Ealing Council

Southall Decentralised Energy Network

Feasibility and Business Case Study

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		Name	Thomas Hurst, Alper Ozmumcu	Thomas Hurst	Stephen Cook
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List of Acronyms

AAP	Area Action Plan
ASHP	Air- Source Heat Pump
CAPEX	Capital Expenditure
CHP	Combined Heat and Power
CO_2, CO_2e	Carbon dioxide and Carbon dioxide equivalent. CO_2e is a unit of measure which incorporates a basket of greenhouse gases.
COP	Coefficient of Performance, a ratio which relates the input energy required (normally electricity) to achieve a given output of energy (normally heat or coolth)
DE	Decentralised Energy
DECC	Department of Energy and Climate Change
DEPDU	Decentralised Energy Project Delivery Unit
DEN	Decentralised Energy Network
DH	District Heating
DHW	Domestic Hot Water
EC	Energy Centre
GHG	Greenhouse gas
GLA	Greater London Authority
GSHP	Ground Source Heat Pump
HIU	Heat Interface Unit
HV	High Voltage
IRR	Internal Rate of Return
NPV	Net Present Value
OPEX	Operational Expenditure
REPEX	Replacement Expenditure
RHI	Renewable Heat Incentive
ROC	Renewables Obligation Certificate
SHN	Strategic Heat Network
SPV	Special Purpose Vehicle
TUoS	Transmission Use of System Charge

Glossary

Broker / Promoter	A role in the delivery of a district heating network: The Promoter is the body which is working to bring a district heating project into being. The role occurs over the pre-development period up to Financial Close of a project. The Broker is a special role within the wider Promoter role which (like a broker on the stock market) describes the body which brings the contracting parties together (e.g. the ESCo and the heat customers) but is not itself a party to that contract.
DisCo	Distribution Company
ESCo	Energy Services Company
GenCo	Generation Company
Governing body	A body which is responsible for the delivery of the heat service which is provided by the operator.
InfraCo	Infrastructure Company
Regulator	A body which is set up or contracted to oversee and regulate the heat service under the terms agreed between the heat supplier and the heat customer.
RetCo	Retail Company
TransCo	Transmission Company

Power and Energy Units

kW, MW	Units of power; these can refer to heat or electrical power. In the case of heat, a “th” is usually appended, while in the case of electricity, an “e” is usually appended. A megawatt (MW) is one thousand times as large as a kilowatt (kW).
kWh, MWh	Units of energy; these can refer to heat, electricity, or fuel energy, as will be explicitly stated. A megawatt hour (MWh) is one thousand times as large as a kilowatt hour (kWh).

Executive Summary

This feasibility study investigates the potential for delivery of an area-wide Decentralised Energy (DE) scheme in Southall, delivering lower-cost, lower-carbon energy to households and businesses.

Southall is a vibrant and bustling place, poised to play a renewed role as one of London's most significant growth areas. With the arrival of Crossrail, significant investment from the Mayor's Regeneration Fund and clusters of major development sites, including the Gas Works, Southall is capable of exploiting the opportunities presented by this enhanced connectivity and committed investment. With capacity for 2-3000 new jobs and 6000 new homes, Southall is one of the biggest Opportunity Areas in west London

The Council's commitment to investigate what delivery options exist and potentially invest early also helps to create the conditions to engage the private sector early in the process and attract them to invest in the area. This is also in line with the objectives and policies set by the London Plan in relation to the Opportunity Areas. In relation to benefits to the Council, a good rate of return on capital investment can create an income stream that can go towards priority infrastructure for the area. In addition, it should be noted that it meets all the Council's corporate objectives and fits in with changing organisational drivers.

While techno-economic modelling indicates a viable commercial scheme, the stakeholder landscape at Southall means that it may not be possible to achieve delivery of an area-wide scheme without some involvement from Ealing Council.

This report presents a technical and financial feasibility assessment for the full scheme, and investigates the means by which the Council might support its delivery.

Techno-economic summary

A viable scheme has been identified. Costing £7.1 million between 2017 and 2035, which is achievable at private sector discount rates (of 12% over 20 years). This includes the pipeline, generation assets, and energy centre CAPEX but excludes the HIU CAPEX and the replacement cost of assets and HIUs.

Heat is provided for the scheme via combined heat and power (CHP) technology, with a large energy centre (EC) housing boilers and gas engines to be constructed on the site of the redeveloped Southall Gasworks. A heat network will take heat from the EC to serve new loads on the Gasworks site, as well as developments to the east, and to the south of the railway. This necessitates a railway crossing for the network, which is expected to be timed to coincide with the planned widening of the South Road Bridge, and likely necessitates early phase developments south of the railway being served by temporary boilers.

Annual carbon emissions savings at full build-out are expected to be 2,300 tCO_2 compared to a counterfactual scenario of individual gas boilers.

Calculations indicate acceptable financial returns could be achieved while still supplying heat at 10% below current average prices paid by domestic gas consumers for the equivalent service, aiding in efforts to combat fuel poverty.

It should be noted that some financial information underpinning the analysis and modelling has been omitted from this version of the report as it is commercially sensitive.

Key risks to the project's future delivery are the willingness of relevant parties to create the necessary commercial structures for a network to be delivered and operated; the upfront capital investment required to extend the heat network to the east; the ability to cross the railway, and timings associated with this; and, the scheme's reliance on the delivery of a number of future developments. Measures have been identified to clarify uncertainties and/or mitigate risks.

Business case options

The network is reliant on a number of expected new developments in the area coming to market. This reliance represents a risk to the project's overall delivery and could inhibit market appetite for the network unless there is a party (e.g. Ealing Council) willing to provide some mitigation of deployment risk.

The EC location is not on land owned by Ealing Council, but instead is part of a site with an outline planning permission for new multi-use development (Southall Gasworks, with St James the developer). Our calculations indicate that an EC sized to serve the wider Southall scheme could fit within the EC footprint previously earmarked to serve the Gasworks site alone.

While the Gasworks site is technically and financially the best candidate to locate the EC, consideration must be given to St James' motivations regarding energy supply to its development. Although St James may look to procure an energy services company (ESCo) to provide heat supply services for its buildings, this desire may not extend beyond the Gasworks boundaries. Multiple, uncoordinated developers exist east of the Gasworks, but these are not guaranteed to connect, and so present a risk to the financial viability of an ESCo for the Gasworks. This is a key risk that the Council may wish to mitigate.

The Council may wish to take a promoter/broker role, using its influence to convene stakeholders, reduce uncertainty, and potentially drive procurement processes. Multiple feasible commercial solutions have been identified that provide acceptable economics for all stakeholders.

The Council may also wish to invest in the transmission pipeline between the Gasworks and eastern Southall sites, a solution which has been shown to greatly reduce the financial risk to private sector actors, but also holds the potential for on-going revenues for the Council.

Depending on its desired degree of involvement, the above options present different risk and reward profiles for the Council.

Table 1. ESCo structure options

Council Role Option	ESCo structure options	
	A: Single ESCo	B: Split ESCos
Option 1: Council acts as Promoter	• "Southall ESCo" supplies all sites and operates energy centre.	• "Southall West ESCo" serves Southall West development and operates energy centre. • "Rest of Southall ESCo" buys heat from Southall West ESCo" and supplies all other sites.
Option 2: The council acts as Promoter and the InfraCo	• "InfraCo SPV" pays for and owns transmission pipe. • "Southall ESCo" supplies all sites and operates energy centre, and pays TUoS charges to InfraCo SPV."	• "InfraCo SPV" pays for and owns transmission pipe. • "Southall West ESCo" serves Southall West development and operates energy centre. • "Rest of Southall ESCo" buys heat from "Southall West ESCo", supplies all other sites, and pays TUoS charges to "InfraCo SPV."
Option 3: The council exercises only its planning function	Same as Option 1	Same as Option 1

Table 2. Financial summary of the commerical delivery options[1]

Recommendations and next steps

The below list highlights the initial recommendations and likely next steps that follow the publication of this study. An initial delivery plan is included in Section 10, although this is expected to evolve following the Council's assessment.

- Ealing Council to review findings and discuss their implications in the context of planning policy and wider economic and environmental goals.
- Ealing Council to review the possible commercial delivery options with varying degrees of Council involvement.
- Ealing Council to engage with existing developers regarding the opportunity and connection to the scheme.
- Ealing Council to identify major infrastructure/developments proposals for the area and their programmes and align these
- Pending decisions to take the project further, a responsible party within the council is tasked with progressing the opportunity.
- Potential network layouts and scheme characteristics entered into planning documents such as AAPs, as well as the London Heat Map.
- Planning policy to require further developments in the area to consider connection to the scheme.
- Depending on commitments from the borough, and further discussions with the GLA, further technical, commercial and financial assistance might be available from Decentralised Energy for London.

1 Introduction

1.1 Background to the project

The UK established through the Climate Change Act 2008 a legal commitment to an 80% reduction in greenhouse gas (GHG) emissions by 2050 versus 1990 levels. Amongst other measures, this goal requires the decarbonisation of the nation's heat supply, which today is responsible for a third of total GHG emissions [1]. District heating represents one potential means of enabling this transition where it can capture and distribute low carbon heat sources such as electricity generating stations, combined heat and power facilities and large scale heat pumps. The growth potential of district heating in urban areas is significant: scenario planning by the UK's Committee on Climate Change indicates a target of 30 million megawatt-hours (MWh) of heat to be provided through district heating systems by 2030, from around 1 million MWh today.[2]

Since 2009 the London Borough of Ealing has worked with the Greater London Authority to bring forward decentralised energy networks in the Borough. The evidence base has progressed from Borough-wide heat mapping to an energy masterplan for the Southall area, which also informed the Southall Opportunity Area Planning Framework.

Arup carried out the original energy masterplan[3] under its role as the Mayor of London's Decentralised Energy Project Delivery Unit (DEPDU), identifying a potentially viable heat network based on existing and future heat loads in central Southall. The data and analysis from that work formed the starting point for this more detailed study, which has been commissioned by the London Borough of Ealing with funding and technical support from the DECC Heat Networks Delivery Unit.

Based on an energy centre located at the "Southall West" development site, the original energy masterplan envisaged a scheme that would start generating heat in 2017, gradually expanding up to 2032 as new residential developments came on line. The scheme was developed as an optimal balance between technical, commercial and planning drivers and risks, taking into account the wider opportunities associated with delivering a low-carbon heat network in the area. Key techno-economic highlights of the scheme were as follows.

Table 3. Technical highlights of the 2013 masterplan study[3]

Annual Heat Demand	17,300MWh/yr
Network Length	2,280m
CHP capacity	1.1MWe
Boiler capacity	6.5MWth
Carbon savings[4]	3,300 tCO2e/yr

[1] The Future of Heating: A strategic framework for low carbon heat in the UK
[2] Committee on Climate Change, 2013: Fourth Carbon Budget Review – part 2: The cost-effective path to the 2050 target.
[3] http://www.ealing.gov.uk/downloads/download/3104/decentralised_energy_for_london-southall_masterplanning_july_2013
[4] Based on current carbon intensity of electricity grid (SAP 3-year projection for 2013-2015)

Table 4. Economic highlights of the 2013 masterplan study[3]

Initial CAPEX	£4.1M
CAPEX on full build-out[5]	£5.7M
Maximum OPEX	£960k
Maximum Revenues	£1.2M
Gap Funding Required at 6%, 25 year[6]	£3.8M
New-build domestic connection charge to meet funding gap	£1,626/unit
Non-domestic connection charge	£1000/kW

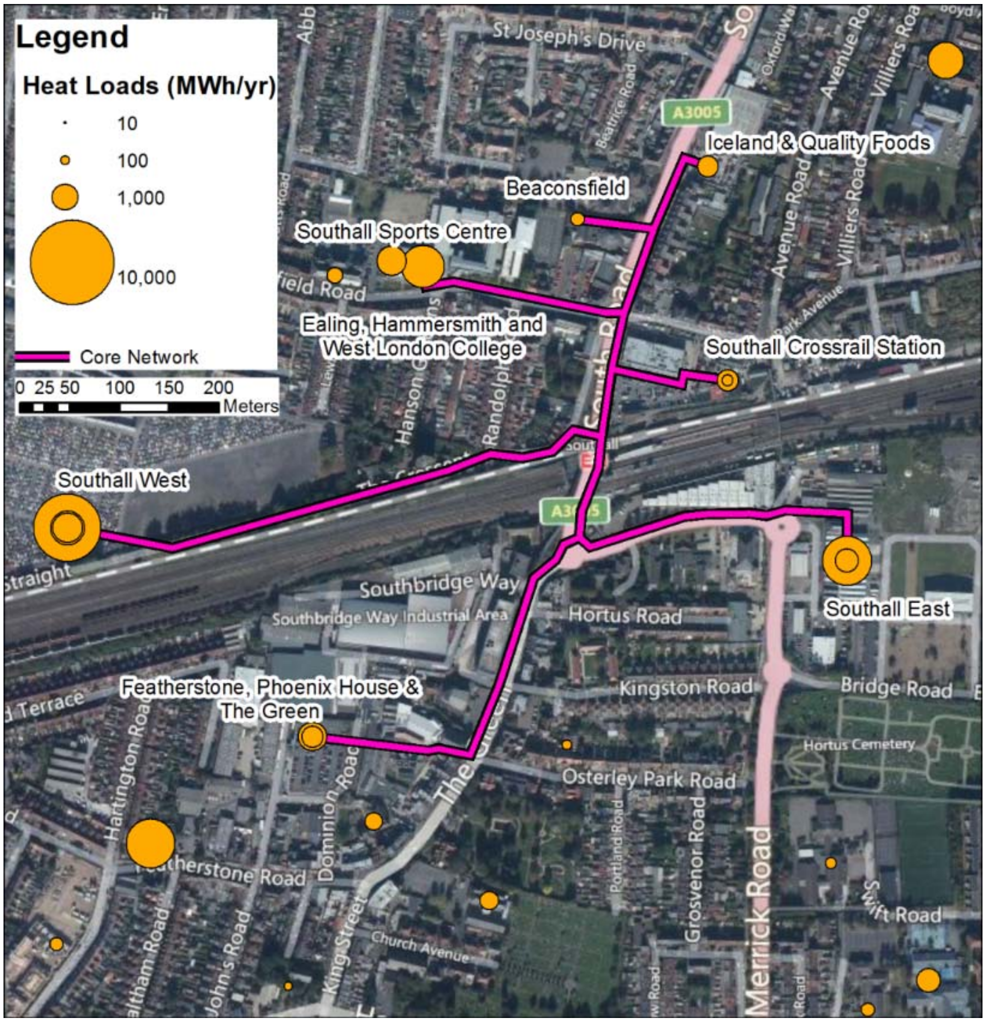


Figure 1. Scheme identified in the 2013 masterplan study

[5] Excluding plant replacement.
[6] If no developer contributions or connection charges.

The aim of this 2015 study was to test the feasibility of the masterplan and to establish a realistic delivery plan for the scheme. Consequently the study has had to consider the scheme from multiple perspectives:

- System technology and design parameters;
- Network route feasibility and land requirements;
- Likely costs and revenues, and potential long term investment performance; and
- Allocation of roles and risks for the design, installation, funding, operation and maintenance of the network.

The report presents the result of a process of analysis and refinement which takes the form of a commercially deliverable “Core Scheme” serving a number of major development sites in Southall. There may be potential to expand on this Core Scheme in the future, but this study focusses on reporting the technically and commercially feasible element.

Depending on the decision taken by Ealing Council on the recommendations of this report, the next stages in the delivery of a decentralised energy network in Southall would be:

- Council decision-making processes on the delivery and business plan for the scheme (and parallel decision-making processes by other key stakeholders);
- Procurement of a contractor or energy services company (ESCo) to construct the network and potentially to operate the heat service; and
- Construction of the network and connection over time of new customers, as planned new development in the area is completed.

1.2 Structure of this report

This report is structured as follows:

- Sections 3 and 4 present the results of the heat demand and supply analysis
- Section 5 presents the network routing options, key considerations and an appraisal of the risks associated with delivering the infrastructure.
- Section 6 covers the business cases for a selection of appropriate delivery mechanisms, from the perspective of the Council.
- Section 7 digests the key messages from the preceding sections to outline a delivery plan for the scheme.

Further technical detail, assumptions and results are presented in the relevant appendices.

It should be noted that some financial information underpinning the analysis and modelling has been omitted from this version of the report as it is commercially sensitive.

2 Introduction to district heating

2.1 Decentralised Energy

Decentralised energy refers to the generation and distribution of energy closer to the locations where energy is consumed. District Heating (DH) involves heat (and often power) generated in energy centres, with heat sent via pipes to customers[7]. Buildings are connected to the network via heat interface units that replace individual boilers for space heating and domestic hot water.

Figure 2. An energy centre.
Source: Islington Council

Currently, electrical power in the UK is generally supplied from a relatively small number of very large power stations, most of which are in remote locations away from population centres. This approach creates a variety of inefficiencies in the overall energy system, of which the greatest is the inability to use the spare heat from power stations for beneficial purposes. By locating a generating station close to where the energy is used, decentralised energy offers the potential for the spare heat to be captured and distributed to buildings or industrial processes which need it.

Figure 3. Heat pipes.

District heating networks offer an affordable way of achieving a low carbon energy supply in densely populated areas such as London, meeting domestic, commercial and some industrial space heating and domestic hot water requirements.

This is a unique opportunity to deliver a sustainable heat network throughout the Southall area that would put Southall at the forefront of sustainable energy supply in London. The Council's vision is to deliver cost-competitive, low carbon energy which will help to eradicate fuel poverty, reduce overall carbon emission, and facilitate the transition to a low carbon economy. To reduce the financial risk of the project, all new development within the Opportunity Area will be required to consider connections to the heat network. Where a development is completed before the Southall Heat Network is available, the development will be designed to allow connection to the network with minimum modifications. The Core DE Scheme establishes a DH spine along the north-south axis of Southall which is designed to have the flexibility to adapt and expand according to future energy demands, including extensions of supply to existing buildings.

[7] So, while the electricity generation is decentralised, the heat generation is actually more centralised than previously.

The project area forms part of an Opportunity Area as identified in the London Plan and in Local Planning Policy documents. Opportunity Areas are to the Capital's major reservoir of brownfield land with significant capacity to accommodate new housing, commercial and other development. The delivery of a heat network in the area will be key to the achievement of a sustainable community in the area, and will support many objectives of the OAPF. Investment in critical infrastructure such as this will create the right conditions to entice developers to invest in the area, though increasing confidence and potentially reducing build costs.

2.2 Combined Heat and Power with District Heating

The use of Combined Heat and Power (CHP) with DH results in the highly efficient use of fuel, up to 80-90% efficiency, with primary energy savings of 30-45% compared with the conventional separate generation to achieve the same quantity of heat and power. Due to the efficiency of CHP, emissions to the environment are approximately 30% less than in separate generation of electricity and heat. This is represented in Figure 4.

The heat generated by CHP is then distributed in the form of hot water from the heat sources by means of district heating pipework to the consumers. Such are reliable, long life assets that can deliver heat regardless of the source. Indeed the heat source may change over time as the energy market and technologies change to favour new generation technologies or other more economic heat sources. The flexibility of district heating is improved as networks are interconnected allowing access to lower cost heat sources. According to DECC's Digest of UK Energy Statistics 2014, there are currently over 340 CHP schemes in the UK with capacities of over 1 MWe.

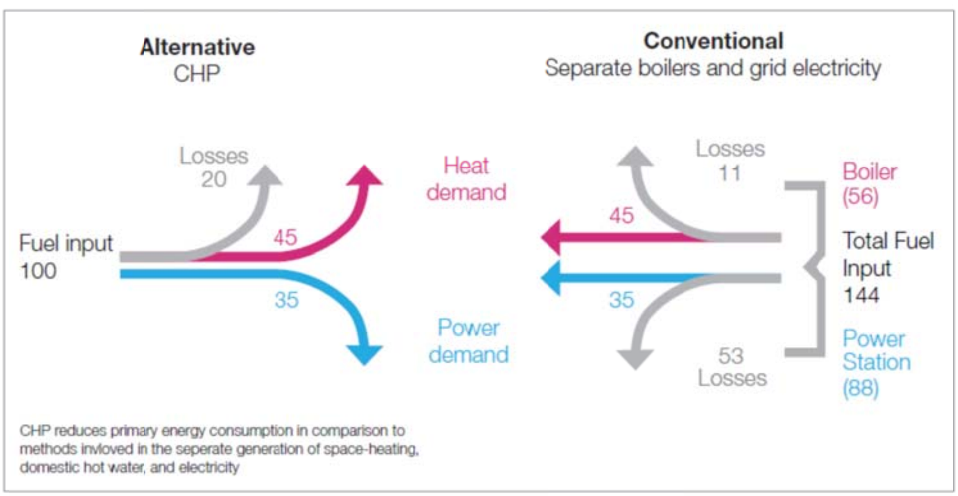


Figure 4. Benefits of Combined Heat and Power. *Source: London Heat Network Manual*

District heating networks are best suited for high "heat density" areas. New development areas provide an opportunity to gain economies of scale to provide heat at lower prices compared to individual building solutions, while meeting carbon reduction targets in a cost-effective way. District heating networks can help London meet its domestic energy needs while reducing the total fuel requirement, thereby delivering some mitigation of energy security risks and fuel price fluctuation.

Today, CHP district heating offers carbon savings over the conventional alternatives (gas boilers and grid-supplied electricity), primarily due to the carbon intensity of the electrical grid. It is noted, however, that as the grid continues to decarbonise (it is projected to reduce its carbon intensity by over 50% in the next five years[8]), the savings achieved by offsetting grid carbon emissions would reduce. There exists the possibility that in the coming years CHP technologies will perform worse in carbon terms than conventional or advanced heat supplies (heat pumps). This said, CHP is currently seen as a cost-effective means of enabling low-carbon district heating; once the engines are life-expired, they may be replaced with future low-carbon options such as heat pumps.

[8] Based on analysis of DECC Updated Energy and Emissions Projections, September 2014

3 Demand Analysis

3.1 Demands connected to Core Scheme

Figure 5 below identifies the location of the heat loads that make up the core scheme, while Table 6 presents more detail.

Figure 5. Core scheme head demands and location

Along with the council itself, the landowners and developers of these loads represent the key stakeholders in the delivery of a DE scheme in Southall. It can be noted that all but one of these loads are new developments. As will be discussed further in Section 9, this is an important risk consideration (due to uncertainty about future levels of development), but also an opportunity (in the ability of the Council to influence connection to the network through planning powers). Section 3.2 contains a summary of the stakeholder engagement.

Table 5. Core scheme heat demand characteristics

Name	Demand type	New or existing	Residential Units	Non-Residential GFA [m^2]	Heat demand (connection year / final build out)
Southall West (Gasworks)	Residential, mixed use	New	3,800	43,000	2019: 1,174 MWh/yr 2043: 15,746 MWh/yr
Southall East	Residential, mixed use	New	1,500	17,000	2017: 487 MWh/yr 2023: 5,641 MWh/yr
Southall Gateway	Residential, mixed use	New	400	3,210	2022: 1,021 MWh/yr 2032: 1,496 MWh/yr
Ealing, Hammersmith & West London College	Educational	Existing	-	5,800*	2026: 669 MWh/yr (no phasing)
Iceland and Quality Foods site	Residential, mixed use	New	140	2,400	2032: 641 MWh/yr (no phasing)
TOTAL	-	**-**	**5,809**	**65,069**	-

** For the existing connected loads, reported fuel consumption figures have been used to estimate their heat demand (instead of benchmarking based on their GFA).*

Based on an EC located at the Southall West development site and the core scheme identified in this feasibility study, the district heating network would gradually expand in line with the phased build-out of the new developments. The scheme would become operational in 2017 with the first heat supply going to the Southall East site. Figure 6 illustrates the phased connections of the heat loads to the core scheme.

The other sites listed in Appendix A1 under the full list of demands considered in the immediate area have been discounted from the network for now on the basis that there is too much uncertainty at present around their assembly and delivery as in the case of The Green or they negatively impact the overall financial viability of the scheme at present. However, there may be a potential for extending the network in the future with these identified loads.

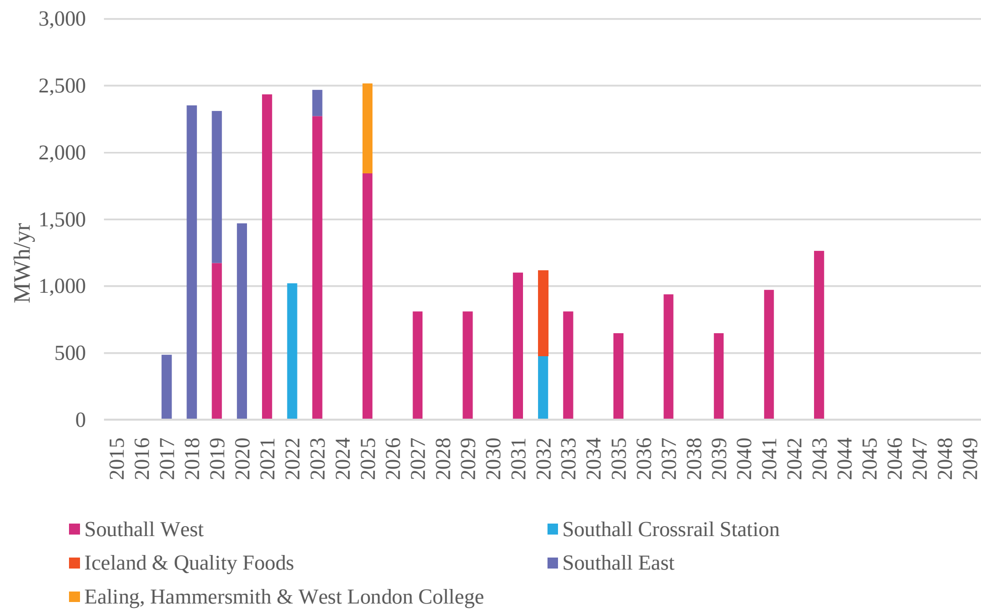


Figure 6. Connected heat loads by site

The Southall East site has the majority share in the total cumulative heat loads for the first 5 years. However, phased over a period of 25 years, the Southall West development site gradually overtakes, and accounts for the majority of the heat loads from 2025 onwards. Figure 7 illustrates the significance of the connection between the Southall East and West sites especially during the initial years of the scheme.

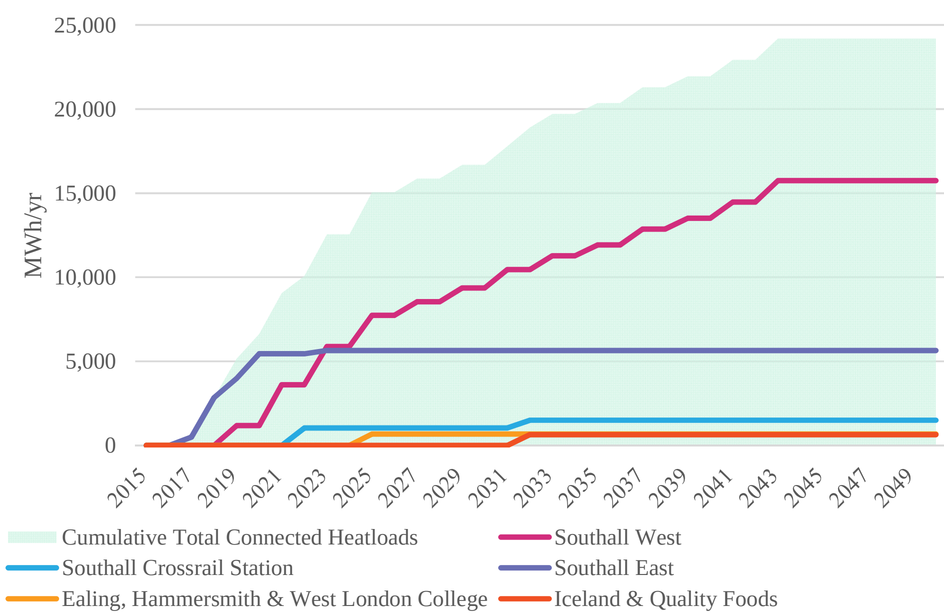


Figure 7. Cumulative Connected Heat Loads by Site

Cumulative heat loads (excluding primary and secondary losses) reach a plateau at 24,000 MWh/year as the full build-out of all connected development sites is expected to happen in 2043. At this point in time, Southall West site is responsible from 62% of the total heat demand, followed by Southall East at 22% as shown in Figure 8.

For the purposes of comparison, the Sheffield heat network provides around 120,000 MWh/annum while Stockholm's city-wide network provides around 5,700,000 MWh/annum, covering around 60% of the customers on the city's heat market. The Southall scheme therefore appears quite modest in comparison to these networks. On the other hand, a 2013 DECC report on heat networks in the UK indicated that there were 75 large schemes in operation, where "large" was defined as serving 500 or more units.

With these connected loads, the Southall network would contain a total of around 5,800 residential units and 65,000 m^2 of non-residential gross floor area.

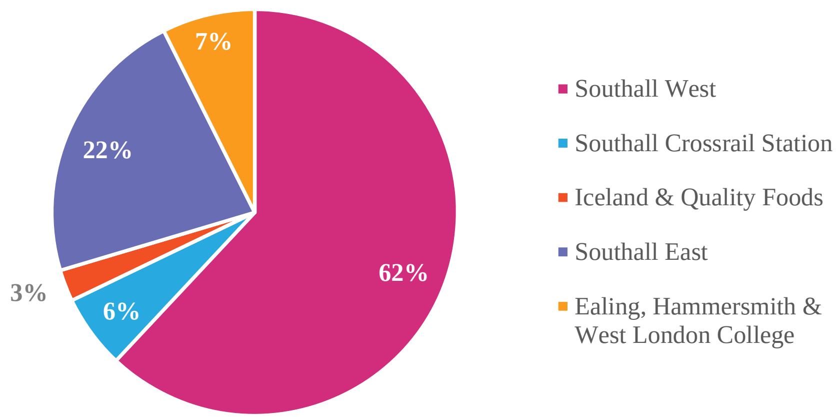


Figure 8. Split of Connected Heat Loads by Site at Full Build-out in 2042 (MWh/year)

3.2 Wider area demand characteristics

The wider area in Figure 9 consists of 43 sites that represent a total load potential of 46,000 MWh/year. The core network identified in the feasibility study continuously supplies low-carbon heat and hot water to 5 sites which constitute just over 50% of the total priority[9] potential in the vicinity. Appendix A1 includes the full list of demands considered in the immediate area, also indicating their type (i.e. residential, mixed use etc.) and the source of their demand data (i.e. actual or benchmark).

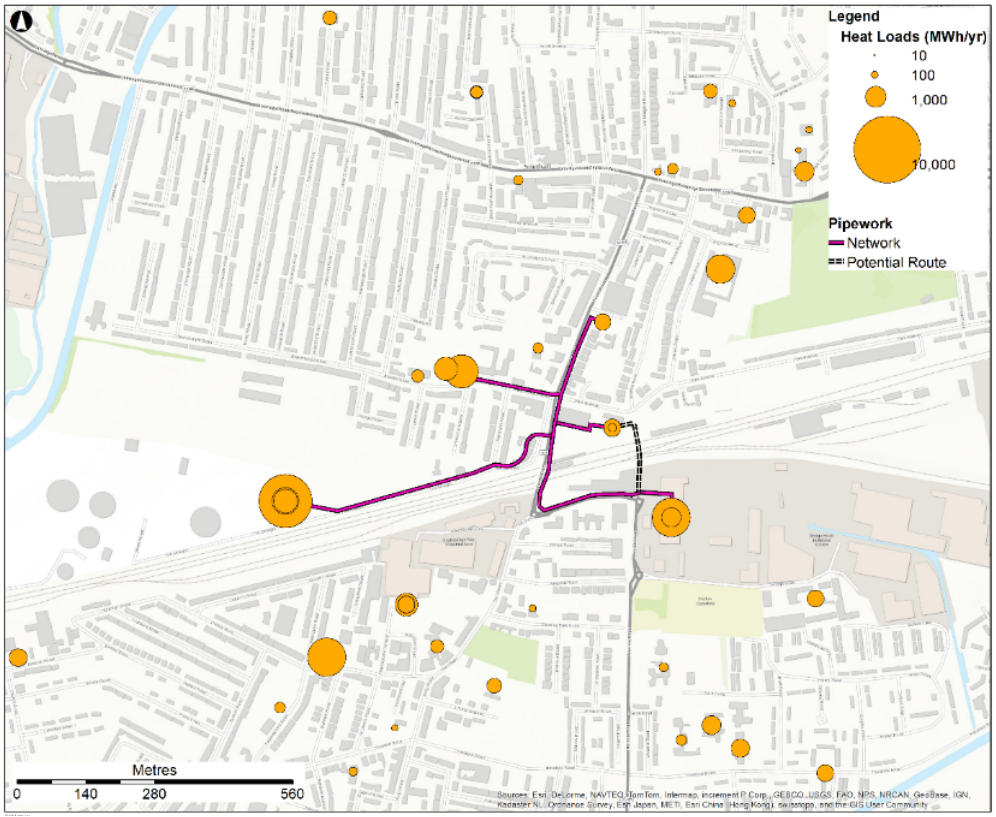


Figure 9. Southall wider area heat loads (circle size indicates annual heat demand estimated). Note indication of alternative potential crossing at pedestrian footbridge.

3.3 Summary of stakeholder engagement

All key stakeholders identified were issued a data request proforma and appetite survey. In most cases this was returned swiftly and with information of suitable quality for the needs of the analysis. The below table presents a summary of this engagement.

[9] "Priority" loads are those that are most suitable for connection to a DH network. The map does not, for example, indicate all residential dwellings as potential loads, as these are mostly in individual private ownership, and not of sufficiently high heat density to justify connection on economic grounds.

Table 6. Summary of stakeholder engagement

Stakeholder	Considerations	Appetite
Southall West: St James	Residential-led development on the former site of the Southall Gasworks, with development being managed by St James. Permission granted in 2010 for delivery of up to 3,750 homes, around 50,000 m^2 of non-domestic floor space. Currently in the process of discharging planning obligations, anticipate finalising energy infrastructure solutions by 2015/16.	Without further information on the potential scheme, St James were not willing to fully set out their position with regards to connection. The key concern for the developer is that it maintains control over the delivery of heat to its consumers. Appendix A4 indicates the uplift cost on the generation assets and distribution pipeline sizing to the site boundary if they were to be sized for an area-wide network.
Southall Gateway: Ealing Council	Site is currently made up of a number of separate plots, with Ealing Council in the process of assembling these, potentially via CPOs. No developer is yet in place. Overall development is somewhat driven by land made available following the completion of the Crossrail project.	Ealing Council is supportive of a DE scheme in the area, and would encourage connection of developments in the Southall Gateway to an area-wide heat network.
Southall East: Various landowners and developers	Several smaller developments make up this area. Currently no coordination between stakeholders. More advanced developments are already moving forward with small on-site heating solutions. The fragmented stakeholder environment and differing stages of development represent a coordination challenge.	Appetites across the developers vary. In general, contacts have been reluctant to host a large area-wide energy centre on their sites, but are not averse in principle to connecting to a scheme.
Ealing, Hammersmith & West London College	Existing gas boilers on the site have a remaining lifetime of around 10 years, and suitable capacity to meet the needs of envisaged expansion. Heat load is still attractive for the network; engagement needs to be maintained into the mid-term to ensure the potential is captured.	While not a candidate for immediate connection to a future DE scheme, the College showed considerable appetite for a future connection. The main concern raised was a perception that the College might not have control over its heat provision; while this was clarified, this misconception is likely to be raised again in the future and should be managed[10]

[10] The fundamental principle of a modern, well-designed district heating system is that all users' heat demands are comprehensively met.

4 Supply Analysis

4.1 Summary of supply options evaluation

A district heating network can be supplied and backed up with a number of possible technologies, with CHP being the most common technology for baseload generation in mixed land-use and high density modern developments. CHP and all other options were evaluated for their suitability across a range of sites along the heat network.

4.1.1 District heating CHP with gas boilers

Combined heat and power (CHP) systems capture the heat released during the power generation process, resulting in increased energy efficiency. The heat to power ratio normally determines the size of the gas CHP unit that is viable for a given building or site load. The typical target for CHP engines is to ensure at least 5,000 running hours per annum (out of a total of 8,760 hours in a year).

A well-designed gas CHP can modestly reduce carbon emissions due to its higher efficiency compared to the alternative case of conventional gas boiler and grid electricity produced mostly by large distant “power only” power stations. As in the case of all other embedded generation options presented here, gas CHPs located close to the point of consumption eliminate electricity transmission and distribution losses and therefore reduce carbon emissions.

District heating CHP technology is very appropriate today from a carbon perspective, but would deliver reduced savings if the grid decarbonises in the future. With today’s electricity grid factor (519 gCO2e/kWh) and mains gas factor (216 gCO2/kWh) based on SAP 2012 3-year projections, district heating CHP with back-up gas boilers reduce carbon emissions compared to counterfactual individual gas boilers if the CHP supplies more than 30% of the heat demand. In the modelled supply solution for this study, CHP supplies 57% of the heat demand (5,000 hours/year runtime) which corresponds to the aggregate baseload of the connected end-users.

In the future, based on SAP 2012 15-year projections for decreasing electricity grid factor (381[11] gCO2e/kWh) and increasing mains gas factor (222 gCO2/kWh), district heating CHP with back-up boilers still offer (reduced) carbon emissions if the CHP runs long enough (min. 5,000 hours/year) based on future-proofing with adequate thermal store capacity and feasible heat demand profiles. More detailed descriptions and the comparison of the supply options are presented in Appendix 2.

In line with the current building regulations in London, this study uses the SAP 3-year projection (2013-2015) of 0.519 kgCO2/kWh constantly carried into the future.[12]

[11] Note, these are average annual figures for the entire generation mix, not the higher emissions for the thermal generation (coal / gas) that would generally be displaced by CHP generation.
[12] http://www.bre.co.uk/filelibrary/SAP/2012/SAP-2012_9-92.pdf

Gas CHPs and most of the other micro generators described here are usually designed for operation in conjunction with the electrical grid connection, contributing to the baseload of a building or site and thereby offering resilience to systemic failures. Typically a CHP system provides the best economics when all electricity is consumed locally, i.e. to offset electricity imported from the grid due to the low export price normally obtainable by a small electricity producer.

Although CHP engines would be installed in modular units, the viability of the CHP investment will be poor until the heat network builds up to a sufficient load to ensure steady operations of the engines. Overall, a hybrid approach where boilers are used to provide top-up heat yields better resilience for the heat network (and better economics). Gas boilers are the most conventional solution for heating in the UK. Gas boilers provide top up and back up when deployed in conjunction with any other technology option discussed here. They are likely to offer the cheapest solution even with the subsidies available to the renewable alternatives discussed here.

The supply strategy proposed in this feasibility and the earlier pre-feasibility studies are based on a district heating CHP with gas boilers to cover the peak load and providing an extra back-up boiler unit for redundancy in any event of component failure.

4.1.2 Other alternatives

Other supply options including biomass CHP and boilers, energy from waste, air, water, and ground source heat pumps, deep geothermal, energy piles, anaerobic digestion, gas let-down station, and solar thermal have been evaluated in Appendix 2. The considerations for air and ground source heat pumps and solar thermal are outlined here.

4.1.2.1 Air-source heat pumps

Air-source heat pumps (ASHP), ground-source heat pumps (GSHP), and solar thermal generation are also investigated as alternative heat-only supply options. ASHPs work like back-to-front refrigerators; turning a unit of electrical energy into multiple units of low-grade heat energy. This ratio of input electric power to output thermal power is called the coefficient of performance (COP). The COP varies through the year with the air temperature (warmer air gives a higher COP). Average – or seasonal – COPs for ASHPs are typically around 2 to 3.

ASHPs have a relatively low power density (which means they require large areas of floor space) and offer limited economies of scale; they are therefore more typically suitable for individual building solutions rather than for a centralised energy centre powering a heat network. They are eligible for Renewable Heat Incentive (RHI) payments that vary according to scale. Electrification of heating and cooling could result in future carbon emissions reductions as the national grid decarbonises. Nevertheless, ASHPs typically represent the poorest heat pump option, with ground source, water source and other secondary heat source heat pumps offering higher COPs and therefore better carbon performance.

4.1.2.2 Ground-source heat pumps

A ground source heat pump system in its most basic form consists of pipes buried in the shallow ground near the building, a pump and a heat exchanger. Deep boreholes (typically 100-200m in depth) are an alternative method of extracting heat which results in a more constant temperature as it is less subject to variations in ambient air temperature as well as higher levels of heat extraction.

Their essential advantage is that they move the heat that already exists and hence do not require that heat to be generated. The system can be used for a variety of applications including preheating of domestic hot water and space heating. The heat pump can also be reversed in the summer to provide cooling with a separate cooling network. The brownfield nature of the gasworks site means this technology is suitable. A typical seasonal COP for a well-designed GSHP system is around 4. Unless the GSHP is assisted with a mechanism for replacing the heat extracted from the ground, it will get increasingly costly to extract heat from the ground that is getting cooler. Inter-seasonal heat transfer is good engineering practice to avoid this. ASHPs and GSHPs are best suited for low temperature heat networks, generally requiring boiler top-up if they are to be used on high temperature networks (and to cope with winter peak demand).

4.1.2.3 Solar thermal

Solar thermal technologies are well-suited for use in urban areas and widely used in many cities. It is a mature and commercially available system. Solar thermal technologies continue to evolve in terms of improved performance, lower costs, greater flexibility and lower deployment costs.

The main applications in the UK are for heating domestic hot water (DHW). Other uses are possible but the limited yield normally makes it more suitable to focus on a single specific use. Commercial solar water heating technologies are mature and there are no fundamental technical issues remaining – however since each installation is unique, technical competence in system design, specification, construction and support is essential. In the UK, winter performance can be significantly reduced versus summer levels.

Solar thermal might be compatible with a low temperature heat network powered by heat pumps or boilers, but it would be less compatible with a CHP engine, since the solar thermal contributions would reduce the running time of the CHP or would mean a smaller engine was specified.

4.1.2.4 Energy from waste

As part of the West London Waste Plan, a possible energy from waste (EfW) plant is being considered at the Western International Market site in Hounslow, almost adjacent to the Southall opportunity area. The opportunity would exist to take off heat from this plant (the nature of which is unknown at this stage), and distribute it to consumers via a heat network. It can be noted that heat offtake from an EfW plant reduces the amount of electricity it can produce.

The timescales of demand phasing for the Southall DE scheme do not lend themselves to the EfW solution in the short run. However, as development of the waste site progresses it may be possible to assess the potential for its integration into the network at a later phase, so negating the need to install future CHP or boiler plant.

A noted risk of this solution was the need for the network to cross the canal.

In previous high-level studies, the Lakeside EfW facility to the west of Heathrow Airport was suggested as a potential supply source. This was not considered in detail for this study. The plant is approximately 8.5 miles from a connection to the Southall Network; ignoring the costs associated with crossing the M25 and a number of major roads, pipework to cover this distance alone would cost in excess of £10 million. It is also noted that the Lakeside site is within the boundaries of the proposed Heathrow Airport third runway.

4.1.2.5 Gas let-down generator

An existing gas let-down station is located on the Gas Works site, serving as a bridge between the high and low pressure transmission and distribution networks. The process of reducing gas pressure can be harnessed to generate electricity (via a turbo-expander), but requires heat to be provided to prevent the gas becoming too cold for onward distribution. A previous proposal for the Gas Works site's energy strategy considered burning biofuels in a CHP engine to reheat the gas, producing electricity and excess heat for supply to the district heating network.

However, the air quality implications and fuel transport requirements for the site led to planning permission being refused; this option was not considered further therefore.

4.2 The Southall energy supply solution

While ultimately a number of energy supply solutions are suitable for the network, the advanced planning stage of the St James site and other key developments in the area serve to limit the options.

St James, having already committed to a very large energy centre and substantial on-site network, presents the most appropriate location for an energy centre to serve the area-wide network. With over 60% of total loads on full network build-out, it is most economical to locate the heat generation close to this "centre of heat mass", and economies of scale in heat generation assets lend themselves to a single supply point.

As already indicated in Table 1 and Figure 5, timelines are tight for a number of the developments, and decision points are fast approaching regarding supply options and the delivery of these. St James is already in the process of discharging planning conditions. To secure a scheme beyond that already committed to by St James is very likely to require proceeding with their solution and available infrastructure, and engaging with the developer for any additional energy centre space / pipe capacity that might be required.

Arup analysis suggests that the plant required to supply all future heat loads in the core scheme (including those in the Southall West site) can be housed in an energy centre with a total area of 600 m^2 (Appendix 4). This implies that St James would not be required make additional investments in plant room space to locate an area-wide energy centre. This is somewhat due to economies of scale, but also the result of switching from a large biomass boiler, small CHP engine, and gas back-up supply solution (as per the original St James proposals) to a CHP and gas boiler-only solution, which is what this study proposes.

The CHP + gas boiler solution takes up less plant room space than a biomass boiler + CHP + gas boiler solution. In addition, it fits into St James' planned energy centre area even when it is sized to supply heat to the wider area network. It is understood that St James is in process of preparing a Section 73 application for the site, which may include proposals for a different energy solution. Once details of this emerge, it will be possible to revisit the above analysis.

It is suggested that, subject to planning consent, by enabling the wider roll-out of low-carbon heat in Southall, the requirement for biomass could be avoided, thus saving significant space and enabling the use of larger, more efficient gas engines. It is also understood that there are concerns around air quality in the area in relation to the use of biomass-based fuels, in addition to the traffic impact of regular biomass deliveries.

The network routing and techno-economic modelling that follow this section are based on the assumption that the energy centre is housed just east of the existing gasholder on the Gasworks site. Discussions with St James indicate this to be the likely location of their own energy centre.

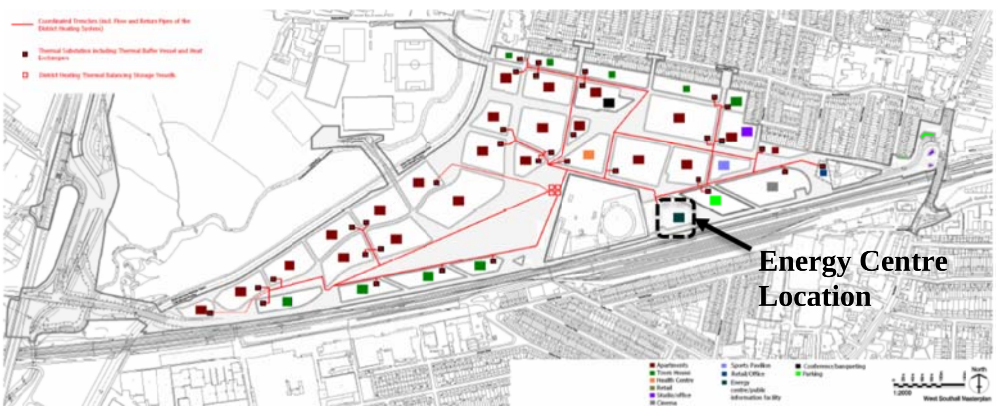


Figure 10. Gasworks Site Heat Distribution Network (From: WYG Engineering (2009), "Appendix 3: Indicative Only District Heat and Power Centres and Networks, Addendum to the West Southall Masterplan Energy Strategy")

4.3 Future low carbon solutions

The typical of life of a CHP engine is around 10-15 years, so if the Southall network were rolled out over the next five years, the first cycle of major plant replacement would occur around 2030. Based on DECC projections of grid carbon intensity, it could be necessary to introduce new sources of generation to continue to achieve a lower carbon network than the alternative of grid electricity and gas boilers.

The focus of this study has been on identifying a commercially viable delivery strategy to initiate a decentralised energy network in Southall; a CHP-led solution achieves this while also providing carbon savings against the business as usual case. In addition to grid decarbonisation, technological development and scaling up of production of alternative heat supply systems over the next 10-15 years will present a different set of commercial and carbon choices in the 2030s than are currently available today. The value of investing in a district heating network today in Southall is to create a heat supply infrastructure which will widen the choices available to decision makers at that time and enable supply switching to take place on a system wide scale.

Recommendations for “future proofing” the network to allow for that supply switch in the 2030s are identified in Section 8, Risk Assessment.

5 Network Routing

This section summarises the key issues concerning the routing of the district heating network.

The core scheme is to link a proposed Energy Centre at Southall West with defined heat load locations with heating pipes (flow and return). The scheme serves heat loads either side of the A3005 (South Road), which runs north-south through Southall with the proposed Energy Centre located at the Gasworks site.

5.1 Crossing the Great Western Railway

Crossing the Great Western railway to access the heat loads to the south is viewed as the single greatest infrastructure challenge and risk to delivery of the scheme. We note that the likely filled weight of the two pipes (one flow, one return) alone (excluding any necessary sleeving or fixings) is of the order of 500 kg/m.

A number of options for crossing the railway have been considered. If crossing over the railway, the options exist to build a new free-standing structure to carry the heat pipes, or to make use of existing crossings at the South Road bridge or the nearby pedestrian crossing, as per Figure 11 below.

Figure 11. Relative location of Great Western Railway crossing points (Options 1 to 4).

Options for this crossing are listed below:

1) Cross within the road bridge taking the A3005 over the rail tracks.
2) Cross attached to the road bridge taking the A3005 over the rail tracks
3) Cross attached to replacement pedestrian bridge over the rail tracks
4) Cross under the rail tracks through existing culvert/passage
5) Install new crossing under or over the rail tracks.

Of the above, Option 1 offers by far the least amount of complications, since the work could be carried out without having to take account of train movements, provided the excavations did not risk damage to the main structure of the bridge.

However, it is understood that the road bridge is to be rebuilt in the near- to mid-term, to meet the needs of a regenerated Southall. Should the pipes be installed before this redevelopment, this would lead to significant abortive and additional costs, as they would need to be removed and later re-installed in line with the new design. Heat supply would also be interrupted. Hence, it would appear appropriate to refrain from crossing the railway until the bridge was rebuilt, which represents a phasing risk for the scheme if this date is not aligned with developments south of the railway. Current discussions with the Council indicate likely delivery for the widening works happening around summer 2017 to the end of 2018, in preparation for commencement of Crossrail services in 2019.

Options 2 and 3 would require structural detailing for the fixings and an engineered transition between underground and aerial installation. The benefits of carrying the pipes across the railway with the widened deck are that the load increase due to the pipes is small in comparison with the new part of the deck and so does not add significantly to the superstructure cost (apart from the brackets). In addition, such a method of carrying pipes under road bridges is common and there is the opportunity here to combine this activity in line with the works of others, i.e. the contractor carrying out the bridge extension work could also fit the pipes.

On the other hand, in the case of the pedestrian bridge, it is likely that considerable extra structural reinforcement would be necessary to enable the large

spans (as visible in Figure 12) to take the additional weight of water filled pipes.

Figure 12. View of pedestrian crossing from Southall Station. Source: Hyder[13] (Option 3).

It is noted that works to the road bridge and eastern pedestrian bridge are already looking to take advantage of a number of upcoming possessions, so any network crossing construction should aim to capitalise on these as well.

With regard to Option 4, a potentially suitable culvert has been identified to the west of the energy centre, as per Figure 13. However, analysis of the pipe route necessary to make use of this crossing indicates highly unsatisfactory economics due to the increased length of pipe necessary, and the inability to pick up significant additional viable heat loads along the way.

[13] Hyder, December 2014. London Borough of Ealing Southall Railway and Pedestrian Cycle Bridge. *Draft for comment.*

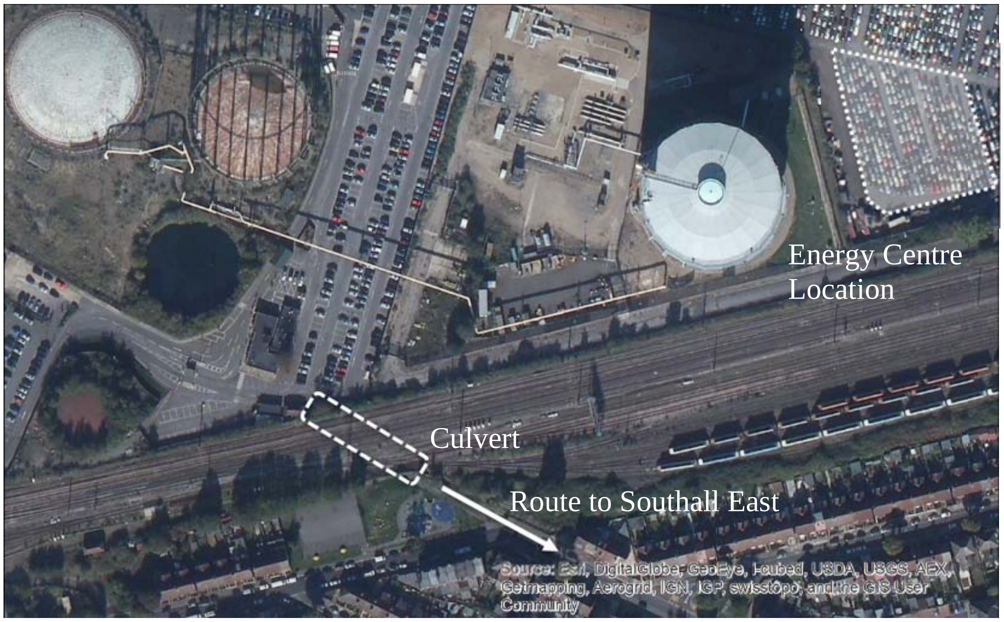


Figure 13. Location of potential below-railway crossing (Option 4)

Option 5, a standalone crossing of the railway, would be a significant undertaking and should be investigated especially if there are plans by other parties to install culverts/passages under the railway. It is understood that St James are planning a diversion of the medium-pressure gas main that crosses at the South Road bridge, and intend to tunnel beneath the railway. Preliminary discussions with St James suggest insufficient space within the proposed bore to co-locate the heat pipes, and a lack of appetite for over-sizing this infrastructure. The option of auguring beneath the railway from an installation shaft on one side of the railway (with a reception shaft the other side) and passing the pipes through the bore requires land for the shafts and has approvals risks, as well as the highest likely costs of any of the considered options.

Option 1, keeping the works within the public highway, is viewed as the least risky and costly undertaking. Further engagement with the Council and St James, who are undertaking studies into the widening of the bridge’s eastern and western elevations respectively, would be required to ensure that appropriate allowances are made within the widening works for pipes.

All options require significant engagement with Network Rail. The lengthy consultation process again points towards a crossing within the bridge being the preferable solution. Exploratory discussions with Network Rail have been initiated by Arup. Appendix A3 provides more information on factors affecting the feasibility of different railway crossing options.

The crossing of the rail tracks is not required according to programme until 2017 so there is some time to consider options and then implement the chosen one. It may even be possible to postpone the crossing until after 2017, if the pipeline is attached to the road bridge. In the case of a later crossing, a temporary energy solution can be achieved within one of the early Southall East area sites. This is discussed further in Section 5.2.

Current cost assumptions for the purpose of modelling presented below assume the pipes are laid within the existing road bridge.

5.2 Phased build-out of the network

The first connected developments to be completed are in the Southall East area in 2017. The Southall East site dominates the total heat load split of the scheme during the first three years and eventually taken over by the developments at the Gasworks site which has a relatively wider phasing spread. The full build-out of loads in the core scheme occurs in 2043 with the completion of last phase at the Gasworks site. The phasing schedule of the transmission pipeline illustrated in Figure 14 reflects the first connection years of the sites in the network,

Figure 14 also reflects the diameters of the transmission pipe branches and the approximate thermal losses in each branch. The network flow temperature and soil temperature assumptions are given in the Appendix 8.

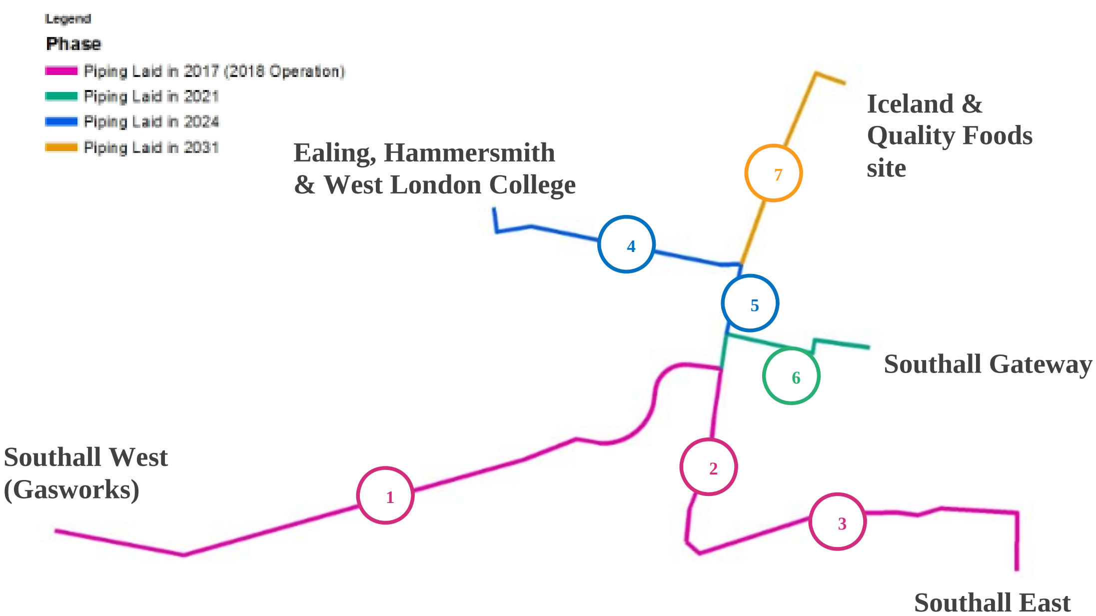


Figure 14. Phased build-out of the transmission network

The pipeline is modelled both on transmission and distribution network based on the spatial layout of the connected heat loads. The transmission pipeline connects the sites and distribution pipelines run within the sites. The main transmission pipeline runs between the Gasworks and Southall East sites, crossing the Great Western railway.

Table 7. Diameter and heat loss details for the transmission branches

Transmission Brach Number	Diameter (mm)	Heat Loss* (W/m)
1	200mm	37 W/m
2	160mm	24 W/m
3	160mm	24 W/m
4	70mm	19 W/m
5	180mm	24 W/m
6	160mm	24 W/m
7	50mm	19 W/m

**Estimated based on 10°C average soil temperature and 80°C flow temperature through insulated pipes*

5.2.1 Phasing considerations

Construction of transmission and distribution pipelines is assumed to precede the phasing of the related developments by a year. Thereby, one-year construction periods are allowed for the distribution pipes to be ready for connection to the secondary heat systems at the dates of development phase completion.

South Bridge crossing

Widening works to the eastern elevation of South Bridge are expected to commence immediately after works on the new Crossrail station are completed circa summer 2016. The indicative finish date for widening works to the eastern elevation is end 2016[14].

On the western elevation, the required diversion of the gas main places a time constraint on works. The works, which include a physical widening of the bridge (and hence good opportunity to make use of newly added free space) are therefore expected to occur between summer 2017 and end 2018. Given the existing utilities in the eastern elevation are unlikely to be relocated, it may be preferable to wait to take advantage of the works to the western elevation. Therefore, heat supply to Southall East might not be available until end 2018, which is up to a year after some of the earliest loads are anticipated to come online.

Pedestrian bridge crossing

It is currently anticipated that the new pedestrian and cycle bridge will, subject to securing funding in Q1 2015/16, be delivered by Q3 2016/17. This timing is therefore more favourable than that for the South Bridge crossing, although the additional cost considerations will likely prove a more important factor.

This option would have to accommodate the bridge being lifted in in separate spans which could complicate pipe sleeving and connections, especially given that access to the pipes is extremely difficult once the bridge is lifted into position.

[14] Parsons Brinkerhoff, 2014. South Road Overbridge East Elevation Widening Engineering Feasibility Report.

Due consideration must be given to the associated cost of approvals, agreements, contractual issues associated with the integration of the pipes to other proposed structures. This process would be lengthy and costly and would have to be accounted for accordingly in costs and time.

Junction improvements

As part of wider plans in the Southall area, junction improvement works are planned for the Beaconsfield Road and Merrick Road junctions with South Road. These works are currently expected to be delivered in 2017, and present an opportunity to minimise disruption and overall costs.

Temporary heat provision

Particularly in the case of a slightly delayed delivery of a crossing at South Bridge, it may be necessary to provide a temporary heating solution to the early heat loads in Southall East.

Supplier quotes indicate annual rental costs of temporary gas boiler solutions of up to £24,000 per year for early-phase heat loads. These have been factored into the techno-economic modelling. Such boilers would have similar performance (efficiency, emissions etc.) to the permanent boilers.

More importantly, it will likely be necessary for the Council as scheme promoter to engage with these early heat loads and assist in the procurement of an ESCo before their go-live date to ensure the opportunity is not missed. If the developers are forced to procure their own solutions this will greatly reduce the likelihood of them connecting to a wider network.

5.3 The Crescent

The current alignment of The Crescent is not favourable for network routing (see Appendix A3). However, it is noted that the reconfiguring of The Crescent in preparation for developments at Southall West is likely to make the pipe turn to the road bridge feasible, as there will be the rare opportunity to re-route all buried utilities. Nevertheless, the route has been modelled assuming a run north through Randolph Road to the west of The Crescent to reflect the current situation and allow for an extra cost contingency.

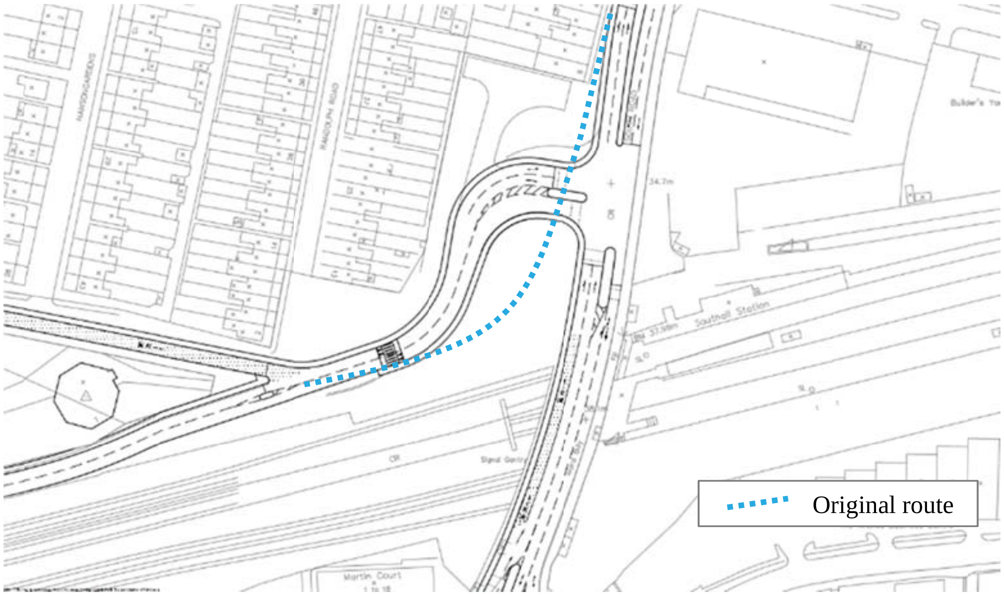


Figure 15. Proposed re-routing of The Crescent. *Based on: SBA, 2008, Drawing 52212/B/35*.

5.4 Costing

Pipework costs account for the pairs of flow and return transmission and distribution pipes, plus the cost of trenching, installation, fitting, and burying in the varying ground conditions. The pipe diameters are sized to allow for the flow rates required to cover the connected peak heat loads with additional heat losses throughout the network. The route is indicated in Figure 14.

The main transmission line between the Southall West and Southall East sites represents around 44% of the up-front capital investment requirements for the area-wide heat network. Distribution pipework costs and the associated connections and HIU costs are spread out across the development phasing of all five connected sites.

Except for the case of the Gasworks site where the Energy Centre is expected to be located, our working assumption for the scheme economic analysis is that the area-wide ESCo will take the network to the development site boundaries and from there onwards, the developers will be responsible from laying the distribution pipelines and the secondary systems within their sites.

Costing of the distribution pipeline within the Gasworks site is accounted for in the techno-economic modelling, based on indicative routing presented in the St James masterplan. It is also used in the uplift analysis for a potential St James ESCo, illustrating the additional costs associated with up-sizing their pipework and Energy Centre for the area-wide network.

6 Scheme Technical Performance

This section highlights the technical performance of the core scheme, presenting the key technical information. The assessment of the core scheme was carried out for a 20-year project analysis period, with year 0 being 2015 and year 20 being 2035. It should be noted that the date of full build-out of heat demands on the scheme occurs after this date.

This whole-system assessment is carried out from the perspective of a single body responsible for financing, design, construction, operation, maintenance, revenue collection, and further expansion, to ensure that the overall viability of the scheme is confirmed.

6.1 Technical characteristics of scheme

Based on the supply options considerations informed by the development plans of St James at the Gasworks site, a district heating CHP solution is proposed in our feasibility analysis. CHP capacity is set to cover the baseload with an annual runtime of 5,000 hours while the combined gas boiler capacity has been set to meet the peak load, without CHP operation, plus an allowance for single boiler downtime. The criteria for CHP sizing is illustrated in Figure 15.

Including the primary and secondary network losses, the total heat load in the area-wide heat network reaches 30,500 MWh/year on full build-out in 2043 while the maximum peak capacity requirement is 9.8 MWth. CHP, gas boilers, and the energy centre that contains them have been sized based on the system demands. With an annual runtime of 5,000 hours for the baseload, total installed CHP covers just under half of the total heat load annually from 2019 onwards. The rest of the supply comes from the gas boilers as illustrated in Figure 17.

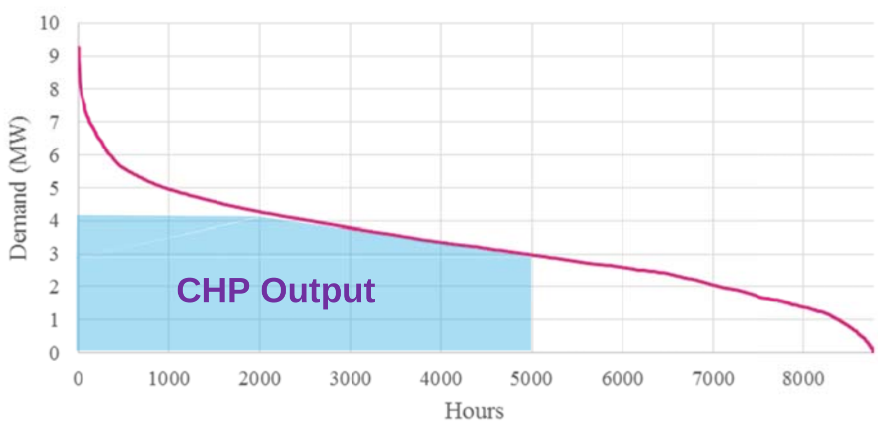


Figure 16. Demand duration curve at full build-out (2043)

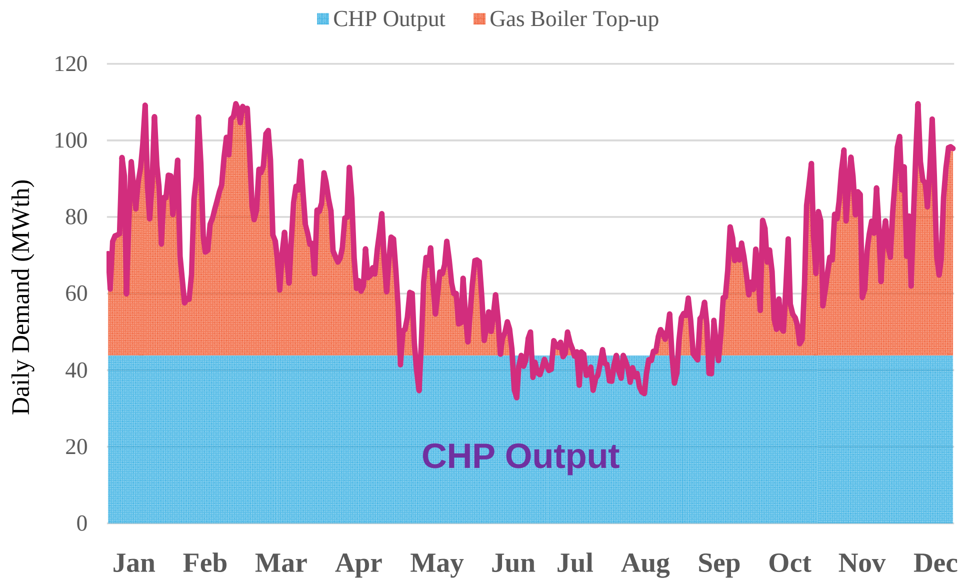


Figure 17. Daily heat demand curve at full build-out (2043) met by CHP and gas boilers

The capital investment for the installation of the first CHP unit and construction of the energy centre occurs during 2018 to start supplying heat in 2019 as the South Bridge construction is completed. Any additional investment for the gas boilers is programmed to occur during years when the peak demand increases.

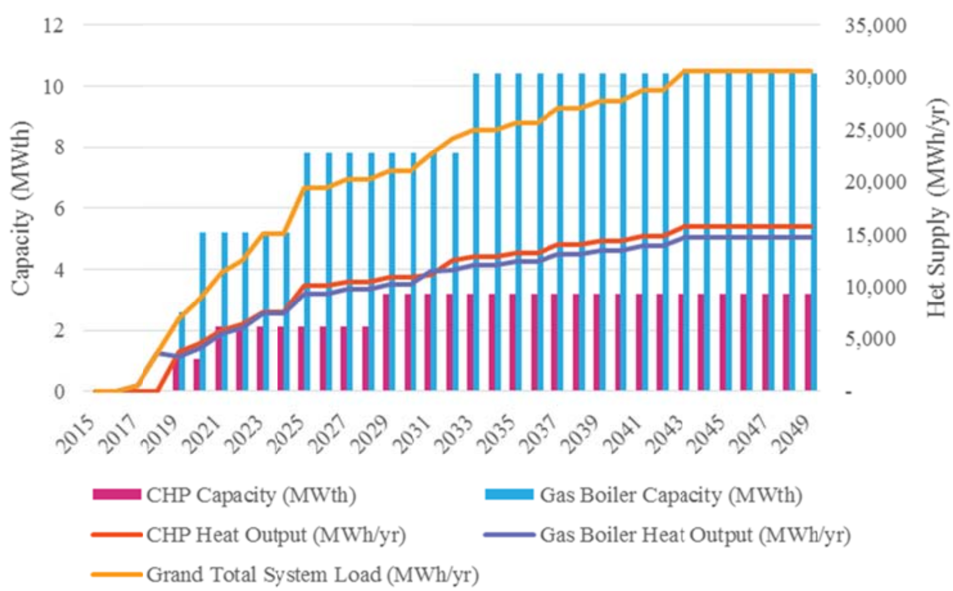


Figure 18. Installed capacity & heat supply of CHP engines and gas boilers

Together with the phased construction of the pipeline that is synchronised with the development phasing, this incremental strategy for the installation of the generation optimises the financial performance of the overall scheme at each step change on the demand as illustrated in Figure 18. At full build-out, the energy centre supplying the network houses three 1.07 MWth (1.04 MWe) CHP engines and four 2.6 MW gas boilers, including one back-up boiler. It is noted that even with the uplift required for an area-wide heat network, the energy centre area required at the Gasworks site is estimated at approximately 590 m^2, which is below the upper limit of 600 m^2 set out in the developer's original masterplan (Appendix A4).

6.2 Carbon performance of the scheme

Annual carbon savings are calculated based on today's electrical grid and gas mains carbon intensity. The district heating CHP with gas boilers solution is compared with the base case of distributed gas boilers. Figure 25 illustrates the upward trend in the annual savings as with the addition of CHP modules. Annual carbon emissions savings by the full build-out in 2043 would reach 2,300 tCO_2. Cumulative carbon savings throughout the 20-year analysis period is 28,200 tCO2.

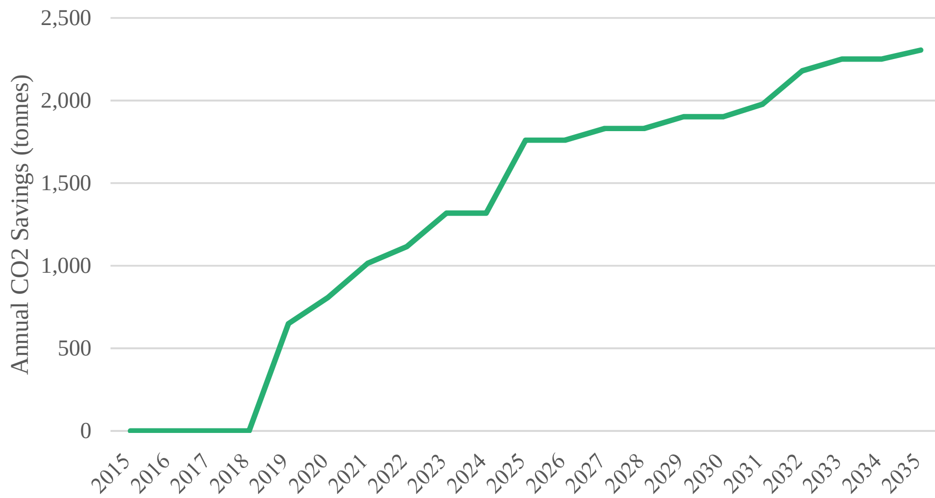


Figure 19. Annual carbon savings against the base case of distributed gas boilers

These savings represent potential value for developers who connect to the network: in addition to compliance with the energy hierarchy set out in London Plan policy 5.2, connection would help future developments achieve relevant CO_2 emissions reductions targets and avoid Allowable Solutions[15] payments following the introduction of the Building Regulations zero carbon standard (expected to occur in 2016).

Over the 30-year period used for Allowable Solutions calculations, the cumulative carbon savings compared to a baseline of individual gas boilers (53,800 tCO_2)

[15] DCLG (2014), "Next steps to zero carbon homes – Allowable Solutions" https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/327842/140626_Government_Response_to_Consultation_-_Next_Steps_to_Zero_Carbon_H__FINAL.pdf

would result in a total cost saving of £3.2M, when priced at £60/tCO_2 (the central price cap from Allowable Solutions which would apply to new buildings).

As noted in the Supply Options section, district heating CHP technology can be used now but it will become less suitable if the grid decarbonises in the future. With today's electricity grid factor (519 gCO2e/kWh) and mains gas factor (216 gCO2/kWh) based on SAP 2012 3-year projections, district heating CHP with back-up gas boilers reduce carbon emissions compared to counterfactual individual gas boilers if the CHP supplies more than 30% of the heat demand. In the modelled supply solution for this study, CHP supplies 57% of the heat demand (5,000 hours/year runtime) which corresponds to the aggregate baseload of the connected end-users.

In the future, based on SAP 2012 15-year projections for decreasing electricity grid factor (381 gCO2e/kWh) and increasing mains gas factor (222 gCO2/kWh), district heating CHP with back-up boilers will be only marginally reducing carbon emissions if the CHP runs long enough (min. 5,000 hours/year) based on future-proofing with adequate thermal store capacity and feasible heat demand profiles.

6.3 Commentary

The techno-economic performance of the core scheme promises a viable business case for a low-carbon Southall district heating solution. The 12.4% IRR over 20 years meets the hurdle rate set at 12% for private sector and thus yields a positive NPV.

It should be noted that some financial information underpinning the analysis and modelling has been omitted from this version of the report as it is commercially sensitive.

The identification of a feasible area-wide ESCo solution allows for the investigation of potentially more attractive business case propositions in various combinations of this general solution. These are presented in Section 8.

7 Commercial and Business Case Analysis

7.1 Network development conditions

The below list summarises the key conditions of network development that have arisen so far during the feasibility study. These strongly influence the delivery routes for a scheme.

1. A very large, residential-led development at the **Southall Gasworks** site is the majority heat load on the network by around 2021. The developer, **St James**, has already committed to providing DH heat to its buildings, supplied by a large energy centre.

   Through initial consultation, St James has indicated that it intends to retain control over the provision of heat to its tenants and leaseholders and has no significant interest in extending its heat network to serve heat demands in the wider area. Nevertheless, St. James indicated a willingness to discuss options with the Council for a wider network including oversizing its energy centre, securing a transmission route westwards to the edge of the site and coordinated procurement arrangements.

2. Developments to the east of the Gasworks site are expected to come forwards over the next 15 years in a piecemeal fashion, with the most promising sites being the **Southall East** group of developments and **Southall Gateway** redevelopment. Please refer to the Section 3.2 for the summary of stakeholder engagement.

   The developers of these smaller sites show limited appetite for hosting large energy centres, and are currently proceeding with plans for small-scale CHP-led on-site networks. However, through demonstration of overall project economic benefits or planning measures it is expected that these developments can be persuaded to commit to connect to a wider area heat network, should one emerge.

3. The above two conditions indicate the scheme has a likely heat “seller” and a number of potential buyers.

4. The techno-economic analysis has shown at a whole-system level that there is a workable scheme with economics that could satisfy the private sector. However, the above stakeholder considerations alone mean that that there are still barriers to delivery. Assuming it is committed to a strategic heat network going ahead in the area, there is a key role for the **Council** to play in addressing some of these barriers.

5. The uncertainties over the crossing of the Great Western railway mean that a scenario must be considered that the crossing happens after some early heat loads at Southall East are expected to come online. This would require an interim heat supply solution for these loads.

7.2 Commercial options

In very simple terms, the above conditions have led to the network configuration below in Figure 31, with a number of roles that must be filled by one or more parties, as indicated in Figure 32.

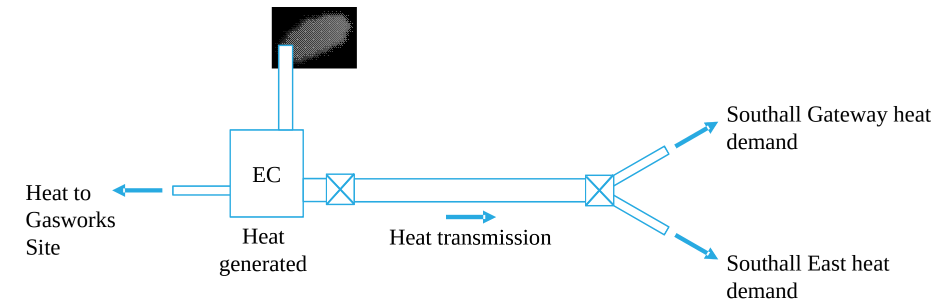


Figure 20. Heat flows. EC = Energy Centre

Figure 32 highlights the main roles that will need to be filled in providing heat to loads at the Gasworks, Southall Gateway, and Southall East. While each role is indicated as a separate "company", there is no reason why a single entity could not fulfil more than one, or indeed all roles.

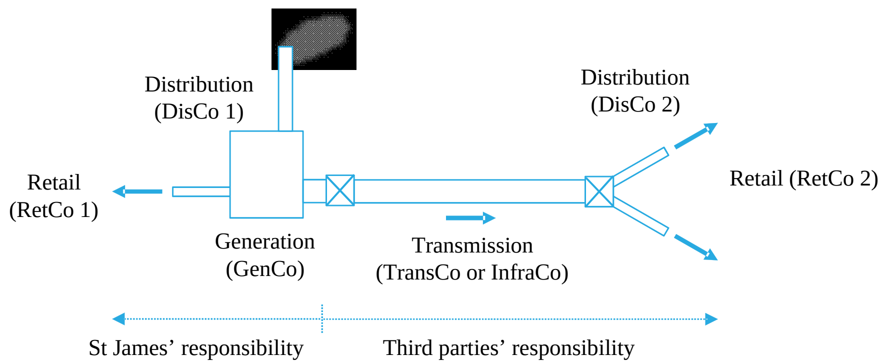


Figure 21. Key roles and responsibilities. "Co" = company.

At this stage it is assumed that St James will procure an entity (likely an Energy Services Company, or ESCo) to manage generation, distribution and retail of heat to the demands on its site. It could also finance the capital costs associated with installing the necessary infrastructure. This ESCo would therefore incorporate the three roles at the left of Figure 31 of DisCo 1, RetCo 1 and GenCo.

A TransCo would purchase heat from the energy centre and sell it to the development DisCos at a sufficient margin to make a suitable return on investment. In practice it might be more likely that the remaining roles on Figure 31 would be wrapped into a second ESCo – that is, TransCo, DisCo 2 and RetCo 2 – or else absorbed into the first ESCo.

An variation on that arrangement would be for the transmission pipe to be funded and owned by a company – called an InfraCo – which would not buy or sell heat but would only own the transmission pipework and receive a Transmission Use of System (TUoS) charge from the ESCo producing or buying heat at the energy centre and selling it to the developments. This would be equivalent to a toll bridge operation or to National Grid's role in the national electricity market.

This role may be particularly appropriate for the Council, since it gives certainty of delivery to a critical risk item in the network while also avoiding the risks associated with heat sales (e.g. billing and metering costs, performance risk and customer credit risk).

7.3 Delivery options

Following the analysis described above and discussion with Council officers, we have identified three plausible options for the role of the Council in the delivery of the Southall heat network, with two sub-options in each case for the ESCo structure. These options and sub-options are shown in Table 12.

Table 8. Council role and ESCo structure options for Southall network

Council Role Option	**ESCo structure options**	
	A: Single ESCo	**B: Split ESCos**
Option 1: Council acts as Promoter	• "Southall ESCo" supplies all sites and operates energy centre.	• "Southall West ESCo" serves Southall West development and operates energy centre. • "Rest of Southall ESCo" buys heat from Southall West ESCo" and supplies all other sites.
Option 2: The council acts as Promoter and the InfraCo	• "InfraCo SPV" pays for and owns transmission pipe. • "Southall ESCo" supplies all sites and operates energy centre, and pays TUoS charges to InfraCo SPV."	• "InfraCo SPV" pays for and owns transmission pipe. • "Southall West ESCo" serves Southall West development and operates energy centre. • "Rest of Southall ESCo" buys heat from "Southall West ESCo", supplies all other sites, and pays TUoS charges to "InfraCo SPV."
Option 3: The council exercises only its planning function	Same as Option 1	Same as Option 1

These options are represented graphically in Figure 33 below, and described in more detail in Sections 7.3.1, 7.3.2 and 7.3.3.

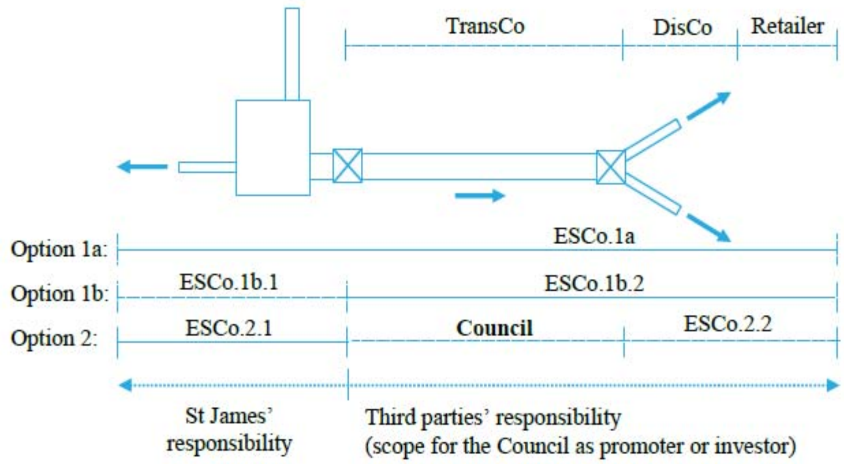


Figure 33. Potential delivery roles for the Council.

7.3.1 Delivery option 1: Council as Promoter

There is a strong case for the Council to act as a "promoter" of an area-wide heat network.

Acting as promoter would see the Council invest staff resources and spending on consultants in bringing together and aligning the interests of the stakeholders in this scheme, as well as it using its planning levers, to ensure that a coherent network was delivered. The majority of this investment would be spent in this pre-development promotional phase, and would cover the items highlighted in Figure 34 below.

The Council's role in procurement would depend on the ESCo structure. In a single ESCo structure, it might be expected that the ESCo is procured by St. James but with active involvement of the Council to represent the interests of other landowners and developers who would be served by the network. The Council might also provide a bond or guarantee to cover the additional cost to St. James (or its ESCo) for oversizing the energy centre (if any oversizing would be needed) and laying transmission pipe to the eastern end of the site.

Such a guarantee would expire once the ESCo secured a heat connection agreement with a third party site. Like any insurance policy, the cost of such a bond would be a risk-adjusted fraction of the total cost of the abortive works. This is discussed further in Section A4.

In a split ESCo arrangement, the Council would undertake the procurement of the second ESCO ("Rest of Southall ESCo" in Table 12), but would not be a party to the eventual contracts to supply heat to the customers on the other sites. This second ESCo would handle the design and construction of the transmission pipe, the purchase of heat from the St James ESCo, the retail of this heat to Southall Gateway and Southall East customers, and ongoing operation and maintenance.

It is important to note that, in this option, the Council would not be providing any direct capital investment in this scenario. It would instead provide the resources and assistance to procure the necessary services on behalf of all stakeholders, and potentially provide a guarantee to cover the extra cost of enabling the future network beyond the Southall West site.

The main benefit for the Council would be the fruition of the district heat network in their area through a procurement of an ESCo, providing low-cost and low-carbon heat to the residents compared to the business-as-usual case of individual gas boilers.

Option 1a business case evaluation

In Option 1a, the ESCo procured by St James for the Gasworks site (labelled as ESCo 1a) extends its investment beyond the site boundary and evolve to become the area-wide ESCo, identical to the scenario described and analysed in Section 6.

Alternatively, as in Option 1b, it may choose to limit its operation to the Gasworks site for the possible reasons of maximising its revenues or minimising its risk, or any combination of these. ESCo 1.b.1 (Southall West ESCo) represents such a down-sized business that still owns and operates the generation assets and energy centre up-sized for the area-wide network.

Option 1b business case evaluation

Option 1b would require the procurement of an eventual “Rest-of-Southall ESCo” (labelled as ESCo 1.b.2) to invest in the transmission pipeline from the Gasworks boundary onwards and to serve the other connected sites. Thereby, Option 1b introduces an extra transaction interface to the commercial system described in Section 5 at which ESCo 1.b.1 sells bulk heat to ESCo 1.b.2.

This transaction represents a revenue for ESCo 1.b.1 at a £/MWh price, with a mark-up on their heat price that ESCo 1.b.2 pays in return for not incurring any of the up-stream capital and operational costs associated with the generation assets and energy centre as well as any of the commodity costs that ESCo 1.b.1 pays for.

In this cascading arrangement, the bulk heat price is the key control variable to make one ESCo better or worse off relative to the other ESCo in Option 1b. That said, the overall objective is to provide commercially attractive returns both to ESCo 1.b.1 and ESCo 1.b.2.

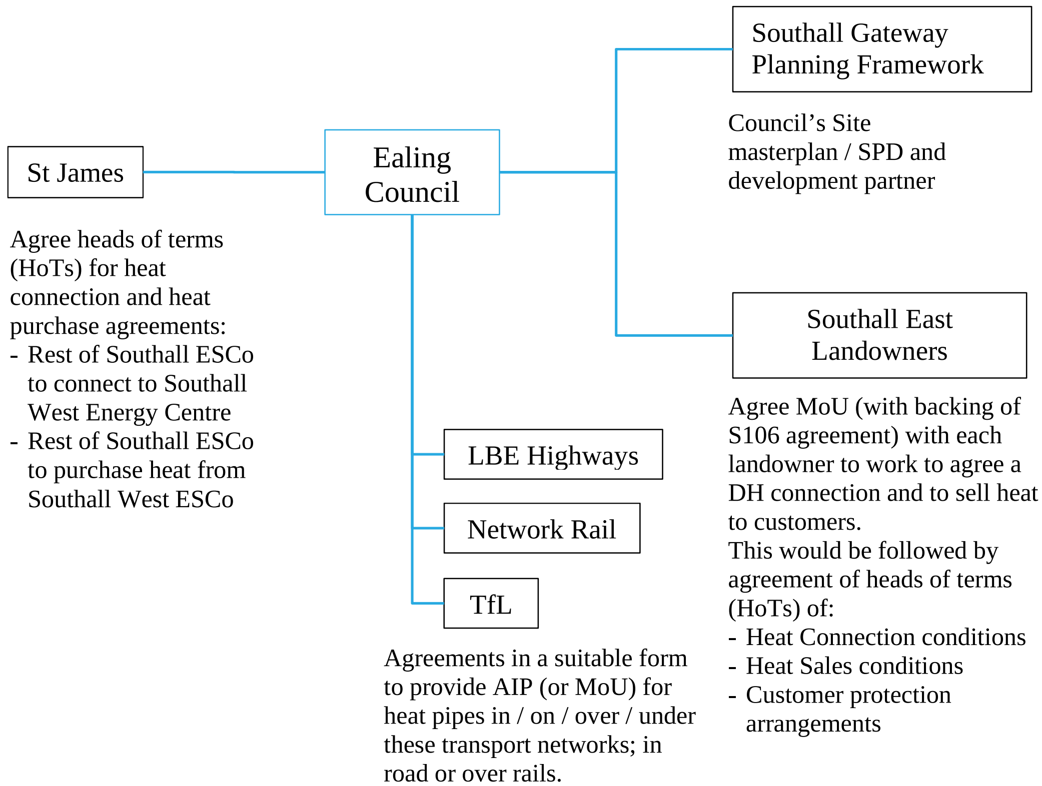


Figure 22. Stakeholders that the Council would be coordinating under a promoter role

7.3.2 Delivery option 2: Council Promoter & Infraco

In this delivery option the Council begins with the same promoter activities as in Option 1. However, it goes further by supplying the investment capital and taking ownership of the main pipe network assets. This may be triggered by a failure to secure a willing bidder for the whole of the "Southall ESCo" opportunity or by a recognition from the start that the investment opportunity is attractive to the council in terms of its risk-reward profile and wider economic and social business case.

Under this scenario the Council would procure a contractor to design and construct the pipe. This could be the ESCo already appointed to build the rest of the network, or a separate contractor. In the latter case the pipe would need to meet design and performance standards to be agreed with the ESCo (or, if not in place, with the body which will procure the ESCo).

If the Council decides to pay for and owns transmission pipe, an SPV would be set up within the Council. This SPV can take on the role of an InfraCo, being remunerated through an annual Transmission use of system (TUoS) charge paid by the ESCo(s) delivering a district heating service to their end-users using the infrastructure provided to them by the Council.

Alternatively, instead of receiving a constant annual TUoS revenue that is independent of the heat demand, the Council can also take on a more hands-on role of a TransCo, buying heat from the St James EC and selling it with a margin to the other sites.

The relative profitability of these options depend on the fixed annual TUoS changed as an InfraCo and the margin on the heat price that can be charged as a TransCo to the ESCo(s). The TransCo business model has a higher demand and market risk as it receives varying revenues based on the heat demand of the end-users and the price of heat negotiated between the InfraCo and the ESCo.

Should the Council decides to invest in the network, the proposed role for the Council as an InfraCo has been modelled in this study.

In this option, the Council itself takes advantage of its low cost of capital to procure the design and construction of the transmission pipe between the St James energy centre and the heat customers at Southall East and Southall Gateway. It then retains ownership of the transmission pipework, receiving income in the form of an appropriate transmission use of service (TUoS) charge from the ESCo that is procured as before (InfraCo solution), or by buying heat from the St James EC and selling it with a margin to the other sites (TransCo solution). This ESCo now has reduced responsibilities compared to Option 1b, but is not required to take as great a risk in the initial pipework investment.

In both options, it is possible that the eventual ESCo is the same ESCo that is operating the St James energy centre

Option 2 business case evaluation

As an alternative to the Southall ESCo and the cascading ESCo solutions represented in Options 1a and 1b respectively, the Council may take on the role of an InfraCo in addition to its role as a promoter in Option 2.

In Option 2, the ESCo procured by St James (now labelled as ESCo 2.1) still remains within the Gasworks site. By investing in the main transmission pipeline between Gasworks and Southall East sites, the Council would free the eventual down-stream ESCo (now labelled as ESCo 2.2) from this investment, taking advantage of its lower cost of capital. The incumbent advantages of ESCo 2.1 mean that it is likely that it would absorb the role of ESCo 2.2 as well. Both are likely to be under a Southall ESCo which is labelled as ESCo 2 from this point onwards, this simplification eliminates the need for a bulk heat transaction at the boundary of the Gasworks site.

In this scenario, the Council is remunerated through a transmission use of system (TUoS) charge, paid by ESCo 2. With the elimination of the bulk heat transaction, effectively the only other control variable is the split of the developer contributions. ESCo 1 has exclusivity over the developer contribution collections from St James site. On the down-stream side, the most favourable solution collectively for the Council and ESCo 2 is reached when Council is remunerated only by a fixed annual TUoS charge (as opposed to a variable £/MWh charge) and ESCo 2 collects the whole of developer connection charges from Non-St James sites.

Based on these commercial delivery structures and the key assumptions, Table 13 summarises the internal rate of return (IRR), net present value (NPV), and the simple payback period (PB) for all relevant parties in Options 1a, 1b, and 2.

Here and anywhere in this report, NPV is calculated as a discount rate of 12% for the ESCo and 6% for the Council, both over 20 years.

In Option 2, benefitting from its lower cost of capital, the Council invests in the network as the InfraCo which is worth £970k in 20 years with 6% discount rate. At a simple payback period of 7 years even under business-as-usual case, this option is also attractive considering the relatively short payback requirement of the Council. This can be brought forward to five years with a potential buy-out.

7.3.3 Delivery option 3: Council as planning authority

Option 3 represents the "do minimum" case, with the council taking no role beyond its statutory role as planning authority. In this case we would expect new developments to be required through planning conditions or Section 106 agreements to connect to a network if one is built[16]. We would not expect such a network to be built, unless evidence emerges that a third party exists which has both the means and the motive to promote and invest in a DH network.

7.3.4 Exit strategies for the Council

The three options described in the previous section lead to four potential exit options for the Council, which will be the subject of the subsequent analysis. These are displayed in Figure 39 below.

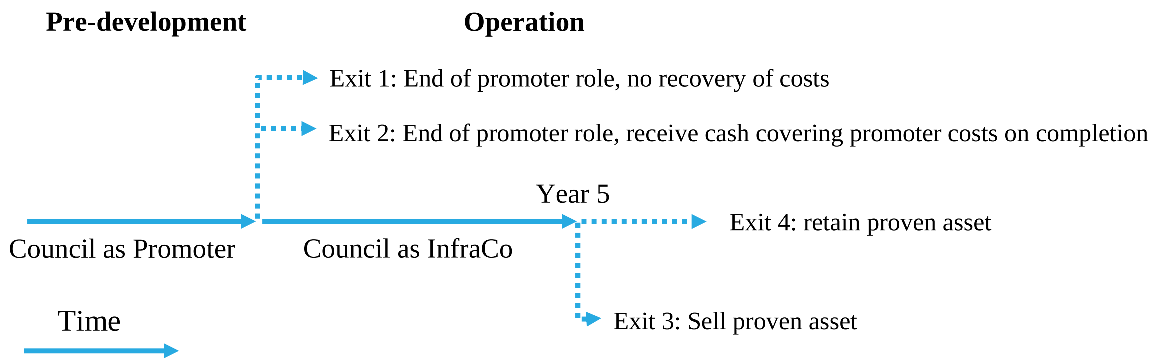


Figure 23. Potential exit routes for the Council

In Exit option 1, the council does not recover from the ESCo transaction the resource costs it sank into the scheme in its role as promoter. Depending on the Council's level of engagement, it might not be appropriate to expect such returns.

In Exit option 2, the Council would be repaid its costs of promotion upon financial close. This would be similar to a broker business model. If the Council played a significant role in achieving the transaction, it would be reasonable for it to expect to be paid a share of the value it created through that promotion role.

[16] The use of planning conditions and Section 106 agreements would need to comply with relevant statutory tests (e.g. CIL Regulations). Non-statutory guidance on their use for district heating can be found in the 2013 London Heat Network Manual (http://www.londonheatmap.org.uk/Content/uploaded/documents/DH_Manual_for_London_February_2013_v1.0.pdf) and the 2011 Decentralised Energy Masterplanning Manual (http://www.londonheatmap.org.uk/Content/uploaded/documents/EMP_Manual_lo.pdf)

In Exit option 3, the first opportunity for exit might come around year five of acting as InfraCo. Five years coincides with the Council's standard requirements for project payback periods, and the possible go-live date of the first phase of development at the Southall Gateway site. After this period, the Council would be in possession of a long-lived asset with reliable returns, and the prospect of these returns increasing further as more developments connected (in existing development areas but also more widely). The investment would, therefore, be substantially de-risked by year 5, making it more attractive to the long-term investment market (e.g. pension funds).

Alternatively, in Exit Option 4 the council could retain the asset continue to benefit from the ongoing revenues from the network into the future, and use its stake to influence further connections.

8 Risk Assessment

The risks highlighted and discussed in this section are those associated with the delivery of a DH scheme at Southall. Depending on the delivery route chosen by the Council, the risk register may be updated to more fully take into account the technical and financial risks.

8.1 Market-led scheme

The most apparent risk is the possibility of a market-led solution not being realised within the opportunity window. The time it takes to make a deal may hinder the expansion progress of the scheme or even jeopardise its existence. The responsibility falls onto the Council intervening as the broker. In order to mitigate this risk, the Council acts as the broker in the promotional phase to secure a deal in a timely manner. With no involvement from the Council, our judgement is that it is unlikely that a large-scale heat network (i.e. extending beyond Southall West) will emerge in the Southall area.

8.2 Coordination

Similarly, due to a lack of coordination, the network may not extend beyond Gasworks site. The return on investment in the short-term may not justify the first expansion of the scheme beyond the Gasworks site at commercial discount rates. In order to mitigate this risk, the Council may need to coordinate a multi-actor approach for the ownership and operation of critical assets. Please refer to the commercial delivery options elaborated on in Section 8.

8.3 Fragmented stakeholder landscape

The fragmented ownership structure of the Southall East site is a potential source of uncertainty with direct effects on the decision to cross the railway. And due to the additional cost and complications of a railroad crossing to access this site, a clear understanding of the stakeholders' intentions is necessary. The Council needs to coordinate the developers through its planning powers and its promoter / broker role. Through planning measures and MoUs, it is expected that these developments can be persuaded to commit to connect to a wider area heat network, should one emerge.

8.4 Developer contributions and connection charges

The financial viability of the scheme highly depends on developer contributions and connection charges. These are justified on the basis of the avoided cost of providing heat and carbon emissions reductions from other means. Should these contributions not be set at a suitable level, this could lead to unsatisfactory economics. Therefore the avoided cost value of connecting to the scheme needs to be effectively communicated. The avoided cost of providing heat from other means should take into account the planning requirements and building regulations regarding carbon compliance of new developments.

8.5 Ability to finance infrastructure

If the Council decides to invest in the main transmission pipeline, the availability of low-cost capital will be the main constraint and there may be a borrowing limit of the Council. If that is the case, the Council can sustain its promoter / broker role without actually investing in the infrastructure. Thereby, the Council would be aligning the interests of the stakeholders, procuring an ESCo and other appropriate parties during the pre-development phase.

8.6 Council commitment of resources

The experience of other schemes in the UK indicate that significant and sustained public sector involvement is normally necessary to deliver a district heating network. If the senior political commitment is not forthcoming to support officer action to promote the network (in either the Promoter or InfraCo + Promoter roles) then the Council’s role may be under resourced and the opportunity window may pass before a deal can be struck.

8.7 Future proofing a low carbon network

As noted in Section 4, the CHP-led solution for the Southall network provides net carbon savings today but would be unlikely to continue to do so by the 2030s. Therefore it would be necessary to implement a switch in the main heat source at the time of major plant replacement (expected to occur around 2030). Two key factors to consider in planning and design the network now to allow for that future switch are:

8.7.1 System operating temperatures

Designing the network, and the building heating systems which will connect to it, for lower flow temperatures will reduce losses in the network and enable more efficient capture of lower grade and secondary heat sources. The system has been conservatively modelled with a 20C flow and return temperature difference for a higher temperature conventional flow temperature of 80°C.

A lower flow temperature could be specified as part of the procurement of the contractor or the ESCo subject to the temperature difference remaining at 20°C. However, existing building systems (such as those in the College) will need to be taken into account, as they will likely require higher flow temperatures. For example, existing radiator systems operating at 82/71°C will have a reduced heat output at a lower supply temperature of 60°C.

We therefore recommend:

- The ESCo procurement specification incentivises the system design towards a lower flow temperature.
- The design of building heating systems to be connected take account of a lower temperature system such as through the use of underfloor heating.

8.7.2 Future energy centres

Some low carbon heating systems require greater land take than gas CHP engines, therefore a switch to a lower carbon supply in 2030 may necessitate the expansion of the existing energy centre or adding a second energy centre to the network. Alternatively, heat could be injected into the system through multiple heat sources (such as geothermal wells or multiple secondary heat sources).

In commercial terms, committing now to significant oversizing of the energy centre would erode the viability of the network, the eventual benefit of that investment would remain highly uncertain; other dispersed heat sources might obviate such oversizing or the improvement of building energy management and network management may enable the system to serve its customers with lower peak capacity than was provided at the start.

Given also that the original investment in the pipe network would by that time largely have been paid off, we would expect the commercial case for the additional capital cost of an energy centre to exist in 2030, particularly if the value of carbon has also increased.

We therefore recommend that energy centre oversizing for a future low carbon heat source is not included, but that planning for supply switching is explicitly planned into the ESCo’s business plan from around 2025.

9 Delivery Plan

This section provides an initial summary of the likely activities that could be required to be undertaken by Ealing Council in support of the successful promotion and delivery of a DH network at Southall. Activities are based on the currently understood position of the Council and the state of development at Southall, as described in the preceding sections. Estimates are indicative at this point in time.

9.1 Promotion phase activities

The “promotion” phase coves the activities necessary to bring the various stakeholders in a DH network at Southall together to secure commitment to delivery of, or connecting to the future network.

Many of these activities would need to commence almost immediately, but are not expected to take up a whole full-time equivalent (FTE) of officer time in the short term at least.

Where an activity includes phrases such as “negotiate with” or secure agreement”, this would include formal documentation of the agreement in a “Heads of Terms” or “Memorandum of Understanding.” These preliminary agreement documents would be followed at a later date by contractually binding documents appropriate to the particular context and purpose. The later documents might include:

- Section 106 agreement
- Heat Connection Agreements – there are emerging industry standard forms of such agreements but customisation would be needed for the Southall network.
- Heat Purchase Agreements
- Joint Venture or Development Partnership Agreement

10 Concluding Remarks

A core Southall scheme has been identified as feasible for a CHP-based district heating network providing low-carbon heat and hot water to five development sites: the Gasworks, Southall East, Southall Gateway, Iceland & Quality Foods, and Ealing, Hammersmith & West London College.

All but one of these loads are new developments with phased construction schedules that would be completed between 2017 and 2043. The total annual demand of these sites at full build-out would reach 24,000 MWh/year with the majority of the demand coming from the Gasworks site.

The network would consist of a transmission pipeline length of 1,500 m between the five sites and distribution pipeline of 3,600 m. Almost all of the costed distribution pipeline is in the Gasworks site, where the proposed energy centre would also be located. Bulk heat would be supplied to the other four sites.

This energy centre would house 1.07 MWth (1.04 MWe) CHP and four 2.6 MW gas boilers, including one back-up boiler. These would not be installed until 2018, a year in advance of the completion of the first phase of the Gasworks development and the South Bridge construction, with traditional boilers providing heat to Southall East in the interim period.

Even with the uplift required for an area-wide heat network, the energy centre area at the Gasworks site is approximately 590 m^2, below the upper limit set out in the developer's original masterplan and access to heat revenues from the wider core scheme outweigh the uplift costs associated with oversizing of generation assets and pipeline.

For the core Southall scheme, the initial CAPEX would be £7.1M and 20-year CAPEX would be £20.5M including the replacement of the generation assets and HIUs at the end of their useful lifetimes. The maximum OPEX would reach £0.9M at full build-out while the annual revenues reach £3.5M.

Calculations indicate that domestic heat could be delivered at 10% below current average prices paid by domestic gas consumers, aiding in efforts to combat fuel poverty. The scheme is most sensitive to residential developer contributions. The upfront gap funding requirement of £5.0M at a 12% discount rate can be covered by one-off developer contributions of £2,750 per dwelling. This is still lower than typical estimated avoided costs to developers.

While providing a relatively modest contribution to the total annual revenue at wholesale prices, the replaced grid electricity brings in significant benefits in terms of carbon savings. Based on the current carbon intensity of the grid, the scheme offers annual carbons savings 2,300 tCO_2 at full build-out compared to a counterfactual individual gas boilers.

Under the promoter/broker role of the Council, whether an area-wide ESCo evolves from the Gasworks site or a downstream ESCo operates the network from the boundary of the Gasworks site onwards, feasible solutions have been identified for all parties at private sector discount rate. If the Council decides to invest in the transmission pipeline between the Gasworks and Southall East sites, there are also feasible solutions identified for the ESCo while the Council is able to satisfy its payback requirements. All possible commercial delivery options are presented for the Council's consideration.

Finally, it should be reiterated that all figures presented in this report are based on a variety of technical and financial assumptions. We have sought in every case to obtain data and assumptions from reputable sources or otherwise to test the validity of our assumptions. Nevertheless, should one or more of these assumptions change, the outcomes in terms of technical and financial performance of the scheme and the businesses which would operate some or all of the system could change significantly.

Appendix A

Additional Supporting Information

A1 Demand Analysis

A1.1 Full list of demands considered in the immediate area

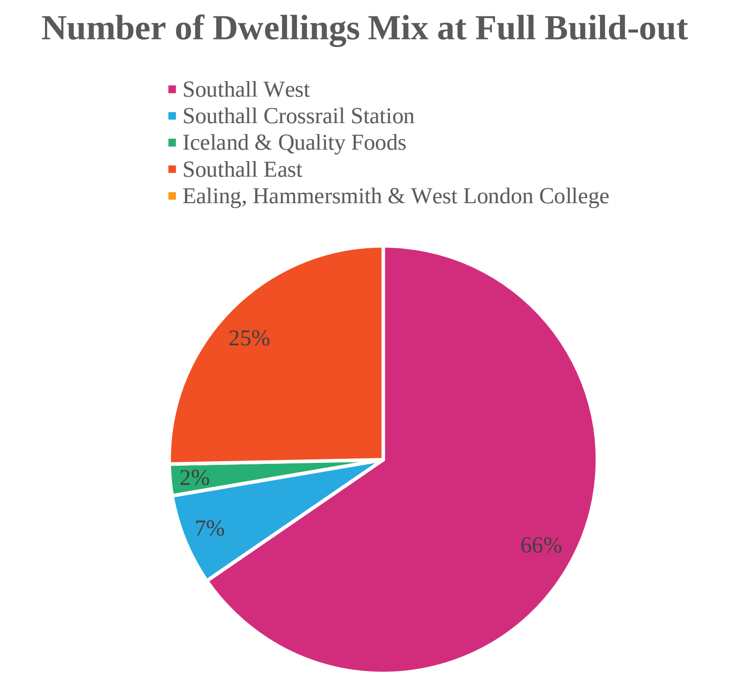
Connection Name	Type	Resi Units	Non-Resi GFA [m^2]	Total Heat Load [MWh/yr]	Potential First Connection Year	Actual[17] / Benchmark Data
Beaconsfield	New Residential	64	1,117	264	2017	Actual
Southall West (Gasworks)	New Mixed-use	3,800	42,589	15,745	2018	Benchmark
Southall Crossrail Station	New Mixed-use	400	3,210	1,497	2022	Benchmark
Southall Market	New Mixed-use	141	2,470	581	2032	Actual
Iceland & Quality Foods	New Mixed-use	138	2,411	641	2032	Actual
Villiers High School	Existing Education	-	N/A	1,397	2017	Actual
Southall Sports Centre	Existing Leisure	-	N/A	930	2017	Actual
Charter Court	Existing Residential	N/A	-	633	2017	Actual
North Primary School	Existing Education	-	N/A	317	2017	Actual
Grove House Children's Centre	Existing Education	-	N/A	96	2017	Actual
Southall Young Adults Centre	Existing Leisure	-	N/A	78	2017	Actual
Phoenix Social Club For Young People	Existing Leisure	-	N/A	49	2017	Actual
Southall Fire Station	Existing Public	-	N/A	191	2017	Actual
Phoenix House	Existing Residential	149	-	483	2017	Actual
Featherstone	Existing Residential	143	-	464	2017	Actual
Southall East	New Mixed-use	1.471	16,859	5,641	2017	Benchmark
Havelock Estate	New	728	-	2,364	2018	Benchmark

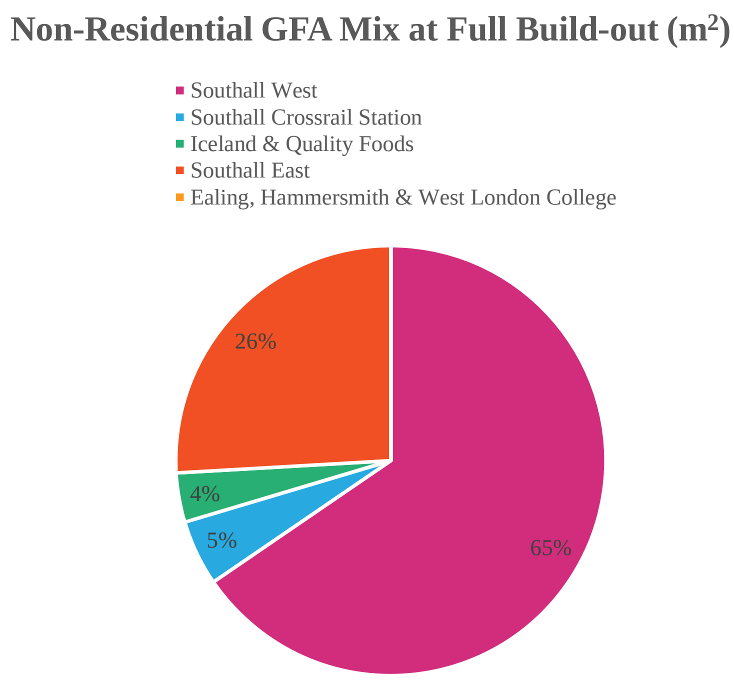
[17] Fuel consumption data converted to heat demand (in MWh/year) at 90% gas boiler efficiency assumed for the new building and 75% for the existing buildings.

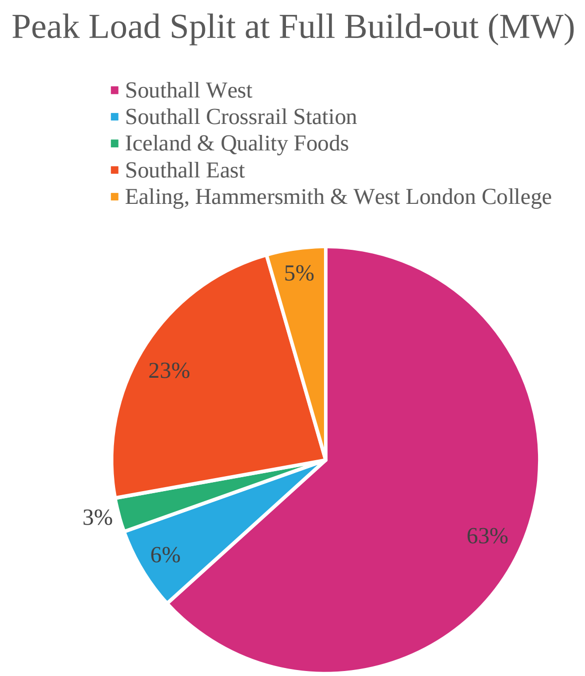
Connection Name	Type	Resi Units	Non-Resi GFA [m²]	Total Heat Load [MWh/yr]	Potential First Connection Year	Actual[17] / Benchmark Data
	Residential					
The Green	New Mixed-use	215	738	1,100	2032	Actual
Johnson St	New Mixed-use	156	2724	643	2032	Actual
Featherstone Road Health Clinic	Existing Hospital	-	N/A	2,514	2017	Actual
Harmony Lodge	Existing Residential	N/A	-	559	2017	Actual
St Anselms Catholic Primary School	Existing Education	-	N/A	363	2017	Actual
Dominion Arts Education Centre	Existing Education	-	N/A	304	2017	Actual
Southall Library	Existing Public	-	N/A	89	2017	Actual
Windmill Lane	Existing Residential		N/A	476	2017	Actual
Albert Dane Centre	Existing Leisure	-	N/A	130	2017	Actual
Waterside Health Centre	Existing Hospital	-	N/A	730	2017	Actual
Broadway Health Centre, Southall	Existing Hospital	-	N/A	164	2017	Actual
Southall North Community Offices (Hvs And Dns)	Existing Office	-	N/A	504	2017	Actual
Rutherford Tower	Existing Residential	N/A	-	335	2017	Actual
Dormers Wells Leisure Centre	Existing Leisure	-	N/A	1,672	2017	Actual
Tudor Primary School	Existing Education	-	N/A	320	2017	Actual
St John’s Church Hall And Bus Depot	New Warehouse	-	N/A	83	2017	Actual
Sybil Elgar School	New Education	-	N/A	739	2017	Actual
Havelock Primary School	Existing Education	-	N/A	204	2017	Actual

Connection Name	**Type**	**Resi Units**	**Non-Resi GFA [m^2]**	**Total Heat Load [MWh/yr]**	**Potential First Connection Year**	**Actual[17] / Benchmark Data**
Dairymead Meadow Primary School	Existing Education	-	N/A	138	2017	Actual
Featherstone Junior Mixed School	Existing Education	-	N/A	195	2017	Actual
Featherstone High School	Existing Education	-	N/A	1,077	2017	Actual
Hambrough First School	Existing Education	-	N/A	182	2017	Actual
Southall Town Hall	Existing Public	-	N/A	77	2017	Actual
Allenby Primary School	Existing Education	-	N/A	17	2017	Actual
Dormers Wells High School Redevelopment	New Education	-	N/A	1,552	2017	Actual
Ealing, Hammersmith & West London College	New Education	-	N/A	669	2025	Actual

A1.2 Demand mixes at full build-out

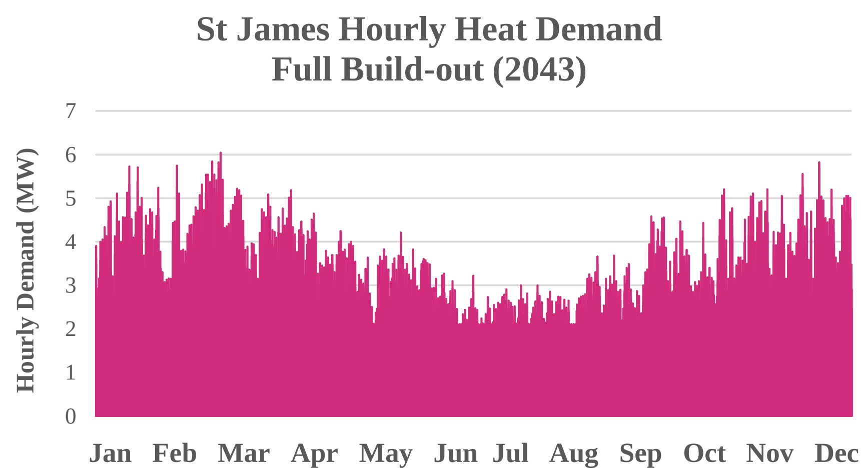


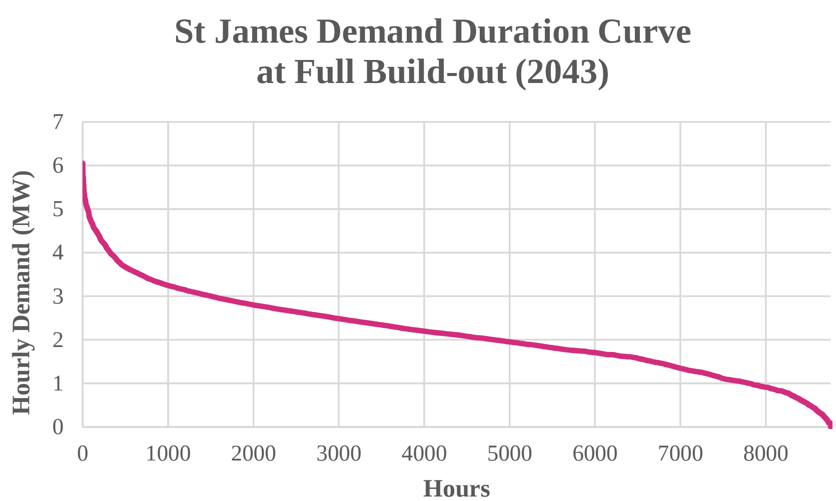


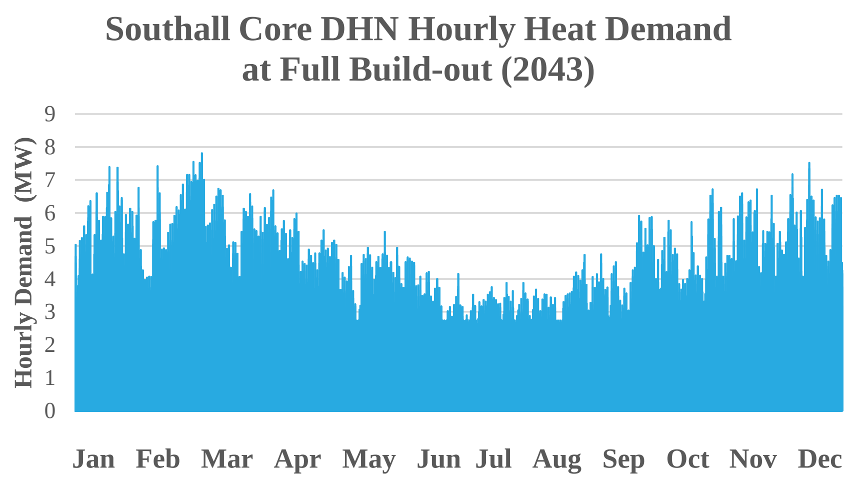

Peak Load Split at Full Build-out (MW)
Southall West
Southall Crossrail Station
Iceland & Quality Foods
Southall East
Ealing, Hammersmith & West London College
5%
23%
3%
6%
63%

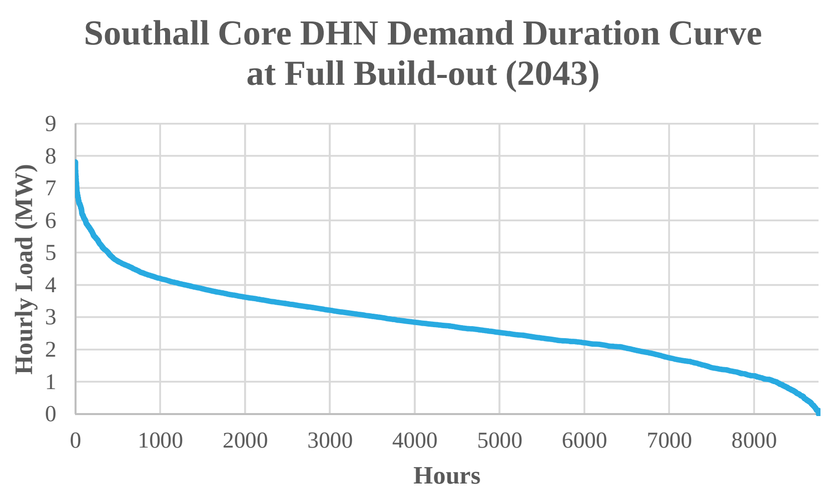

Heat Load Split at Full Build-out (MWh)
Southall West
Southall Crossrail Station
Iceland & Quality Foods
Southall East
Ealing, Hammersmith & West London College
3%
23%
3%
6%
65%

A1.3 Demand profiles






Southall Core DHN Hourly Heat Demand
at Full Build-out (2043)
Hourly Demand (MW)
0
1
2
3
4
5
6
7
8
9
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Southall Core DHN Demand Duration Curve
at Full Build-out (2043)
Hourly Load (MW)
0
1
2
3
4
5
6
7
8
9
0
1000
2000
3000
4000
5000
6000
7000
8000
Hours

A2 Supply Options

A2.1 Summary

This note gives an overview of initial considerations regarding energy, specifically heat, provision for a potential Decentralised Energy (DE) network in the Southall area. Every supply technology that has been considered is outlined with a brief description of its particulars, as well as notable commentary on its greenhouse gas emissions reduction potential, system resilience implications, and notable risks.

All options are able to provide heat to the area via a district heating network. As such, the focus is on analysing potential sources of supply for the energy centre.

The table below provides a brief summary of the options, their key features and whether they are suitable or unsuitable for consideration as a supply source for a DE network at Southall.

Apart from two options that have been rejected from the analysis due to their low likelihood of receiving planning permission, all options are considered to be technically feasible at this point, at least in some locations. Initial prioritisation is given below.

Table 9. Summary of heat supply options

Option	**Comments**	**Potential in a Decarbonising Grid**	**Preliminary Conclusion**
Gas			
Gas boilers	Ubiquitous, reliable, flexible, cheap, no carbon savings	Low	Secondary / top-up option
Gas CHP	Ubiquitous, reliable, cheap, modest carbon savings	Low	Shortlisted option
Gas CCHP	More complex but reliable, suitable where large cooling loads are present, modest carbon savings	Low	Option to keep in mind
Solid fuels including biomass and waste			
Biomass boilers	Reliable, requires storage and supply chain, low carbon	High	Option to keep in mind
Biomass CHP	Less common, requires storage and supply chain, air quality and transport concerns, less flexible, low carbon	High	Rejected
Energy from Waste	Suitable where residual waste supply is secure, low carbon	High	Option to keep in mind

Option	Comments	Potential in a Decarbonising Grid	Preliminary Conclusion
	in CHP mode, may be strongly opposed locally.		
Heat pumps			
Air source heat pumps	Reliable, flexible, low COP, low power density, lower output temperature, can be used for heat and cooling, modestly low carbon	High	Shortlisted option
Water source heat pumps	Similar to ASHP but with better COP, some challenges with installation	High	Shortlisted option
Ground source heat pumps	Similar to ASHP but with better COP, ground works can be challenging	High	Shortlisted option
Deep geothermal	Very good COP, very high capital costs, reliable	High	Option to keep in mind
Energy piles	Special form of GSHP, suitable where piled foundations are required	High	Option to keep in mind
Other options			
Anaerobic digestion	Low carbon, requires supply chain, requires significant space for operation, risks from odour and traffic	High	Rejected
Gas let-down station	Novel technology, suitable for site, previous proposal was refused	Low	Option to keep in mind
Solar thermal	Very low carbon, reliable, low yield	High	Shortlisted option

A2.2 Supply Options Evaluation

The following pages present an evaluation of the various supply options that show potential for a heat network at the Southall site. Options are grouped according to common characteristics, with a brief summary of the common themes. They have been colour coded according to their appropriateness for further investigation in this study, as shown in the key below.

Colour Code:

Investigate
Neutral – keep in mind
Do not proceed

Gas-based technologies: Gas delivered by pipeline, fossil fuel (GHGs), flexible, ubiquitous, reliable, currently cheap.

- Gas boilers
- Gas CHP
- Gas CCHP

Technology	Technology Description	Greenhouse Gas Reduction	Resilience Implications	Risk Review
Gas Boiler	Gas boilers provide top up and back up when deployed in conjunction with any other technology option discussed here. They are likely to offer the cheapest solution even with the subsidies available to the renewable alternatives discussed here.	Gas boilers are the most conventional solution for heating in the UK. They have higher carbon emissions compared to CHP. This technology can be used now but it will become less suitable if the grid decarbonises in the future.	Being a well-developed technology, gas boilers can offer resilience at low costs. They can be used in conjunction with a variety of primary heat supplies to provide top up and back up heat.	No significant risks.
Gas Combined Heat and Power and Gas Combined Cooling, Heat and Power	Combined heat and power (CHP) systems capture the heat released during the power generation process, resulting in increased energy efficiency. The heat to power ratio normally determines the size of the gas CHP unit that is viable for a given building or site load. The typical target for CHP engines are to ensure at least 5,000 running hours per annum (out of a total of 8,760 hours in a year). The economics of gas CHPs are most favourable in mixed land-use and high density developments. On a micro-generation level, gas CHP systems are usually not much more expensive than gas boilers, while the additional heating benefit they provide is an integral part of the building. Gas CHP systems are easy to install, use, and maintain. They use the same natural gas	A well-designed gas CHP can modestly reduce carbon emissions due to its higher efficiency compared to the alternative case of conventional gas boiler and grid electricity produced mostly by large distant “power only” power stations. As in the case of all other embedded generation options presented here, gas CHPs located close to the point of consumption eliminate electricity distribution losses and therefore reduce carbon emissions. It is important to consider, however, that in line with UK Climate Change Act targets (for an 80% reduction in national GHGs by 2050 vs. 1990 levels) grid electricity will need to almost completely decarbonise. In a decarbonised, or rapidly decarbonising, grid scenario, gas-fired CHP does not offer CO_2 savings over a boiler-only + grid electricity solution, resulting in lock-in of excess emissions until the end of the system’s	Gas CHPs and most of the other micro generators described here are usually designed for operation in conjunction with the electrical grid connection, contributing to the baseload of a building or site and thereby offering resilience to systemic failures. The systems can also be sized and designed to provide a full islanded operation with a mini-grid serving a defined network of electric loads. This can provide benefits where there are significant limitations on the capacity of the distribution network but will add considerably to the complexity of the energy system. A mini-grid may also introduce new vulnerabilities if the system is not connected to the main grid. Overall, a hybrid approach where boilers are used to provide top-up heat yields better resilience for the heat network	Local air quality restrictions may lead to objections to deployment of large scale CHP. However this risk can be mitigated through appropriate siting and stack height. Typically a CHP system provides the best economics when all electricity is consumed locally, i.e. to offset electricity imported from the grid due to the low export price normally obtainable by a small electricity producer. Over-sizing CHPs (e.g. to meet peak load) will erode the marginal viability of the additional plant. This situation can be improved by selling electricity privately through a private wire connection or by retailing electricity (possibly through the Licence Lite programme). Although CHP engines would be installed in modular units, the viability of the CHP investment will be poor until the heat network builds up to a sufficient load to ensure steady operations of the engines. It may be appropriate to run a network initially on a boiler-only basis in the early phases

Technology	Technology Description	Greenhouse Gas Reduction	Resilience Implications	Risk Review
	supplied by any gas provider. In cases where there is a significant cooling baseload such as a data centre, combined cooling, heat, and power (CCHP) systems can become feasible as well. The total gas consumption from a CHP will be higher than if gas is used locally only for heat production. This is likely to result in a net increase in local emissions of NOx and other pollutants, compared with a base case of a building-by-building solution of gas boilers.	lifetime or its premature retirement (which would be financially unattractive). This technology can be used now but it will become less suitable if the grid decarbonises in the future.	(and better economics).	of the scheme. The high temperature heat delivered by CHP systems may be incompatible with low-carbon heating solutions which might wish to use a DH network at Southall in the future, as most favour relatively low temperature heat provision. The choice of temperature regime of the network is also crucial for developers, who will need to specify internal systems appropriately.

Solid fuels including biomass and waste: require surface transport and on-site storage, partially or wholly renewable, supply chains and provenance must be investigated and secured.

- Biomass boilers
- Biomass CHP
- EfW

Technology	Technology Description	Greenhouse Gas Reduction	Resilience Implications	Risk Review
Biomass Boiler	Biomass resources include wood and wood wastes, agricultural crops and their waste by-products, municipal solid waste, animal wastes, waste from food processing and aquatic plants and algae. Biomass boilers are a proven technology that is able to provide reliable base-load capacity. In many applications, they can be relatively capital-light (although always more expensive than equivalently sized gas boilers). They are eligible for Renewable Heat Incentive (RHI) payments.	The sustainability of biomass can differ greatly by how it is harvested, and can lead to air quality issues (due to particulate matter and NOx emissions) if inadequate abatement measures are in place. The actual net emissions also depend significantly on the distance of the biomass supply and the means of transport to deliver it to site. This technology can be used now and it will have a greater potential if the grid decarbonises in the future.	Biomass boilers are a well-developed and resilient technology. They can provide a reliable baseload or back up / top up renewable sources such as solar thermal to improve overall reliability. Dependence on fuel deliveries can be a resilience issue, though readily mitigated by building in appropriate redundancy in storage capacity.	Compared to gas fired boilers, biomass boilers are generally less capable of load modulating due to start and stop lags of the heat source, with the exception of biodiesels. Modulation can, however be managed by using appropriately sized and dispatched thermal storage. Planning and transport risk are the same as for biomass CHP. Biomass energy generally suffers from poor air quality perceptions, due to relatively high NOx and particulate emissions. However, NOx emissions for well-commissioned boilers and good feedstock are generally equivalent to those from gas CHP. Particulates, meanwhile, can be reduced to sub 2.5 microns with relatively inexpensive catalytic filters. Further investigation and detail into the suitability of biomass boilers will depend on the final route and connected customers to the district heating network.

Technology	Technology Description	Greenhouse Gas Reduction	Resilience Implications	Risk Review
Biomass CHP	Biomass resources include wood and wood wastes, agricultural crops and their waste by-products, municipal solid waste, animal wastes, waste from food processing and aquatic plants and algae. Biomass CHP is a mature technology that is based on either (i) Organic Rankine Cycle (ORC) or (ii) gasification processes. Anaerobic digestion is not considered here. As in gas CHPs, the heat to power ratio determines the size of the biomass CHP unit. Biomass CHP is eligible for Renewable Heat Incentive (RHI) payments. In both cases biomass system will require considerably more space than a gas CHP engine. The generation plant itself is larger and the biomass will need to be stored on site in a silo or bunker sufficient for a few days' supply. As a general rule, NOx performance is similar or better than gas CHP but PM10 is generally worse, though this can be significantly mitigated with the use of filters. Large scale combustion would normally be accompanied by active stack emissions control technologies such as regenerative thermal oxidation (RTO).	Biomass CHPs significantly reduce net carbon emissions. However the actual net emissions depend significantly on the distance of the biomass supply and the means of transport to deliver it to site. This technology can be used now and it will have a greater potential if the grid decarbonises in the future.	The resilience implications for biomass CHO are similar to those for gas CHP. A further resilience consideration relates to the supply chain. Resilience of biomass is potentially higher due to the on-site storage of fuel (gas would be piped on site to meet demand as it occurs). However the reliability of the fuel source would be more uncertain than for the gas network.	Fuel storage and delivery capacity can be the main risks related to the operation of biomass CHP. In case of a district heating scheme that is based on biomass CHP, the security of biomass fuel supply becomes even more critical. It is noted that a previous biofuel solution proposed for the Gasworks site was refused planning permission, with air quality a principal concern; this solution is therefore not prioritised here. A biomass solution would require consideration of transport/traffic implications, as regular pellet / chip / fuel deliveries by truck would be necessary. Noise impacts can be minimised by sizing long-term storage capacity to reduce the frequency of deliveries necessary; gasholder superstructures could make an appropriate (albeit very large) storage solution.

Technology	Technology Description	Greenhouse Gas Reduction	Resilience Implications	Risk Review
Energy from Waste (EfW)	As part of the West London Waste Plan, a possible energy from waste (EfW) plant is being considered at the Western International Market site in Hounslow, almost adjacent to the Southall opportunity area. Incineration at high temperatures (above 850°C) to generate electricity and heat is the most well-known process for EfW, with the heat able to be exported to the Southall network. Different EfW thermal processes for different commercial technologies include: - incineration (fluidised bed or moving grate) - gasification (draft, draft down, entrained flow, fluidised bed) - pyrolysis (not commercially developed in the UK) - plasma gasification (emerging technology; limited new facilities under construction in the UK such as Tees Valley). Non-thermal processes include anaerobic digestion (AD) (see below).	There is active debate about the overall emissions associated with EfW systems. In general it is better to reuse and recycle waste materials rather than recover energy from them. For residual waste which cannot be recycled, EfW offers a significant carbon performance compared with other disposal options such as landfill. Typically around half of municipal solid waste (MSW) is from organic sources (i.e. biomass) and is therefore residual MSW considered a partially renewable fuel. Where a heat offtake can be secured for the EfW facility then the carbon performance is even better. This would of course be the scenario contemplated for this study This technology can be used now and it will have a greater potential if the grid decarbonises in the future.	Conventional incineration is tried and tested technology which offers very high reliability for a well-designed and maintained system. Other EfW technologies are more novel and therefore their reliability and longevity remains to be proven. As with biomass, fuel supply chains can represent a risk to the long term operation of a facility. Municipal facilities have a secure supply through the collection of household waste, although arisings are closely correlated with the performance of the local economy, therefore a recession will reduce waste arisings. Commercial waste is contracted on relatively short terms and can therefore be more variable.	Stringent European and national environmental regulatory requirements make larger plants more cost effective through economies of scale. Local opposition can delay or frustrate EfW development proposals. If an EfW facility is included in the potential waste site at Western International Market, crossing the canal will be required, although there is an existing bridge on the potential core route.

Heat pumps: use refrigerants (GHGs), performance expressed in terms of COP, work better with low temp systems, can provide heat and coolth, lower power density (can be space hungry but depends on the heat source or sink), goes with the grain of grid decarbonisation.

Technology	Technology Description	Greenhouse Gas Reduction	Resilience Implications	Risk Review
Air source heat pump (ASHP)	ASHPs work like back-to-front refrigerators; turning a unit of electrical energy into multiple units of low-grade heat energy This ratio of input electric power to output thermal power is called the coefficient of performance (COP). The COP varies through the year with the air temperature (warmer air gives a higher COP). Average – or seasonal – COPs for ASHPs are typically around 2 to 3. ASHPs have a relatively low power density and offer limited economies of scale, they are therefore more typically suitable for individual building solutions rather than for a centralised energy centre powering a heat network. They are eligible for Renewable Heat Incentive (RHI) payments that vary according to scale.	Electrification of heating and cooling brings significant carbon emissions reductions given that electricity comes from on-site renewable sources or as the national grid is being decarbonised. Nevertheless, ASHPs typically represent the poorest heat pump option, with ground source, water source and other secondary heat source heat pumps offering higher COPs and therefore better carbon performance. Heat pumps use refrigerant fluids (Hydroflourocarbons, or HFCs) which are themselves potent greenhouse gases. This technology can be used now and it will have a greater potential if the grid decarbonises in the future.	In the non-extreme weather conditions of London, ASHP can provide a resilient solution in tandem with other technologies such as boilers.	When external temperatures are very low, ASHPs may produce almost the same amount of heat as electricity consumed, leading to low efficiencies and carbon benefits. ASHPs are best suited for low temperature heat networks, generally requiring boiler top-up if they are to be used on high temperature networks (and to cope with winter peak demand).
Deep Geothermal Energy	Heat from the earth or geothermal energy, can be access by drilling water or steam wells in a process similar to drilling for oil. It is widely accepted that geothermal energy is an enormous underused heat and power resource that is clean and reliable (95% average system reliability). It has 2 key applications: 1. Power generation – Where suitable geology exists, wells of over 2,000m	Despite their high capital costs, geothermal energy systems have very low maintenance costs and provide low carbon energy over long lifetimes, given the availability of adequate geothermal sources at the site. The COP of heat-only geothermal systems can be 20 or higher, depending on how the heat is used. This technology can be used now and it will have a greater potential if the grid	As stated, this is an extremely reliable means of renewable energy with 95% average system availability. This means a robust and resilient installation. Ground storage of building heat energy can provide resilience in the form of time-shifting.	Risks include the undermining of building foundations (likely not relevant in the expansive gasworks site), and potential complications that would be caused by the amount of existing services in the ground around that area (utilities, trains, underground), which, with the exception of the high-pressure gas system at the Gas Works, are possibly less likely than in some more heavily built-up urban areas in London. In addition to the drilling risks, temperatures and

Technology	Technology Description	Greenhouse Gas Reduction	Resilience Implications	Risk Review
	depth can be drilled into underground reservoirs to tap steam and very hot water to propel turbines that drive electricity generators. London geology does not lend itself to this application, and in Southall a straightforward grid connection is far more suitable for electricity provision. 2. Heating – wells if up to 2,000m depth can be drilled into underground reservoirs to tap hot water that can be brought to the surface for use in a variety of applications. The brownfield nature of the Gasworks site, in particular, means that drilling rigs could readily be used pre-development to produce hot water boreholes.	decarbonises in the future.		water permeability at the target depth are not certain; therefore the operational performance and cost of a geothermal system cannot be firmly predicted. This risk is higher for CHP systems but is not negligible for heat-only systems. Capital costs are likely to prove a greater barrier to this technology, particularly with the expected build-out profile, but it is noted that geothermal heat does qualify for the non-domestic RHI.
Ground source heat pumps (GSHP)	A ground source heat pump system in its most basic form consists of pipes buried in the shallow ground near the building, a pump and a heat exchanger. Deep boreholes (typically 100-200m in depth) are an alternative method of extracting heat which results in a more constant temperature as it is less subject to variations in ambient air temperature as well as higher levels of heat extraction. Their essential advantage is that they move the heat that already exists and hence do not require that heat to be generated. The system can be used for a variety of applications including preheating of domestic hot water and space heating. The heat pump	Similar to ASHP, electrification of heating and cooling services though GSHP brings carbon reductions if that electricity is supplied from on-site or near-site renewable sources or as the national grid is being decarbonised. A typical seasonal COP for a well-designed GSHP system is around 4. Heat pumps use refrigerant fluids (Hydrofluorocarbons, or HFCs) which are themselves potent greenhouse gases. This technology can be used now and it will have a greater potential if the grid decarbonises in the future.	These systems have low maintenance costs and can be expected to provide safe, reliable and low carbon heating for well over 20 years (typically).	Risk of ground loops freezing when they remove too much heat from the ground. Use of coiled loops to reduce this risk is good engineering practice. Unless the GSHP is assisted with a mechanism for replacing the heat extracted from the ground, it will get increasingly costly to extract heat from the ground that is getting cooler. Inter-seasonal heat transfer is good engineering practice to avoid this. GSHPs are best suited for low temperature heat networks, generally requiring boiler top-up if they are to be used on high temperature networks (and to cope with winter peak demand).. Ground loops are unlikely to extract sufficient heat to meet the heat demands of large buildings at a

Technology	Technology Description	Greenhouse Gas Reduction	Resilience Implications	Risk Review
	can also be reversed in the summer to provide cooling with a separate cooling network. As with geothermal, the brownfield nature of the gasworks site means this technology is particularly suitable. See below for energy piles, a variant of GSHP suitable for new development situations.			building scale or sufficient heat to supply a district heating network. Boreholes would be capable of extracting sufficient heat to meet the heat demands of individual buildings however a large amount of open space and boreholes would be required to serve a district heating system.
Water source heat pumps (WSHP)	WSHPs function identically to GSHPs, but use water as the heat source. They may work via direct abstraction or indirectly with coolant pipes. The presence of the Grand Union canal next to the Gas Works site is noted.	WSHPs generally achieve better efficiencies than GSHPs or ASHPs. . The COP depends on the temperature profile of the water source, with a typical range of 4 to 6 being achievable. This technology can be used now and it will have a greater potential if the grid decarbonises in the future.	These systems have low maintenance costs and can be expected to provide safe, reliable and low carbon heating for well over 20 years (typically).	The nature of the water source may present a challenge. The canal may not have sufficient throughput of water to deal with future heat demands. Additionally, it may prove difficult to receive an abstraction licence. Apparatus placed in navigable waterways can present a risk to craft.
Energy Piles	Energy piles are heat exchangers usually formed by incorporating single U-shaped loops of plastic pipes along the length of reinforcement cage for concrete structural piles. These loops are fabricated off-site and filled with heat transfer fluid. The advantage of using energy piles instead of conventional GSHP coils is the lower cost of installation. The total output of an energy pile system will be lower than for a conventional coil system due the slower rate of heat transfer from the ground through the concrete walls of the piles. Energy piles are also typically shallower than standard GSHP boreholes.	The COP of energy piles is normally similar to that of other GSHP systems, i.e. around 4. This technology can be used now and it will have a greater potential if the grid decarbonises in the future.	Typically ground energy systems cost more to install than conventional systems, however they have very low maintenance costs and can be expected to provide reliable and low carbon energy for many years. When combined with a small conventional chiller and boiler, energy piles can offer a very resilient solution.	Energy piles are only suitable for new construction where piling is required for building foundations. Significant ground heave may be caused due to ground reaching sub-zero temperatures at the soil-pile interface. Depending on the density of the proposed new developments and pile depth, it is unlikely sufficient heat could be extract to supplement a district heating network in addition to the individual building heat demand.

Other: a mix of unusual options.

- AD
- Gas let-down
- Solar

Technology	Technology Description	Greenhouse Gas Reduction	Resilience Implications	Risk Review
Anaerobic Digestion	Anaerobic digestion (AD) is a commercially developed biomass conversion technology that can be used to recover both the nutrients and the energy contained in organic wastes. This process generates gases with a high content of methane which can be used in an engine or boiler or (with additional treatment) fed into the gas grid. Feedstock for AD can include food waste, farm waste or other wet organic material. Woody waste can also be used but is less suitable. The dry residue is called digestate and can be used as a soil conditioner. An AD plant could either be sited at the Gasworks development, or located offsite, with certificates for low carbon gas grid injection purchased by the development to qualify as low carbon generation.	AD plants use organic material as a feedstock and are therefore a renewable energy technology providing a low carbon fuel with similar properties to fossil fuel gas. As with other solid fuel options, the overall carbon performance depends greatly on the distance the material travels between source and AD plant. This technology can be used now and it will have a greater potential if the grid decarbonises in the future.	With no additional capital requirement for gas pipeline infrastructure, AD can offer a sustainable heat (and electricity if coupled with a CHP) supply to end-users. The main issues are: - the dependence on feedstock, - the (costly) need to inject propane to meet the grid standard, - the current lack of long-term contracts.	In gas-to-grid schemes, required compliance with the quality bands for national gas pipelines makes the business case very sensitive to the chemical processes at the plant. Storage of feedstock and / or digestate near to the site may not be particularly popular with residents or developers, meaning this is a solution more suitable as an off-site measure.
Gas Let-Down Generators	The gas infrastructure network is made of transmission and distribution pipes at different pressures. Gas let-down stations area located at the points of connection between high pressure transmission pipes and lower pressure distribution pipes. A station	Capture and use of the energy released through the pressure reduction process would provide lower carbon heat and power compared with a conventional system which uses gas. One particularly attractive option would be to	The steady flow of gas through the critical gas infrastructure at the heart of this system would make this a highly resilient solution in relation to fuel supply.	This is a relatively novel approach – means technological and commercial risks such as high capital costs and limitations in handling fluctuations in gas flow rates and pressure. Likely to be a more costly way of generating electricity than BAU.

Technology	Technology Description	Greenhouse Gas Reduction	Resilience Implications	Risk Review
	is located on the Gas Works site. The process of reducing gas pressure can be harnessed to generate electricity. However, it also causes the gas to cool significantly (well below 0°C) which, in turn, may damage distribution pipes. Normally, additional gas is burned to increase its temperature to safely inject it into the local distribution grid. There is already a proposal in the West Southall Masterplan Energy Strategy (2008) to consider a gas turbo expander scheme linked to the gas let-down facility located on Gas Works site, which would be supplemented with a biofuel CHP engine to reheat the gas and provide heat for the district heating network.	locate computer data centres – which typically require massive and continuous cooling – near the gas let-down facility to use the temperature drop to replace their refrigeration and air conditioning units. This technology can be used now but it will become less suitable if the grid decarbonises in the future.		The previously proposed “Blue NG” low-carbon solution (turbo-expanders + biofuel CHP) was previously refused on air quality and traffic safety grounds. Any future scheme would need to demonstrate how these concerns could be addressed.
Solar Thermal	Solar thermal technologies are well-suited for use in urban areas and widely used in many cities. It is a mature and commercially available system. Solar thermal technologies continue to evolve in terms of improved performance, lower costs, greater flexibility and lower deployment costs. The main applications in the UK are for heating domestic hot water (DHW). Other uses are possible but the limited yield normally makes it more suitable to focus on a single specific use	Solar thermal is perhaps the lowest carbon heat technology available. This technology can be used now and it will have a greater potential if the grid decarbonises in the future.	Roof-top solar thermal is currently not able to provide 100% of heating needs in the UK, but is a good complementary supply solution, providing resilience benefits.	Commercial solar water heating technologies are mature and there are no fundamental technical issues remaining- however since each installation is unique, technical competence in system design, specification, construction and support is essential. In the UK, winter performance can be significantly reduced versus summer levels.

A3 Route Feasibility

A3.1 Introduction

This file note contains the route walk findings. The route walk findings cover the overall description of the core scheme and the comments related to the main pipework from the energy centre, and the network sections north and south of the Great Western rail tracks.

A3.2 Route walk findings

A3.2.1 Core Scheme

Principal route feasibility investigation focussed on the "Core Scheme" proposed in the original pre-feasibility study, and the route associated with this.

The Core Scheme is to link a proposed Energy Centre at Southall West with defined heat load locations with heating pipes (flow and return). The shape of the Scheme is shown in Figure 5 and in principle services heat loads either side of the A3005 which runs north-south through Southall from a proposed Energy Centre at Southall West which is the site of a proposed major development just north of the Great Western rail tracks and west of the A3005.

The Great Western railroad runs east-west dividing the area and is presently crossed by a road bridge carrying the A3005, and a pedestrian bridge further to the east.

The network routing of the core scheme proposed in the earlier pre-feasibility study (see Figure A2.1) has been refined based on the route walk findings which identified a potential complication at the point of connection from The Crescent to the embankment onto the A3005 (see Figure A2.2). Additionally, heat load assessment has indicated a limited economic case for connecting the potential developments at Featherstone and The Green. The phasing and cost considerations in the route feasibility section reflect this change.

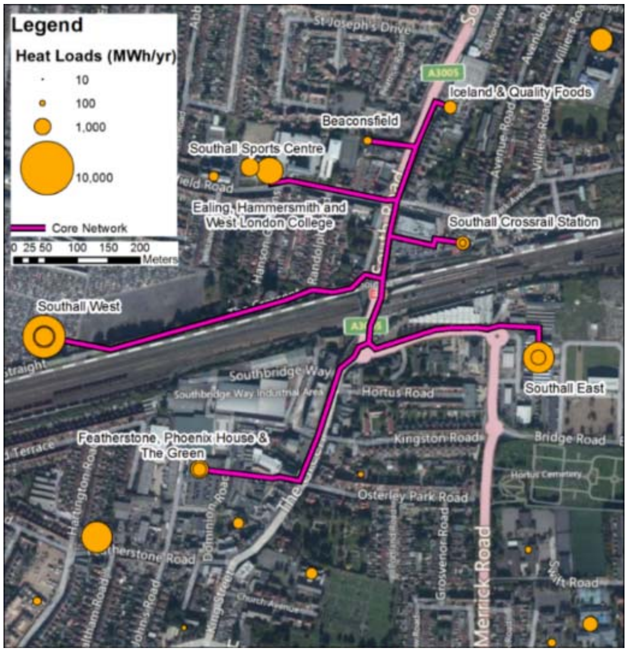


Figure A2.1: Core scheme from the pre-feasibility

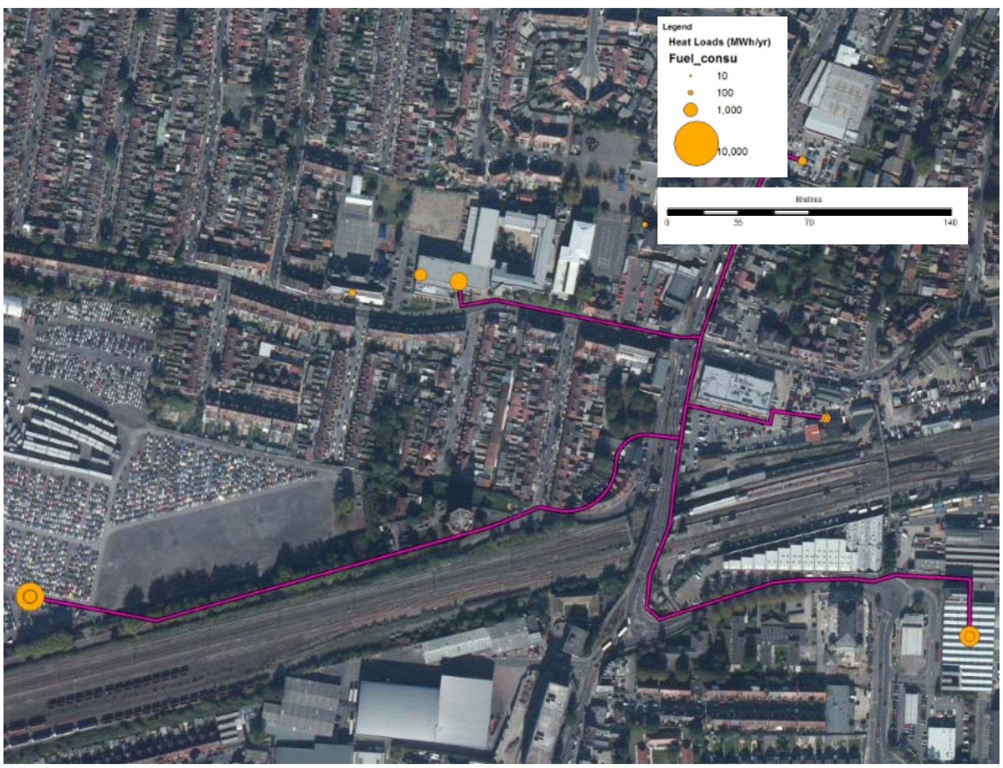


Figure A2.2: Core scheme refined based on route walk conclusions and load connection cost-benefit assessment

A3.2.2 General Route Comments

A3.2.2.1 Main pipe from the energy centre

The route from the proposed Southall West EC runs along The Straight which is understood to be the old access road into the disused gas works site where the Southall West EC is proposed to be located (Figure A2.3).

Figure A2.3: The Straight

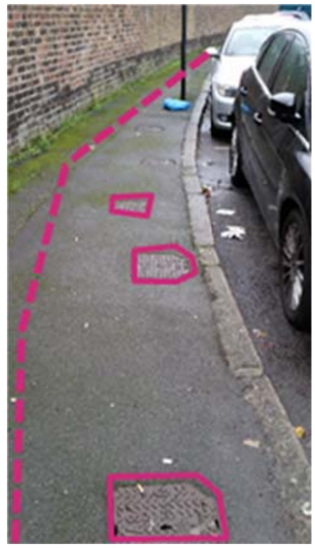


Figure A2.4: Existing gas apparatus

The Straight is lightly trafficked so trench works should progress well. Existing apparatus is present, mostly gas pipes (Figure A2.4).

The proposed scheme has the route running up part of The Crescent and then through an embankment onto the A3005 as it rises up to cross over the rail tracks.

This route through the embankment is not practical and too complicated considering the pipe bending required to turn the pipes to go over the bridge (Figure A2.5).

Figure A2.5: Complicated turn to the bridge from The Crescent

It would be preferable to route the pipes up Randolph Road as this would be a shorter distance to the heat loads at Southall Sports Centre and Ealing, Hammersmith and West London College on Beaconsfield Road (Figure A2.6). This route would also avoid the complicated junction between The Crescent and A3005 for the pipes if they were to go over the rail tracks via the road bridge (Figure A2.7).

However, it is also noted that with a view to minimising costs in early phases of construction, achieving the shortest route possible should be prioritised. Given that the College is not likely to connect for another ten years, the Randolph road route presents an unnecessary early investment. As discussed in the main report in Section 5.3, as The Crescent is likely to be significantly reconfigured, there now exists the opportunity to route the pipes along this road and minimise overall construction costs and disruption.

Figure A2.6: Alternative routing through Randolph Road (orange line)

Figure A2.7: Alternative approach to the road bridge (orange line)

Crossing the Great Western rail tracks will be a complicated matter. A consultation with Network Rail has commenced with the first option being installing apparatus in the road bridge. There is also an existing unused pedestrian bridge over the track east of the station which has been included within the consultation. Other options such as crossing under the tracks would be considered if necessary.

Using the road bridge to cross the rail tracks is the conventional approach and in this case, if it were possible, it would most likely be installed within the road (as opposed to the pavement).

A3.2.2.2 South of the Great Western Rail Tracks

Once over the bridge and heading south, the roundabout has very varied levels around it and thus crossing the road in the vicinity of the roundabout may be complicated (see Figure A2.8).

Figure A2.8: Roundabout south of the road bridge

Figure A2.9: A3005 with wide footpaths

The proposed route goes south down The Green. The route to Southall East goes down A3005 which is a busy through road with relatively wide footpaths (Figure A2.9). This route goes past and provides access to the entrance to the pedestrian foot bridge over rail tracks.

On the basis of the above it would be better to cross the road bridge on its east side rather than its west side as this would make routing to Southall East more straightforward.

A3.2.2.3 North of the Great Western Rail Tracks

The next main section of the route is up South Road as far as Iceland and Quality Foods taking in a possible connection off to Beaconsfield Primary School (Figure A2.10).

Figure A2.10: The core scheme expands until the site of the Iceland and Quality Foods towards North

The route to Southall Sports Centre goes down Beaconsfield Road, which is a busy local road with a relatively high pedestrian use. The footpaths are narrow and contain existing utilities, so the pipes will most likely have to be installed within the road (Figure A2.11).

Figure A2.11: The route to Southall Sports Centre

Figure A2.12: Route up South Road

South Road is the busy A3005 through Southall and, though some of the footpaths are wide, there are restrictions due to property boundaries extending into the footpaths and there is much existing utility apparatus in the footpaths. It is again likely that a large proportion of the route up South Road would have to be installed in the road (Figure A2.12).

The connection to Beaconsfield Primary is from South Road through a private entrance. The works here would need to be managed with school times and the safety of the pupils in mind.

A section of the route goes east to the proposed Southall Gateway site. This is shown going past the front of the present location of the Sikh Temple. This would seem to be private land. The route could go down Park Avenue to the proposed site of the Southall Gateway. The footpath here is relatively wide and thus the likelihood of being able to install pipes within it is higher than in South Road. This length of pipe also goes close to where the pedestrian bridge crosses over the railway and thus if the pedestrian bridge was used to cross the railway then this length of pipe would have to be sized accordingly.

Looking further ahead than the Core Scheme, the potential full extent of the network includes installation in Uxbridge Road. This road is presently being upgraded with environmental improvements, re-surfacing and public realm works. This area should be avoided for the next few years so as to prevent excavating recently re-laid surfacing.

The whole route area is within a busy London suburb with busy local shopping areas and active streets. Trenching works in the area will cause disruption and inconvenience, some of which could be disruptive to business.

The management of information, regarding the intentions and benefits of the scheme, the extent of the works and the disruption and inconvenience they may cause, must be diplomatically carried out and well in advance of the proposed works.

Publicity regarding benefits should outweigh the possible disruption and inconvenience. All events that do occur on a day to day basis must be recorded and then openly and expeditiously managed so that response to concerns is seen as being well managed.

A3.3 Route Walk Summary

The route north of the rail tracks could be rationalised to go up Randolph Road instead of The Crescent. This reduces the amount of installation within South Road (A3005) and avoids early installation work close to the bridge which requires details of the bridge crossing to inform the works which would be premature without it.

The proportion of trench works in footpath and carriageway may need to be revisited since the majority of the route will be in-road, due to some narrow and congested footpaths. This will have an effect upon the cost (due to the higher costs for traffic management, excavation and reinstatement, and protection of existing services).

It is advised that as much as possible of the route is installed in public adopted highway. This provides the installation with a workable legal framework over it rather than the individual negotiations and drawing up of easements/wayleaves for installations in private land.

The crossing of the rail tracks must be addressed urgently since the southern part of the proposed full scheme depends upon it and if a crossing is viable the timing of it needs to be taken into account within the overall scheme programme since the arrangements for a crossing are likely to take a long time.

The area is a very busy suburb with active streets which will be disrupted during the works. The management of this disruption and the associated public relations management should be high on the list of project objectives since these matters, without adequate management, could be very problematic.

The routing as presently proposed supplies a scheme with an up to 15 year programme. The extent of the scheme over time and spatially requires early decisions on aspects of the route which may change over time. The risks of these early decisions need to be assessed, for example on pipe size, so that consequences are well known and understood.

A3.4 Route Risk Summary

The route feasibility analysis highlights a number of risks associated with the delivery of the network:

- Crossing the railway corridor
- Existing buried services along planned routes
- Traffic management and business / residential disruption

Mitigation of these risks would at this stage involve the acquisition of more information, i.e. to engage with Network Rail and the highway authority and to obtain buried services information.

The study scope does not include buried services surveys but this could be discussed. Buried services information should be provided as part of any procurement of pipe design and installation, therefore purchase of that information is usually postponed until a time closer to the start of procurement (to ensure it is reliable).

A4 Uplift Analysis

A4.1 Executive Summary

High-level cost modelling for the St James Southall Gasworks site indicated that additional costs associated with extending the network beyond the Gasworks are marginal. The investments that St James would make by up-sizing their pipework and Energy Centre for the core Southall DHN represent a 3% uplift on their site-wide network.

These calculations have been carried out to give an initial understanding of St James' role in any future network in the Southall area. Depending on the eventual delivery route, it may be appropriate for the council to guarantee the uplift costs in the near-term, offset this uplift against other payments received from St James, or for an area-wide ESCo to take these on fully.

Please note that our assumptions for the St James network have not been validated by St James.

A4.2 Cost Comparison

The following tables compare the key parameters for the site-wide St James network and core Southall DHN, based on the core scheme identified within previous work. In Table 1, CHP capacity is set to cover the baseload with an annual runtime of 5,000 hours while the combined gas boiler capacity has been set to meet the peak load, without CHP operation, plus an allowance for single boiler downtime. Please refer to the Appendix A1.3 for the heat demand profiles that are used in determining generation capacity and mix.

Table A3.1 Generation Capacity

	St. James Network	**Southall DHN**
CHP Capacity (MWth)	2.0	3.3
Gas Boiler Capacity (MW)	8.4	10.4

Required Energy Centre (EC) dimensions for the two cases are summarised below. The smaller EC only for St James site-wide network contains 2x 1.0 MWth CHP and 4x 2.1 MW gas boilers. The larger EC for core Southall DHN contains 3x 1.07 MWth CHP and 4x 2.6 MW gas boilers. In each case, gas boilers have an N+1 arrangement for redundancy. Figures 1 and 2 overleaf illustrate the respective layouts.

Table A3.2 Energy Centre Dimensions (with allowances)

	St. James Network	**Southall DHN**
EC Width (m)	38.0	49.8
EC Depth (m)	11.9	11.9
EC Height (m)	4.3	4.3
EC Area with allowances (m^2)	452	593

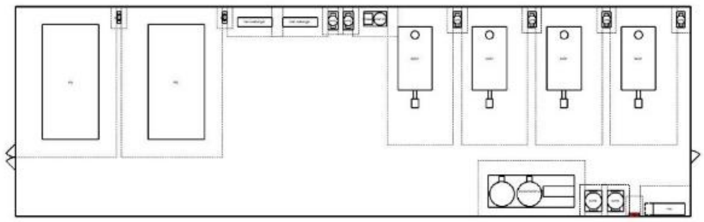


Figure A3.1 Energy Centre for St James site-wide network

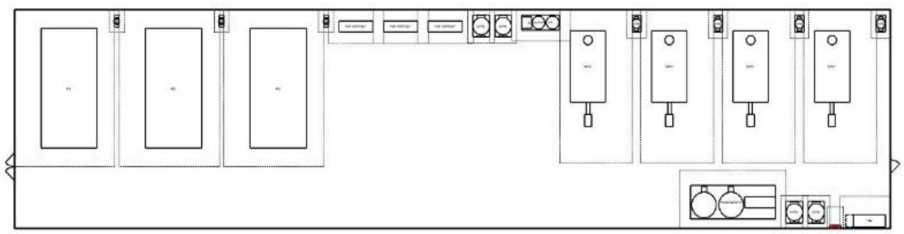


Figure A3.2 Energy Centre for core Southall DHN

It is noted that the indicative layouts for an Energy Centre serving the wider area are lower than the total area indicated in St James' previous proposals, which contain allowances for a 600m^2 Energy Centre.

Cost calculations for the standalone Energy Centre are based on a £410/m^2 rate for a factory with incoming services only. There is a 30% "form factor" allowance for aesthetical considerations of the Energy Centre facade. Please note that the Energy Centre has no thermal stores in either case, as these are assumed to be elsewhere on the Gasworks site as per St James drawings.

CHP, gas boiler, and pipework costs are based on typical industry assumptions. Brown field terrain type is assumed for the St James development site. The distribution pipeline length within the Southall West site is 3,250 m. The cost estimates are summarised in Table 3 and 4.

Table A3.3 Cost Estimate Comparison

	St. James Network Cost (£)	**Southall DHN Cost (£)**	**Uplift Cost (£)**	**Uplift Cost (%)**
CHP	1,302,000	2,090,000	788,000	61%
Gas Boilers	184,000	229,000	45,000	24%
Energy Centre	241,000	316,000	75,000	31%
Distribution Pipework within Southall West site	2,899,000	2,926,000	27,000	1%
TOTAL	**4,626,000**	**5,631,000**	**1,005,000**	**22%**

From the point of view of St James, only the additional cost of Energy Centre and distribution pipework will be incurred, both of which are repeated in Table 4 below. There is a possibility that St James will also cover the £310,000 cost of a pipework extension beyond their development boundary up the road bridge. However, this cost is not included in the uplift calculations.

Table A3.4 Cost Estimate Comparison (excluding generation assets)

	St. James DHN Cost (£)	**Southall DHN Cost (£)**	**Uplift Cost (£)**	**Uplift Cost (%)**
Energy Centre	241,000	316,000	75,000	31%
Distribution Pipework	2,899,000	2,926,000	27,000	1%
TOTAL	**3,140,000**	**3,242,000**	**102,000**	**3%**

A5 Funding Options Review

A5.1 Funding Options

A project such as this involves significant capital outlay and therefore may require alternative funding options to be considered. There are various funding options available to the Council; a brief summary of these has been included below for review.

A5.1.1 Public Sector Sources

A5.1.1.1 Public Works Loan Board

The Public Works Loan Board (PWLB) is a statutory body of the UK Government that provides loans to public bodies from the National Loans Fund. The PWLB provides loans to local authorities of all types in Great Britain, primarily for capital projects, but also as a lender of last resort.

A few years ago this source of capital was very cheap for local authorities, but its cost has recently been rising compared to other sources of funding as the economy in Europe has improved.

A5.1.1.2 London Green Fund

The London Energy Efficiency Fund (LEEF) is managed by Amber Infrastructure and can fund private and public sector energy efficiency investment, including investment in District Heating.

Often the rates that can be offered are better than Public Works Loan Board (PWLB), depending on the credit rating of the organisation asking for capital from this low interest loan facility. Further details can be found at www.leef.co.uk.

For the purposes of full disclosure, Arup is the technical advisor to LEEF. This role includes introducing potential clients and technical due diligence on the client’s proposed use of the loans.

A5.1.1.3 Green Investment Bank

The GIB has been set up under the auspices of the Department for Business Innovation and Skills (BIS). Currently the GIB is in the process of sourcing its project pipeline which could include DE projects.

Funding from the GIB could be in the form of debt or equity instruments however it is mostly likely to be debt. Indicative costs of capital are likely to be marginally lower than the market rate of 2 to 3 per cent above LIBOR.

A5.1.1.4 European Investment Bank

The European Investment Bank (EIB) grants medium to long term loans to energy efficiency and renewable energy projects. It can provide project finance to projects over EUR 25m in value or intermediate loans through credit lines to banks or other financial institutions if projects are less than EUR 25m in value.

The EIB can lend at rates lower than the commercial market: technically, they can lend at the country-specific reference rate to avoid State aid issues.

Generally the EIB can only finance 50 per cent of project costs. In rare cases the EIB will finance 100 per cent of a loan granted by an intermediary bank.

A5.1.1.5 Project and municipal bonds

Legislation passed in 2004 allows local authorities to issue bonds for capital projects without permission from central government. However, to date there has been little issuance because bond finance generally has high transaction costs. That said, the finance itself can be cheaper than other types of debt if at sufficient scale because it is secured on typically high credit.

One option for bond finance is to pool multiple investments into a single bond, either as multiple different projects within a single city or a single type of project (e.g. district heating networks) across multiple cities. This is a topic of active discussion among global cities networks (e.g. ICLEI[18] and C40), but there is limited experience in delivery of multi-city bond financing.

A5.1.2 Private Sector Sources

A5.1.2.1 Senior Debt secured against the Council

The project sponsor could take out senior debt from a commercial bank secured on the organisation's assets. Senior debt is generally long term (in excess of 20 years) and interest is generally higher than the public sector loans.

A5.1.2.2 Refinancing

Pension funds and insurance companies are interested in providing very long term finance secured on the assets of district heating networks, for example the primary pipe network, once they have been installed and have a secure income stream. Such a facility can be used to refinance a scheme after it has started operations.

A5.1.2.3 Climate Change / Green Investment Funds

There are some investment funds such as Triodos, Climate Change Capital and Earth Capital Partners that have been established with a specific remit to invest in projects that contribute to climate change reduction such as energy efficiency and renewable energy projects.

These funds tend to be interested only in projects that have relatively high returns (10-20 per cent) and with short investment periods (5-10 years). In addition, they

[18] http://issuu.com/resilientcities/docs/rc2014__congressreport_2014_final

will be looking for projects or project portfolios with a large scale investment potential rather than individual small-scale projects.

For these reasons they may not be appropriate for the majority of DE projects where returns are less certain and scale is small.

A5.1.3 Grants, incentives and subsidies

A5.1.3.1 Allowable Solutions

The UK Government has recognised that achieving actual zero carbon in new development on site is unlikely to be viable in most cases and indeed may not be technically achievable in many cases. It has therefore proposed to implement a system of “allowable solutions” to deliver carbon reductions to offset residual emissions in new development.

Allowable solutions would include low carbon measures away from a new development, for example, standalone renewable energy installations, a district heating network or building retrofit.

It is likely that limited funds will be collected through such a system before 2016. For the time being, the most likely route for developer contributions to be available to fund DE schemes will be through Section 106 agreements or through CIL payments.

A5.1.3.2 Enhanced capital allowances

Tax incentives like ECAs are focused on providing incentives to the private sector to encourage the delivery of energy saving plants, low carbon generation and infrastructure. ECAs will enable a private sector organisation to write off the whole of the capital cost of an investment against taxable profits for the period in which they make the investment.

A6 Overview of Delivery Options

The Council has three options for delivery of the heat network beyond the St James site.

- Option 1: The council acts as Promoter
- Option 2: The council acts as Promoter and the InfraCo
- Option 3: The council exercises only its planning function and leaves the market to provide a solution.

These options are represented graphically in Figure A7.1 below.

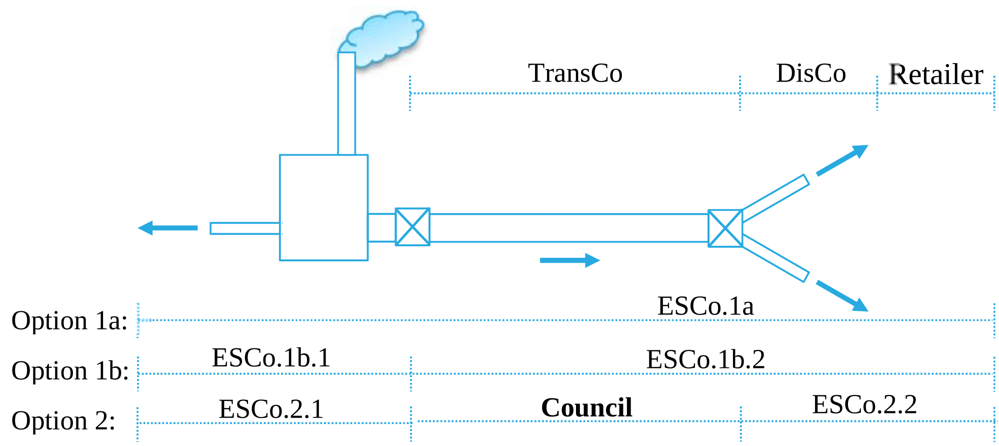


Figure A7.1. Potential delivery roles for the Council.

In Options 1b and 2, it is possible that the eventual ESCo is the same ESCo that is operating the St James energy centre. In the analysis, ESCo 2.1 and 2.2 are assumed to be the same.

In Option 1b, the bulk heat price determines the allocation of cashflows between the ESCo 1.b.1 and ESCo 1.b.2.

Similarly in Option 2, the TUoS determines the allocation of cashflows between the Council and the ESCo 2.

A7 Technical Assumptions

A7.1 Technical Assumptions

Equipment Lifetimes	
CHP	10 years
Gas Boiler	15 years
HIU	15 years

Efficiency		
CHP (< 800 kW)	Thermal	40%
	Electrical	39%
CHP (> 800 kW)	Thermal	43%
	Electrical	36%
Gas Boiler - New		90%
Gas Boiler- Existing		75%

System Losses	
Energy Centre	0.5%
Distribution	9%
Heat Substations	0.5%
Secondary System	15%
TOTAL (Heat Loss Factor)	25%

CHP Sizing Criteria	
Runtime	5000 hours/year

Heat Benchmarks	
Residential	3,247 kWh/unit
Office	50 kWh/m^2
Retail	80 kWh/m^2
Restaurant	324 kWh/m^2
Hospital	148 kWh/m^2
Education	108 kWh/m^2
Hotel	260 kWh/m^2
Leisure	206 kWh/m^2
Public	50 kWh/m^2
Warehouse	50 kWh/m^2

Peak Heat Load Factors (diversified)	
Residential	0.03801%
Office	0.04991%
Retail	0.04039%
Restaurant	0.02941%
Hospital	0.02633%
Education	0.06394%
Hotel	0.03399%
Leisure	0.03069%
Public	0.03672%
Warehouse	0.03702%

District Heating Network Specifications	
Flow Temperature	80°C
Return Temperature	60°C
Soil Temperature	10°C
Max. Allowable Flow rate	1.5 m/s

Emissions Factors	
Grid Electricity Emissions Factor	0.519 kgCO_2/kWh
Mains Gas Emissions Factor	0.216 kgCO2/kWh