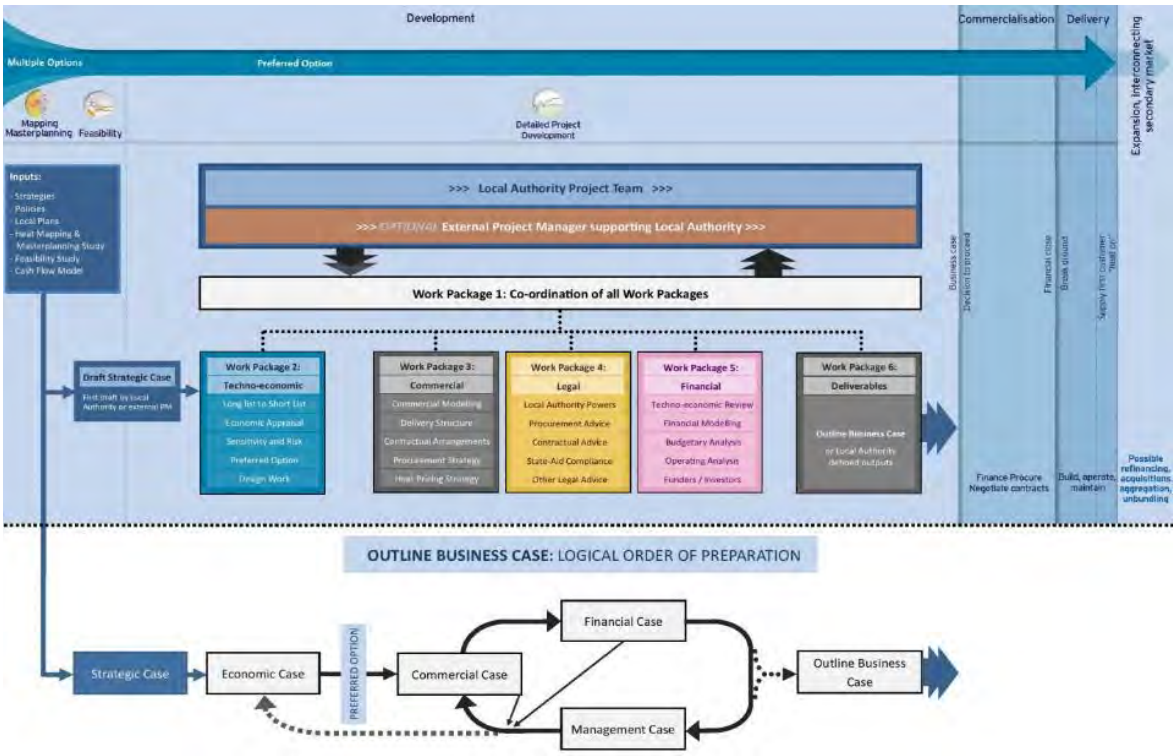


Figure 11-2: HNDU Indicative Detailed Project Development (DPD) Workflow Programme

11.1 Governance

To progress this project from its current ‘detailed feasibility’ to heat network detailed development , design, and commercialisation stages, it is advisable for the appropriate project-level governance that was put in place following the HMMP study, to continue and scale over time in line with the organisational requirements.

Project governance in the context of heat network and infrastructure project development, ensures that the investing organisation – in this case likely to be London Borough of Hounslow for the near future as a minimum, in tandem potentially with several other parties in future – has the appropriate mapping of personnel, authority, and accountability, to define, control, and steer the cross-cutting infrastructure project, ultimately leading the scheme to realise its benefits of carbon emissions reduction and financial returns.

This project governance approach will establish key roles throughout the Hounslow DHN project delivery lifecycle, identifying responsibilities and accountabilities within the core LBH team, in addition to their aligned internal stakeholders / departments, external stakeholders, and project advisors. The core governance roles/team will apply financial and technical control over the works, ensure decisions are made in an informed and effective way, and ensure sufficient capability and capacity is maintained in the LBH organisation. The governance framework should set out appropriate limits of authority, delegated responsibilities, and clearly define escalation routes within the project environment.

Effective governance provides:

- Control over project delivery – ensuring check and balances are in place e.g.
  - appropriate signoffs and assurances are received for each stage of the project lifecycle, before further stages are commenced,
  - project finances are understood, communicated, tracked, and reported upon,
  - project schedule is reported, appropriate, and cross-organisational integration is in place, and
  - decision points and gateways are monitored and controlled
- Confidence to the project sponsor and senior LBH leaders that adequate project control and reporting is in place, with sufficient information provided to them to inform necessary decisions, and
- Confidence to LBH’s board of directors, executives, councillors and members of the council’s cabinet, that the infrastructure works are well managed and under control, the sponsor can advocate for the project and seek authority where needed, and generally there is an increased likelihood of the project realising the value proposed.

Finally, governance of the DHN project must be integrated into the wider LBH governance framework, if not already done to-date. LBH’s corporate level, where broad council / borough strategy and vision originate, must be effectively managed and integrated with the project’s governance and the LBH business as usual operational decisions, to ensure the project has the best chance of approval, support and ultimately success.

A tried and tested way in which appropriate governance can quickly be implemented is through the formation of a project board, with all associated roles in a project delivery/management team. Following our prior recommendation that LBH should consider forming a project/programme board and in-house management function to provide sufficient governance and oversight for the ongoing scheme(s), the group is planned to be operational by January 2024.

As detailed in prior recommendations, it is essential that this board be made up of:

- Senior members of staff from LBH, one of which can act as a project sponsor, and others including discipline / departmental heads and decision makers;
- LBH subject matter experts, who will support the board internally by providing essential LBH subject matter expertise context to the works and decisions before the board;
- Independent experts from beyond LBH, notionally from engineering institutions or organisations specialising in the DHN works proposed, and ideally several with each able to support the board in different areas e.g. contracting, construction, commercial development, etc.;

- Technical advisors, notionally a team of dedicated engineers and consultants providing resource to the board and capacity to act on the decisions / action generated at board;
- Officers of other Local Authorities or entities who have undertaken similar projects;
- Representatives and independent expertise from central government (DESNZ), who are the public sector experts in this field.

In addition to this project board extant at the time of writing, it should be considered what further steps should be undertaken to coincide with the upcoming stage. During the Developed Project Development stage it is essential, that in addition to the above, the following requirements and considerations are met for LBH governance:

- Ensuring that project board has:
    - reinforcement with further key personnel from within the organisation, such that sufficient authority is present within the board composition to enable decisions to be made
    - representation from the LA's Chief Financial Officer (CFO) – to ensure timely sign-off of the coming OBC
    - representation from the LA's Chief Economist – to ensure robust review and development of the coming OBC
    - representation from the LA's key departments (or deputised to make decisions) including Head of Planning, Head of Highways, Head of Procurement, and Head of Environment – to ensure these key stakeholder departments are fully sighted on key developments as the project progresses
    - an identified party who will be the scheme's main LBH advocate, who will be able to drive local support in the community, lead public engagement, and generate positive publicity for the scheme
    - suitable and relevants Terms of Reference (ToRs) developed, outlining decision making process, quorate levels, collateral required in support of decisions
- Ensuring that key parties are suitably qualified and prepared to make decisions on:
    - Project objectives – e.g. relevance of carbon saving vs financial performance, social value delivered, recharging (or otherwise) of capital costs to participants of the heat network, LBH response to fuel poverty and heat tariffs resulting
    - Critical Success Factors (CSFs) to be used within optioneering assessments
    - Long listing to short listing exercise, and the weightings and subsequent scores attributed through multi-criteria decision matrices
    - Delivery strategy, including structure of the delivery vehicle, LBH view on risk appetite and level of desired control
    - Procurement strategy for the heat network
    - LBH approach to enforcement of heat network roll out within the borough, including planning obligations, and incentives
    - LBH approach to public consultation and to what extent local residents and businesses will be engaged on the journey to heat network roll out
    - Ultimately business case sign off and approval, in order to proceed to future design and commercialisation stages

Appendix A Summary of Previous Work

A.1 Heat Mapping & Masterplanning

AECOM were commissioned to deliver the previous stage of the Hounslow district heating opportunity – Heat Mapping and Masterplanning (HMMP) – which was issued in September 2023.

The HMMP stage of works compiled and aggregated energy demand data across the borough, evaluated low-carbon heat sources, and assessed energy centre locations. Six 'clusters' of heat demand were identified as follows:

1. Hounslow Town Centre
3. Central and Hounslow West
4. Cranford and Heston West
5. Feltham
6. Brentford
7. Isleworth

Techno-economic modelling was undertaken for each standalone cluster, as well as for a borough-wide solution incorporating all clusters bar Cranford and Heston West, due to its relatively low demand and geographic isolation from the main network. Although not modelled, the possibility of connecting the network to serve Heathrow Airport (in the neighbouring London Borough of Hillingdon) was also investigated.

The study identified the significant potential of Mogden Sewage Treatment Works, located in Isleworth, as a waste heat source. Using modelled data provided by Thames Water (the facility's operator), an estimated 1.6 TWh of extractable heat was found to be available, upgradable to over 2 TWh using heat pumps. This capacity would be far in excess of that required to serve all identified compatible buildings in the borough, as well as Heathrow Airport ([redacted]).

Based on techno-economic modelling performance at this stage, Brentford was deemed to be the only standalone cluster which would be financially viable. However, combining clusters allowed for other viable solutions to be identified, which would also have the benefit of accessing the waste heat source at Mogden STW. As such, it was recommended that the following network extent areas be taken forward to this Feasibility Study:

1. Borough-wide Solution (excluding Cranford), with the addition of Heathrow Airport as a sensitivity.
2. Isleworth, Brentford, and Hounslow Town Centre network – referred to as 'East of Borough'.
3. Brentford standalone network.

A.2 Work Package 1: HMMP Refresh

In May 2023, AECOM were commissioned to undertake the Feasibility Study for the district opportunity in the borough. The first package of these works, issued in June 2023, involved a 'refresh' of much of the energy data (Section 2) and technical optioneering (Section 3) from HMMP. The works at this stage also included:

- Updated techno-economic modelling of the Brentford and Borough-wide network extents.
- New modelled scenarios for the East of Borough extent and Borough-wide including Heathrow.
- New modelling of a local-scale, ASHP-led 'Comparator Network', against which initial results for the district-level solutions have been presented (Appendix B).
- Identification of local clusters of cooling demand and optioneering of suitable cooling pipework routes and satellite cooling energy centre locations.

Appendix B WP1: Local Comparator Network

Given the scale of the recommended network solution, it was considered valuable to carry out a value assessment against a smaller, reduced complexity network. Through this, the recommended network could then be benchmarked against the range of scales of alternative decarbonisation options i.e. building level air source heat pumps and small scale heat network. A hypothetical, local-scale network was identified, using a small cluster of loads anchored by the LBH owned Hounslow House and public sector Police Station with an energy centre on LBH land. This was modelled as part of Work Package 1 as follows:

Item	Value
No. Connecting Buildings	11
Annual Heat Demand	4.2 GWh
Primary Heat Source / Capacity	ASHP / 580 kW
Peaking/Resilient Plant	Gas Boilers
Proposed Energy Centre Location	Hounslow House Car Park

Table B-1: Comparator Network Parameters

In continuation from HMMP, all WP1 solutions were modelled with a maximum lifetime carbon intensity of 100 gCO_2e/kWh (note that this methodology has since been superseded by the environmental KPI in Section 1.2). A map of the comparator network is shown below in Figure B-1.

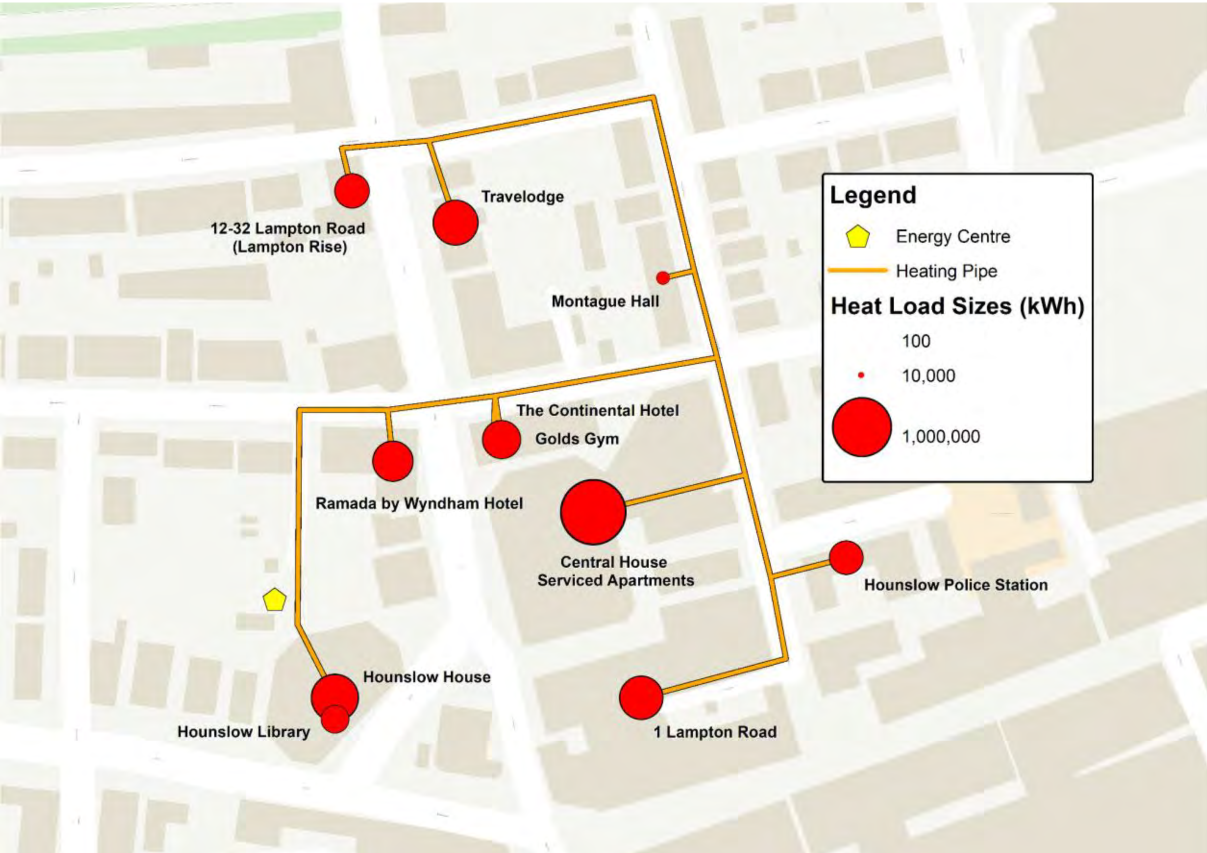


Figure B-1: Comparator Network Loads and Route.

As shown in Figure B-2, it is demonstrated that the Comparator Network, being an ASHP-led solution, fails to deliver similar lifetime Value for Money in comparison to the district-scale schemes, which are better placed to utilise higher-yield low-carbon heat sources, having both the highest levelised cost of heat generation and lowest Internal Rate of Return.

IRR (pre-grant, 40-years)

[redacted]

LCoH (p/kWh)

Figure B-2: Preliminary Modelling Results versus Comparator Network.

Appendix C Cooling

C.1 Cooling Networks

Six distinct cooling network 'clusters' were identified as part of Work Package 1, listed in the table below.

Cooling Cluster Name	Proposed Energy Centre Location	Annual Coolth Demand [MWh]
TV Triangle	Harlequin Avenue Former Substation	10,600
GSK / UWL	Boston Manor Park (Land beneath Chiswick Flyover)	9,300
Brentford Hotels	Layton Road Car Park	1,600
Thames Path North	Brentford Towers	4,600
Hounslow High Street	Hounslow House (Car park at rear of building)	5,900
Feltham	Feltham Assembly Hall Car Park	9,800

Table C-1: Proposed District Cooling Network Extents.

The routes for each cooling network have been shown in Appendix J.2.

C.2 Cooling Energy Centre

As described in Section 2.4, the dispersed nature of cooling demand within the borough in contrast to the more widespread heating demand and the fact that cooling pipework is significantly larger and therefore more difficult to install over a long area, lends itself to a strategy which include remote cooling energy centres.

A strategy was developed to enable waste heat from these remote cooling energy centres to be captured and reused by the heating network as opposed to rejected to atmosphere. This would improve the efficiency of both the heating and cooling networks. The principle of the remote cooling energy centres is demonstrated in Figure C-1 below.

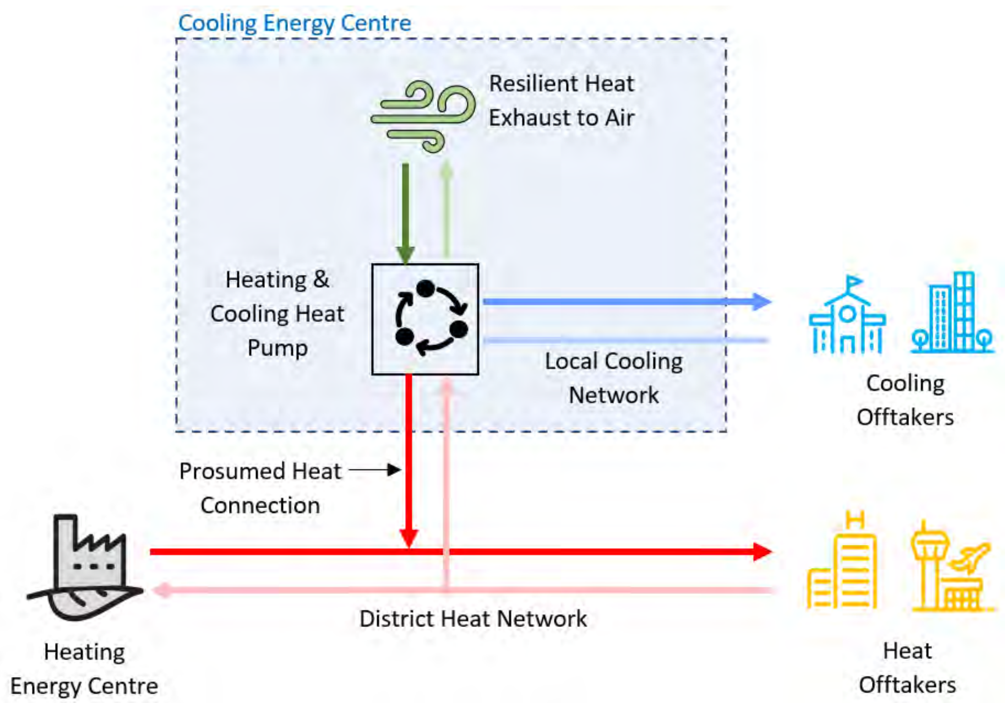


Figure C-1: Graphical Representation of Interface Between District Heating and Local Cooling Networks.

As demonstrated, the district heat network can operate in isolation to the cooling networks and if a cooling network is desired, it can be designed to interface with the heat network to enable recovery of waste heat from the cooling process. Whilst assessed, network options which included this cooling strategy were not recommended as a preferred solution as part of this feasibility study, due to quantitative and qualitative reasons, e.g., uncertainty over demand from cooling through the engagement process. However, over time this may change should more confidence in the customer appetite from cooling be obtained and/or due to increased demand for cooling, which is explored in Section 0.

C.3 Cooling Projections

With the anticipated increases in average global temperatures due to the impact of climate change, it is expected that demand for cooling in the UK will increase over time. To assess the impact this may have on the estimated cooling demand within the study boundary at the time of writing, an assessment has been carried out based on the study BEIS Research Paper 2021/050 ‘Cooling in the UK’, Department for Business, Energy, and Industrial Strategy, August 2021.

This study provides long-term projections of cooling demand to 2100 under two climate emission scenarios:

- Low emissions, projected to reach a mean global temperature rise of **1.5°C** by 2081-2100.
- High emissions, projected to reach a mean global temperature rise of **4.0°C** by 2081-2100.

The extent to which cooling demand is increased will depend on the government policy scenario. To evaluate the impact on cooling demand in Hounslow, two policy scenarios from the study have been considered:

- **No Intervention:** The market determines the uptake of different measures. Basic adaptive measures are deployed with no strategic foresight; a combination of portable cooling and cost-effective passive measures have been modelled. When these reach the limits of their effectiveness or are found to be otherwise unsuitable, a low efficiency fixed refrigeration cooling system replaces the portable cooling.
- **Passive First:** Government intervenes to prioritise passive cooling measures. Government promotes higher cost, higher disruption passive measures than the basic adaptive measures of the other two scenarios. The government also requires any subsequent use of active refrigeration cooling systems to be high efficiency.

The baseline cooling consumption in Hounslow is taken as the estimate consumption at the time of writing from **only** the buildings included within the assessment. The projected increase in consumption uses index projections from Figure 24 of the ‘Cooling in the UK’ study, which considers the impact of **both** increased demand from buildings with existing cooling, and the introduction of cooling into buildings which previously did not.

The results of this study, applied to Hounslow, are demonstrated in Table C-2 and Figure C-2.

Scenario	2023 (MWh/yr)	2030 (MWh/yr)	2050 (MWh/yr)
1.5°C, Passive First	111,574	111,902	112,776
1.5°C, No Intervention	111,574	115,706	126,726
4.0°C, Passive First	111,574	114,340	121,717
4.0°C, No Intervention	111,574	130,851	182,257

Table C-2: Cooling Demand Scenarios.

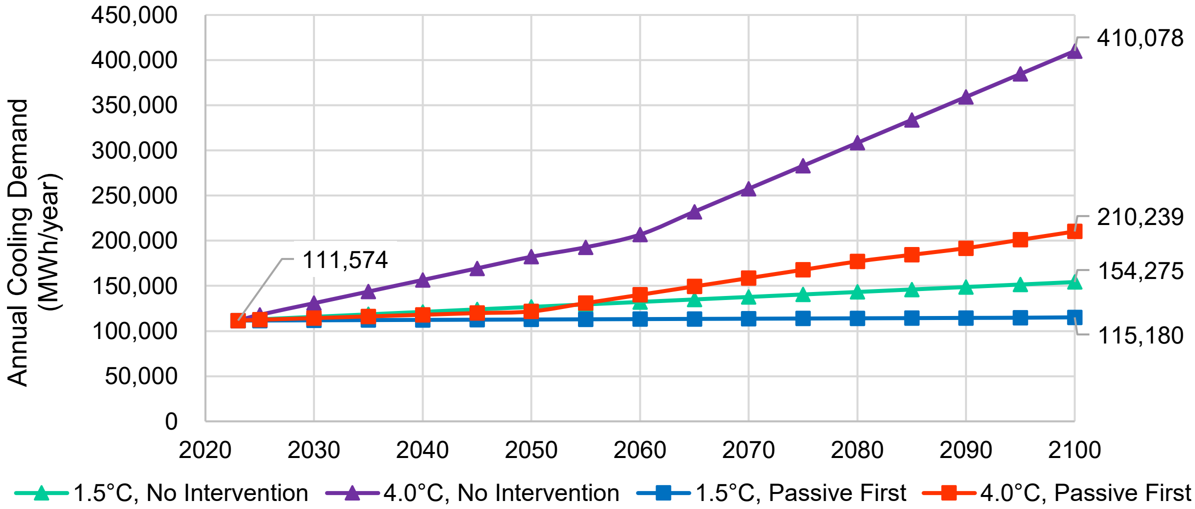


Figure C-2: Projected Change in Cooling Demand.

Appendix D Low Carbon Technologies

D.1 Heat Pump Technology

A large number of low carbon technologies proposed within this list are centred around the use of heat pumps. A heat pump works using refrigeration cycle to convert low grade ambient (or waste) heat to that of a useful temperature. This requires electricity to facilitate this process but typically for every unit of electricity inputted into a heat pump, 2-5 units of useful heat are output for use into a heating system.

The efficiency of this process depends on the ambient heat source temperature and the heat supply temperature used by the building. The closer together these temperatures are, the more efficient is heat pump operation. Therefore, warmer heat sources (data centre waste heat and sewers) are preferable to cooler heat sources (such as air).

Heat can be extracted from a number of different ambient heat sources (air, water, ground, and sewers). The process can also be used to support the cogeneration of heating and cooling where both the cooled fluid and the warmed fluids are useful products (data centre heat rejection, for example).

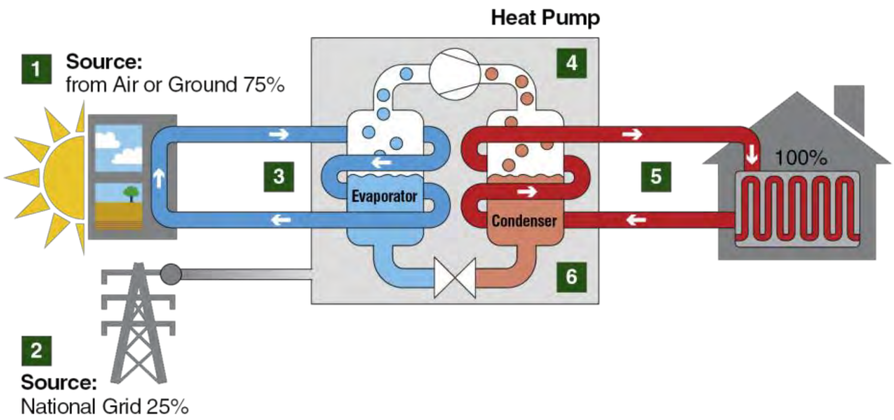


Figure D-1: Operating Principle of a Heat Pump.

Source: Dimplex

D.2 Ground Source Heat Pump

A Closed Loop GSHP system collects shallow ground energy held within the soil. The system incorporates an array of boreholes, typically 150 m deep (or shallow trenches), within which plastic pipes are installed (coiled in shallow trenches). In order to extract the energy, a working fluid mixture of water and glycol is pumped through these plastic pipes, which is heated or cooled (as required) as it is pumped through the buried pipework.

An Open Loop GSHP scheme typically involves the abstraction of groundwater from one or more boreholes, which is passed through a heat exchanger and subsequently discharged through separate borehole(s) to the same aquifer. These boreholes should be at least 200 m (horizontally) apart to ensure an efficient system and avoid recirculation of groundwater, although in specific circumstances a reduced horizontal distance may be feasible depending on ground conditions.

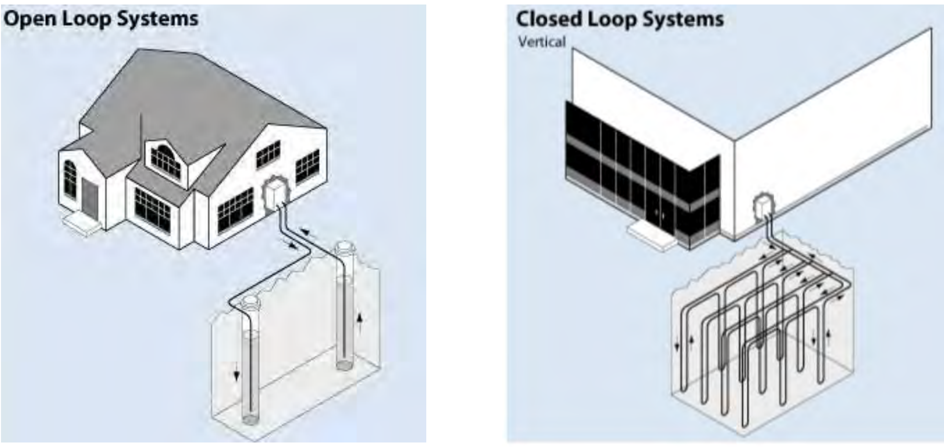


Figure D-2: Two Variants of Ground Source Heat Pump Systems.

Source: https://www.energy.gov/energysaver/geothermal-heat-pumps

D.3 Sewer Source Heat Pump

The wastewater within the sewer systems contains latent thermal energy. Sewage due to heated water discharge from showers, appliances and also rainwater can be harnessed. This heat is captured by abstracting and passing a proportion of the wastewater flow from a typical sewer through a heat exchanger assembly, which is specially designed to account for the nature of the fluid, prior to reinjection back into the sewer.

A number of technologies are available for recovery of heat from sewers, however as the medium contains untreated sewage, some form of screening and filtration plant is required to protect the heat pump plant. The technology must be acceptable to the water utility company, which in this case is Thames Water, as it will form part of their infrastructure and they will also have concerns over the impact that cooling may have on settlement and blockages.

To recover heat, Heads of Terms (or a Use of Sewer Agreement) must be in place with the water utility company. At the time of writing, there are no standardised Thames Water Heads of Terms or process in place which potential offtakers must follow. However, it is understood that this are currently being developed and are anticipated to be available by the time they would be required for this project.

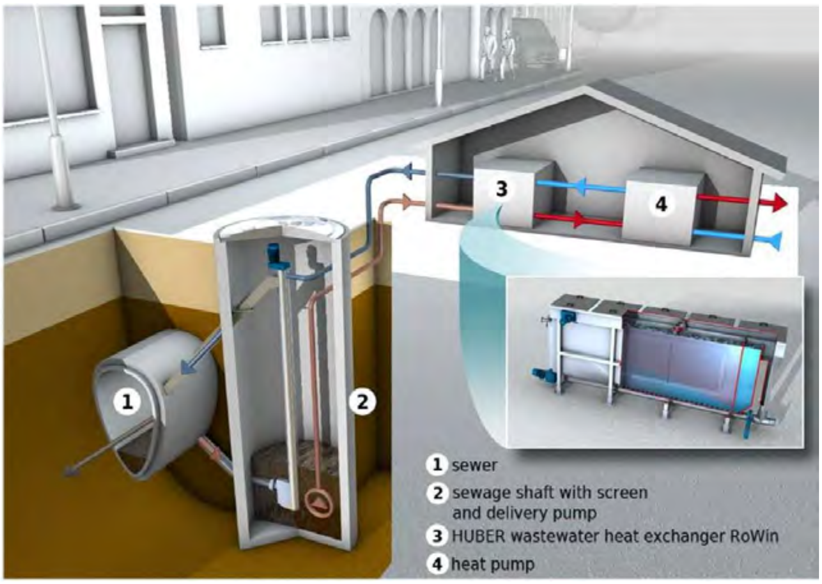


Figure D-3: Sewer Heat Recovery System by Huber.

Source: https://www.huber.co.uk/solutions/heating-and-cooling-with-wastewater/sewers-sources-of-energy.html

D.4 Sewage Treatment Works Heat Pump

Heat recovery from sewage treatment works operates similar to that of direct sewer heat recovery, with the key difference being that the point of heat recovery is the treated effluent outfall from the treatment works back into the environment. As demonstrated in Figure D-4, this final outfall from the existing system in Malmo is to the sea, and in Hounslow is the River Thames.

Heat recovery at this point has a number of advantages over direct sewer heat recovery, which include:

- There will be no suspended solids in the water so there is no requirement for filtration and screening plant to protect the heat pumps, reducing operational cost and complexity.
- A greater temperature reduction (more heat recovery) can be achieved as there is a reduced risk of blockages due to the effect of cooling the effluent. In addition, this cooling can benefit the environment by mitigating increases to sea/river water temperature rises.
- The treated effluent may be warmer than the untreated sewer water due to the heat input via the treatment processes at the plant, albeit some temperature loss may occur during the settlement process.
- The infrastructure required for heat recovery can be installed in a more accessible location i.e. at the treatment plant as opposed to being integrated within buried and often very old sewers.

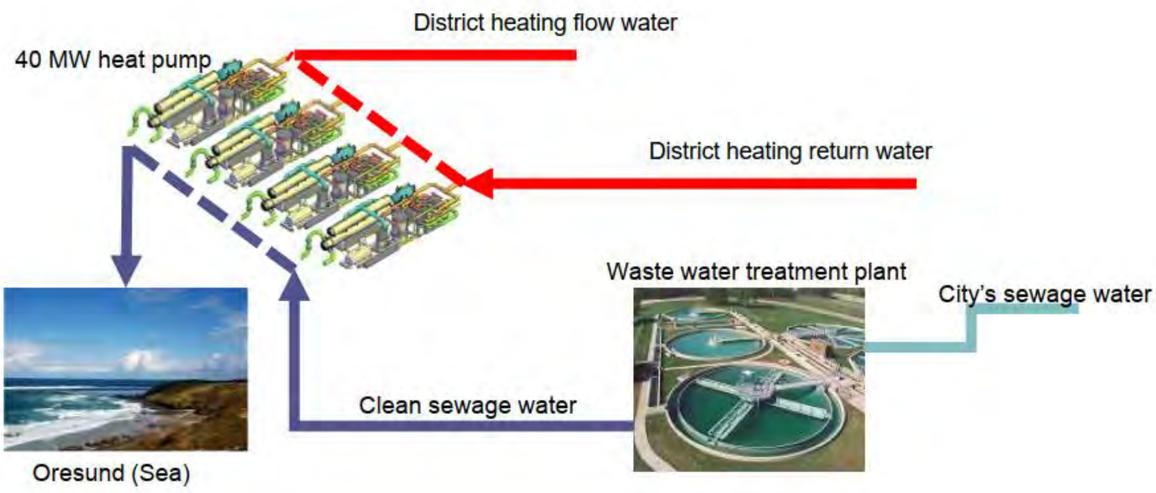


Figure D-4: Depiction of the Malmo Sewage Treatment Works Heat Recovery

D.5 Biogas Energy Generation

Biogas is a mixture of methane (CH_4), Carbon Dioxide (CO_2) and small quantities of other gases produced by anaerobic digestion of organic matter in an oxygen-free environment. The precise composition of biogas depends on the type of feedstock and the production pathway, such as:

- Biodigesters
- Landfill gas recovery
- Wastewater treatment plants

The methane content of biogas typically ranges from 45% to 75% by volume, with most of the remainder being CO_2. This variation means that the energy content (calorific value or lower heating value) of biogas can vary. Biomethane (also known as "renewable natural gas") is a near-pure source of methane produced by "upgrading" biogas (a process that removes any CO_2 and other contaminants present in the biogas). Biomethane has a highly similar energy content to natural gas and so can be used without the need for any changes in transmission and distribution infrastructure or end-user equipment.

The chemical reaction for the burning of biomethane is primarily[30] the same as the that of burning natural gas in that the two main products are carbon dioxide (CO_2) and water (H_2O). From a carbon perspective, the key difference is that biomethane can be considered to be carbon neutral as the CO_2 that is released was originally

[30] With the exception of the reaction of trace gases

captured from the atmosphere by the organic materials that were processed to produce it. Additionally, if not harnessed, the gases would eventually make their way back into the atmosphere via natural processes and in the meantime, if released to the atmosphere as methane has a much higher GHG factor until it eventually decomposes back into CO_2.

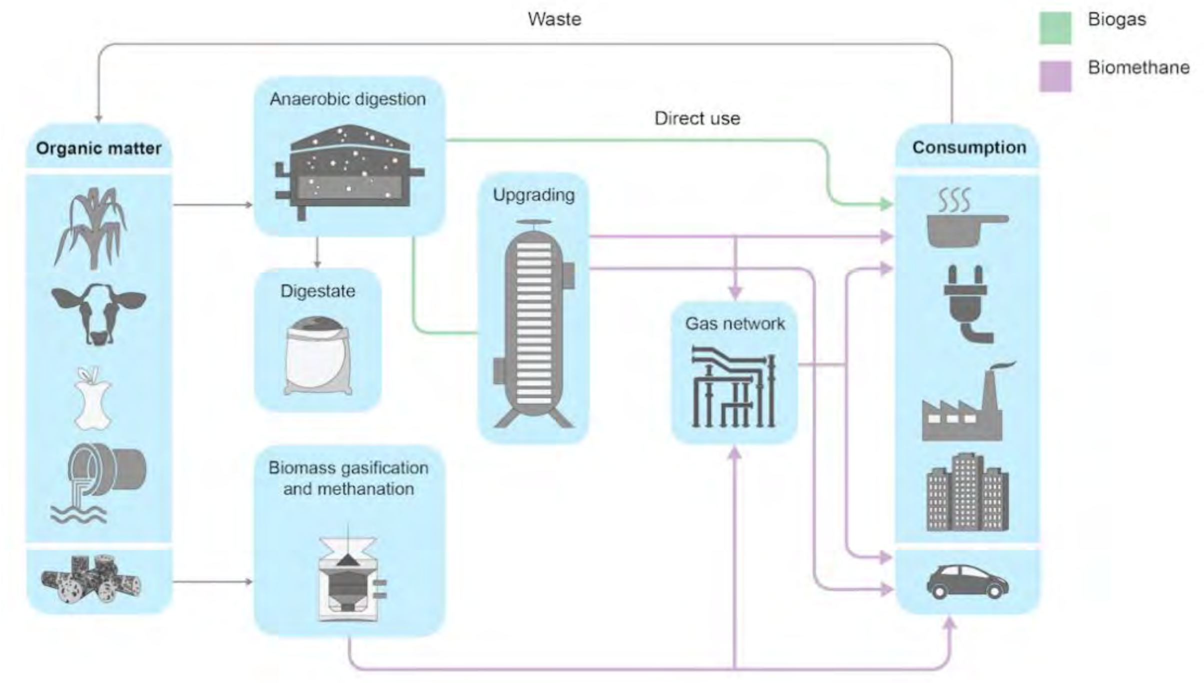


Figure D-5: Production and Use of Biogas and Biomethane

Biogas / biomethane can be burned by boilers to produce heat or by combined heat and power (CHP) to produce both heat and electricity. At wastewater treatment plants, the heat and power produced can be used by the on-site treatment processes with excess exported to local energy grids. Any excess biomethane can also be exported into a local gas grid. At Mogden for example, any power that is not used on site is exported to the electrical grid. This principle could also be achieved for excess heat if a local heat network existed. Thames Water are currently developing a number of projects on their Mogden site which would enhance the efficiency of gas capture and provide a new biomethane gas-to-grid plant[31].

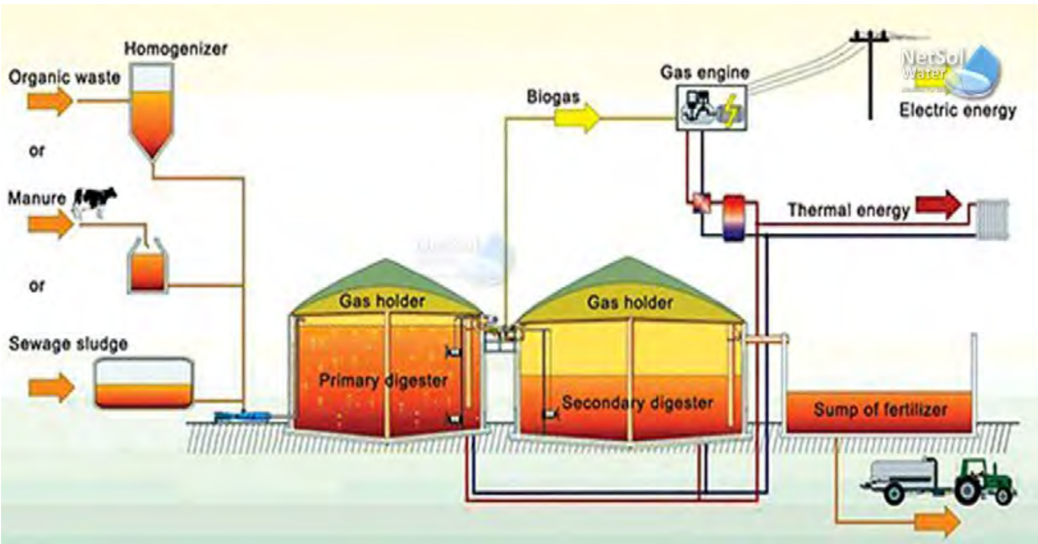


Figure D-6: Biogas Generation from Wastewater Treatment Plants

Source: https://www.netsolwater.com

[31] Mogden Sewage Treatment Works Residents Liaison Meeting 27/02/2022 (thameswater.co.uk)

D.6 River/Marine Source Heat Pump

Marine source heat pumps collect ambient heat stored in sea water, rivers, canals, or estuaries. To abstract the required quantity of water, an open loop system is typically used, similar to an open-loop GSHP system. However, the water abstraction system would likely be highly bespoke to every project as it is very much based upon the geographical conditions of the site.

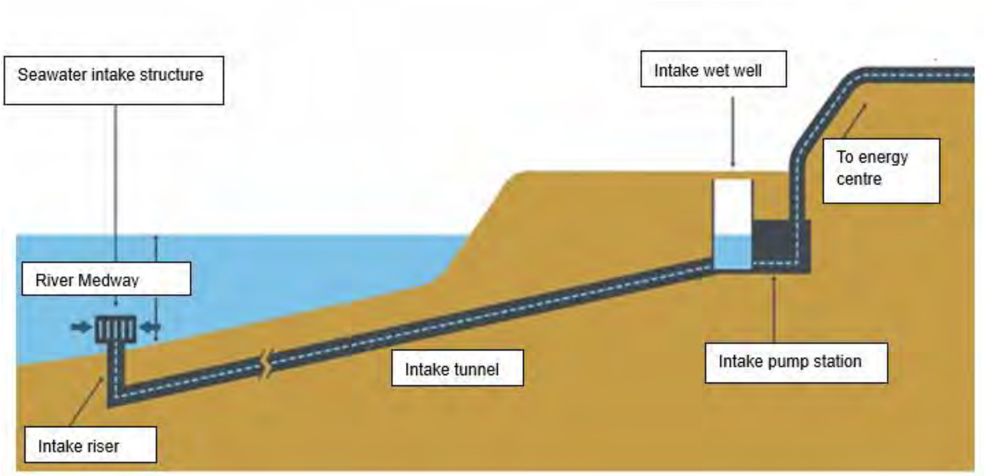


Figure D-7: Seawater Abstraction System Illustration.

D.7 Air Source Heat Pumps

Air Source Heat Pumps (ASHPs) extract energy from the ambient air and are able to function even when temperatures are as low as -5°C.

To extract energy from the ambient air, a portion of the equipment, the collector coil (which functions as either the condenser or compressor, depending on if the heat pump is in heating or cooling mode, respectively) is located externally. This is typically achieved by placing the coils on roof-spaces (which are flat to enable plant access) or at ground level.

In order to absorb enough energy from the air, the resultant collector coil(s) need to be very large to serve the demands of a centralised district heating system, which typically results in this technology taking up a larger footprint than the other viable heat pump solutions discussed in this section.

Figure D-8: Sewer Heat Recovery System by Huber.

Source: Star Refrigeration

D.8 Waste Heat from Data Centre

Data centres consume large amounts of power to provide their services to companies around the globe. These buildings are often designed to 2 kW of electrical demand per m^2 of floor area, a value at least 10 times greater than most buildings. The majority of this electrical demand is converted to heat; as such, data centres need significant cooling to prevent them from overheating. Typically, this heat is rejected to the air, presenting an opportunity for this waste heat to be recovered for district heating. As a potential heat source, data centres would have the advantage of rejecting a relatively consistent volume of heat throughout the year, in comparison to more seasonally-affected technologies such as air source heat pumps.

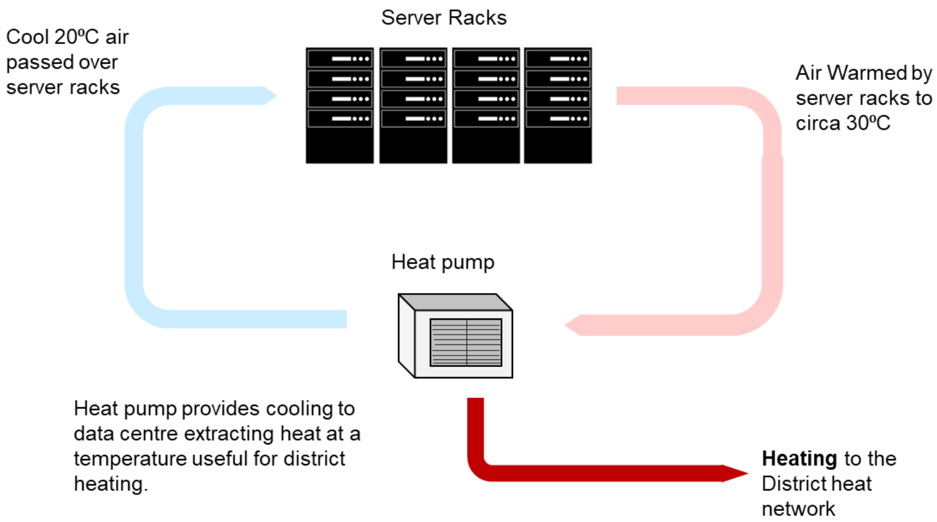


Figure D-9: Data Centre Heat Recovery Illustration.

D.9 Waste Heat from Retail

Similarly to data centres, supermarkets require constant cooling for their refrigerators and freezers. This is a constant baseload required to make sure that chilled products remain at the specified temperature. The rejected heat (to provide cool) will usually be rejected externally via chillers; however, a number of options are available.

The accessibility of this waste heat will depend on the MEP systems installed. Replacement cycles of refrigeration often afford the best opportunity to integrate waste heat recovery. The rejected heat can be used both within the supermarket and externally on a district energy network to ensure that all of the rejected heat is utilised. This opportunity has not been demonstrated at scale within the UK. Therefore, it is challenging to evaluate the potential of this technology and the impact it could make.

D.10 Waste Heat from Electrical Transformers

High voltage electrical transformers generation a significant amount of heat due to resistive losses. It is possible (although not widely implemented) to capture and utilise this heat whilst also improving transformer performance. Hot air is currently vented from substations to cool via oil-cooling radiators. Instead, a plate heat exchanger would extract heat from the cooling effluent and distribute via the district heat network.

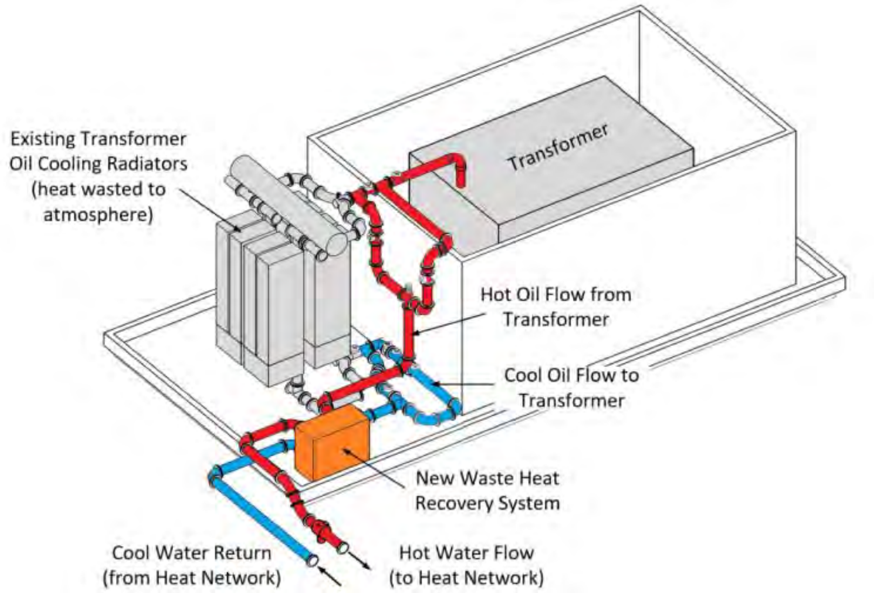


Figure D-10: HV Transformer Heat Recovery Interface.

Source: SSE Energy Solutions.

Appendix E Low Carbon Heat Source Appraisal

E.1 Appraisal Methodology

The first stage of the appraisal subjected each low/zero carbon heat source/technology (LZC) to a pass / fail 'gate' considering two questions:

1. Is the technology technically viable?
2. Is the heat source accessible from a suitable energy centre?

Each technology was then scored against factors with the following weightings:

Category	Scoring Criterion	Weighting /5
Technical	Technology maturity and availability	5
Technical	Suitability for scale and profile of heat demand	5
Technical	Security of supply	3
Technical	Suitability for required supply temperatures	4
Technical	Proximity to heat demands	2
Environmental	Level of CO2 emission savings	5
Environmental	Air quality implications	5
Environmental	Wider environmental impacts	2
Financial	Technology cost	3
Financial	Impact on scheme financial viability	5
Financial	Long term financial risks	3
Deliverability	Planning Implications	4
Deliverability	Implications for energy centre size/design	3
Deliverability	Implications for additional space requirements	2
Deliverability	Reliance on third parties	2
Operational	Ease and cost of maintenance	2

Table E-1: LZC Scoring Criteria.

E.2 Scoring Results

Technology	Score	Borough-wide Rank
Mogden STW Waste Water Heat Recovery	81%	1
Mogden STW Biogas CHP/Boiler Excess Heat	80%	2
Open loop ground water abstraction: Redlees Park	79%	3
Open loop ground water abstraction: Boston Manor Park	78%	4
Open loop ground water abstraction: Goals Gillette Corner	76%	5
Open loop ground water abstraction: Thornby Park	76%	5
Open loop ground water abstraction: Hounslow Heath	76%	5
Open loop ground water abstraction: Syon Park	76%	8
Air Source Heat Pump	76%	8

Technology	Score	Borough-wide Rank
Mogden STW Biogas supply Heat Network Biogas Boiler	76%	10
Feltham Corporate Centre Data Centre Heat Recovery	75%	11
Open loop ground water abstraction: Inwood Park	75%	12
Open loop ground water abstraction at Saint Dunstan's Meadow	75%	13
Open loop ground water abstraction: Beaversfield Park	75%	13
Serverfarm LON1 London Data Centre	74%	15
Open loop ground water abstraction: Hanworth Park	73%	16
Waste Heat from Tesco Extra Isleworth	72%	17
Open loop ground water abstraction: Cavalry Barracks	72%	18
Open loop river water abstraction from the Brent	65%	19
SSEN Electrical Transformer (Vicarage Farm Road)	62%	20
SSEN Electrical Transformer (Bridge Road)	61%	21
SSEN Electrical Transformer (SunGard)	60%	22
Open loop river water abstraction from the Thames	Fail	Fail
Open loop ground water abstraction: St. Pauls Recreation Ground	Fail	Fail
Open loop ground water abstraction: Gunnersbury Park	Fail	Fail
Open loop ground water abstraction: Osterley Park	Fail	Fail
Sewer Source Heat Pump	Fail	Fail
Open loop ground water abstraction: Lampton Park	Fail	Fail
Waste heat from the Blenheim Centre	Fail	Fail
SSEN Electrical Transformer (North Feltham)	Fail	Fail
SSEN Electrical Transformer (Feltham)	Fail	Fail
Open loop ground water abstraction: Chester Road Park	Fail	Fail
Heat Recovery from Asda Feltham Superstore Cooling	Fail	Fail

Table E-2: LZC Appraisal Score – Borough-wide.

Technology	Score	East of Borough Rank
Mogden STW Waste Water Heat Recovery	81%	1
Mogden STW Biogas CHP/Boiler Excess Heat	80%	2
Open loop ground water abstraction: Redlees Park	79%	3
Open loop ground water abstraction: Boston Manor Park	78%	4
Open loop ground water abstraction: Goals Gillette Corner	76%	5
Open loop ground water abstraction: Thornby Park	76%	5
Open loop ground water abstraction: Syon Park	76%	7
Air Source Heat Pump	76%	7
Mogden STW Biogas supply Heat Network Biogas Boiler	76%	9
Open loop ground water abstraction: Inwood Park	75%	10
Waste Heat from Tesco Extra Isleworth	72%	11
Open loop river water abstraction from the Brent	65%	12
SSEN Electrical Transformer (Vicarage Farm Road)	62%	13

Technology	Score	East of Borough Rank
SSEN Electrical Transformer (Bridge Road)	61%	14
Open loop river water abstraction from the Thames	Fail	Fail
Open loop ground water abstraction: St. Pauls Recreation Ground	Fail	Fail
Open loop ground water abstraction: Gunnersbury Park	Fail	Fail
Open loop ground water abstraction: Osterley Park	Fail	Fail
Sewer Source Heat Pump	Fail	Fail
Open loop ground water abstraction: Lampton Park	Fail	Fail
Waste heat from the Blenheim Centre	Fail	Fail

Table E-3: LZC Appraisal Score – East of Borough.

Technology	Score	Brentford Rank
Open loop ground water abstraction: Boston Manor Park	80%	1
Open loop ground water abstraction: Goals Gillette Corner	78%	2
Open loop ground water abstraction: Syon Park	78%	3
Air Source Heat Pump	78%	3
Open loop river water abstraction from the Brent	67%	5
SSEN Electrical Transformer (Vicarage Farm Road)	62%	6
Open loop river water abstraction from the Thames	Fail	Fail
Open loop ground water abstraction: St. Pauls Recreation Ground	Fail	Fail
Open loop ground water abstraction: Gunnersbury Park	Fail	Fail
Open loop ground water abstraction: Osterley Park	Fail	Fail
Sewer Source Heat Pump	Fail	Fail

Table E-4: LZC Appraisal Score – Brentford.

Appendix F Energy Centre Location Appraisal

F.1 Appraisal Methodology

A total of 48 energy centre (EC) locations for heating and/or cooling were evaluated against the criteria listed in Table F-1. A pass / fail 'gate' was applied where no viable heat sources were in the proximity of the EC site.

Scoring Criterion	Weighting /15	Note
Access	6	
Utility Connections	3	
Implications for Current & Planned Use	3	
Suitability for Flueing	2	Heating Only
Flood Risk	3	
LZC Proximity / Viability	15	Heating Only
Land ownership	6	
Reliance on 3rd parties	6	
Future expansion capability	3	
Proximity to Offtakers	10	
Space Availability	8	
Visual Impact	2	
Environmental Impact	3	
Potential to achieve fully electrified solution	9	Heating Only
Deliverability	6	
Programme Implications	6	
Impact to Residents	5	
Write-off cost for existing plant	2	Heating Only

Table F-1: EC Scoring Criteria.

F.2 Scoring Results

Location	Score	Borough-wide / East of Borough Rank
Ivybridge Social Housing (Boxing Gym Site)	84%	1
Langdale Centre	83%	2
On site at Mogden	81%	3
Capital Vehicle Maintenance	79%	4
Redlees Park Car Park	78%	5
Land at Bull Field	77%	6
On site at Mogden [SINC]	76%	7
Isleworth Leisure Centre and Library	75%	8
West Middlesex University Hospital	74%	9
Land rear of Industrial Park	73%	10
Twickenham Stadium	71%	11

Table F-2: Heating EC Appraisal Score – Borough-wide / East of Borough.

Location	Score	Brentford Rank
Profile West Car Park [Site Allocation]	82%	1
Land under Chiswick Flyover	78%	2
Boston Manor Park Car Park	78%	3
Bolder Academy / Rear of Sky Campus	77%	4
Brent Lea Social Housing	72%	5
Harlequin Avenue Plot [Site Allocation]	68%	6
GSK Car Park	67%	7
Gillette Studios	65%	8
London Museum of Steam	Fail	Fail
Brentford Towers	Fail	Fail
Layton Road Car Park	Fail	Fail
Albany Riverside [Site Allocation]	Fail	Fail

Table F-3: Heating EC Appraisal Score – Brentford.

Location	Score	TV Triangle Rank
Harlequin Avenue Plot [Site Allocation]	91%	1
Bolder Academy / Rear of Sky Campus	79%	2
Gillette Studios	71%	3

Table F-4: Cooling EC Appraisal Score – TV Triangle Cluster.

Location	Score	GSK / UWL Rank
Land under Chiswick Flyover	95%	1
Boston Manor Park Car Park	91%	2
Substation Rear of GSK Building	85%	3
Substation Rear of GSK Building	85%	4
GSK Car Park	67%	5
Profile West Car Park [Site Allocation]	64%	6

Table F-5: Cooling EC Appraisal Score – GSK / UWL Cluster.

Location	Score	Brentford Hotels Rank
Layton Road Car Park	96%	1
Layton Road Warehouses [Site Allocation]	84%	2

Table F-6: Cooling EC Appraisal Score – Brentford Hotels Cluster.

Location	Score	Thames Path North Rank
Brentford Towers	91%	1
Albany Riverside [Site Allocation]	89%	2
Former Railway Arches	79%	3
Brent Lea Social Housing	76%	4

Table F-7: Cooling EC Appraisal Score – Thames Path North Cluster.

Location	Score	Hounslow High St Rank
Land rear of 2-4 Lampton Road	97%	1
LBH Vehicle Maintenance	88%	2
Montague Road Car Park	87%	3
Land beside Greenham House	78%	4
Blenheim Centre Plantroom	73%	5

Table F-8: Cooling EC Appraisal Score – Hounslow High St Cluster.

Location	Score	Feltham Rank
Feltham Assembly Hall Car Park	86%	1
Ashmead Road Depot	85%	2
Springwest Academy	83%	3
Land near Rose Gardens	82%	4
Storage lockers / car park near Glebelands Road	81%	5

Table F-9: Cooling EC Appraisal Score – Feltham Cluster.

Appendix G Electrical DNO Engagement

For assumptions made on the cost of electrical connections, refer to Appendix N.6.

When assessing the options for connecting the new energy centre to the local grid infrastructure, initial engagement was held with the relevant electrical district network operator (DNO), Scottish and Southern Electricity Networks (SSEN). The original energy centre strategy introduced to SSEN during this initial connection clinic was as demonstrated in Table G-1. Note: non-specific energy centre locations were used in this initial engagement, given the high-level strategic purpose of the call where approximate locations were sufficient.

Energy Centre Name	Function	Site Electrical Demand (MVA)
Mogden	Single Heating Energy Centre for Borough-wide Solution	24
Mogden	Single Heating Energy Centre for East of Borough Solution	12
Brentford	Single Heating Energy Centre for Brentford Solution	11
TV Triangle	Single Cooling Energy Centre for the TV Triangle Network	3.8
GSK / UWL	Single Cooling Energy Centre for the GSK / UWL Network	3.1
Brentford Hotels	Single Cooling Energy Centre for the Brentford Hotels Network	0.6
Thames Path North	Single Cooling Energy Centre for the Thames Path North Network	1.7
Hounslow High Street	Single Cooling Energy Centre for the Hounslow High Street Network	2.1
Feltham	Single Cooling Energy Centre for the Feltham Network	3.5

Table G-1: Electrical Demand from Initial Energy Centre Strategy.

The electrical grid constraint within West London has been widely reported by the Greater London Authority (GLA) and others, with early discussions about potential bans on new developments until 2030-2035 until reinforcement works were completed. The latest information indicates that any development which requires a connection of greater than 1MVA, could only be connected in 2037[32], which was echoed by SSEN during the connection clinics. This date would cause a significant delay in the Hounslow heat network deployment strategy, which originally sought connection to the grid in 2028 in order to begin offering carbon savings ahead of LBH net-zero target date of 2030.

However, the GLA, SSEN and others have developed short term “ramping up” strategy[32] to mitigate some of the issues this may cause. With this, new developments could be providing with an electrical supply of no greater than 1MVA immediately, which could be increased by 1MVA per year up to a maximum of 10MVA. To comply with these requirements, AECOM developed a phasing strategy which included splitting up a single large energy centre into multiple smaller, geographically distinct sites, each of which could be increased by 1MVA per year (3MVA total per year) and which at full build out did not exceed the 10MVA cap. This strategy has been aligned to the phased build out of the heat network and customer building connection, electrical capacity is added at an equivalent rate as is required by the customer demand for heat supply.

For the recommended Borough-wide solution, the three site locations and their respective loads are shown in Table G-2, Figure G-1, and Figure G-2 below.

Site	Postcode	What3Words Location	Full Site Demand (MVA)
EC1 – Mogden	TW7 7LP	///master.pocket.festivity	9.8
EC2 – Ivybridge	TW7 7QL	///wallet.index.sake	9.8
EC3 – Private	TW7 6DS	///cure.asleep.famous	7.5

Table G-2: Energy Centre Separated Locations and Demand.

[32] West London Electricity Capacity Constraints (premierenergy.co.uk)

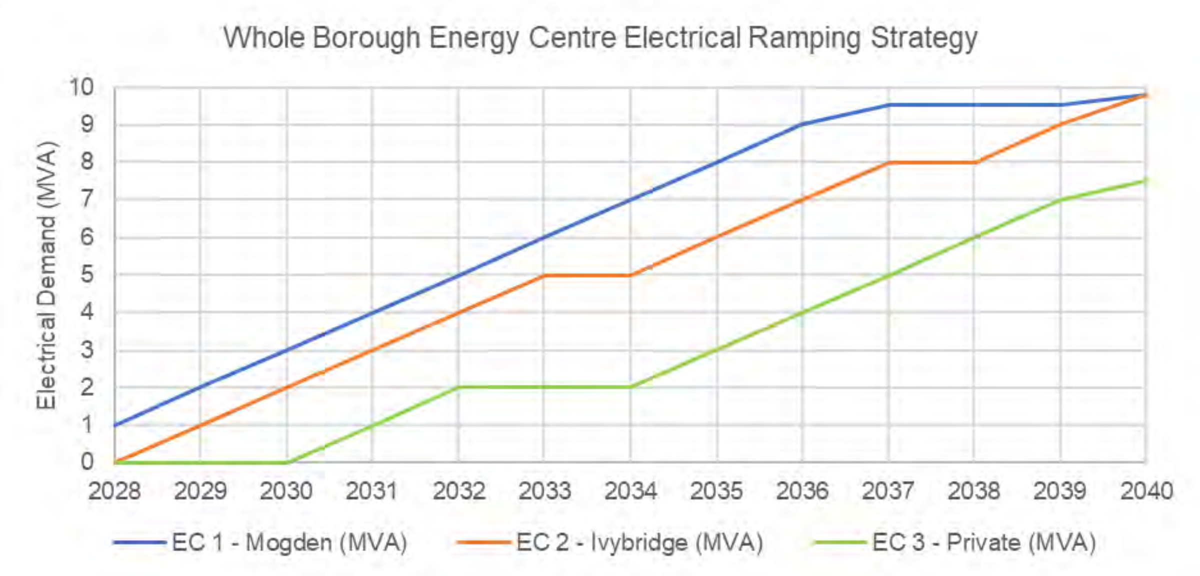


Figure G-1: Borough-wide Energy Centre Electrical Ramping Strategy.

Figure G-2: Energy Centre Locations.

The sites chosen were three of the highest scoring locations from the EC appraisal and offered good connectivity with the Mogden treatment works, to reduce the length of connecting infrastructure from the likely point of heat recovery. The phasing of the energy centres was determined as follows:

- **1st – on site at Mogden:** Closest to the point of connection to heat recovery, owned by Thames Water and potentially offers an opportunity for quicker and larger capacity electrical supply (explained below)
- **2nd – existing Ivybridge plantroom:** Owned and controlled by the London Borough of Hounslow
- **3rd – Capital Vehicle Maintenance Site:** Good connectivity to the point of connection to heat recovery but privately owned and would require land purchase or lease agreement.

There is potential for the 3rd energy centre site (EC3) not to be required, should one of the below occur:

1. Heathrow Airport decide they do not wish to connect to the network.
2. A larger capacity electrical supply can be achieved at Mogden (see below).

The energy centre sizing strategy has been completed so that EC3 can be omitted in the event that 1. above occurs, without impacting EC1 and EC2.

On further investigation, it was found that EC2 and EC3 fall within the remit of SSEN and are, as such, ready to go forward with feasibility studies with the DNO. The third site, EC1, however, falls within the territory of UK Power Networks (UKPN). Whilst this site is shown within the currently understood SSEN boundary, it transpires that Mogden Sewage Treatment Works was provided with a 33kV supply, which crosses the DNO boundary, from the UKPN grid to the south, as indicated on Figure G-3.

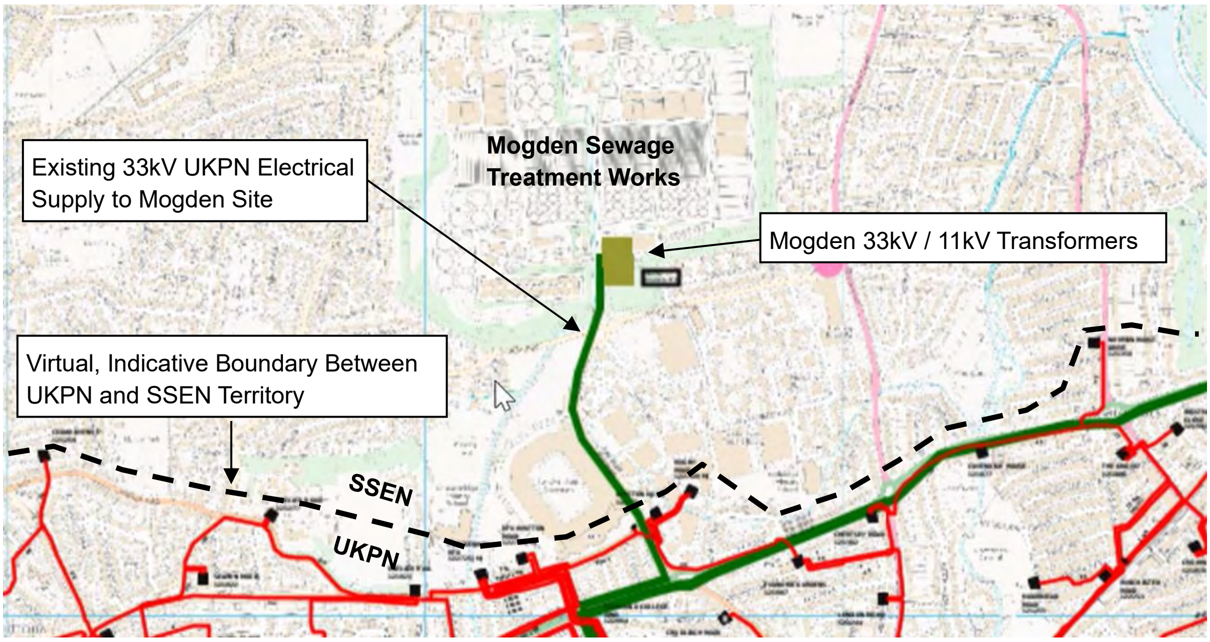


Figure G-3: Existing Electrical Supply to Mogden Site

The presence of this existing connection brings both opportunities and potential complications which are initially discussed with UKPN in a connection surgery on the 21st of September. It should be highlighted that any strategy would require approval by Thames Water, and these have not been discussed as part of this feasibility study.

In the UKPN surgery, it was confirmed the same ramping agreement as described for SSEN also applied for UKPN connections in this area of West London. This means that the same strategy described above for ensuring capacity at a transmission level is also applicable to this site, although, with the UKPN network possibly being less constrained, it may be better to centralise more load in this site if possible. It was confirmed by UKPN that the ramping strategy would not apply to the existing supply to the site, so if there is headroom available within the supply, this could allow for a faster deployment and larger capacity energy centre at this site as it would not be restricted by the 1MVA/year and max 10MVA restrictions. This may be a key strategic factor in accelerating the deployment of the Hounslow heat network and should be explored in future stages.

The different options for electrical supply at the Mogden site are therefore as follows:

a) Use spare capacity within the existing 33kV UKPN supply and the UKPN Mogden 33kV/11kV substations.
   - Stepping the voltage down to 11kV and 440V would require investment by the heat network in transformers and associated infrastructure.
   - Thames Water may not accept a reduction in the spare capacity in the supply to their treatment works.
   - The “spare” capacity is approximated at being 15-20MVA which could supply a significant scale energy centre but what capacity Thames Water may accept giving the energy centre is unknown.

b) Use spare capacity within the existing 33kV UKPN supply and install new 33kV/11kV substation.
   - Investment required by the heat network in 33kV/11kV/400V transformers and associated infrastructure.
   - This would not impact the capacity of the existing UKPN supplies.
   - The “spare” within the UKPN cable is unknown.
   - Thames Water may not provide space for a new 33kV11kV transformer.

c) 11kV cabling extended up into the Mogden site from the UKPN 11kV network.

- Laying the cable could be a large investment.
- Avoids loading the Mogden 33kV transformers and UKPN 33kV supply more.
- Subject to restrictions of the ramping up agreement.

d) Cabling connecting the Mogden site to the SSEN 11kV network.

- SSEN may be reluctant to provide power to a postcode currently supplied by UKPN.
- Cabling could prove more expensive than the UKPN 11kV cabling option.
- Subject to restrictions of the ramping up agreement.

It is clear that options a) and b) could offer a means to accelerate the deployment of the heat network, however require close coordination with Thames Water, UKPN and the project team. The choice of these options will also depend on the allowable capacity from UKPN as well as whether SSEN or UKPN cabling options are cheaper.

The next steps are as follows:

- Communicate with the relevant stakeholders to get information:
  - With UKPN and Thames Water regarding the capacity and viability of 11kV and 33kV connection at the Mogden site.
  - With SSEN and Thames Water to confirm viability of extending an 11kV line into the Mogden STW site.
- Based on this, decide which of the above connection options should be taken forward.
- Proceed with three feasibility studies with the relevant DNO’s.
- Once feasibility of connection is established, plans can be made to progress to a formal application, once ready.

Appendix H Plant Phasing Programme

The proposed phasing of plant in each energy centre is detailed in Table H-1. This has been developed for the Borough-wide including Heathrow Airport phasing strategy (Section 6).

EC / Plant Type		2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
EC1 – Mogden:														
Heat Pump	MW	2	2	5	8	11	11	11	15	15	20	20	20	20
Gas Boilers	MW	10	10	20	30	40	40	40	50	50	50	50	50	65
Thermal Stores	m^3	100	100	250	400	525	525	525	750	750	1,000	1,000	1,000	1,000
EC2 – Ivybridge:														
Heat Pump	MW	-	2	4	6	8	8	8	8	8	15	15	15	20
Gas Boilers	MW	-	20	20	20	30	30	30	30	30	50	50	50	65
Thermal Stores	m^3	-	100	200	300	400	400	400	400	400	750	750	750	1,000
EC3 – Private:														
Heat Pump	MW	-	-	-	2	4	4	4	6	6	10	10	10	15
Gas Boilers	MW	-	-	-	10	20	20	20	20	20	40	40	40	40
Thermal Stores	m^3	-	-	-	100	200	200	200	300	300	500	500	500	750
All ECs Total:														
Heat Pump	MW	2	4	9	16	23	23	23	29	29	45	45	45	55
Gas Boilers	MW	10	30	40	60	90	90	90	100	100	140	140	140	170
Thermal Stores	m^3	100	200	450	800	1,125	1,125	1,125	1,450	1,450	2,250	2,250	2,250	2,750

Table H-1: Proposed Plant Phasing Programme.

Appendix I Energy Centre General Arrangements

Please refer to accompanying document *Hounslow Feasibility Appendix I: Energy Centre General Arrangements.*

Appendix J Network Routes

J.1 Heating

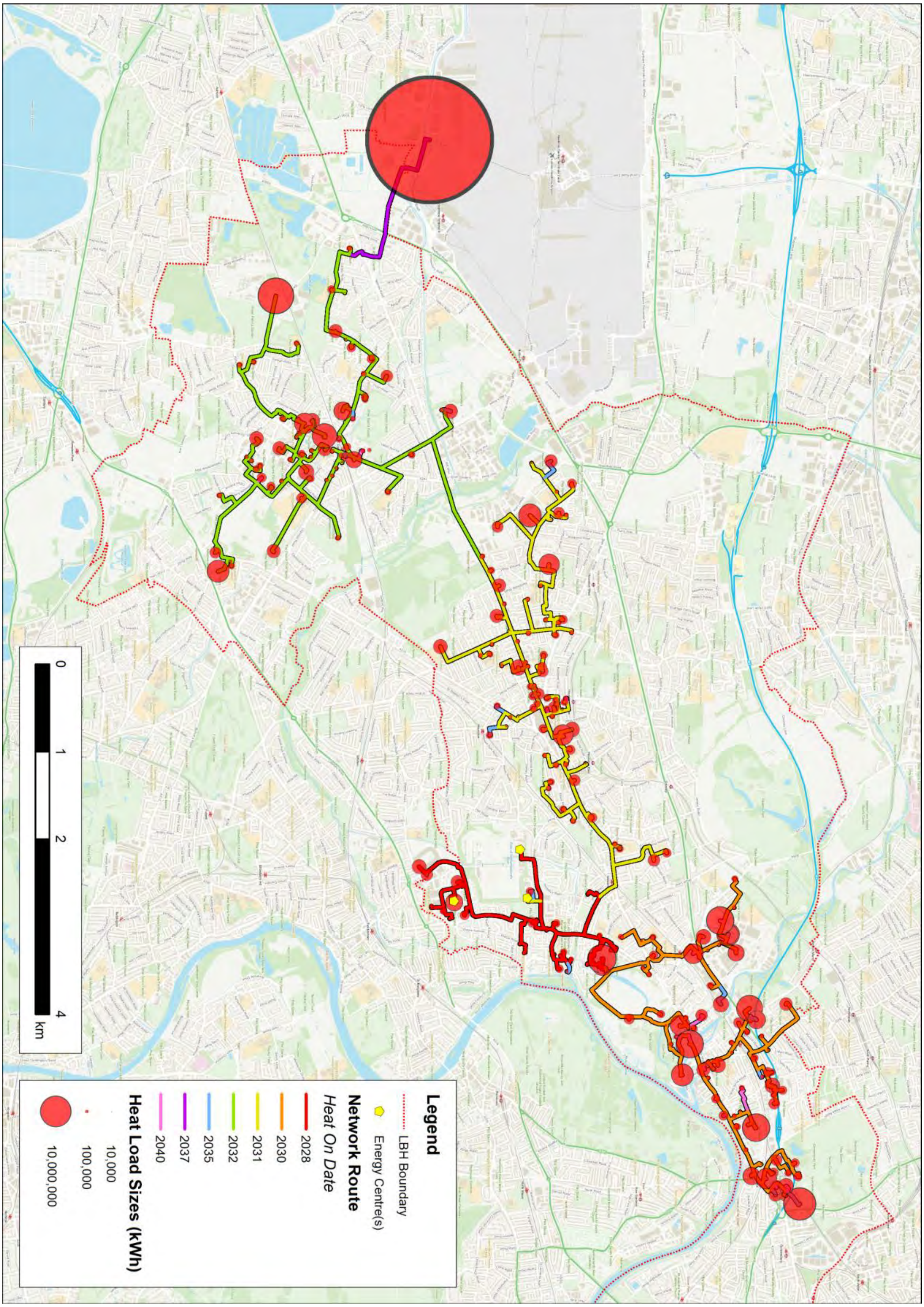


Figure J-1: Borough-wide + Heathrow District Heating Network Phased Route and Loads.

J.2 Cooling

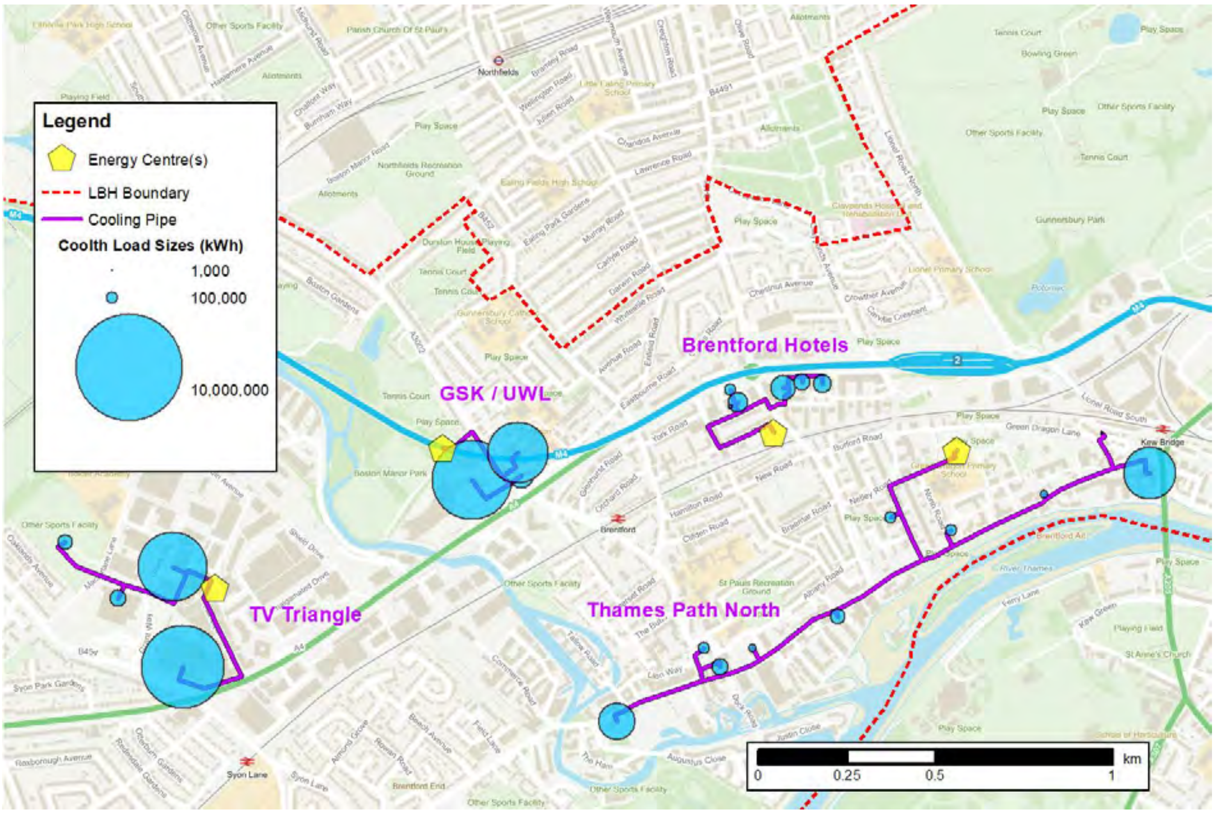


Figure J-2: Brentford Area Cooling Network Routes.

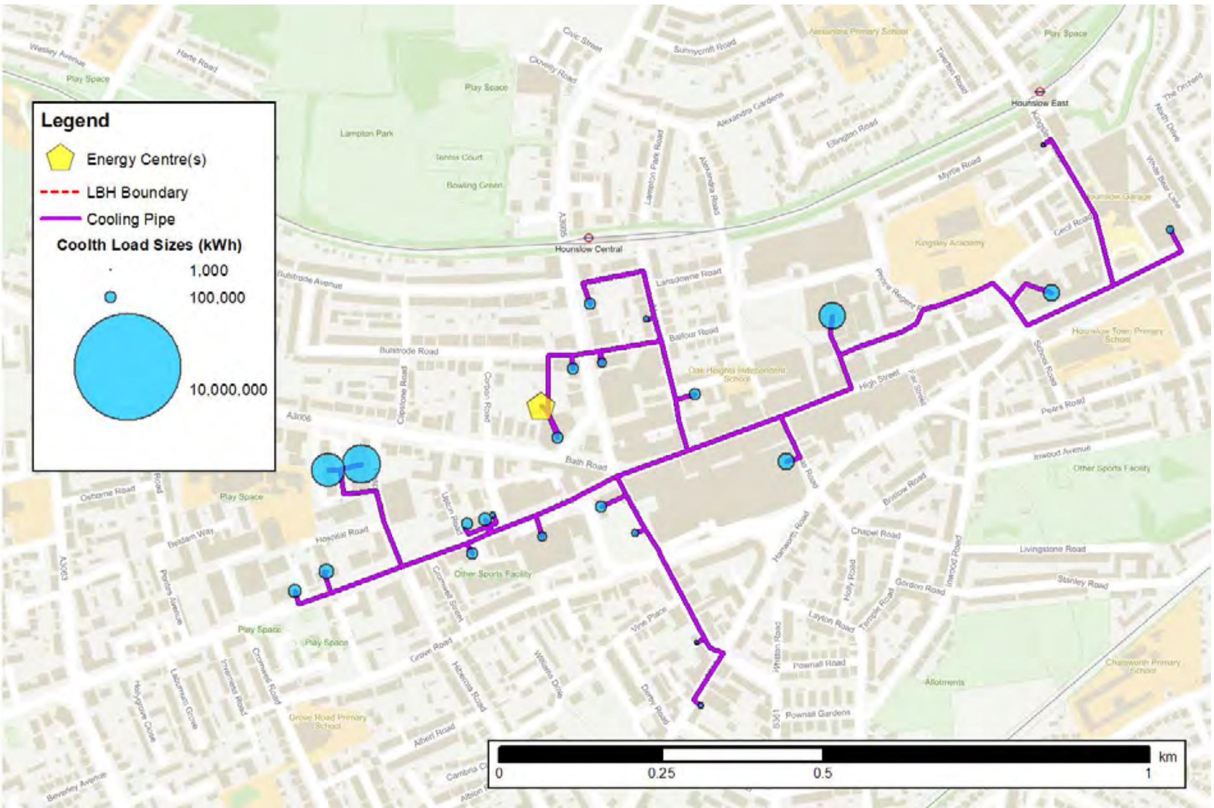


Figure J-3: Hounslow High Street Cooling Network Route.

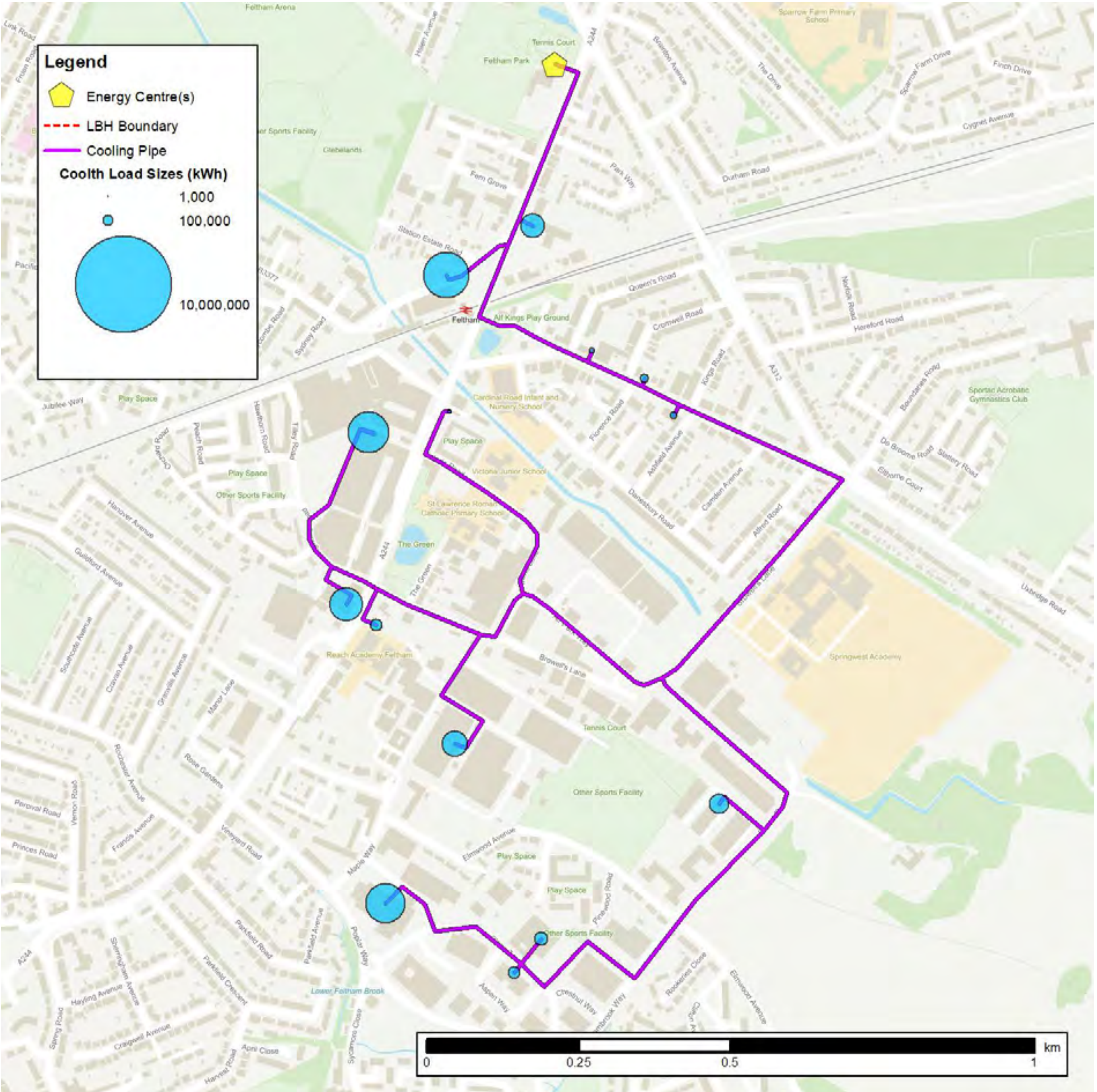


Figure J-4: Feltham Cooling Network Route.

Appendix K Specialist Crossing Strategies

The Borough-wide network route is required to cross railways, major roads, and waterways in a number of locations in order to serve the extent of the borough. This section serves as general guidance for such types of crossings and suggests the factors which should be considered at the next stage of the project's development. Typical options available are as follows:

- **Open-cut trench** – The most commonly-used solution for crossings, reliant on sufficient roadbed depth in existing bridges over the target obstacle. This approach may not be suitable for masonry arch structures. Existing buried utilities should also be considered.
- **Existing services conduit** – Some bridges constructed in the last 50 years may have in-built conduits for existing utilities, presenting an opportunity to significantly reduce construction costs for the DH crossing. Not all instances will have a large enough unoccupied space to accommodate DH flow and return pipework.
- **Pipe fixed to external parapet / edge girder** – This can be an option where there is limited available space within the existing bridge deck for an open-cut trench. DH pipework is bracketed to the side of an existing bridge, mounted on rollers to allow for material expansion. In some cases, flow and return pipes are mounted on opposite sides of the same bridge to spread the total load across the structure.
- **Dedicated pipe bridge** – Where a suitable existing bridge cannot be found, a purpose-built structure can be constructed, typically with a portal-frame design. This approach minimises road disruption but would be subject to more stringent procedures with the local asset operator.
- **Subterranean crossing** – Underground crossings reduce rail/road/canal closures and produces a tunnel asset which can in some cases be leased to other utilities. Two drilling methods are typically used:
    - Thrust-Boring – Pipe is driven hydraulically from a thrust pit on one side, to a reception pit on the other.
    - Horizontal Directional Drilling – A directional drill head is controlled using GPS, allowing existing buried services to be avoided.

These solutions are relevant to each crossing type as follows:

Crossing Type	Railways	Major Roads	Canals and Rivers
Open-cut trench	Yes	Yes	Yes
Existing services conduit	Where available	N/a	Where available
External pipe fixture	Where available	N/a	Where available
Dedicated pipe bridge	Yes	N/a	Yes
Subterranean crossing	Yes	Yes	Yes

Table K-1: Specialist Crossing Options – Relevance by Crossing Type.

At the next stage of design, it is recommended that these options be evaluated on a case-by-case basis for each of the proposed crossing locations, considering factors such as:

- Cost of each solution.
- Bridge deck depth (if applicable).
- Age and integrity of existing structures (if applicable).
- Potential for localised disruption.

K.1 Railways

Rail crossing locations identified within the current Borough-wide network route have been listed in Table K-2.

Crossing	Train Operator	What3words Location
B454 by Syon Lane station	South Western	///scans.faster.helps
A3002 by Brentford Station	South Western	///necks.likes.hiking

Crossing	Train Operator	What3words Location
A315 by Kew Bridge Station	South Western	///alarm.email.novel
A224 by Feltham Station	South Western	///plans.sands.club
Lionel Road South	South Western (no passenger services)	///detail.zeal.flip

Table K-2: Rail Crossing Locations.

K.2 Major Roads

The proposed network route crosses major roads, particularly the M4 Flyover, in a number of locations, as detailed in Table K-3.

Route Location	Major Road	What3words Location
Capital Interchange Way	Beneath M4 (Chiswick Flyover)	///commented.else.fills
Lionel Road N / S	Beneath M4 (Chiswick Flyover)	///last.strike.angel
West London Audi	Beneath M4 (Chiswick Flyover)	///scouts.arts.arrive
Windmill Road	Beneath M4 (Chiswick Flyover)	///usual.wrong.sample
Shield Drive	A4 (Great West Road)	///wage.given.drift
Stanwell Road	A30 (Great South West Road)	///gifted.cowboy.courier

Table K-3: Major Road Crossing Locations.

K.3 Canals and Rivers

Canal and river crossings (via existing road bridges) have been identified at the locations listed in Table K-4.

Route Location	Waterway	What3words Location
Augustus Close	River Brent (Grand Union Canal)	///decay.atomic.locate
A310 (Twickenham Road)	Duke of Northumberland's River	///stale.liability.nation
On site at Mogden	Duke of Northumberland's River	///nature.strike.fired
A315 (Staines Road) – Baber Bridge	River Crane	///inform.surely.goals
A312 (Faggs Road)	Duke of Northumberland's River	///cargo.nodded.wake
New Road	Longford River	///ground.laser.snows
Browells Lane	Longford River (subterranean)	///worked.keeps.teach
Beacon Road	Duke of Northumberland's River; Longford River	///pepper.smiles.aware

Table K-4: Canal and River Crossing Locations.

Appendix L Building Connection Strategies

Please refer to accompanying documents

Appendix L - Building Connection Strategy Syon Estate

Appendix L - Building Connection Strategy WMUH (West Middlesex University Hospital)

Appendix L - Building Connection Strategy Hounslow House

Appendix M Futureproofing of LBH Infrastructure

Heat demand from London Borough of Hounslow (LBH) buildings represents a considerable proportion (over 20%) of the total heat demand of the recommended solution. Revenue from the sale of heat to these buildings therefore has a significant impact on the economic viability of the network and the guarantee of heat sale to these loads would provide confidence to a prospective developer of the heat network[33]. Equally, the heat network provides low carbon heating at a lower cost to the alternatives and potentially is the only technically viable source for many of the existing buildings. It is paramount therefore that the design of the heat network is compatible with existing and/or replacement building level heating systems.

LBH Asset & Investment are managing a number of capital projects which may include upgrades and replacement of existing heating systems. The purpose of this appendix is to provide guidance as to the design considerations that should be made for these projects to ensure, as a minimum, they remain compatible with the heat network and also aspire to optimise the energy performance of both the building level and district heating systems.

Where new or replacement heating systems are designed and installed, LBH should ensure that these comply with the requirements of the Heat Networks Code of Practice for the UK (2020) CP1, which applies to communal heat networks as well as district heat networks.

M.1 Minimum Requirements

1. Heating System Type

The district heating system uses water as a medium for heat transfer (known as a wet or hydronic heating system) is only compatible with other wet heating systems. It is likely that the majority of existing heating systems are wet using Low Temperature Hot Water (LTHW) circulating through pipework heat emitters for space heating and to domestic hot water generation plant. A summary of the most common compatible and non-compatible technologies is detailed in Table M-1. LBH should avoid installation of the non-compatible technologies during new-build or retrofit projects.

Purpose	Compatible with District Heating	Non-Compatible with District Heating
Space Heating	• LTHW radiators • LTHW underfloor heating • Fan coil units with LTHW coil • Air handling units with LTHW coil	• Electric radiators • Electric underfloor heating • DX / VRF[34] fan coil units • Air handling units with DX coil • Exhaust air heat pumps
Domestic Hot Water	• Indirect hot water cylinders • Heat interface units • DHW plate heat exchangers	• Direct gas fired water heaters • Direct electric hot water cylinders • Electric showers • Electric point of use water heaters

Table M-1: Compatible and Non-Compatible Technologies with District Heating

2. Operating Temperature

As detailed in 8.2.1, the district heating network regime has been initially selected to provide 80°C flow in Winter to satisfy the demand for space heating. Heating systems were traditionally design to operate at 82°C flow and 71°C return but commonly had large margins designed in so are capable of operating at lower temperatures. More recent heating systems have typically been designed to operate at lower temperatures. The selected regime is intended to provide a balance between being compatible with existing heating systems, but also providing a challenge to existing building operators to test whether their existing systems can operate at lower

[33] In lieu of the impact of heat zoning mandating buildings to connect.
[34] DX = Direct Expansion, VRF = Variable Refrigerant Flow. Both systems use refrigerant as a transfer medium rather than water

temperatures through recommissioning and scheduling. The winter regime is detailed in Figure M-1 for two common scenarios:

1. A bulk DH supply to a building (typically commercial) at a thermal substation with a secondary network supplying space heating and domestic hot water generation via indirect hot water cylinder.
2. A bulk supply to a building (typically residential block) at a thermal substation with a secondary network providing heating to individual HIUs which subsequently supplying space heating and generate domestic hot water instantaneously at the HIU[35].

LBH should, as a minimum, ensure that heating systems are compatible with the winter regime detailed below, however, should endeavour to improve upon this where possible as detailed in M.2.

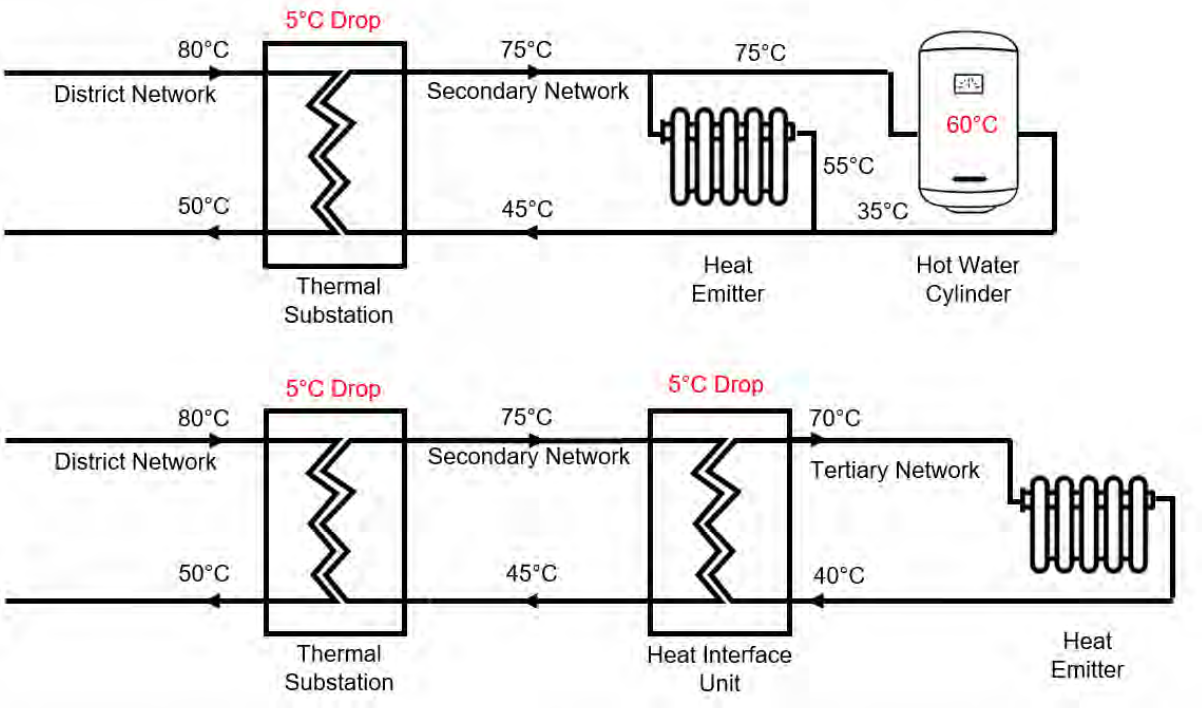


Figure M-1: Winter Temperature Regime to Satisfy Space Heating Demand

M.2 Optimisation

The lower the operating temperature of the district heating network, the greater its efficiency and therefore the lower the energy consumption and carbon emissions. The same also applies to secondary and tertiary networks. Therefore, whilst the initial temperature regime has been selected for the reasons described above, the ambition is to reduce the operating temperature of the network over time. This reduction can only be achieved however if the connected buildings are capable of operating at the reduced temperatures. Therefore, LBH should endeavor to design replacement heating systems at the lowest possible operating temperatures.

The new Building Regulations Part L, which came into force in June 2022, sets the requirements for operating temperatures of both new and replacement heating systems, as detailed in Figure M-2.

[35] The delivery time for providing water at a temperature of at least 45°C to the kitchen tap for each dwelling should be less than 45 seconds.

5.10 Where a wet heating system is either:

a. newly installed

b. fully replaced in an existing building, including the heating appliance, emitters and associated pipework

all parts of the system including pipework and emitters should be sized to allow the space heating system to operate effectively and in a manner that meets the heating needs of the dwelling, at a maximum flow temperature of 55°C or lower.

Where it is not feasible to install a space heating system that can operate at this temperature (e.g. where there is insufficient space for larger radiators, or the existing distribution system is provided with higher temperature heat from a low carbon district heat network), the space heating system should be designed to the lowest design temperature possible that will still meet the heating needs of the dwelling.

Figure M-2: Excerpt from Building Regulations Part L

Of equal importance to the use of the lowest possible flow temperature, is the maximisation of the difference between the flow and return temperatures, known as ΔT. Table 3 of CIBSE CP1 (20), shown in Figure M-3 below, sets the maximum return temperatures for different heating systems. In all cases, the ΔT should be as large as is technically viable.

Circuits	Flow temperature (°C)	Return temperature (°C)
Radiators	Max 70 (see note 1)	Max 40
Fan coil units	Max 60	Max 40
Air handling units	Max 70	Max 40
Underfloor heating	See note 2	See note 2
DHW instantaneous heat exchanger on maximum load (district heating side)	Max 70	Max 25 for 10 °C cold feed temperature
DHW cylinder with coil (district heating side)	Max 70	Max 45 when starting to heat up from cold at 10 °C (see note 3)
DHW calorifier with external plate heat exchanger (district heating side)	Max 70 (see note 4)	Max 25 for 10 °C cold feed temperature

Note 1: Where direct connection is used, the radiators shall be sized in accordance with this table. However, in operation, a higher flow temperature may be used to suit the network design, provided that radiator return temperatures shall be less than 40 °C.

Note 2: Wet screeded underfloor heating systems will typically operate with floor temperatures below 35 °C and typically flow temperatures of 45 °C or less and return temperatures below 35 °C. This is generally advantageous for heat networks as it will result in low return temperatures. Other types of underfloor heating system may require higher flow and return temperatures.

Note 3: The return temperatures will be higher than 45 °C most of the time as heating up from cold will rarely occur.

Note 4: A central hot water calorifier would normally be designed to store water at 60 °C and with a minimum recirculation temperature of 55 °C. Typically a flow temperature of 70 °C would be needed.

Note 5: In all cases, the variation of flow temperature across the primary network needs to be considered, especially for the summer low-flow condition where temperature drops can be significant. The temperatures given in this table are at the consumption point and higher flow temperatures will be needed at the energy centre supply point.

Figure M-3: Table 3 from CIBSE CP1(20)

Whilst space heating demand will influence temperatures during colder weather, the temperatures required to generate domestic hot water (DHW) safely will provide a baseline which must be provided year-round. Different technologies for DHW generation offer the potentially to work at lower temperatures. The most commonly seen are ranked from best to worst in Table M-2. LBH should prioritise the higher-ranking technologies where possible.

Commercial	Domestic
1. Centralised Instantaneous Plate Heat Exchanger	1. Instantaneous Heat Interface Unit
2. Centralised Semi-Instantaneous Plate Heat Exchanger	2. Individual Indirect Hot Water Cylinder
3. Centralised Indirect Hot Water Cylinder	3. Centralised Indirect Hot Water Cylinder

Table M-2: Ranking of Common DHW Generation Technologies

Appendix N Modelling Assumptions

N.1 Counterfactual Cost of Heat

To assess the techno-economic viability of a district energy project, considering the counterfactual heating/cooling solution is crucial. It determines the maximum heating/cooling tariff that can be applied, preventing any customer from paying more for heating than they would otherwise pay, thus preventing customer detriment.

As agreed with LBH and aligned with GHNF requirements, it has been assumed that the counterfactual cases presented in the

table below will be used to derive the tariffs that off-takers can pay without financial detriment.

Network Relevance	Counterfactual Technology	Applicable Customers	Notes
District Heating	Gas Boilers	Existing residential customers and micro-businesses[36].	For the purposes of GHNF, existing domestic customers and micro-businesses are considered "at risk" and must not be offered a price of heat greater than a gas counterfactual[37].
District Heating	ASHPs	All other customers including existing and future private and public sector buildings.	Regarding public buildings, it is assumed that each building would need to transition to a low carbon heat source, even if the District Heating Network (DHN) project does not proceed, in order to meet net zero ambitions. The current business-as-usual (BAU) solution of gas boilers in some buildings may not be suitable, as it does not align with the council's decarbonisation plans or those of other public sector bodies. Additionally, it is assumed that all future developments will require a low carbon heating solution to comply with Building Regulations Part L and comply with the Future Buildings Standard (currently anticipated to come into effect from 2025).
District Cooling	Air-cooled chillers	All customers with a cooling load.	This is the most common cooling generation technology for large commercial buildings and so is considered to be most representative of the loads which are identified as potential connections.

Table N-1: Counterfactual Technologies Considered in the Techno-economic Model.

To calculate the heat tariff for each customer, a counterfactual cost of heat was first calculated for each site (on the basis outlined above), giving a pence per kilowatt-hour value every year during the lifetime of the project. This value accounts for the replacement and maintenance of the counterfactual heating plant and fuel costs.

The heat tariffs are dependent on the peak demand for each customer and the size of the counterfactual plant, with larger demands and plant sizes resulting in smaller per-unit tariffs. Heat tariffs based on gas counterfactuals are lower than those based on heat pump counterfactuals. Whilst heat pumps are more efficient than gas boilers, the higher cost of electricity and the higher plant costs result in an overall higher heat cost.

[36] Guidance for Microbusinesses | Ofgem
[37] Green Heat Network Fund: guidance for applicants, Round 6 (publishing.service.gov.uk)

N.2 Connection Charges

In addition to the heat tariffs, a one-off payment is anticipated to be paid by all customers to help cover the cost of connection to the network - as connection charges typically cover the cost of constructing the connection to each building / site. This fee is based upon the cost savings to be made as a result of the development of a DHN. In each case this corresponds to the initial CapEx cost of the counterfactual heating system and does not account for the additional benefit of potentially abated grid reinforcement costs. These have been calculated at a rate of [redacted] of peak demand for heating and at a rate derived from counterfactual system costs (i.e., air-cooled chillers) for cooling.

The connection charge for heating has been selected to correspond to typical market rates from other low carbon heat networks, but must also offer value against the counterfactual system. The final value will be subject to agreement between the network operator and the customers through a process of negotiation. The total heating connection charge [redacted] for all customers equates to approximately [redacted] of the estimated total cost of the counterfactual [redacted], so there is potential for the average rate to be increased whilst still offering value, subject to the network developers pricing strategy.

Table N-2 shows a breakdown of the assumed charged per building.

Building	Heating Network Connection Charge	Cooling Network Connection charge
1 Lampton Road	[redacted]	
12-32 Lampton Road (Lampton Rise)		
206-210 Hanworth Road (existing) - Treaty Lodge Hotel		
34 Staines Road Hounslow (new) Development		
714-746 London Road (Charter Place, Ostler's Court)		
80-82 Staines Road (existing) - Xercise4Less Gym		
Blenheim Centre Hounslow		
Central House Serviced Apartments		
Euro House (existing)		
Falcon House		
Frogley House		
Golds Gym (within Continental Hotel)		
Greenham House		
Grove Road Primary School		
Heart of Hounslow Health Centre		
High Street Quarter Development		
Holdsworth House		
Hounslow Central Hotel		
Hounslow House		
Hounslow Library		
Hounslow Police Station		
Hounslow Town Primary		
Hyde House Estate		
Ibis Hotel		
Inwood Business Park (new) Development		
Kingsley Academy		
Kingsley Road Youth Centre (existing)		
Land at Bell Road Development		
Land at Hanworth Road Development		
Land at James Street Development		

LBH Council: Vehicle maintenance Bridge Road	[redacted]
Montague Hall	
Phoenix House	
Quest House	
Ramada by Wyndham Hotel	
Royal Mail Delivery Office (existing)	
Sceptre House	
Spring Grove Primary School	
St Marks School (6no. DECs)	
Star Road Estate	
The Continental Hotel	
The Everglades	
The Star Centre	
The Treaty Centre	
Travelodge	
Triangle Day Centre	
Trinity Square	
Wellington Primary School	
Beavers Community Primary School: New Sports Complex	
Benham Gardens Estate	
Boswood Court	
Cooper House, Maitland Close	
Eaton House	
George Chatt House	
Heath Court	
Heathrow Corporate Park	
Heathrow International Trading Estate (new) Development	
Hounslow Cavalry Barracks	
Hounslow Education Centre	
Hounslow Heath Infant and Nursery School	
Hounslow Heath Junior School	
Land at Former Travis Perkins Site 379-389 Staines Road Development	
Lascar Works Site, Staines Road Development	
Maitland Close Estate	
Midsummer Avenue Estate	
Old Farm Close Estate	
Orchard Primary School	
St. Michael & St Martin Primary School	
Sycamore Court	
Tesco Dukes Green Avenue (new) Development	
The Heathland School	
The Hub Community Centre	
The Meadows Centre for Health	
The Vista Centre	
Tivoli Road Estate	

Wellington Day Centre	[redacted]
2A Kinex, Plane Tree Crescent	[redacted]
61 Fern Grove (new) Development	[redacted]
80-86 High Street Feltham (existing) - Aldi	[redacted]
Anytime Fitness Feltham	[redacted]
Bedfont Children's Centre	[redacted]
Browells Lane (existing)	[redacted]
Cardinal Road Infant & Nursery School	[redacted]
Council Depot, Ashmead Road (existing)	[redacted]
CRC Bedfront Office	[redacted]
Edward Pauling House	[redacted]
Edward Pauling School	[redacted]
Fairholme School	[redacted]
Feltham Centre for Health	[redacted]
Feltham Constitutional Club	[redacted]
Feltham Hill Infant & Nursery School	[redacted]
Feltham Library/The Centre	[redacted]
Feltham Magistrates Court	[redacted]
Feltham North Children's Centre aka Alf King Centre	[redacted]
Feltham Police Station	[redacted]
Hanover House, Plane Tree Crescent	[redacted]
Hanworth Air Park Leisure Centre & Library	[redacted]
Hanworth Youth Centre	[redacted]
Highfields & Homecourt Estate	[redacted]
HMP/YOI Feltham	[redacted]
Land Adjacent To Tesco Manor Lane Development	[redacted]
Land at Feltham Magistrates Court Development	[redacted]
Land at New Road Triangle Development	[redacted]
Lavender Court Estate	[redacted]
Leisure West (existing)	[redacted]
Lidl Feltham (existing)	[redacted]
Lindon Bennett Specialist Nursery	[redacted]
Longford Community School / Rivers Academy West	[redacted]
Manor Park (existing)	[redacted]
MOD Feltham (existing)	[redacted]
Network House Feltham (new) Development	[redacted]
New Chapel Square Estate	[redacted]
Oak Hill Academy West London	[redacted]
Oriel Academy West London	[redacted]
Oriel Estate (blocks)	[redacted]
Owen House	[redacted]
Pinewood Road Estate	[redacted]
Reach Academy	[redacted]
Rose Gardens & Manor Lane Estate	[redacted]
Russell Finnex	[redacted]
Sandalwood Road Estate	[redacted]

Sandbanks Resource Centre	[redacted]
Shore Close Estate	[redacted]
Smith House, Elmwood Avenue (new) Development	[redacted]
South Ville Community Centre	[redacted]
Southville Infants & Junior School	[redacted]
Sparrow Farm Infants & Primary School	[redacted]
Spring West Academy	[redacted]
St. Giles Hotel	[redacted]
St. Lawrence R C School	[redacted]
Tesco Feltham - 98 High Street (existing)	[redacted]
The Hollands Estate	[redacted]
The Longford Centre: "The Centre"	[redacted]
UPS House (existing)	[redacted]
Vector Park	[redacted]
Victoria Junior School	[redacted]
Waterloo Estate	[redacted]
Watermead Estate	[redacted]
West London Family Court	[redacted]
West Thames College: Skills + Logistics Centre	[redacted]
1020 Great West Road (existing) - Toyota	[redacted]
125 Harlequin Avenue (existing) - Classic Cars	[redacted]
2 Harlequin Avenue (existing)	[redacted]
40 and 40A High Street (Albany Riverside) Development	[redacted]
971 Great West Road (existing) - DFS	[redacted]
Aparthotel Adagio London Brentford	[redacted]
B&Q Chiswick (new) Development	[redacted]
Bolder Academy	[redacted]
Brent Lea and Danehurst (communal)	[redacted]
Brentford County Court	[redacted]
Brentford Day Nursery (Half Acre)	[redacted]
Brentford Docks Estate	[redacted]
Brentford FC Community Stadium	[redacted]
Brentford FC Community Stadium Residential Development	[redacted]
Brentford Fountains Leisure Centre (new) Development	[redacted]
Brentford Group Practice (existing)	[redacted]
Brentford Library	[redacted]
Brentford Lock West Commerce Road Development	[redacted]
Brentford Project Development	[redacted]
Brentford School for Girls	[redacted]
Brentside Park (new) Development	[redacted]
EMC Tower (existing)	[redacted]
Fenn House Lodge	[redacted]
Former Alfa Laval Site (other business)	[redacted]
Former Alfa Laval Site (resi & micro business)	[redacted]
Former Brentford Police Station Development	[redacted]

Former Citroen Site Capital Interchange Way Development	[redacted]
Gillette Building Studios (existing)	[redacted]
Goddards, The Ham Development	[redacted]
Great West house	[redacted]
Green Dragon Lane Estate - Brentford Towers and Harnage House (communal)	[redacted]
Green dragon Primary School	[redacted]
Griffin Court	[redacted]
Griffin Park Stadium Redevelopment	[redacted]
GSK 980 Great West Road	[redacted]
Gunnersbury Catholic School for Boys	[redacted]
Holiday Inn Brentford Lock	[redacted]
Holly House Estate	[redacted]
Homebase Syon Lane (new) Development	[redacted]
Kew Bridge Road and Thameside Centre	[redacted]
Kia 963 Great West Road	[redacted]
Lambert Lodge	[redacted]
Layton road Warehouses (new) Development	[redacted]
London Museum of Water & Steam	[redacted]
Marlborough School	[redacted]
Mille Building (existing)	[redacted]
Morrison's 228-246 High Street (new) Development	[redacted]
Novotel London Brentford	[redacted]
Our Lady & St. John Rc J	[redacted]
Parkview Development	[redacted]
Pets at Home Brentford	[redacted]
Premier Inn Brentford	[redacted]
Premier Inn Kew Bridge	[redacted]
Q West	[redacted]
Sky Campus (existing)	[redacted]
Sky Campus (new) Development	[redacted]
St. Pauls CE Primary School	[redacted]
Syon Clinic	[redacted]
Tesco Syon Lane Development	[redacted]
The Musical Museum	[redacted]
Travelodge London Kew Bridge	[redacted]
Trimmer Walk Depot	[redacted]
University of West London Brentford Campus	[redacted]
Vantage West	[redacted]
Volkswagen, Capital Interchange Way	[redacted]
Wallis House	[redacted]
West Cross Industrial Park (existing)	[redacted]
West London Audi	[redacted]
30 Rugby Road (new) Development	[redacted]
Argyle Health Isleworth Practice	[redacted]
Europa House (new) Development	[redacted]

Green School for boys	[redacted]
Green School for girls	[redacted]
Gumley House Convent School	[redacted]
Heston Fire Station	[redacted]
Isleworth & Syon School	[redacted]
Isleworth Ambulance Station	[redacted]
Isleworth Crown Court	[redacted]
Isleworth Leisure Centre & Library	[redacted]
Isleworth Public Hall	[redacted]
Isleworth Town Primary School	[redacted]
Ivy Bridge Retail Park	[redacted]
Ivybridge Estate (communal)	[redacted]
Ivybridge Primary School	[redacted]
Kirstone Lodge	[redacted]
Langdale Amenity Community Centre	[redacted]
Marlborough Primary School	[redacted]
Queen Mary Maternity Unit	[redacted]
Redlees Children's Centre	[redacted]
Saracen House	[redacted]
Smallberry Green School	[redacted]
South Isleworth Children's Centre	[redacted]
St. Johns Centre	[redacted]
Tesco Isleworth (existing)	[redacted]
The Blue CE Primary School	[redacted]
Twickenham Stadium	[redacted]
Victory Business Centre (new) Development	[redacted]
West London Mental Health NHS Trust: MHU	[redacted]
West London Mental Health NHS Trust: O Block	[redacted]
West London Mental Health NHS Trust: T Block	[redacted]
West Middlesex University Hospital: East Wing	[redacted]
West Middlesex University Hospital: Main Block	[redacted]
West Middlesex University Hospital: Marjory warren building	[redacted]
West Thames College: Atrium & Millennium Building	[redacted]
West Thames College: Sir Joseph Banks Building	[redacted]
West Thames College: Spring Grove House	[redacted]
Worple Primary School	[redacted]
Wynne Court	[redacted]
Grasshopper RFC	[redacted]
Hounslow Sports Club	[redacted]
Redlees Centre (YOS)	[redacted]
Heathrow Airport	[redacted]
Hatchett Road	[redacted]
The Pines	[redacted]
The Old Vicarage	[redacted]
Syon House Estate	[redacted]
1-4 Capital Interchange Way	[redacted]

Land at Glebelands Road	[redacted]
Feltham Corporate Centre (new)	[redacted]
St Catherine's House (existing)	[redacted]
Cromwell Estate	[redacted]
Clements Court Estate	[redacted]
Percy Gardens Estate	[redacted]
Hilton Syon Park	[redacted]
Snakes and Ladders Brentford	[redacted]
Buttercups Day Nursery	[redacted]

Table N-2: Connection Charges

It is assumed that infrastructure costs of the network are shared with the developers. The network has currently been costed to reach the building's modelled, however costs beyond that point have assumed to be with the developer (for example, within a block of flats).

N.3 Modelling Timing and Demand Assumptions

The model assumes that network operation will begin in 2028 with connection to the first phase of buildings. There will then be numerous subsequent phases as shown in the figure below.

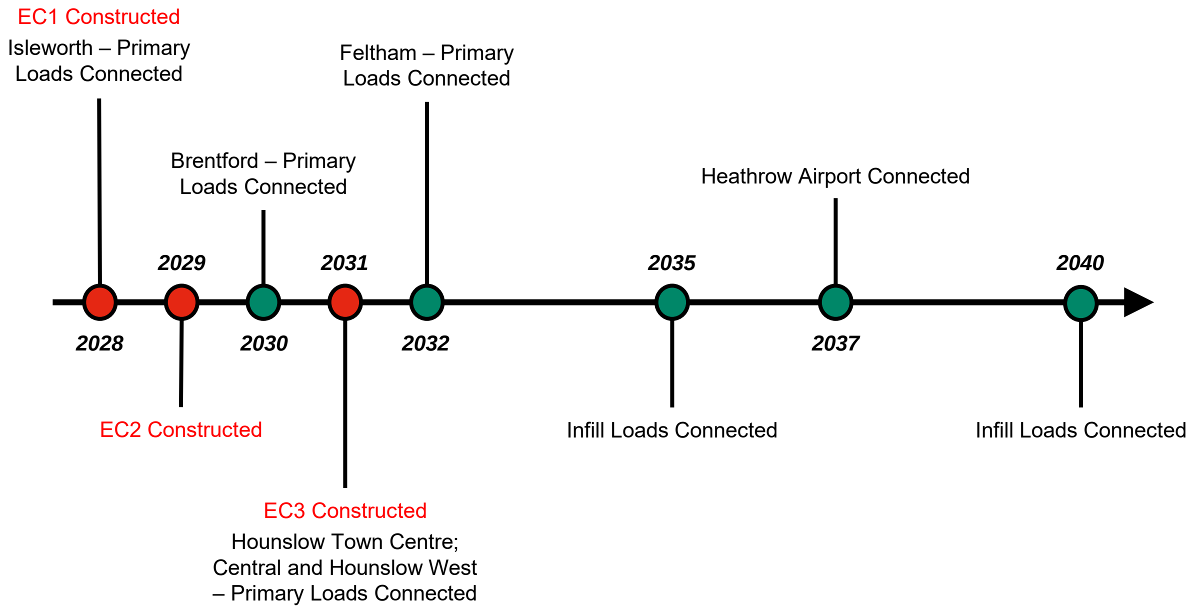


Figure N-1: Proposed Borough-wide Network Phasing (including Heathrow)

AECOM and the project team have engaged with potential off-takers within the study area to determine their energy demands during WP1 and WP2. Where engagement has been unsuccessful or data is unavailable (e.g. future developments), demands have been calculated based on other sources, such as energy benchmarks. The table below shows the annual energy demands identified. All buildings below have been included in the techno-economic modelling.

Building	Heating Consumption (kWh)	Cooling Demand (kWh)	Connection Year
1 Lampton Road	721,862	-	2040
12-32 Lampton Road (Lampton Rise)	449,685	-	2040
206-210 Hanworth Road (existing) - Treaty Lodge Hotel	164,450	37,835	2031
34 Staines Road Hounslow (new) Development	774,416	75,516	2035
714-746 London Road (Charter Place, Ostler's Court)	1,375,819	54,754	2031

80-82 Staines Road (existing) - Xercise4Less Gym	502,500	108,000	2031
Blenheim Centre Hounslow	2,328,000	-	2031
Central House Serviced Apartments	1,200,000	-	2031
Euro House (existing)	308,629	233,665	2031
Falcon House	228,208	172,778	2031
Frogley House	264,078	-	2031
Golds Gym (within Continental Hotel)	32,806	2,765	2031
Greenham House	319,655	-	2031
Grove Road Primary School	195,626	-	2031
Heart of Hounslow Health Centre	1,275,372	1,339,900	2031
High Street Quarter Development	4,436,214	612,966	2040
Holdsworth House	207,746	157,286	2031
Hounslow Central Hotel	135,135	31,090	2031
Hounslow House	644,179	671,371	2040
Hounslow Library	231,115	117,461	2031
Hounslow Police Station	329,472	123,552	2031
Hounslow Town Primary	382,352	-	2031
Hyde House Estate	575,894	-	2031
Ibis Hotel	500,500	115,150	2031
Inwood Business Park (new) Development	540,504	-	2035
Kingsley Academy	922,925	-	2031
Kingsley Road Youth Centre (existing)	56,603	22,853	2031
Land at Bell Road Development	718,462	67,697	2040
Land at Hanworth Road Development	532,521	-	2035
Land at James Street Development	414,183	-	2035
LBH Council: Vehicle maintenance Bridge Road	481,265	-	2031
Montague Hall	52,483	39,735	2031
Phoenix House	939,800	1,008,697	2031
Quest House	231,801	175,498	2031
Ramada by Wyndham Hotel	471,900	108,570	2031
Royal Mail Delivery Office (existing)	330,912	-	2031
Sceptre House	137,378	104,010	2031
Spring Grove Primary School	108,356	-	2031
St Marks School (6no. DECs)	698,322	-	2031
Star Road Estate	911,048	-	2031
The Continental Hotel	429,000	98,700	2031
The Everglades	213,366	-	2031
The Star Centre	35,127	26,830	2031
The Treaty Centre	776,000	243,600	2031
Travelodge	572,000	131,600	2031
Triangle Day Centre	39,456	-	2031
Trinity Square	1,200,000	-	2031
Wellington Primary School	227,095	-	2031
Beavers Community Primary School: New Sports Complex	175,648	-	2031
Benham Gardens Estate	197,745	-	2031
Boswood Court	578,209	-	2031

Cooper House, Maitland Close	1,014,175	-	2031
Eaton House	351,000	-	2031
George Chatt House	990,639	-	2031
Heath Court	461,098	-	2031
Heathrow Corporate Park	5,566,752	-	2031
Heathrow International Trading Estate (new) Development	1,728,000	-	2035
Hounslow Cavalry Barracks	4,500,000	-	2031
Hounslow Education Centre	159,442	-	2031
Hounslow Heath Infant and Nursery School	173,568	-	2031
Hounslow Heath Junior School	201,559	-	2031
Land at Former Travis Perkins Site 379-389 Staines Road Development	220,824	-	2035
Lascar Works Site, Staines Road Development	278,094	-	2040
Maitland Close Estate	285,000	-	2031
Midsummer Avenue Estate	1,916,640	-	2031
Old Farm Close Estate	327,072	-	2031
Orchard Primary School	230,904	-	2031
St. Michael & St Martin Primary School	229,960	-	2031
Sycamore Court	533,496	-	2031
Tesco Dukes Green Avenue (new) Development	2,041,988	-	2035
The Heathland School	2,092,901	-	2031
The Hub Community Centre	28,800	-	2031
The Meadows Centre for Health	250,860	-	2031
The Vista Centre	1,215,627	-	2031
Tivoli Road Estate	1,973,951	-	2031
Wellington Day Centre	28,706	-	2031
2A Kinex, Plane Tree Crescent	234,300	177,390	2032
61 Fern Grove (new) Development	355,014	-	2040
80-86 High Street Feltham (existing) - Aldi	391,500	1,200,000	2032
Anytime Fitness Feltham	99,294	21,341	2032
Bedfont Children's Centre	19,553	-	2032
Browells Lane (existing)	288,000	-	2032
Cardinal Road Infant & Nursery School	306,035	-	2032
Council Depot, Ashmead Road (existing)	208,507	-	2032
CRC Bedfront Office	11,636	-	2032
Edward Pauling House	806,076	-	2032
Edward Pauling School	282,578	-	2032
Fairholme School	701,115	-	2032
Feltham Centre for Health	234,490	350,741	2032
Feltham Constitutional Club	182,542	73,699	2032
Feltham Hill Infant & Nursery School	294,464	-	2032
Feltham Library/The Centre	17,248	82,077	2032
Feltham Magistrates Court	146,317	40,133	2032
Feltham North Children's Centre aka Alf King Centre	53,043	-	2032
Feltham Police Station	165,344	54,734	2032
Hanover House, Plane Tree Crescent	195,250	147,825	2032

Hanworth Air Park Leisure Centre & Library	1,926,476	-	2032
Hanworth Youth Centre	111,506	-	2032
Highfields & Homecourt Estate	2,320,433	-	2032
HMP/YOI Feltham	13,452,696	-	2032
Land Adjacent To Tesco Manor Lane Development	615,358	-	2040
Land at Feltham Magistrates Court Development	165,673	-	2035
Land at New Road Triangle Development	650,859	-	2035
Lavender Court Estate	507,748	-	2032
Leisure West (existing)	2,607,360	-	2032
Lidl Feltham (existing)	716,184	2,195,200	2032
Lindon Bennett Specialist Nursery	637,263	-	2032
Longford Community School / Rivers Academy West	1,472,400	-	2032
Manor Park (existing)	388,000	-	2032
MOD Feltham (existing)	1,972,000	734,400	2032
Network House Feltham (new) Development	1,183,381	-	2035
New Chapel Square Estate	1,809,014	-	2032
Oak Hill Academy West London	300,688	-	2032
Oriel Academy West London	416,542	-	2032
Oriel Estate (blocks)	5,065,691	-	2032
Owen House	390,490	-	2032
Pinewood Road Estate	503,792	-	2032
Reach Academy	136,504	138,292	2032
Rose Gardens & Manor Lane Estate	22,660	-	2032
Russell Finnex	624,000	-	2032
Sandalwood Road Estate	457,630	-	2032
Sandbanks Resource Centre	774,397	-	2032
Shore Close Estate	660,000	-	2032
Smith House, Elmwood Avenue (new) Development	1,183,381	-	2040
South Ville Community Centre	53,714	-	2032
Southville Infants & Junior School	348,696	-	2032
Sparrow Farm Infants & Primary School	390,449	-	2032
Spring West Academy	1,171,083	-	2032
St. Giles Hotel	2,860,000	658,000	2032
St. Lawrence R C School	269,270	-	2032
Tesco Feltham - 98 High Street (existing)	4,332,600	-	2032
The Hollands Estate	1,316,012	-	2032
The Longford Centre: "The Centre"	6,308,674	1,853,416	2032
UPS House (existing)	215,040	-	2032
Vector Park	729,600	399,000	2032
Victoria Junior School	170,466	-	2032
Waterloo Estate	3,515,708	-	2032
Watermead Estate	1,916,022	-	2032
West London Family Court	193,752	-	2032
West Thames College: Skills + Logistics Centre	280,458	-	2032
1020 Great West Road (existing) - Toyota	57,600	-	2030
125 Harlequin Avenue (existing) - Classic Cars	96,000	-	2030

2 Harlequin Avenue (existing)	67,200	-	2030
40 and 40A High Street (Albany Riverside) Development	911,386	-	2040
971 Great West Road (existing) - DFS	543,200	-	2030
Aparthotel Adagio London Brentford	2,402,400	552,720	2030
B&Q Chiswick (new) Development	10,932,221	-	2035
Bolder Academy	190,880	185,343	2030
Brent Lea and Danehurst (communal)	4,061,191	-	2030
Brentford County Court	137,045	53,050	2030
Brentford Day Nursery (Half Acre)	103,000	-	2030
Brentford Docks Estate	5,100,000	-	2030
Brentford FC Community Stadium	870,400	-	2030
Brentford FC Community Stadium Residential Development	4,368,722	-	2040
Brentford Fountains Leisure Centre (new) Development	1,884,449	-	2035
Brentford Group Practice (existing)	302,660	-	2030
Brentford Library	115,954	-	2030
Brentford Lock West Commerce Road Development	1,456,753	-	2040
Brentford Project Development	8,059,549	1,198,200	2040
Brentford School for Girls	2,444,000	-	2030
Brentside Park (new) Development	2,706,324	-	2035
EMC Tower (existing)	781,000	-	2030
Fenn House Lodge	323,302	-	2030
Former Alfa Laval Site (other business)	365,274	375,251	2030
Former Alfa Laval Site (resi & micro business)	960,685	13,885	2030
Former Brentford Police Station Development	969,025	119,923	2035
Former Citroen Site Capital Interchange Way Development	2,086,950	-	2040
Gillette Building Studios (existing)	2,250,000	5,985,000	2030
Goddards, The Ham Development	364,800	-	2040
Great West house	1,124,640	-	2030
Green Dragon Lane Estate - Brentford Towers and Harnage House (communal)	8,167,645	-	2030
Green dragon Primary School	-	-	2030
Griffin Court	262,512	-	2030
Griffin Park Stadium Redevelopment	443,768	-	2040
GSK 980 Great West Road	7,263,300	5,499,090	2030
Gunnersbury Catholic School for Boys	1,736,627	-	2030
Holiday Inn Brentford Lock	700,700	-	2030
Holly House Estate	404,400	-	2030
Homebase Syon Lane (new) Development	4,198,960	-	2040
Kew Bridge Road and Thameside Centre	3,280,200	2,483,460	2030
Kia 963 Great West Road	576,000	-	2030
Lambert Lodge	610,361	-	2030
Layton road Warehouses (new) Development	236,676	-	2035
London Museum of Water & Steam	34,352	8,208	2030
Marlborough School	388,713	-	2030
Mille Building (existing)	710,710	538,083	2030

Morrison's 228-246 High Street (new) Development	1,790,807	253,527	2040
Novotel London Brentford	1,001,000	230,300	2030
Our Lady & St. John Rc J	244,830	-	2030
Parkview Development	1,727,736	-	2030
Pets at Home Brentford	313,200	-	2030
Premier Inn Brentford	572,000	131,600	2030
Premier Inn Kew Bridge	806,520	185,556	2030
Q West	393,761	298,119	2030
Sky Campus (existing)	5,467,000	4,139,100	2030
Sky Campus (new) Development	4,061,200	-	2035
St. Pauls CE Primary School	248,009	-	2030
Syon Clinic	148,000	-	2030
Tesco Syon Lane Development	8,236,638	243,600	2040
The Musical Museum	249,685	59,659	2030
Travelodge London Kew Bridge	573,859	132,028	2030
Trimmer Walk Depot	35,388	118,260	2030
University of West London Brentford Campus	3,408,000	3,251,232	2035
Vantage West	848,920	-	2030
Volkswagen, Capital Interchange Way	1,544,000	-	2030
Wallis House	1,727,670	-	2030
West Cross Industrial Park (existing)	2,880,000	-	2030
West London Audi	768,000	-	2030
30 Rugby Road (new) Development	1,522,946	-	2035
Argyle Health Isleworth Practice	59,200	-	2028
Europa House (new) Development	118,338	-	2035
Green School for boys	153,048	-	2030
Green School for girls	745,912	-	2030
Gumley House Convent School	644,879	-	2028
Heston Fire Station	293,615	-	2031
Isleworth & Syon School	785,627	-	2031
Isleworth Ambulance Station	280,000	-	2028
Isleworth Crown Court	1,501,794	-	2031
Isleworth Leisure Centre & Library	1,156,892	-	2028
Isleworth Public Hall	71,823	-	2028
Isleworth Town Primary School	358,275	-	2028
Ivy Bridge Retail Park	970,000	-	2028
Ivybridge Estate (communal)	3,117,108	-	2028
Ivybridge Primary School	178,338	-	2028
Kirstone Lodge	694,954	-	2028
Langdale Amenity Community Centre	55,760	-	2028
Marlborough Primary School	329,306	-	2030
Queen Mary Maternity Unit	1,607,144	-	2028
Redlees Children's Centre	12,421	-	2028
Saracen House	624,800	-	2028
Smallberry Green School	296,801	-	2030
South Isleworth Children's Centre	69	-	2028

St. Johns Centre	70,164	-	2028
Tesco Isleworth (existing)	1,827,000	-	2028
The Blue CE Primary School	262,461	-	2028
Twickenham Stadium	2,176,000	-	2028
Victory Business Centre (new) Development	670,080	-	2035
West London Mental Health NHS Trust: MHU	282,917	-	2028
West London Mental Health NHS Trust: O Block	104,554	-	2028
West London Mental Health NHS Trust: T Block	119,953	-	2028
West Middlesex University Hospital: East Wing	4,304,308	-	2028
West Middlesex University Hospital: Main Block	8,416,454	-	2028
West Middlesex University Hospital: Marjory warren building	1,032,072	-	2028
West Thames College: Atrium & Millennium Building	565,753	-	2031
West Thames College: Sir Joseph Banks Building	276,131	-	2031
West Thames College: Spring Grove House	86,980	-	2031
Worple Primary School	169,112	-	2028
Wynne Court	528,361	-	2028
Grasshopper RFC	393,583	-	2030
Hounslow Sports Club	63,005	-	2031
Redlees Centre (YOS)	33,394	-	2028
Heathrow Airport	165,000,000	-	2037
Hatchett Road	313,362	-	2032
The Pines	63,957	-	2030
The Old Vicarage	50,961	-	2030
Syon House Estate	1,145,241	-	2030
1-4 Capital Interchange Way	2,340,073	-	2040
Land at Glebelands Road	414,183	-	2035
Feltham Corporate Centre (new)	2,151,655	1,629,031	2040
St Catherine's House (existing)	242,550	-	2032
Cromwell Estate	3,630,900	-	2031
Clements Court Estate	1,245,000	-	2031
Percy Gardens Estate	314,900	-	2028
Hilton Syon Park	715,000	-	2030
Snakes and Ladders Brentford	203,300	-	2030
Buttercups Day Nursery	76,095	-	2030

Table N-3: Annual Energy Demand Connection Dates

N.4 Heat Pump Capacities & Performance Parameters

The temperatures used to model the heat sources are shown in Table N-4.

Using modelled data provided by Thames Water (the facility's operator), an estimated 1.6 TWh of extractable heat was found to be available, upgradable to over 2 TWh using heat pumps. Hourly heat available from Mogden has been derived from high-resolution flow and temperature data for Mogden. A temperature difference of 7°C has been assumed as advise by Thames Water.

Additionally, biogas combustion excess heat has been calculated from Mogden's assumed process heating requirements, with an assumption of 5MWth biogas boiler capacity installed.

Average Temperature (°C)	Mogden STW Measured Temperature (°C)
January	14.2
February	14.4
March	15.4
April	16.8
May	18.6
June	20.3
July	21.6
August	21.5
September	20.1
October	18.0
November	15.9
December	14.4
Average	**17.6**

Table N-4: Monthly Average Sewer Temperatures Used in Technoeconomic Modelling.

Using the measured temperature data from Mogden Sewage Treatment Works (STW) and considering the required design parameters, the Seasonal Coefficient of Performance (SCOP) for the SSHP is calculated to be 3.4.

N.5 Network Temperatures

In continuity with the Heat Mapping stage, weather-compensated network temperatures have been modelled, which improve heat pump performance throughout the year, whilst ensuring compatibility with all customers' existing heating systems. These are as follows:

Heating / Cooling Network	Operation Type	Flow Temperature	Return Temperature
Heating Network	Normal operation	70°C	40°C
Heating Network	Coldest ambient conditions	80°C	50°C
Cooling Network	All operation	6°C	12°C

Table N-5: Proposed District Heating and Cooling Network Design Temperatures.

N.6 Network Heat Losses

Primary Losses

The calculation of primary heat losses has been conducted using Logstor pipework model, assuming pre-insulated steel pipes. Insulation thickness calculations are based on Series 2 (Equal Pair – Trad type) pipes within Logstor. The network's primary heat losses are determined to be [redacted] and [redacted] for the Borough-wide Incl Heathrow and Borough-wide options, respectively.

Secondary Losses

For residential buildings, when applicable, secondary losses are assumed to be 876 kWh per dwelling per year, in accordance with CP1 guidelines. In cases where the number of dwellings for the developments is not available, an estimated figure of [redacted] of the total annual heat consumption is utilised.

Additionally, the HIUs standby heat losses are assumed to be [redacted] per day at this stage. Further work on this KPI will be undertaken as part of the technical work at the DPD stage.

N.7 Modelling CAPEX Assumptions

Values are derived from AECOM experience and suitable industry standards, 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. In line with a RIBA Stage 2 design, costs are accurate to ±30%. These assumptions include an allowance for inflation that may affect the initial construction spend[38]. The impact of inflation and its effect should continue to be monitored as the project progresses. A breakdown of the capital costs is provided in Appendix O.

The total cost for electrical connections at the three proposed energy centre locations (*Ancillary Plant & Utilities > Utility Connections*) has been estimated at [redacted] derived from AECOM previous project values.

It should be noted that the final cost of electrical grid connection(s) will only be determined following completion of feasibility studies by the DNO, after which formal applications can be made (discussed in Appendix G). The cost of connection modelled has been compared in Table N-6 against a recent figure provided to OPDC (Old Oak and Park Royal Development Corporation) by SSEN, for a ramped connection in a similarly constrained region of west London. This offer includes costs attributed to grid reinforcement – this requirement is yet to be determined for Hounslow; hence this cost rate has not been adopted in modelling.

Scheme	Connection Cost Rate	Source	Note
OPDC	[redacted]	Connection Offer from SSEN	Ramped connection
Hounslow Feasibility	[redacted]	AECOM Past Projects	Three separate ramped connections required.

Table N-6: Cost Rate Comparison of Ramped Electrical Connection.

The following assumptions have been made on the required replacement cycles of plant and equipment on the basis that a like-for-like replacement will be sought throughout the network lifespan. Plant replacement at the end of the lifespan is assumed to be accounted for as additional CAPEX cost items when required. All other plant and equipment are assumed to last beyond the project lifetime or is funded by ongoing maintenance costs.

Technology / Asset	Replacement Cycle	Source
EC boilers, incl. ancillary equipment	Every 20 years	CIBSE Guide M
Sewer source heat pumps	Every 20 years	Manufacturer's data
Ground source heat pumps	Every 15 years	Manufacturer's data
Communal Thermal Sub Stations	Every 15 years	Manufacturer's data
Heat distribution pipework and civils works	Every 50 years	Manufacturer's data

Table N-7: REPEX Assumptions

Repair and Replacement Strategy

During the design stage of the study, a comprehensive repair and replacement strategy will be developed. Following this, detailed method statements will be prepared by the relevant contractor(s), suppliers, and/or appointed plant movement specialists, tailored to the specific nature of the activities outlined in the design package. This section articulates the key assumptions made at this stage that could be used as the basis for the final plant repair and replacement strategy.

In the initial plant installation phase, the delivery and positioning of plant will be executed as 'entire units' wherever feasible. The structure and architecture shall be designed to accommodate the weights and clearances of the plant items. Clearances shall be maintained by the installing Contractor (s) to ensure that services do not need to be dismantled and removed, unless specifically identified.

For plant replacement, it has been assumed that where feasible plant can be broken down into component parts for installation and removal. It is expected that specialist attendance may be required to carry out assembly, disassembly and plant movement as necessary.

[38] The economic assessment detailed in this report does not account for the effect of inflation post the initial construction spend. A financial assessment will be completed at the next stage of the project to account for the effect of tax and inflation.

N.8 Modelling OPEX Assumptions

Fuel Costs

Projected fuel unit prices for gas and electricity are based on energy price analysis published by the Department for Business, Energy and Industrial Strategy (BEIS) published in April 2023[39].

Within the Treasury Green Book tables, three bands of electricity prices are given: High, Central and Low for three scales of consumption: large scale (Industrial), medium scale (Public Sector/Commercial) and small scale (Domestic). Gas prices are also provided in the tables, under four different scenarios: A (low prices), B (average prices), C (high prices) and D (high long term fuel prices). For the purposes of the model, it is assumed that the scheme operators and customers are currently paying the Central and scenario B prices within the relevant consumption category for electricity and gas, respectively.

The figure below shows the HM Treasury Green Book future fuel price projections for these scenarios, for electricity and gas. Whilst these projections have been used in the model, it should be noted we are currently observing much higher energy prices as international energy markets are going through an unprecedented period of rapid change and it is unclear what future energy prices may emerge in the short to medium term. Nonetheless, the energy tariffs used in this analysis show the relative performance of the options considered compared to the counterfactual. The effects of energy price fluctuations should be monitored closely as the project progresses. The sensitivity analysis will test the impact of different energy prices on the economic viability of the scheme.

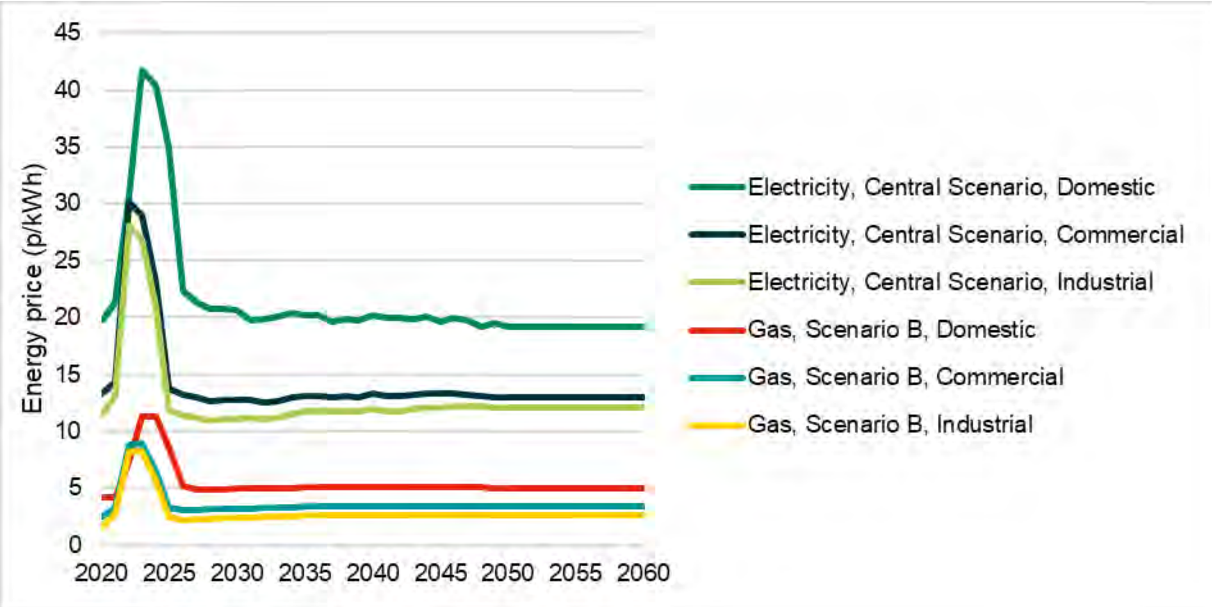


Figure N-2: HM Treasury Green Book Future Fuel Price Projections

A Sewage Outfall Waste Heat Recovery of [redacted] has been assumed in modelling, a value which has been suggested by Thames Water as a guide price during engagement.

Biogas Combustion Excess Heat Recovery has been assumed to be [redacted]. Prices have been indexed against industrial gas from 2026 onwards to exclude the current – 2025 spike in gas prices which is projected to be temporary.

Operation and Maintenance Costs

Operation and Maintenance costs are assumed to be constant (fixed element of the tariff) over the lifespan of the project. The figures given in the table below are based on AECOM experience and recent quotes from contractors and developers.

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

OPEX item	Metric	Based on
EC fabric	[redacted]	Undertaking PPM activities associated with the building. Primary activity will be clearing of gutters and rainwater drainage
All generation services (primary low carbon heating plant, back-up gas boilers, thermal stores, and ancillaries)		Value based on SFG20 assessment and based on PPM lead maintenance strategy with limited reactive time. Energy centre to be unstaffed for the majority of the time, other than PPM activities. Value includes allowance for consumables but not reactive replacement of components as this is covered under Sinking Fund
Pipework		Conventional PPM (as per SFG 20)
Metering and billing		Cost of meter maintenance and data collection

Table N-8: OPEX Assumptions

N.9 Modelling Parasitic Load Requirements

The model assumes that a 'parasitic' electrical load accounting for the power used for pumping, water treatment, control systems and other small power use within the energy centre is applied every year equal to 5% of the total annual thermal generation.

Control strategy

This section outlines some of the key assumptions and requirements for the Network and EC (Energy Centre) Control Strategy, serving as a foundational framework for the final strategy to be developed during the design stage. An energy centre schematic and description of operations should be produced at a later stage of design; the energy control system will be required to achieve this philosophy.

Energy Control System (ECS)

The designed systems shall include an ECS to control and monitor heat network plant items as required to deliver an easily maintainable, reliable, and efficient solution which complies with the Project KPIs and Performance Values.

The Energy Centre System (ECS) shall be designed to permit remote access via a broadband connection or a similar method. This capability enables personnel situated away from the energy centre to engage in system monitoring, control, and set point changes. The access provided is structured to allow visibility of the entire system, eliminating the need for multiple access connections to individual controllers or control panels.

Additionally, the ECS shall be configured to monitor all control parameters and record them at intervals of 15 minutes or less. This ensures that comprehensive data on control parameters is captured regularly, facilitating effective system management and analysis.

Energy Management System (EMS)

The EMS shall be a standalone, network-wide AMR system connected to the ECS, network energy meters and fiscal energy meters. The EMS shall facilitate gathering, visualisation and reporting of relevant data, and shall provide a means of investigating and reporting on Heat Network performance to support the CP1 requirements.

The EMS should monitor relevant inputs, including but not limited to:

- Fuel/energy consumption
- Energy generation

Data should be recorded at intervals of 30 minutes or less to allow heat network performance to be analysed and improved where necessary.

All data should be received and integrated into the wider data set in an automatic fashion such that no external interference is required. The EMS should generate notifications if the data is delayed, incomplete or unable to be included without manual intervention.

The EMS shall have the ability to export data to external software for data analysis and reporting and shall allow remote access via a broadband connection or similar.

N.10 Modelling Carbon Emission Assumptions

Scheme carbon savings depend on the input fuel and the associated carbon factors of the fuel which is being offset by the heat generation technology. Emission factors 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_{2e}/kWh, based on UK Government GHG Conversion Factors. Emission factors associated with electricity are assumed to decarbonise over time and are taken from the grid average emission factors from the HM Treasury Green Book (Data Table 1), as illustrated in Figure N-3.

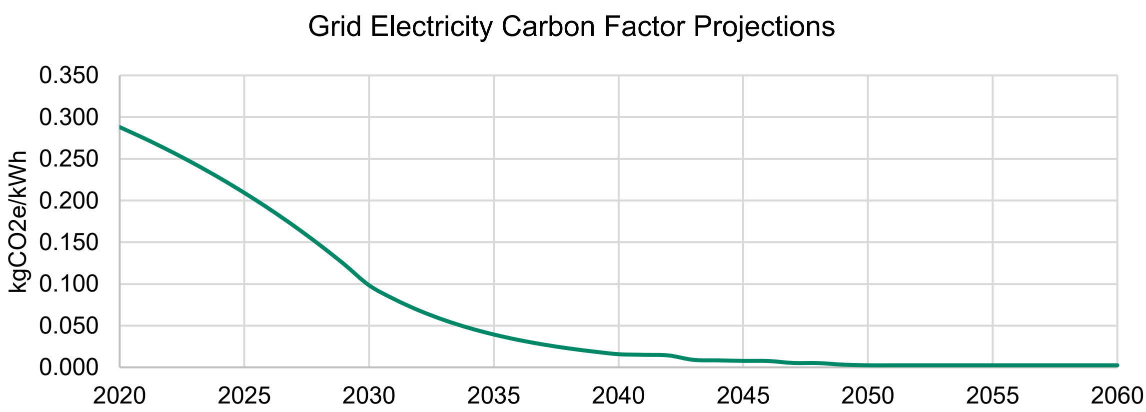


Figure N-3: BEIS Green Book Supplementary Guidance: Grid Electricity Emission Factors[40].

Biogas has been modelled as a zero-carbon source, aligned with SAP 10.1 guidance. This is under the assumption that residual carbon emissions are associated with transport, which is not applicable at the point of generation, i.e., Mogden STW.

NOx Emission

Heat Network

The boiler plant to be installed in the energy centre has not yet been selected, although they are likely to be of the “tube and shell” type rather than the condensing type. Boiler plant of this type are routinely capable of achieving low NOx emissions, typically 40 mg/kWh. Lower emissions could potentially be achieved subject to the final plant selection and design.

BaU

In this assessment, the assumed NOx emission rate for existing gas boilers is 100 mg/kWh, while for new boilers, a rate of 40 mg/kWh has been considered.

N.11 Modelling Scheme Ownership Assumptions

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 LBH buildings, then they are treated as any other customer on the network, experiencing the same costs and savings as the other customers.

[40] BEIS Green Book Supplementary Guidance (Nov 2022) Long-run marginal, Commercial/ Public sector, include transmission and distribution losses.
https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

N.12 Modelling 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 [redacted].

N.13 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.

N.14 Tax

VAT is not included in the model.

[41] Based on values taken from https://data.gov.uk/sib_knowledge_box/discount-rates-and-net-present-value,

Appendix O Developed Options Capital Cost Breakdown

The table below shows a capital cost breakdown for the network options modelled in Section 7. Values are derived from AECOM experience and suitable industry standards, 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. In line with a RIBA Stage 2 design, costs are accurate to ±30%.

Cost Category	Cost Subcategory	Borough-wide	Borough-wide + Heathrow
Energy centre construction	EC Fabric	[redacted]	[redacted]
Generation Plant	Boiler	[redacted]	[redacted]
	SSHP	[redacted]	[redacted]
Ancillary Plant & Utilities	EC Fit Out	[redacted]	[redacted]
	Energy Storage	[redacted]	[redacted]
	Utility Connections	[redacted]	[redacted]
External Works & Distribution System	DH Pipework	[redacted]	[redacted]
	Network Civils Costs	[redacted]	[redacted]
	Building Connections	[redacted]	[redacted]
Project on costs	EC Overheads	[redacted]	[redacted]
	DH Network Overheads	[redacted]	[redacted]
	Secondary Overheads	[redacted]	[redacted]
Total		[redacted]	[redacted]

Table O-1: Developed Options Capital Cost Breakdown.

Appendix P Developed Options Pipework Sizing

The tables below provide a breakdown of pipe sizes and dig types for the proposed network route. Pre-insulated steel pipework has been proposed due to the network's temperature regime.

Pipe Size	Borough-wide	Borough-wide + Heathrow
[mm]	[m]	[m]
20	1,894	1,894
25	239	239
32	544	544
40	4,011	4,011
50	5,252	4,678
65	6,383	6,383
80	5,555	4,981
100	6,569	6,569
125	5,062	4,556
150	4,737	4,231
200	5,984	5,159
250	2,291	2,291
300	2,059	2,059
350	1,771	1,771
400	3,522	271
450	1,081	5,911
500	2,442	1,281
600	3,677	4,300
700	0	3,978
800	3,404	0
900	0	3,404
Total	66,476	68,510

Table P-1: Breakdown of Pipe Diameters for the Proposed Network

Dig Type	Borough-wide	Borough-wide + Heathrow
Soft Dig/Closed Site [m]	6,591	7,369
Urban Dig [m]	51,983	52,805
Extra Urban Dig [m]	7,571	8,004
Specialist Crossing [m]	331	331
Total trench	66,476	68,510

Table P-2: Breakdown of Dig Type for the Proposed Network

Appendix Q Teddington Direct River Abstraction

The Teddington Direct River Abstraction scheme is being proposed to combat future water shortages during ‘extreme drought events’ at the Lee Valley reservoirs. Water will be extracted from the Thames upstream of Teddington before being transferred across the city to Lee Valley. Treated water from Mogden STW will be used to replenish this supply, requiring construction of a new 4.5 km pipeline between the locations and a purpose-built tertiary treatment facility on-site at Mogden. Construction of the scheme is currently expected to take place from 2029-2033, becoming operational in 2033. A diagram of the proposal is shown in Figure Q-1.

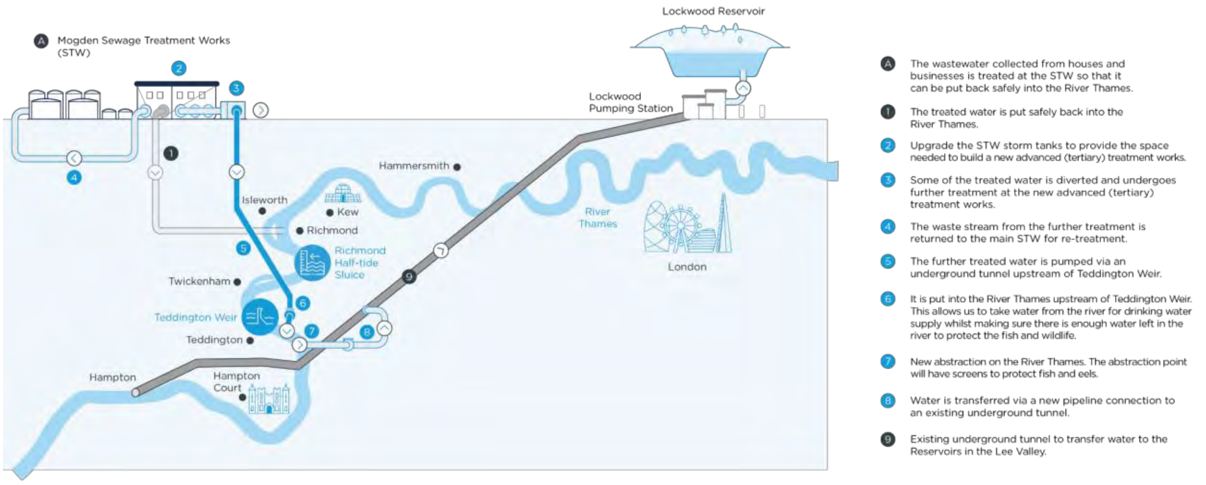


Figure Q-1: Teddington Direct River Abstraction Scheme Overview

Source: https://thames-wrmp.co.uk/new-water-resources/teddington-river-abstraction/

The proposed scheme presents a number of opportunities for coordination with the district heating offtake:

- The Teddington DRA scheme was assessed to have a ‘moderate negative effect on aquatic ecology receptors’, potentially caused by increased water temperatures[42]. The district heating scheme could eliminate this threat by extracting heat from the flow at Mogden before it is discharged at Teddington.
- The DRA scheme would require a new tertiary treatment facility due to the environmentally sensitive freshwater outfall location at Teddington. Treatment processes, such as coagulant dosing and multi-stage filtration, would make the effluent flow more attractive for heat extraction as less complex heat exchangers (without self-cleaning functions) could be employed.

[42] gate-one-submission-london-reuse.pdf (thameswater.co.uk)

Appendix R Commercial Delivery Options

Please refer to accompanying document *Appendix R: Commercial Delivery Options.*

Appendix S CP1 Checklist

Please refer to accompanying document *Appendix S - CP1 Checklist Stage 2*.

Appendix T CP1 Recommended Statement of Applicability

Please refer to accompanying document *Appendix T - CP1 Recommended Statement of Applicability*.

Appendix U Risk Register

Please refer to accompanying document *Appendix U - Risk Register*.

Appendix V HNDU Project Opportunities Metrics Template

Please refer to accompanying document *Appendix V - HNDU Project Opportunities Metrics Template*.

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