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Wembley Regeneration Area Energy Masterplan

LONDON BOROUGH OF BRENT
WEMBLEY REGENERATION AREA ENERGY MASTERPLAN

LONDON BOROUGH OF BRENT

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EXECUTIVE SUMMARY

Wembley in northwest London is undergoing large-scale redevelopment and regeneration with the potential to provide approximately 10,000 new jobs and more than 11,500 new homes between 2013 and 2026.

Delivering this opportunity efficiently, at lowest cost to developers and through a market led approach will be challenging in the context of London's targets for carbon reduction, developers' obligations under future anticipated changes to the building regulations and the wide number of options available to them under current building regulations and the government's proposed future Allowable Solutions mechanism under the Government's Zero Carbon Homes policy for the delivery of zero carbon new homes from 2016.

In the absence of a coherent Energy Masterplan based on a firm evidence base, London Borough of Brent will be unable to assess, evaluate or influence individual developers' energy strategy proposals in a meaningful way. There is a risk that developers will implement their own individual solutions to achieve compliance, which risks failing deliver the full carbon reduction potential for the area, failing to capitalise on synergies between existing supply assets and future energy from waste opportunities and failing to deliver lowest cost, lowest carbon heat to the area and its inhabitants.

London Borough of Brent have therefore have decided to commission a decentralised energy masterplan for the Wembley Regeneration Area, to enable them to assess and influence individual developers' energy strategy proposals.

The objectives of this Energy Masterplan have been to provide a supporting document and a robust evidence base to inform London Borough of Brent's policy on how best to deliver the regeneration opportunities in line with future Building Regulations (2013 and 2016).

The study has been carried out in three main parts:-

1. An Evidence Base to evaluate the suitability and limitations of different technical solutions to achieve energy efficiency and compliance targets for new developments in the Wembley Regeneration Area and to compare the options in economic and carbon compliance terms.

2. A Decentralised Energy system appraisal to examine the extent of a decentralised energy scheme that has the potential to supply market competitive, low carbon energy to new developments and existing properties.

3. An appraisal of the prospect for integrating an energy from waste opportunity with the decentralised energy scheme identified under item 2 above

The main findings of the study are set out below.

The evidence base modelling has compared a number of development level, developer led LZC scenarios with a decentralised energy opportunity based on heat delivered through a heat network. For each development level, developer led LZC scenario, carbon compliance levels, LZC technology investment costs, heat production costs and residual carbon compliance costs have been calculated. These have been compared to the equivalent costs arising under decentralised energy opportunities involving a 2.5 MWe biomass facility for which Seneca has planning permission, and a gas fired CHP energy centre as an alternative in the event that this does not materialise. The identified decentralised energy opportunities have been found to provide a number of potential economic benefits over the alternative developer led LZC scenario options and offers the potential to deliver lower carbon content heat than can be generated at development level through the developer led LZC scenarios.

The scale and density of consented and planned development coming forward over the coming decades also suggests a significant commercial opportunity to develop both district heating and district cooling networks in the Wembley Regeneration area. The district heating opportunity could potentially be developed in conjunction with the 2.5 MW biomass CHP facility at Seneca's SMRF facility or, if this does not materialise, a newly constructed gas fired CHP energy centre. The district cooling opportunity would be likely to materialise through a centralised electric vapour compression chillier configuration. The investigation into surplus heat from potential WtE plant at Seneca shows there will be little if any surplus heat available for use in absorption chillers. Ramboll's experience from other projects shows that using absorption chillers fed from gas fired CHP is very sensitive in terms of carbon dioxide balance and it is not certain this would lead to carbon dioxide savings. The opportunity for absorption cooling is therefore considered to be limited based on the scenarios identified in this report.

If the identified decentralised energy opportunities are to be taken forward, a series of steps will need to be implemented. and London Borough of Brent has a key role to play in supporting the development opportunity. These next steps are outlined in the subsequent section of this Chapter. London Borough of Brent's role might include securing a stake in the infrastructure assets or it may involve London Borough of Brent taking a facilitation role and ensuring that its local planning framework supports the future development of a heat network whilst leaving the construction of the heat network to the market to deliver.

In the absence of the opportunity materialising, new developments within the Wembley Regeneration area will come forward with individualised piecemeal solutions involving a range of low carbon technologies. This approach risks missing the opportunity to capitalise on the advantages highlighted through the Evidence Base modelling as set out in Section 3.5 of this report.

As a minimum, London Borough of Brent should consider implementing the planning policy recommendations set out in Sections 7.1, 7.2 and 7.3 of this report. London Borough of Brent may also choose to take an active role in developing the identified project opportunities in which case, it is recommended that some or all of the actions highlighted in Section 7.4 of this report are pursued.

1. INTRODUCTION

1.1 Introduction, Background and Context

Wembley in northwest London is undergoing large-scale redevelopment and regeneration with the potential to provide approximately 10,000 new jobs and more than 11,500 new homes between 2013 and 2026.

Delivering this opportunity efficiently, at lowest cost to developers and through a market led approach will be challenging in the context of London's targets for carbon reduction, developers' obligations under future anticipated changes to the building regulations and the wide number of options available to them under current building regulations and the government's proposed future Allowable Solutions mechanism under the Government's Zero Carbon Homes policy for the delivery of zero carbon new homes from 2016.

In the absence of a coherent Energy Masterplan based on a firm evidence base, London Borough of Brent will be unable to assess, evaluate or influence individual developers' energy strategy proposals in a meaningful way. There is a risk that developers will implement their own individual solutions to achieve compliance, which risks failing deliver the full carbon reduction potential for the area, failing to capitalise on synergies between existing supply assets and future energy from waste opportunities and failing to deliver lowest cost, lowest carbon heat to the area and its inhabitants.

LBB therefore have decided to commission a decentralised energy masterplan for the Wembley Regeneration Area, to enable them to assess and influence individual developers' energy strategy proposals. With a coherent decentralised energy masterplan based on a firm evidence base, London Borough of Brent will be in a position to assess and influence individual developers' energy strategy proposals and ensure that the full carbon reduction potential for the area can be delivered. London Borough of Brent will also be able to capitalise on synergies between existing supply assets and future energy from waste opportunities, and ensure that the lowest cost and the lowest carbon heat will be delivered to the area, and its inhabitants and local businesses.

The Wembley Programme Board has therefore commissioned Ramboll Energy to develop an Energy Master plan for the Wembley Regeneration Area. This is intended to append to the Wembley Area Action Plan (WAAP) as a supporting document and provide a robust evidence base to inform the London Borough of Brent's policy on how best to deliver the regeneration opportunities in line with future Building Regulations.

The scale of regeneration, together with the nature and mix of building uses, indicates a strong potential for district heating as a market competitive heat source for the area and the strategic vision to 2026 for the Wembley Regeneration Area encompasses both district energy and energy from waste as potential key elements in the future energy supply mix.

1.2 Study Objectives

The objectives of this Energy Masterplan have been to provide a supporting document and a robust evidence base to inform London Borough of Brent's policy on how best to deliver the regeneration opportunities in line with future Building Regulations (2013 and 2016).

The study has been carried out in three main parts, which are identified below, together with the associated objectives under each element.

The Energy masterplan has focused on identifying a strategic vision to 2042 which is both in line with best available international practice and deliverable by the market and therefore grounded in commercial reality.

The masterplan has focused on the potential role of district heating and energy from waste, but has also evaluated the role for building level and plot level renewable technologies. In view of the significant amount of commercial redevelopment in the area, a potential role for district cooling has also been identified and the scope for such an opportunity has also been assessed within the report.

The Energy masterplan has sought to provide a whole life costing and carbon appraisal of the identified opportunities, together with an outline implementation plan for delivery.

1.2.1 Evidence Base

The objectives of the Evidence Base modelling have been to:-

1. understand the current energy loads in the Wembley Regeneration Area and anchor loads in the adjacent areas and the likely phased energy loads in the future.
2. evaluate the suitability and limitations of different technical solutions to achieve energy efficiency and compliance targets for new developments in the Wembley Regeneration Area.
3. advise London Borough of Brent if these technical solutions could deliver the economic benefits and carbon dioxide savings on their own or in combination with others
4. To identify the delivery mechanism for the identified options.
5. help unlock regeneration proposals, particularly when new building regulations and Code Levels become adopted in policy and legislation.
6. Establish the extent to which high value space earmarked for energy generation e.g. roof space, thermal stores can be relieved and relocated to somewhere with lower development value.
7. establish whether a decentralised energy scheme can complement renewable energy solutions for the area.

1.2.2 Decentralised Energy System

The objectives of the Decentralised Energy system modelling have been to:-

1. examine the extent of a decentralised energy scheme that has the potential to supply market competitive, low carbon energy to new developments and existing properties.
2. identify major barriers, issues and constraints (such as crossing the River Brent, rail lines, roads; public realm works, etc. and make recommendations.
3. spatially map the decentralised energy vision and establish an incremental decentralised energy delivery plan based on consecutive construction phases, clearly identifying where the scheme should be ‘kick-started’, whether temporary Energy Centres should be considered and taking into account the energy loads development etc.
4. identify indicative costs and revenues for the various phases and appraise financial viability of the proposed DE scheme over its whole life cycle
5. develop a discrete and well defined project with a delivery plan and a financial model.
6. To advise London Borough of Brent about whether feasibility study is necessary for a decentralised energy scheme in the Wembley Regeneration Area.

1.2.3 Energy from Waste

The objectives of the Energy from Waste modelling have been to:-

1. examine the prospect for energy from waste facilities in Wembley
2. link the findings to the evidence base and decentralised energy scheme analyses presented above.

2. ENERGY DEMAND ASSESSMENT

2.1 Methodology

This project opportunity has been developed on the basis of information contained within a range of data sources, these are summarised below.

For existing buildings heat demand data has been collected from the following sources:-

a) Reference to recent energy statements for known development applications in the planning process
b) Display Energy Certificates
c) Benchmarking based on modelled existing energy consumption in the evidence base developed for this project

For new buildings heat demand projections have been calculated based on existing energy statements where available and benchmarked energy demands from the evidence base as described in Section 3 of this report. Data sources used to determine development phasing and building use classes to aid energy benchmarking are:-

a) Brent Council's Development Schedule for the Regeneration Area
b) Brent Council's Projected Floor Area Assessment for the Regeneration Area
c) Existing Planning Documents
d) Project Brief

Energy demand benchmarks, both residential and non-residential are taken from the evidence base as described in Section 3. The energy benchmarks developed to reflect current (2010) energy standards are based on calculations using the methodology required by Part L of the UK 2010 Building Regulations. Furthermore results that achieve a BREEAM Excellent rating were targeted, as this is a requirement for the Wembley Regeneration Area for commercial developments seeking planning permission, and are set out in London Borough of Brent's policy as the London Plan. This benchmark is equivalent to a 25% reduction in building CO_2 emissions over the Target Emission Rate (TER) that is outlined by the methodology used, as stipulated by the Building Regulations.

Energy benchmarks for the period covered by the 2013 Building Regulations are similar to those for 2010. However in line with the London Plan targets for 2013, the TER outlined under the 2010 Building Regulations, has been improved upon by 40%. This approach has been taken as no firm energy and CO_2 emission calculation methodologies exist for the 2013 Building Regulations at the time of writing. Assumptions regarding the required building fabric performance standards are presented in Appendix 3.

For the period covered by the 2016 Building Regulations residential building benchmarks reflect the Government's "Zero Carbon Homes" policy. Assumptions that incorporate the policy have been incorporated into the modelling. For non-residential buildings the "Zero Carbon Building" guidelines are less defined at the present time and assumptions have been made regarding equivalent fabric standards. Assumptions regarding the requisite building fabric performance standards are presented in Appendix 3.

Due to anticipated delays in the adoption of future building regulations, benchmarks for 2013 and 2016 have been applied to buildings constructed four years after the nominal year of introduction, this is highlighted in Table 1 below. Updates to building regulations for domestic buildings to reflect Zero Carbon Homes policy are assumed to come into effect in 2016. For non-domestic buildings the equivalent transition to Zero Carbon Buildings policy is not anticipated to be introduced until 2019 and thus the effects shall not be seen until 2023. This has been accounted for in the energy demand and supply modelling carried out in subsequent sections of this report.

Benchmark Nominal Year	Residential	Non-Residential
	Used for.....	**Used for.....**
2010	<2017	<2017

2013	2017 - 2020	2017 - 2020
2016/2019	2020 +	2023 +

Table 1 Assumed Year of Introduction of Energy Benchmarks

The information from the data sources described above has been used to determine annual energy demands for all buildings in the regeneration area to 2042.

Peak demands for each building are based on assumed diversification factors for each building usage class. Hourly energy demands for each year from 2018 to 2042 are calculated based on annual demand increases arising from development phasing as described below and hourly demand profiles that have been constructed for each category of building use.

These hourly demand profiles have been developed on the basis of season (using degree day modelling), building type and diurnal and weekly profile assumptions that account for variance in factors such as occupancy and external temperature, etc. Separate profiles have been developed for space heating and domestic hot water (DHW) in order to capture both the base and peak heating demand per use class.

2.2 Development Profile

The calculated annual heat demand by building type at full build out (in 2042) is shown in Figure 1:-

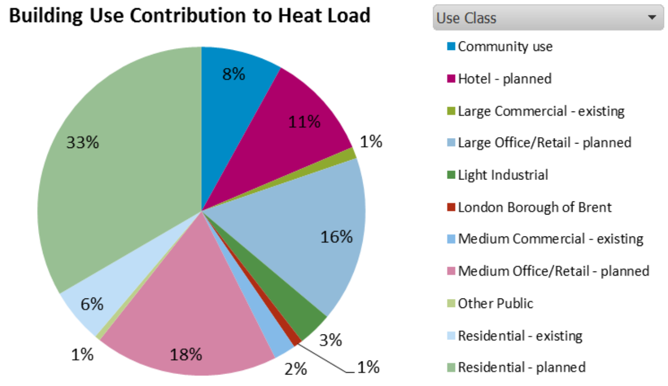

Figure 1 Annual heat demand by building type at full build out (in 2042)

Nearly 50% of all heat demand is expected to be from Residential buildings and Hotels. This implies that there will be a significant base heat load for a potential decentralised energy scheme due to the high DHW requirement for each of these building types.

The relative contributions to the heat demand from each of the building types shown above vary as each phase of development comes forward. However the figure represents the projected demand composition for the last 12 years of the project lifetime, during which time the estimated total annual demand within the Wembley Regeneration Area is calculated to be approximately 83.9GWh/year.

Sections 2.3 and 2.4 below consider the heat demands for each phase of development in greater detail. These sections include heat demands associated only with buildings that have been identified as viable for connection to the heat network opportunity. This basis for this is as follows:-

1. Buildings to the east of Forth Way, have been excluded, on the basis that there are no major regeneration proposals in this area and that existing buildings are predominantly light commercial/industrial without significant demands and without any certainty that they would connect
2. Existing buildings to the west of Forth Way and those with existing planning applications have been assessed for connection suitability based on known information about their internal heating systems taken from planning applications together with knowledge of similar building types based on our experience on similar projects in the past. Any buildings with an existing community heating scheme are considered capable of connecting to the heat network opportunity.

3. It is assumed that buildings within the identified network opportunity area to the west of Forth Way that are as of yet in very early or pre-planning stages, shall be required as a condition of planning permission to be capable of connecting to the district heating opportunity and are therefore assumed to be available for connection to the scheme.

2.3 Heating Demands in Existing Buildings

There are relatively few existing buildings (nine) within the Regeneration Area that shall remain in place for the lifetime of the project. These have been identified based on discussions with London Borough of Brent's planning department. The buildings that shall remain include a mix of recent developments (such as some of the Quintain Stage 1 buildings) and existing large sites such as Wembley Arena and Wembley stadium.

Tables detailing the energy demands and attributes of these buildings are contained in Appendix 1. The results of the demand assessment are shown graphically in Figure 2. The existing heat demand, although comprised of a small number of buildings is relatively high. This is due to the presence of large high demand "anchor-loads" such as Wembley Arena, Wembley Stadium and two 82-bed hotels.

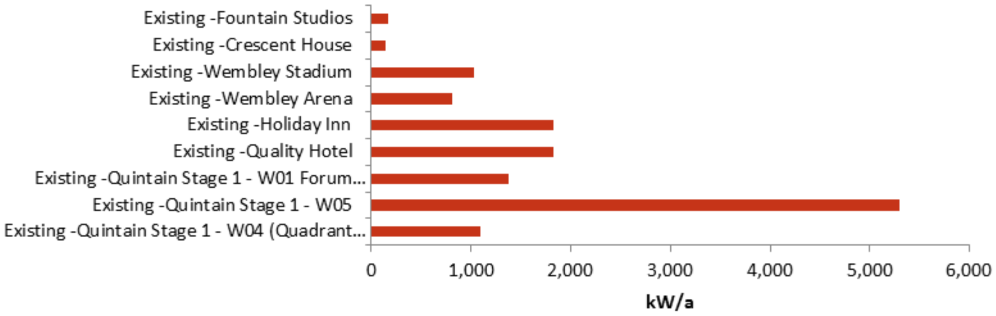

Figure 2 Energy demands of existing buildings within Wembley Regeneration Area

The most significant contribution to the overall heat demand is expected to come from the Quintain W05 development as this a primarily residential/hotel development, with additional significant contributions from both the Holiday Inn and Quality Hotels. The existing heat demand based on this analysis already accounts for approximately 16% of the projected 2042 demand.

2.4 Heating Demands in new Developments

The increase in heat demand over the lifetime of the project is significant. The heat demand in the regeneration area in 2018 is predicted to be of the order of 48GWh. This is projected to rise by a further 70% to 83.9 GWh in 2030. It has been assumed here that the regeneration area will be fully built out by this date; this assumption is in accordance with the information provided by London Borough of Brent. The increase in heat demand occurs in phases, with the largest increases occurring between 2016 and 2018 and 2021 and 2023 respectively. In total, the heat demand growth over these two periods accounts for 45% of the total annual heat demand in the regeneration area at full build out in 2030.

The annual heat demand growth and the annual peak demand for each year of the project's lifetime is shown in figure 4 below.

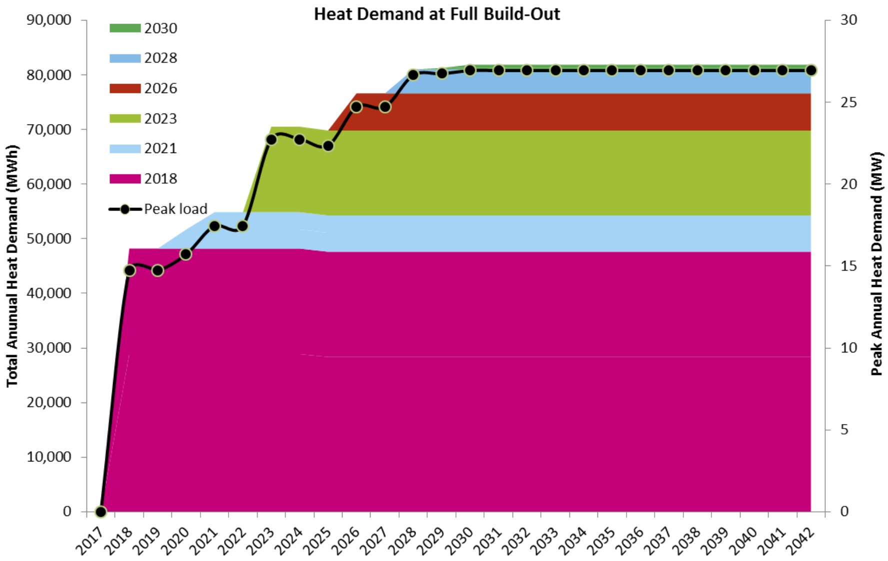

Figure 3 Phased Heat Demand at Full Build Out

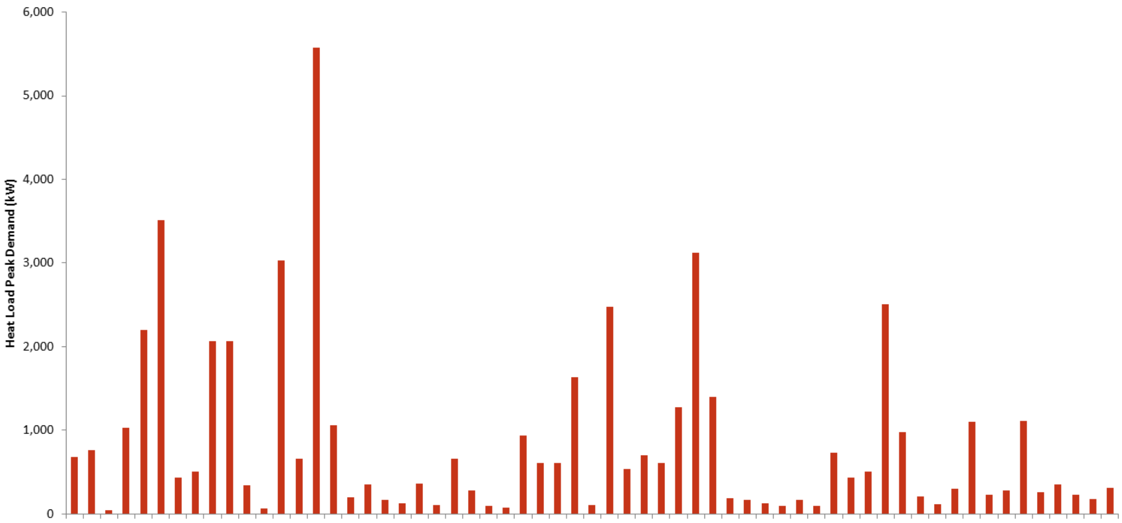

Figure 4 Peak Heat Load in Buildings at Full Build Out

As can be seen in the image above there is a slight decrease in energy demand in the scheme in the year 2025. This is due to the predicted adoption of energy efficiency measures in this year in existing buildings. Energy efficiency improvements have been assumed to result in a 10% reduction in annual heat demand for all existing buildings and those to be constructed within the next year. It is assumed that there would be no further energy efficiency measures introduced into buildings constructed beyond 2014.

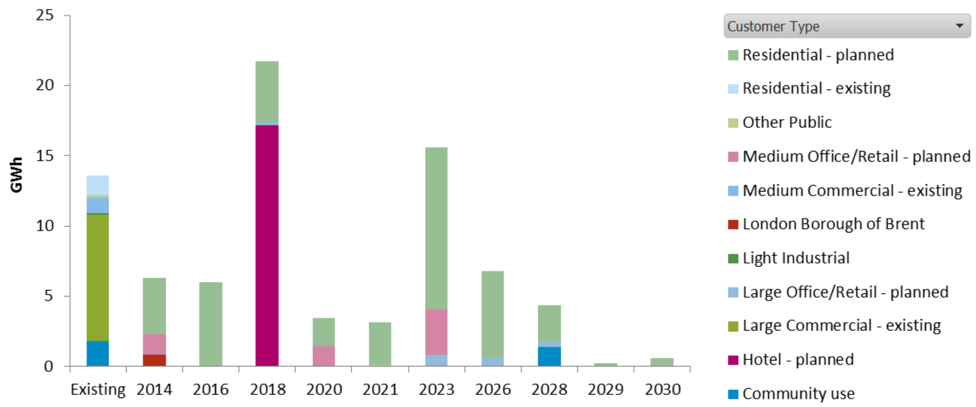

Figure 5 Annual Growth in Heating Demand per Customer Type

Figure 5 above shows the annual variation in demand growth sub-divided into the relative contributions from varying customer types. As discussed previously in Section 2.2 the effect of this variation in customer types has the effect of changing the demand profile characteristic of the scheme, i.e. a higher proportion of hotels will results in a higher more consistent base load, whereas an increased contribution from offices will give a demand profile with a higher peak load.

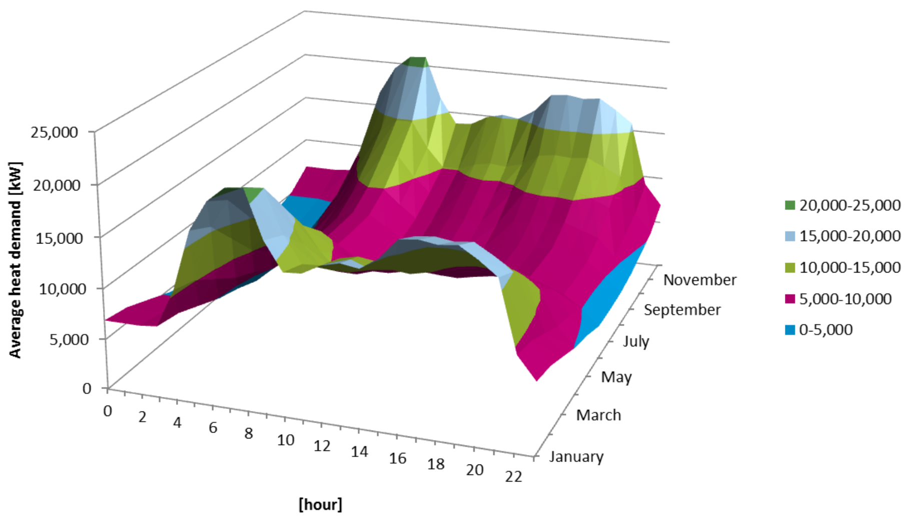

Figure 6 Average Hourly and Monthly Heat Demands

Figure 6 above shows the average heat demand in the network for the fully built out project. The average hourly heat demand profiles for each month of the year is shown on this chart. As expected the summer profile is lower than that for winter and is less variable reflecting the fact that the summer demand is driven primarily by the significant domestic hot water demand.

Figure 7 shows the result of the heat mapping exercise carried out for the entire Wembley Regeneration Area. Based on this and in conjunction with the methodology as discussed in Section 2.1 the developments shown below were identified as suitable for connection. The original development proposals as received from LBB are also shown marked in blue on the map. The detailed development growth associated with these heat loads are shown in series in Figure 25 to Figure 33. The heat network growth is also contained in these figures, from Figure 28 onwards.

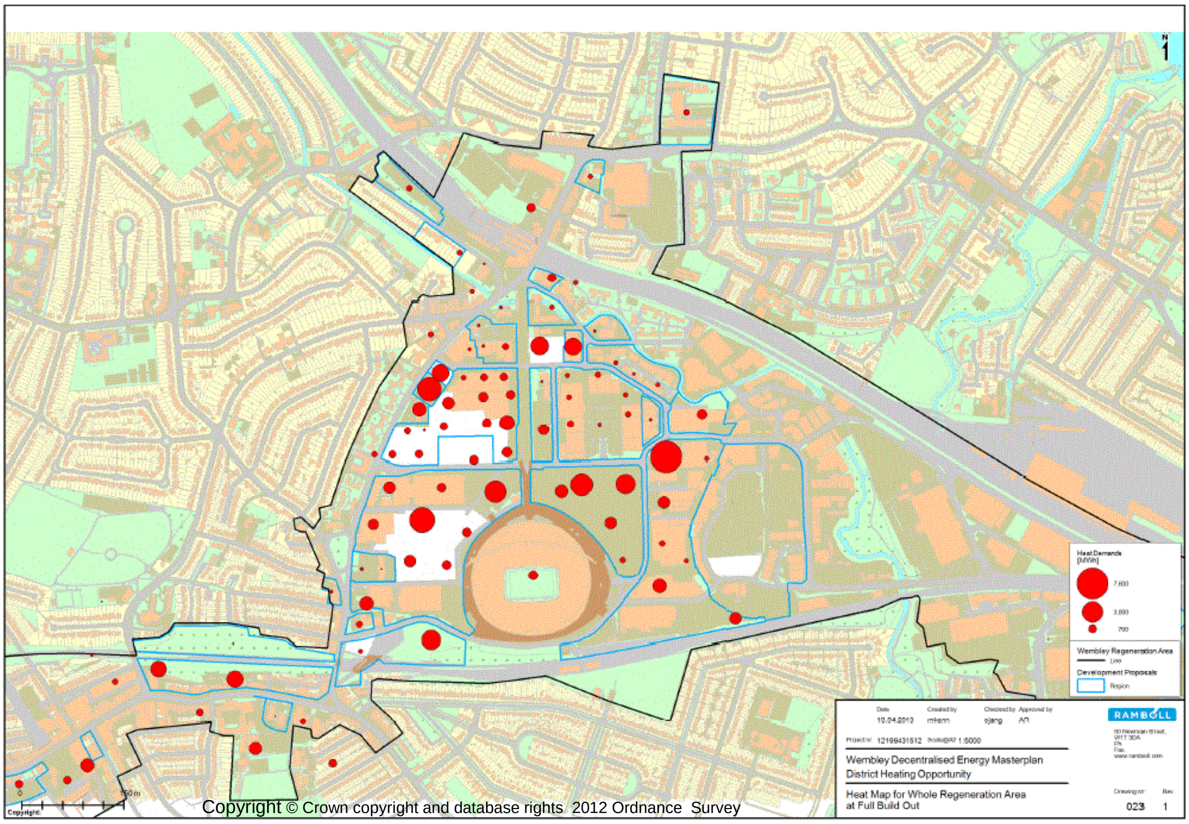

Figure 7 Heat Map for Wembley Regeneration Area

Figure 8 below, shows the relative size of heat demands in the Central Wembley Regeneration Area at full build out from 2030 to the end of the project lifetime. This map shows the area identified as suitable for a heat network opportunity.

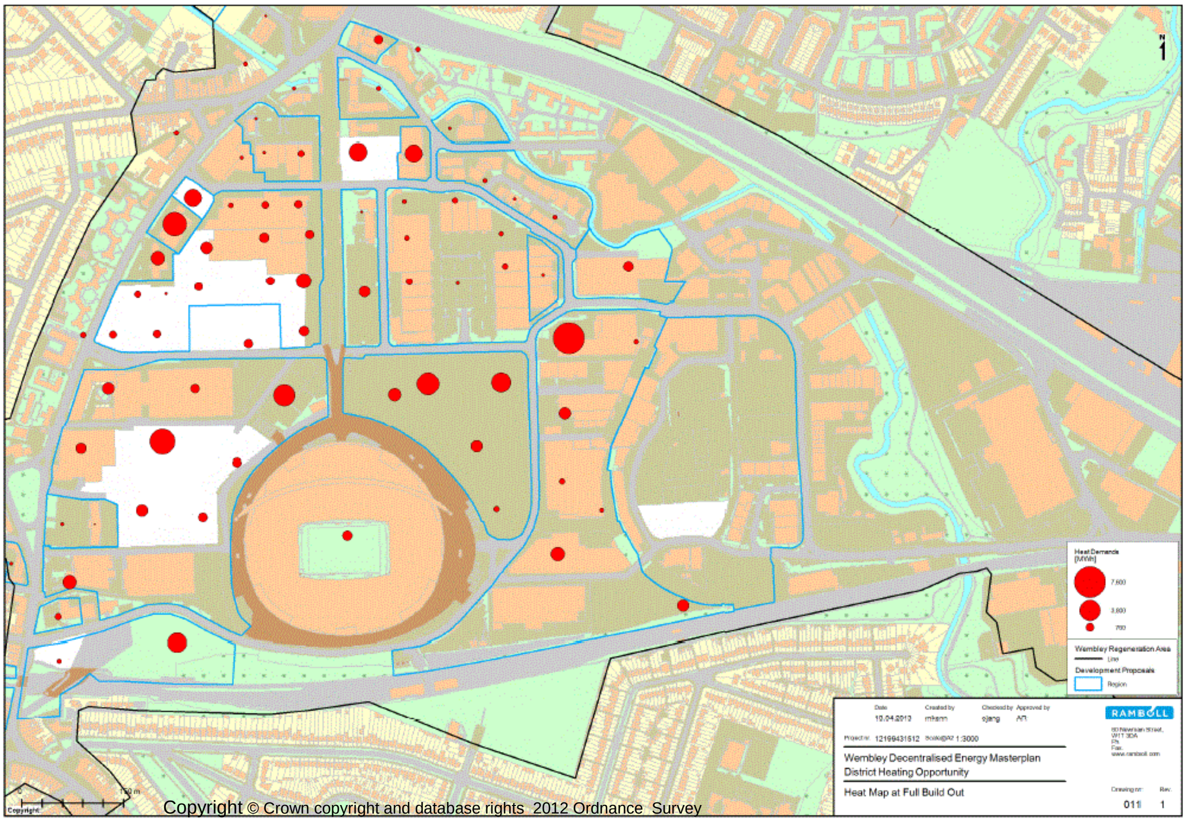

Figure 8 Central Wembley Regeneration Area Heat Map

2.5 Cooling Demands

The cooling demands are, like most heat demands, mainly based on individual energy strategies or modelling carried out as part of the evidence base. Where only the electricity for cooling was available a Seasonal Energy Efficiency Ratio[1] (SEER) of 4 was used to convert electricity to thermal coolth.

The largest demand comes from planned residential developments. These cooling demands are based on submitted energy statements. It has been assumed that there is no cooling requirement for future residential developments. Some of the energy statements were hard to decipher in terms of for what building use types the cooling would be used. In these cases we have attributed the cooling based on proportion of floor areas.

Figure 9 indicates that the cooling from residential developments is substantial. It can be argued that future planned residential developments may include cooling and this would increase the demand further, however, as building regulations and carbon dioxide requirements get tougher it can also be argued that some of this cooling demand could be avoided through improved building design. Hence they have been left out from this analysis.

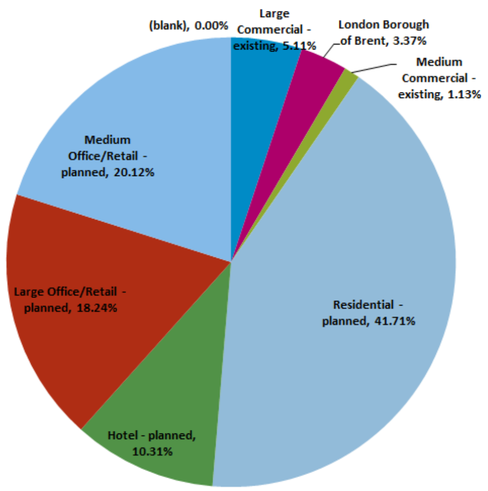

Figure 9 Proportion of demand per customer types

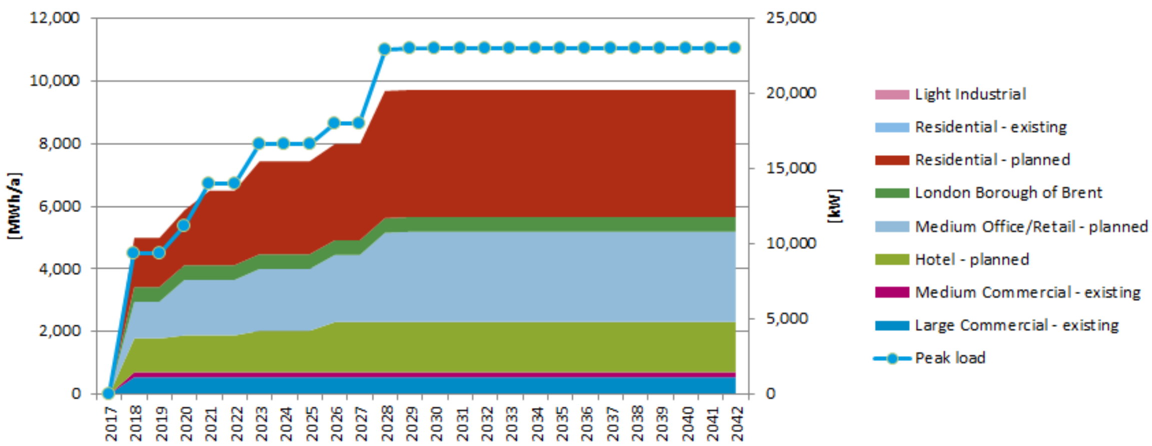

Figure 10 Cooling demand growth as areas against the left axis and annual peak demand growth as dotted line against the right axis

Figure 10 indicates the calculated growth projection. The district cooling project reaches full demand in 2029. Figure 12 below illustrates the overall increase in demand per annum, per customer type from today to 2029. See Figure 11 for the geographical layout of the loads.

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[1] The Seasonal Energy Efficiency Ratio (SEER) is defined as the cooling output during a typical cooling season divided by the total electrical (or thermal) energy input during the same period. It therefore characterises the performance of the chilling plant over a season under varying ambient conditions. The Coefficient of Performance represents the instantaneous output divided by the electrical (or thermal) energy input

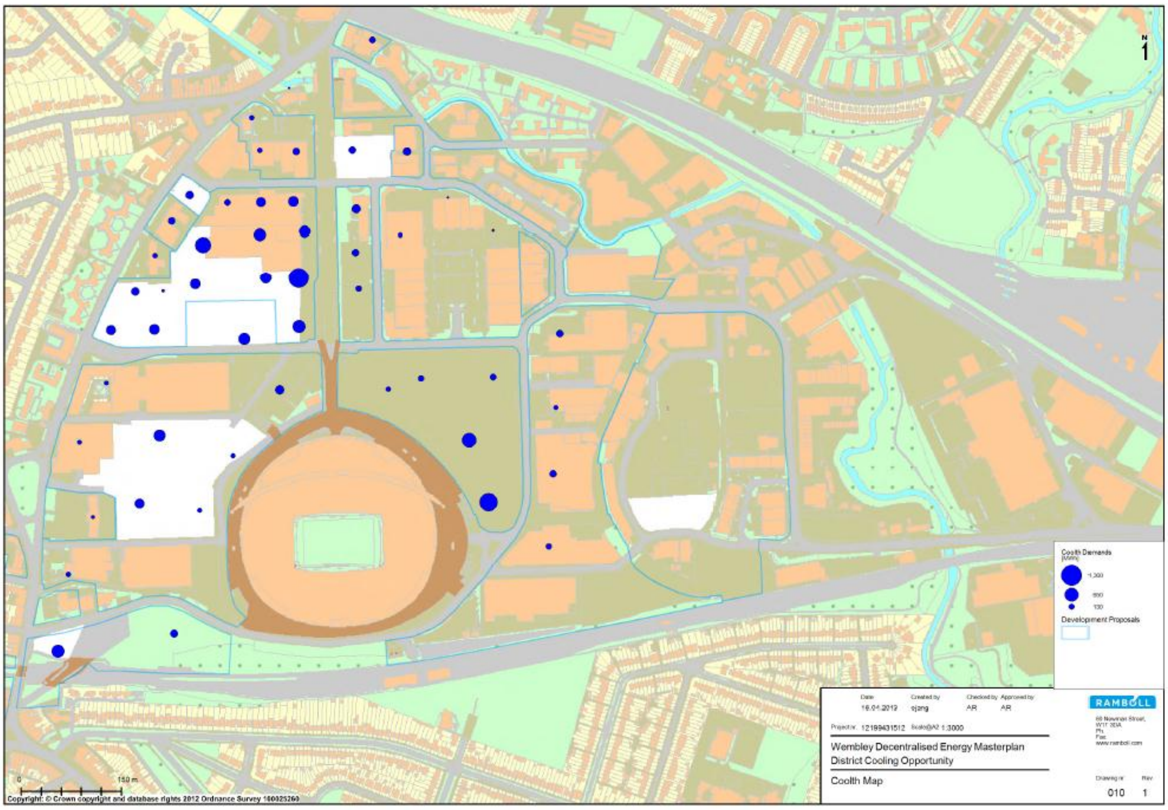

Figure 11 Coolth Map

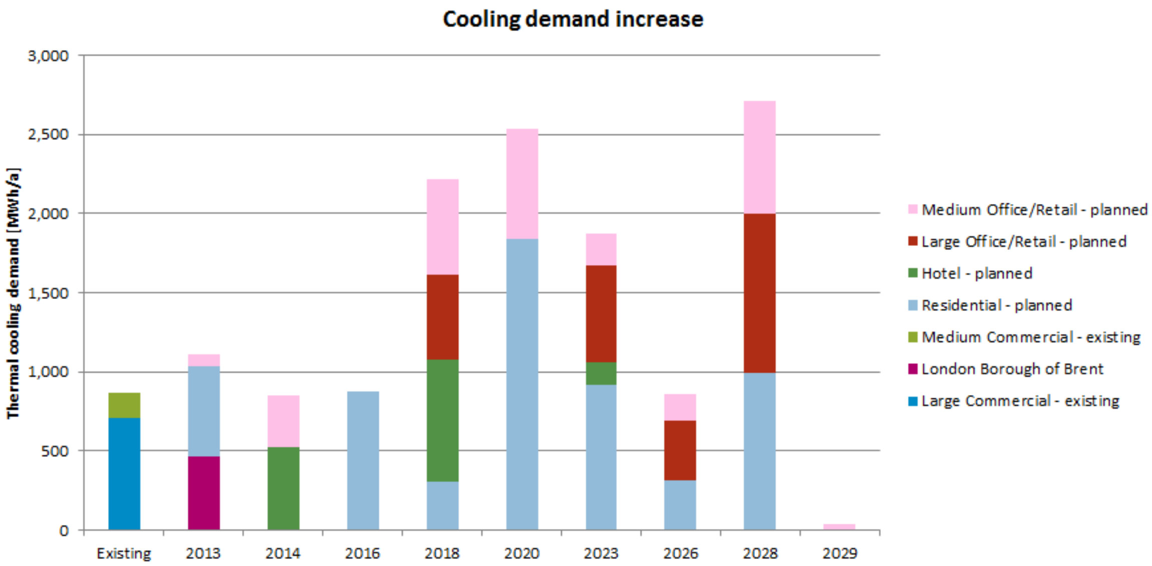

Figure 12 Cooling demand increase per year shown per building type

At full build out, the average profile can be plotted in order to understand when most of the cooling demand is required. See Figure 13, but note that this does not show the system peak as it is the average demand.

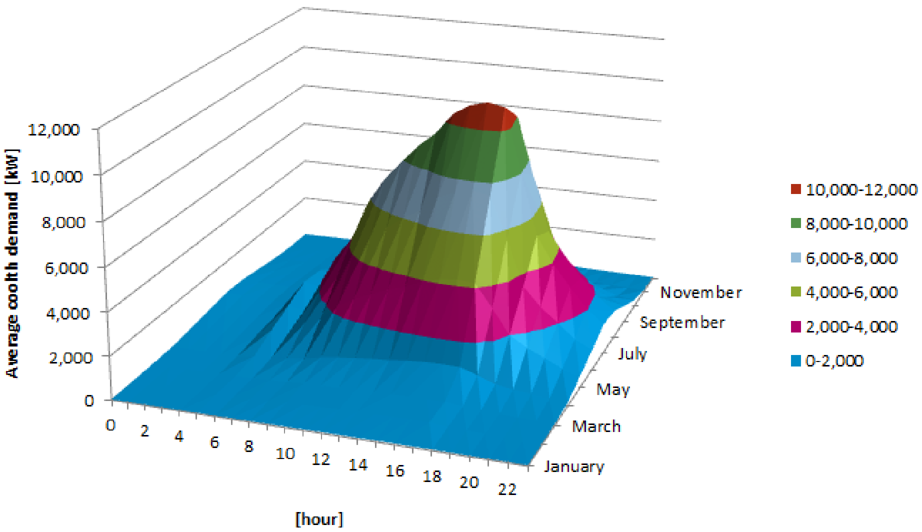

Figure 13 Average hourly profile per month

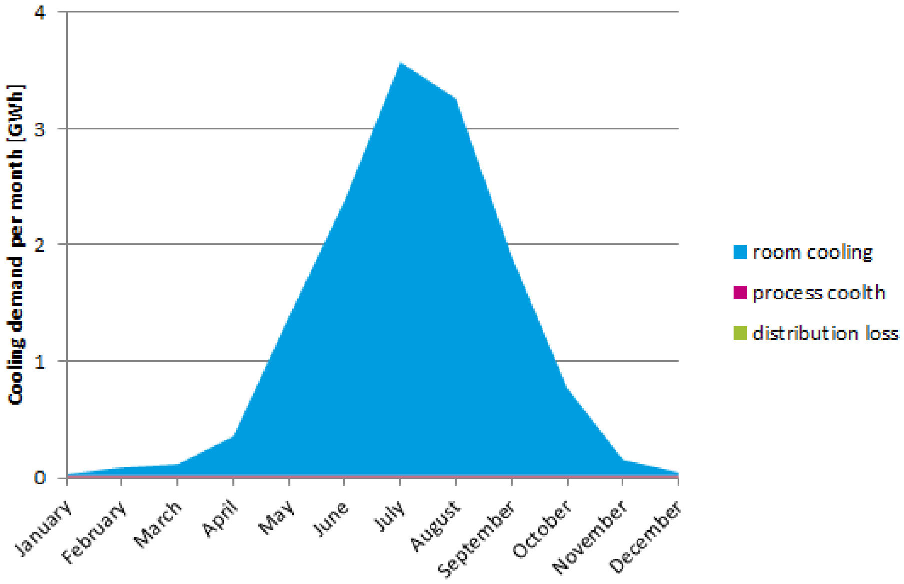

Figure 14 Annual distribution of demand

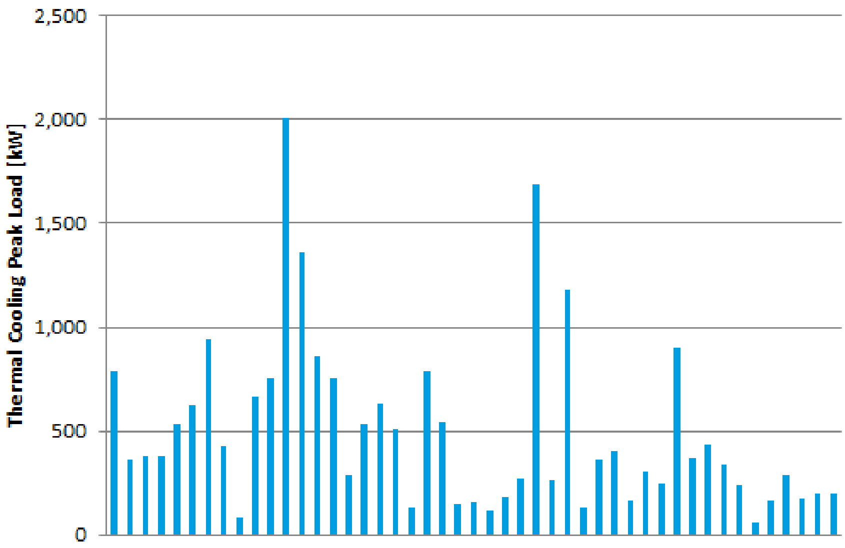

Figure 15 Peak loads of buildings

A diagram showing all individual loads is presented in Figure 15. The average of all the estimated peak loads is 468 kW.

2.6 Cooling Demands in Existing Buildings

The cooling demand in existing buildings is limited. Five buildings have been identified for connection. It has been assumed that the district cooling network connectable area would be the same as for the heat network for the reasons set out for the heat network. Although not all buildings identified for the heat network are assumed to have cooling demand.

There could potentially be a general overall increase in cooling demand for existing buildings. However, it is more prudent to not bank on such demands as they are more uncertain.

The existing buildings' cooling demands are based on energy statements and benchmarks from building regulations Part L modelling.

2.7 Cooling Demands in new Developments

The total demand is almost entirely made up of new developments. A total of 42 buildings have been identified for connection as planned with future cooling demand including three buildings constructed in 2013.

3. EVIDENCE BASE

3.1 Methodology

Options for decarbonising the energy supply for new developments at building and at development plot level have been identified and evaluated. A range of low and zero carbon supply technology options have been appraised in qualitative terms, taking into account economic, commercial deliverability, planning, environmental and technical factors and from these a shortlist of options has been developed.

The long list of technology options is set out below:-

1. Solar PV,
2. Solar thermal,
3. Gas fired CHP,
4. Air, ground source and hybrid heat pump systems
5. Biomass boilers
6. Bioliquid boilers
7. Bioenergy CHP (bioliquid, biogas and biomass)
8. Mini and Micro wind

A summary of shortlisting process is presented in Appendix 2.

The shortlisted options have been analysed and compared in greater detail against the factors set out below:-

1. Current developer led preferences and strategies
2. Implications for leaseholders, tenants and the associated value to these under the alternative approaches.
3. Impact of Allowable solutions on possible outcomes and options for developers
4. Cost and carbon content of heat delivered,
5. Risk to investors (including technology risk, revenue risk, operating risk).
6. Physical barriers such as existing infrastructure constraints
7. Route to market ~ how each option can be delivered, the appetite amongst the private sector and the role that the Local Authority will need to play
8. Planning and environmental factors.

A summary of this analysis is presented in Appendix 2.

The shortlisted scenarios are summarized in Figure 16.

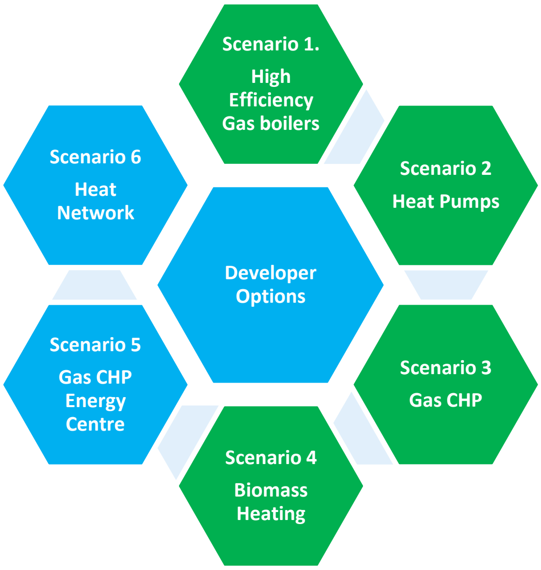

Figure 16 Evidence Base Options

Scenarios 1 to 4 represent block level solutions for each of the individual building types.

Scenarios 5 represents a community level solution at development plot level involving all buildings on a single plot connected through one supply system (via a community heat network) and Scenario 6 represents a district heating network solution, from a remote energy centre.

For the zero carbon homes (2016) and non-residential option, a biofuel CHP variant option has also been carried out for the building level solution (Option 3) in place of the gas CHP option.

Building types with London Borough of Brent, based on the mix under allocated developments in the Opportunity area, and may produce indicative, pro-rated, carbon abatement scenarios for up to three developments with varying proportions of each building usage type.

3.2 Quantitative Analysis of Options

A quantitative analysis of the shortlisted options has been carried out. This has included consideration of each technology's ability to achieve compliance under current and anticipated future policy requirements as set out below:-
:-

1. 2010 Building Regulations and anticipated 2013 Building Regulations
2. Government's proposed Zero Carbon Homes policy due to be implemented in 2016[2].
3. BREEAM Excellent for non-residential buildings, as required under London Borough of Brent's policy for the Opportunity area.
4. Policies 5.6 of the London Plan 2011 which states that development proposals should evaluate the feasibility of Combined Heat and Power (CHP) systems, and where a new CHP system is appropriate also examine opportunities to extend the system beyond the site boundary to adjacent sites. The policy requires major development to select energy systems in accordance with the following hierarchy; Connection to existing heating or cooling networks; Site wide CHP network; Communal heating and cooling.
5. Policies 5.7 of the London Plan 2011 which places a presumption that all major development proposals should seek to reduce carbon dioxide emissions by at least 20 per cent through the use of on-site renewable energy generation wherever feasible.

The analysis has been carried out for a notional development that was considered to be representative of the type of development expected to come forward in the Wembley Regeneration Area in the near to medium term. The notional development consists of two residential 20 storey blocks, one 10 storey hotel, with retail space at first 3 floors and one 12

[2] Refer to Appendix 3 for further discussion on the assumptions around the approach to modelling the Government's Zero Carbon Policy.

storey office with retail space at first 2 floors. Further details of the modelling assumptions and parameters for the notional development are presented in Appendix 3.

Each of the scenario options for the notional development have been evaluated using simulation models developed in IES (for non-residential) and NHER (for residential). Target Emission Rates (TER), required Building Emission Rates (BER) and the consequent impact of achieving them have been calculated. A comparison of the following indicators has subsequently been carried out:-

1. marginal investment cost in new low / zero carbon technology
2. marginal heat production costs
3. space requirements for new low / zero carbon technology and implications on forfeited lease space
4. carbon compliance achieved and residual offsetting requirement to deliver compliance under BREEAM, Building regulations and Zero Carbon Homes (and non-residential) policy

Details of the building modelling assumptions are provided in Appendix 3.

Subsequent sections in this chapter present the main findings of the analysis. Whilst analysis has been carried out for 2010, 2013 and 2016, the bulk of the analysis presented in the report refers to results for 2013 and 2016.

Economic viability for the shortlisted options has been addressed through indicators such as carbon abatement potential and net present cost of the identified options.

For the 2016 analysis, scenario 1 has not been modelled since it can be assumed that a gas boiler only scenario would not meet the minimum requirements at the time. Where relevant, results from 2013 have been transposed to 2016 results. As an alternative, scenario 3 (block level CHP option), has been modelled both as gas CHP and as biofuel CHP to establish the impact of the alternative biofuel based option. Based on the options shortlisting appraisal presented in Appendix 2, this is considered to be the most realistic alternative CHP option at block level.

All results in subsequent sections are based on scenario 6 being the Seneca option (Option A) under Section 5 of the report.

3.2.1 Building Emission Rates and Residual Compliance Requirements

Calculated building emission rates, dwelling emission rates and target emission rates[3] to achieve BREEAM compliance and Dwelling Compliance are shown in Table 2 for each of the scenario options for 2010, 2013 and 2016.

Building emissions rates reflect value prior to application of PV or other residual offsetting compliance measures.

The residual compliance[4] requirements for each scenario are presented in Table 3.

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[3] Definitions for Building emission rate, Dwelling emission rate, Target emission rate (TER) and Residual Compliance are set out below:-

Building emission rate (BER): The actual building's CO2 emissions rate calculated using the National Calculation Methodology (NCM) for non-domestic buildings, together with a set of energy-performance related assumptions specified in the Building Regulations. The BER is used to calculate compliance with Part L of the UK Building Regulations, when compared against the TER.

Dwelling emission rate (DER): The actual building's CO2 emissions rate calculated using the Standard Assessment Procedure (SAP) methodology for domestic buildings, together with a set of energy-performance related assumptions specified in the Building Regulations. The DER is used to calculate compliance with Part L of the UK Building Regulations, when compared against the TER.

Target emission rate (TER): The CO2 emissions rate calculated based on the notional building in each of the SAP (domestic) and NCM (non-domestic) methodologies respectively. Part L of the building regulations (both parts L1A and L2A) require that the BER/DER is below the TER in order for buildings to achieve compliance.

This has been calculated based on the difference between the buildings / dwelling emission rates and the target emission rates to deliver BREEAM/ Dwelling Compliance as presented in Table 2. Refer to the footnotes on Page 23 for definitions of the relevant parameters in Table 2. In the final row of the tabulated data, TER's are presented under BREEAM (for non-residential) and under Zero Carbon Homes policy (for residential).

The costs associated with achieving residual compliance are also presented for each scenario, together with the costs relative to Scenario 6, the decentralised energy option assuming a carbon price of £50 / Tonne CO_2. The figure of £50 / Tonne CO_2 is based on a rounded up value of the national market price of carbon (set at £46 / Tonne CO_2) which has been the basis for the work carried out by the Zero Carbon Hub in relation to the proposed Allowable Solutions framework and equates to the value referenced in the Zero Carbon Homes Impact Assessment carried out by DCLG in May 2011[5].

Noting that the Zero Carbon Hub report does not propose a ceiling price for carbon and that local authorities would in principle be at liberty to set a higher carbon buy out price providing that they do not make developments non-viable, a value of £80 / Tonne CO_2 has been tested and presented later in this chapter as a sensitivity on the £50 / Tonne CO_2 assumption (refer to Table 7, Table 8 and Table 9). Equally it is recognised that the proposed 'central repository' price under the Allowable Solutions framework could potentially float between the national market price and a proposed floor price which is intended to be aligned to the Electricity Market Reform stated floor price[6]. On this basis, a value of £30 / Tonne CO_2 has also been tested as a sensitivity on the £50 / Tonne CO_2 assumption (refer to Table 7, Table 8 and Table 9).

Costs are presented as a total sum over a 25 year period. The residual compliance costs relative to Scenario 6 are also shown graphically in Figure 17 based on the central £50 / Tonne CO_2 price assumption.

The difference compliance costs between each scenario and Scenario 6 represents the value to the developer of connecting to the network under Scenario 6. From 2016 it also represents the theoretical savings in "allowable solutions" and potentially therefore the reduction in contribution that the developer could pay into an allowable solutions fund in lieu of other compliance measures. In principle this cost could be captured and used to support construction of the project.

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[4] Residual Compliance relates to the emissions still required to be offset in order to bring the development's BER/DER into line with the BREEAM /Zero Carbon Homes TER, which becomes more onerous with each time period (i.e. 2010, 2013, 2016, and 2019). The Residual Compliance measurement is independent of whether the DER/BER has bettered the 2010 TER.

[5] Reference "Zero Carbon Homes Impact Assessment May 2011, DCLG" and "Allowable Solutions Evaluating Opportunities and Priorities, Zero Carbon Hub – September 2012"

[6] With reference to "Carbon Price Floor Standard Note: SN/SC/5927, 15th March 2013 House of Commons Library" the floor price will start at £16 per tonne in 2013 and rise to a target price of £30 per tonne of carbon dioxide in 2020.

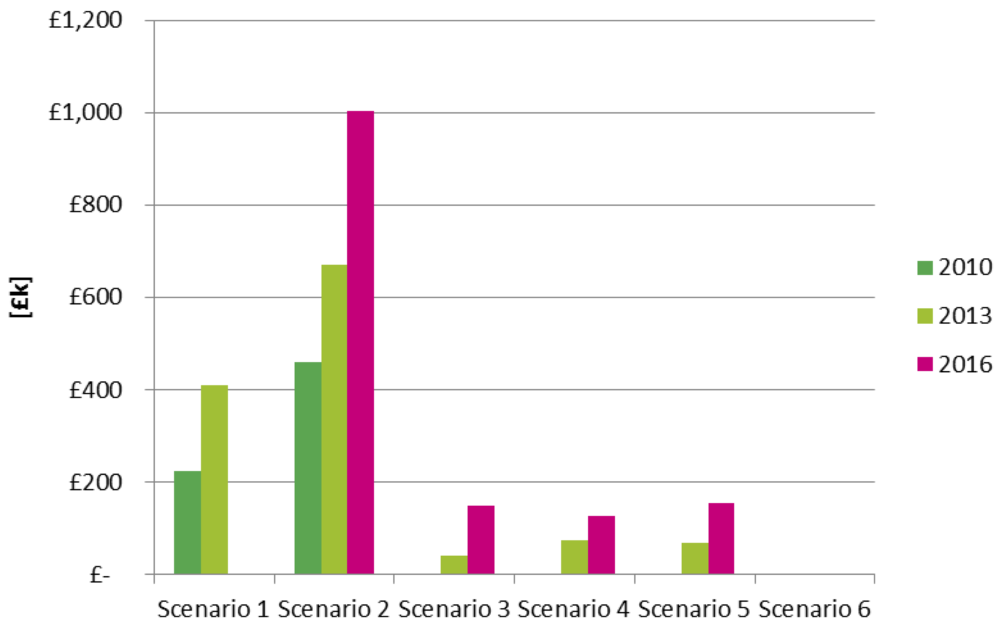

Figure 17 Residual Compliance Cost over 25 years relative to Scenario 6 (Seneca Option)

The equivalent residual compliance costs relative to scenario 6 are also shown graphically in Figure 18 for the case that scenario 6, the decentralised energy option is based on gas CHP.

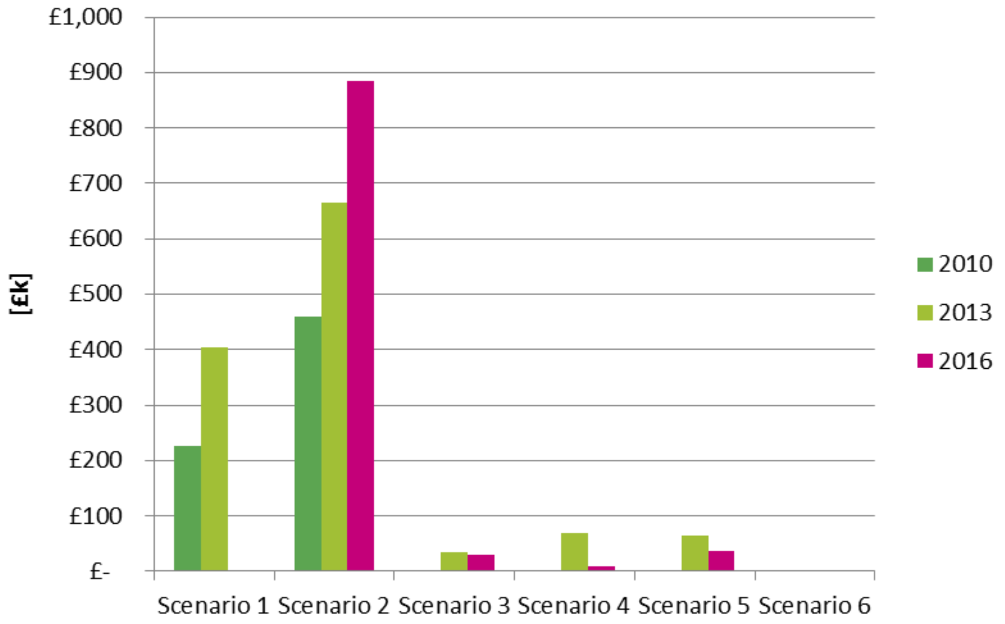

Figure 18 Residual Compliance Cost over 25 years relative to Scenario 6 (gas CHP Option)

In all cases, the residual offsetting requirement for the air source heat pump option (scenario 2) is considerably higher than the alternative scenario options and the gas boiler option This is due to the fact that the notional building used to create the target emission rate (TER) has a servicing strategy and system that is based on the system of the actual building being checked. In the case of the gas boiler the fuel efficiency of the notional building's system is less than the actual building; in the case of the heat pump, the efficiency of the notional and actual heat pump systems are on par. Therefore when a comparison between BER and TER is made, the actual building only looks slightly better than the notional building due to fabric efficiency improvements under the heat pump option, whereas for the gas boiler option the actual building looks far better based on same fabric efficiency improvements and a better system fuel efficiency.

		Scenario 1 Gas Boiler			Scenario 2 Air Source Heat Pump			Scenario 3 Gas CHP		
		Hotel	Office	Resi	Hotel	Office	Resi	Hotel	Office	Resi
2010	Building / Dwelling Emission Rate	51.5	19.8	14.3	58.4	26.5	13.8	24.5	19.4	8.9
	Target Emission Rate (2010 Part L)	60.5	27.1	14.8	59.2	26.5	14.8	60.5	27.1	14.8
	TER BREEAM/ZCH	45.4	20.3	11.1	44.4	19.9	11.1	45.4	20.3	11.1
2013	Building Emission Rate	49.9	18.7	12.5	57.5	25.9	12.1	22.9	18.4	9.2
	Target Emission Rate (2010 Part L)	60.5	27.1	14.8	59.2	26.5	14.8	60.5	27.1	14.8
	TER BREEAM/ZCH	36.3	16.3	8.9	35.5	15.9	8.9	36.3	16.3	8.9
2016	Building Emission Rate	n/a	n/a	n/a	57.3	25.9	11.7	22.6	18.2	8.9
	Target Emission Rate (2010 Part L)	n/a	n/a	n/a	59.2	26.5	14.8	60.5	27.1	14.8
	TER BREEAM/ZCH	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0

		Scenario 4 Biomass Boiler			Scenario 5 district Gas CHP			Scenario 6 district heating		
		Hotel	Office	Resi	Hotel	Office	Resi	Hotel	Office	Resi
2010	Building / Dwelling Emission Rate	23.8	19.3	10.1	24.5	19.3	9.8	22.8	16.3	6.4
	Target Emission Rate (2010 Part L)	33.5	26.6	14.8	60.5	27.1	14.8	60.5	27.1	16.7
	TER BREEAM/ZCH	25.1	20.0	11.1	45.4	20.3	11.1	45.4	20.3	12.5
2013	Building Emission Rate	22.2	18.2	9.0	22.9	18.3	8.9	22.8	16.6	5.4
	Target Emission Rate (2010 Part L)	33.5	26.6	14.8	60.5	27.1	14.8	60.5	27.1	14.8
	TER BREEAM/ZCH	20.1	16.0	8.9	36.3	16.3	8.9	36.3	16.3	8.9
2016	Building Emission Rate	21.9	18.1	8.7	22.6	18.0	8.5	22.8	16.8	5.3
	Target Emission Rate (2010 Part L)	3.5	26.6	14.8	60.5	27.1	14.8	60.5	26.5	14.8
	TER BREEAM/ZCH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 2 Calculated building emission rates, dwelling emission rates and target emission rates to achieve BREEAM compliance and Dwelling Compliance

			Scenario 1 Gas Boiler			Scenario 2 Air Source Heat Pump			Scenario 3 Gas CHP		
			Hotel	Office	Resi	Hotel	Office	Resi	Hotel	Office	Resi
2010	Residual Offsetting Required (pa)	[kgCO2]	87,931	-	92,499	200,984	88,219	78,554	-	-	-
	Offsetting Cost over 25 years	[£k]	£110	£0	£116	£251	£110	£98	£0	£0	£0
Total	Cost of Compliance	[£k]	£ 226			£ 460			£ -		
	Cost Relative to Scenario 6		£ 226			£ 460			£ -		
2013	Residual Offsetting Required (pa)	[kgCO2]	195,242	32,491	104,327	315,545	133,160	91,950	-	28,496	8,181
	Offsetting Cost over 25 years	[£k]	£244	£41	£130	£394	£166	£115	£0	£36	£10
	Cost of Compliance	[£k]	£415			£676			£46		
	Cost Relative to Scenario 6	[£k]	£409			£670			£40		
2016	Residual Offsetting Required (pa)	[kgCO2]				822,599	344,884	337,852	324,446	242,351	255,365
	Offsetting Cost over 25 years	[£k]				£1,028	£431	£422	£406	£303	£319
	Cost of Compliance	[£k]				£1,882			£1,028		
	Cost Relative to Scenario 6	[£k]				£1,002			£149		

			Scenario 4 Biomass Boiler			Scenario 5 district Gas CHP			Scenario 6 district heating		
			Hotel	Office	Resi	Hotel	Office	Resi	Hotel	Office	Resi
2010	Residual Offsetting Required (pa)	[kgCO2]	-	-	-	-	-	-	-	-	-
	Offsetting Cost over 25 years	[£k]	£ -	£ -	£ -	£ -	£ -	£ -	£ -	£ -	£ -
	Cost of Compliance	[£k]	£ -			-			-		
	Cost Relative to Scenario 6	[£k]	£ -			£ -			£ -		
2013	Residual Offsetting Required (pa)	[kgCO2]	30,148	29,828	4,333	-	59,535	637	-	4,527	-
	Offsetting Cost over 25 years	[£k]	£38	£37	£5	£0	£74	£1	£0	£6	£0
	Cost of Compliance	[£k]	£80			£75			£6		
	Cost Relative to Scenario 6	[£k]	£75			£70			£0		
2016	Residual Offsetting Required (pa)	[kgCO2]	314,396	241,020	250,255	324,446	258,813	44,471	327,317	223,709	152,313
	Offsetting Cost over 25 years	[£k]	£393	£301	£313	£406	£324	£306	£407	£280	£190
	Cost of Compliance	[£k]	£1,007			£1,035			£879		
	Cost Relative to Scenario 6	[£k]	£130			£155			£0		

Table 3 Calculated Compliance requirements based on £50/TCO_2[7]

[7] Note that residual compliance costs scale linearly with carbon price assumption. Refer also to Page 24 and to Tables 7, 8 and 9.

3.2.2 Compliance Using Solar PV as a Proxy

The calculated PV requirement to achieve compliance is shown in Table 3. This table shows theoretical installed PV capacity, theoretical PV area requirement and theoretical annual PV contribution and has been used as an alternative measure to that of the cost of carbon as presented in Table 2.

Table 4, Table 5 and Table 6 provide a further breakdown by building type for 2010, 2013 and 2016 respectively. These present the actual achievable compliance through on site PV, the associated cost of this compliance and the cost of forfeited leasable space in lieu of siting PV. The amount of PV that can be implemented for each building within the notional development has been calculated assuming that 50% of the available roof space can be allocated to PV and that the PV is deployed with a spacing ratio of 1.33[8]. The leasable value of the roof space based on the assumptions in Appendix 3.

Onsite PV Requirement to Achieve Compliance				
Scenario	Hotel	Office	Residential	Total
	[m2]	[m2]	[m2]	[m2]
Scenario 1	618	0	414	1,032
Scenario 2	618	539	414	1,571
Scenario 3	0	0	0	0
Scenario 4	0	0	0	0
Scenario 5	0	0	0	0
Scenario 6	0	0	0	0

Cost of Onsite PV Requirement to Achieve Compliance				
Scenario	Hotel	Office	Residential	Total
	[£]	[£]	[£]	[£]
Scenario 1	£132,358	£0	£88,776	£221,133
Scenario 2	£132,358	£115,521	£88,776	£336,654
Scenario 3	£0	£0	£0	£0
Scenario 4	£0	£0	£0	£0
Scenario 5	£0	£0	£0	£0
Scenario 6	£0	£0	£0	£0

Lease Value of PV for On Site Compliance (including spacing ratio)				
Scenario	Hotel	Office	Residential	Total
	[£]	[£]	[£]	[£]
Scenario 1	£151,257	£0	£111,020	£262,276
Scenario 2	£151,257	£121,554	£111,020	£383,831
Scenario 3	£0	£0	£0	£0
Scenario 4	£0	£0	£0	£0
Scenario 5	£0	£0	£0	£0
Scenario 6	£0	£0	£0	£0

Table 4 PV area requirement and associated cost of delivering Compliance on site for 2010

[8] I.e. for every m2 of panel, 1.33 m2 of roof area is necessary

Onsite PV Requirement to Achieve Compliance				
Scenario	Hotel	Office	Residential	Total
	[m2]	[m2]	[m2]	[m2]
Scenario 1	618	539	414	1,571
Scenario 2	618	539	414	1,571
Scenario 3	0	473	136	609
Scenario 4	500	495	72	1,067
Scenario 5	0	457	11	467
Scenario 6	0	75	0	75

Cost of Onsite PV Requirement to Achieve Compliance				
Scenario	Hotel	Office	Residential	Total
	[£]	[£]	[£]	[£]
Scenario 1	£132,358	£115,500	£88,776	£336,633
Scenario 2	£132,358	£115,521	£88,776	£336,654
Scenario 3	£0	£101,357	£29,085	£130,442
Scenario 4	£107,180	£106,071	£15,405	£228,657
Scenario 5	£0	£97,909	£2,267	£100,176
Scenario 6	£0	£16,096	£0	£16,096

Lease Value of PV for On Site Compliance (including spacing ratio)				
Scenario	Hotel	Office	Residential	Total
	[£]	[£]	[£]	[£]
Scenario 1	£151,257	£121,532	£111,020	£383,809
Scenario 2	£151,257	£121,554	£111,020	£383,831
Scenario 3	£0	£106,651	£36,373	£143,023
Scenario 4	£122,484	£111,611	£19,265	£253,360
Scenario 5	£0	£103,022	£2,835	£105,858
Scenario 6	£0	£16,936	£0	£16,936

Table 5 PV area requirement and associated cost of delivering Compliance on site for 2013

Onsite PV Requirement to Achieve Compliance				
Scenario	Hotel	Office	Residential	Total
	[m2]	[m2]	[m2]	[m2]
Scenario 1				
Scenario 2	618	539	414	1,571
Scenario 3	618	539	414	1,571
Scenario 4	618	539	414	1,571
Scenario 5	618	539	414	1,571
Scenario 6	618	539	414	1,571

Cost of Onsite PV Requirement to Achieve Compliance				
Scenario	Hotel	Office	Residential	Total
	[£]	[£]	[£]	[£]
Scenario 1				
Scenario 2	£132,358	£115,521	£88,776	£336,654
Scenario 3	£132,358	£115,521	£88,776	£336,654
Scenario 4	£132,358	£115,521	£88,776	£336,654
Scenario 5	£132,358	£115,521	£88,776	£336,654
Scenario 6	£132,358	£115,521	£88,776	£336,654

Lease Value of PV for On Site Compliance (including spacing ratio)				
Scenario	Hotel	Office	Residential	Total
	[£]	[£]	[£]	[£]
Scenario 1				
Scenario 2	£151,257	£121,554	£111,020	£383,831
Scenario 3	£151,257	£121,554	£111,020	£383,831
Scenario 4	£151,257	£121,554	£111,020	£383,831
Scenario 5	£151,257	£121,554	£111,020	£383,831
Scenario 6	£151,257	£121,554	£111,020	£383,831

Table 6 PV area requirement and associated cost of delivering Compliance on site for 2016

Whilst under 2016 regulations, there is no material benefit under scenario 6, (since all options require full coverage of PV), a significant benefit arises under 2013 regulations. The benefit associated with investment in PV cannot be captured through an Allowable Solutions mechanism prior to 2016. It is nevertheless tangible and of value to developers, who may see it as an incentive to connect to the heat network if available. It also represents a basis on which to measure the value of the heat network opportunity and on which to negotiate other compliance measures.

The value of leasable roof space is also a tangible benefit to the developer. Whilst it is not considered appropriate to recognise this as a potential basis for developer contributions, it nevertheless represents an incentive for developers.

The calculated cost of residual compliance (i.e. net of on-site PV) under 2010, 2013 and 2016 regulations is shown in Table 7, Table 8 and Table 9, assuming that the quantities of PV shown in Table 4, Table 5 and Table 6 are employed on site and assuming prices per of £30 / $TC0_2$, £50 / $TC0_2$ and £80 / $TC0_2$.

year	2010

Cost of Offsite Residual Compliance per annum based on £30/Tonne p.a.				
Scenario	Student Acc	Office	Residential	Total
	[£]	[£]	[£]	[£]
Scenario 1	£1,521	£0	£2,026	£3,547
Scenario 2	£4,476	£1,672	£1,607	£7,755
Scenario 3	£0	£0	£0	£0
Scenario 4	£0	£0	£0	£0
Scenario 5	£0	£0	£0	£0
Scenario 6	£0	£0	£0	£0

year	2010

Cost of Offsite Residual Compliance per annum based on £50/Tonne p.a.				
Scenario	Student Acc	Office	Residential	Total
	[£]	[£]	[£]	[£]
Scenario 1	£2,535	£0	£3,376	£5,911
Scenario 2	£7,460	£2,786	£2,679	£12,925
Scenario 3	£0	£0	£0	£0
Scenario 4	£0	£0	£0	£0
Scenario 5	£0	£0	£0	£0
Scenario 6	£0	£0	£0	£0

year	2010

Cost of Offsite Residual Compliance per annum based on £80/Tonne p.a.				
Scenario	Student Acc	Office	Residential	Total
	[£]	[£]	[£]	[£]
Scenario 1	£4,056	£0	£5,402	£9,458
Scenario 2	£11,936	£4,458	£4,287	£20,680
Scenario 3	£0	£0	£0	£0
Scenario 4	£0	£0	£0	£0
Scenario 5	£0	£0	£0	£0
Scenario 6	£0	£0	£0	£0

Table 7 Cost of Residual Compliance after on site PV for 2010

year	2013

Cost of Offsite Residual Compliance per annum based on £30/Tonne p.a.				
Scenario	Student Acc	Office	Residential	Total
	[£]	[£]	[£]	[£]
Scenario 1	£4,740	£0	£2,381	£7,121
Scenario 2	£8,349	£3,020	£2,009	£13,378
Scenario 3	£0	£0	£0	£0
Scenario 4	£0	£0	£0	£0
Scenario 5	£0	£0	£0	£0
Scenario 6	£0	£0	£0	£0

year	2013

Cost of Offsite Residual Compliance per annum based on £50/Tonne p.a.				
Scenario	Student Acc	Office	Residential	Total
	[£]	[£]	[£]	[£]
Scenario 1	£7,901	£0	£3,968	£11,868
Scenario 2	£13,916	£5,033	£3,349	£22,297
Scenario 3	£0	£0	£0	£0
Scenario 4	£0	£0	£0	£0
Scenario 5	£0	£0	£0	£0
Scenario 6	£0	£0	£0	£0

year	2013

Cost of Offsite Residual Compliance per annum based on £80/Tonne p.a.				
Scenario	Student Acc	Office	Residential	Total
	[£]	[£]	[£]	[£]
Scenario 1	£12,641	£0	£6,348	£18,989
Scenario 2	£22,265	£8,052	£5,358	£35,676
Scenario 3	£0	£0	£0	£0
Scenario 4	£0	£0	£0	£0
Scenario 5	£0	£0	£0	£0
Scenario 6	£0	£0	£0	£0

Table 8 Cost of Residual Compliance after on site PV for 2013

year	2016

Cost of Offsite Residual Compliance per annum based on £30/Tonne p.a.				
Scenario	Student Acc	Office	Residential	Total
	[£]	[£]	[£]	[£]
Scenario 1				
Scenario 2	£23,561	£9,372	£9,386	£42,319
Scenario 3	£8,617	£6,296	£6,912	£21,825
Scenario 4	£8,315	£6,256	£6,759	£21,329
Scenario 5	£8,616	£6,227	£6,585	£21,429
Scenario 6	£8,703	£5,736	£3,820	£18,259

year	2016

Cost of Offsite Residual Compliance per annum based on £50/Tonne p.a.				
Scenario	Student Acc	Office	Residential	Total
	[£]	[£]	[£]	[£]
Scenario 1				
Scenario 2	£39,268	£15,620	£15,644	£70,532
Scenario 3	£14,361	£10,493	£11,521	£36,375
Scenario 4	£13,858	£10,426	£11,264	£35,549
Scenario 5	£14,361	£10,378	£10,975	£35,714
Scenario 6	£14,504	£9,561	£6,367	£30,432

year	2016

Cost of Offsite Residual Compliance per annum based on £80/Tonne p.a.				
Scenario	Student Acc	Office	Residential	Total
	[£]	[£]	[£]	[£]
Scenario 1				
Scenario 2	£62,830	£24,991	£25,030	£112,851
Scenario 3	£22,978	£16,790	£18,433	£58,201
Scenario 4	£22,173	£16,682	£18,023	£56,878
Scenario 5	£22,977	£16,606	£17,560	£57,143
Scenario 6	£23,207	£15,297	£10,187	£48,692

Table 9 Cost of Residual Compliance after on site PV for 2016

3.2.3 Low and Zero Carbon Technology Investment Costs

The calculated investment costs in LZC technologies under each of the scenario options are presented in Table 11 and Table 12 for 2013 and 2016 respectively. These costs include for heat production assets (LZC plant and top up boilers), thermal and biomass fuel storage for relevant options and estimated marginal costs for balance of plant items under each scenario (flues, control, M&E). They also include for planned overhaul/replacement costs of the main heat supply assets over the life of project. LZC technologies and thermal stores are sized on energy consumption[9], whilst top boilers are sized on 120% of calculated peak demands, which for residential blocks include diversification on domestic hot water according to the Danish Standard.

Solar PV costs and costs beyond the point of tie in of the plant assets to the plantroom LTHW header are not included in these figures. Differences in costs between the years reflect the marginally different installation capacities under each compliance year.

year	2010

LZC Plant Investment Costs					
Scenario	Energy Centre &/or Community Heat Network	Hotel	Office	Residential	Total
	[£]	[£]	[£]	[£]	[£]
Scenario 1		£166,142	£188,820	£254,219	£609,180
Scenario 2		£356,039	£366,937	£444,340	£1,167,317
Scenario 3		£503,780	£313,465	£435,723	£1,252,968
Scenario 4		£440,003	£349,348	£535,359	£1,324,709
Scenario 5	£1,516,294	£14,075	£16,279	£26,095	£1,572,743
Scenario 6	£104,967	£14,075	£16,279	£26,095	£161,417

Table 10 Calculated investment costs in LZC technologies 2010

year	2013

LZC Plant Investment Costs					
Scenario	Energy Centre &/or Community Heat Network	Hotel	Office	Residential	Total
	[£]	[£]	[£]	[£]	[£]
Scenario 1		£161,476	£179,295	£254,219	£594,990
Scenario 2		£337,327	£308,739	£443,012	£1,089,078
Scenario 3		£499,120	£303,940	£420,348	£1,223,409
Scenario 4		£435,343	£339,823	£524,514	£1,299,681
Scenario 5	£1,478,702	£13,674	£15,300	£26,095	£1,533,770
Scenario 6	£102,916	£13,674	£15,300	£26,095	£157,985

Table 11 Calculated investment costs in LZC technologies 2016

[9] Using relevant benchmarking methods for each technology type

year	2016

LZC Plant Investment Costs					
Scenario	Energy Centre &/or Community Heat Network	Hotel	Office	Residential	Total
	[£]	[£]	[£]	[£]	[£]
Scenario 1		£125,000	£125,000	£125,000	£375,000
Scenario 2		£241,650	£254,731	£366,125	£862,507
Scenario 3		£497,706	£299,986	£434,645	£1,232,337
Scenario 4		£433,929	£335,869	£533,004	£1,302,801
Scenario 5	£1,473,047	£13,555	£14,917	£26,095	£1,527,613
Scenario 6	£102,115	£13,552	£14,915	£26,095	£156,677

Table 12 Calculated investment costs in LZC technologies 2016

The tables indicate comparable investment costs under scenarios 3 and 4, marginally lower costs under scenario 2 and 4, higher investment costs under Scenario 5 and significant reductions in investment under Scenarios 1 and 6. Scenario 6 has by far the lowest investment costs, reflecting only the cost of installing a community heat network plus heat exchanger stations at each of the buildings.

Under Scenario 5, a central energy centre is assumed to be constructed within a basement of an existing building. The energy centre houses a gas CHP with top up boilers, distribution pumps, pressurisation, water treatment, thermal storage and M&E balance of plant. Civil and structural works are not included. However, the forfeited lease space associated with this option is accounted for under Section 3.4. A community heat network of 100 m is also assumed for this option. The investment costs at building level under this option reflect the main plantroom heat exchanger station costs.

It is noted that a temporary energy centre constructed in advance of a heat opportunity may potentially avoid the cost of gas CHP, thermal storage and a degree of M&E balance of plant costs, depending on prevailing building regulations at the time. It is noted that any such avoided costs could potentially be negotiated as a developer contribution to the heat network. The cost of future interconnection to the heat network opportunity (presented in Section 6) is not included in these costs. This would involve allowance for a heat exchanger station and a section of pipework from the heat network distribution main to the energy centre.

For Scenario 6, heat network connection costs are captured assuming a 150 m section of service pipe to the boundary of the development to allow connection into the distribution heat network and plantroom heat exchanger stations at building level.

3.3 Installed Capacity of Heating Plant Assets

Indicative low and zero carbon technology capacities for 2016 are shown in Table 13. These are not repeated for other years since differences are marginal.

year	2016

LZC Plant Installed Capacity					
Scenario	E/C	Hotel	Office	Residential	Total
	[kW]	[kW]	[kW]	[kW]	
Scenario 1					n/a
Scenario 2		81	72	125	air source heat pump
Scenario 3		349	38	114	gas CHP
Scenario 4		1,460	30	452	biomass boiler
Scenario 5	515	815	1,191	3,387	gas CHP/ Heat exchanger
Scenario 6		814	1,191	3,387	Heat exchanger

Table 13 Low and zero carbon technology capacities 2016

3.4 Forfeited Lease Value of Heating Plant Assets

Forfeited annual lease value[10] associated with heating plant assets are shown for 2016 in Table 14. These are not repeated for other years, since differences are marginal.

year	2016

LZC Forfeited Lease Value					
Scenario	E/C	Hotel	Office	Residential	Total
	[£]	[£]	[£]	[£]	[£]
Scenario 1					
Scenario 2		£2,935	£2,808	£3,991	£9,735
Scenario 3		£4,016	£3,539	£4,917	£12,472
Scenario 4		£3,723	£3,510	£4,810	£12,044
Scenario 5	£27,450	£542	£554	£1,216	£29,763
Scenario 6		£542	£554	£1,216	£2,313

Table 14 Forfeited lease value of heating plant assets in 2016

3.4.1 Cost of Heat production

The calculated cost of heat production under each scenario is presented in Table 15, Table 16 and Table 17 for 2010, 2013 and 2016. Two values are presented in the tables.

- The simple cost of delivering the heat taking into account the fuel costs, operations and maintenance and annualised asset replacement costs but excluding the initial investment costs.

- The whole life cost of delivering the heat taking into account the above and also the initial investment costs, with an assumed internal rate of return of 10%.

year	2010

Cost of Heat (FUELEX, OPEX, REPEX, incl CHP revenue)				
Scenario	All	Hotel	Office	Residential
	[£/kWh]	[£/kWh]	[£/kWh]	[£/kWh]
Scenario 1	£0.034	£0.032	£0.040	£0.035
Scenario 2	£0.037	£0.034	£0.044	£0.040
Scenario 3	£0.024	£0.027	£0.043	£0.015
Scenario 4	£0.035	£0.041	£0.033	£0.025
Scenario 5	£0.001	£0.001	£0.001	£0.001

Whole Life Cost of heat based on target IRR %				
Scenario	All	Hotel	Office	Residential
	[£/kWh]	[£/kWh]	[£/kWh]	[£/kWh]
Scenario 1	£0.051	£0.041	£0.119	£0.056
Scenario 2	£0.071	£0.052	£0.191	£0.077
Scenario 3	£0.060	£0.052	£0.173	£0.051
Scenario 4	£0.074	£0.063	£0.179	£0.071
Scenario 5	£0.047	£0.047	£0.047	£0.047

Table 15 Calculated Cost of Heat Production 2010

[10] Forfeited lease value represents the lost income associated with not being able to lease internal floor space within the building as a result of space taken up by LZC heating assets and solar PV. The value of this space has been factored according to whether it is located at roof level or at basement level and is lower than the value attributable to floor area space within the main part of the building.

year	2013

Cost of Heat (FUELEX, OPEX, REPEX, incl CHP revenue)				
Scenario	All	Hotel	Office	Residential
	[£/kWh]	[£/kWh]	[£/kWh]	[£/kWh]
Scenario 1	£0.034	£0.032	£0.044	£0.036
Scenario 2	£0.037	£0.034	£0.047	£0.042
Scenario 3	£0.025	£0.026	£0.048	£0.019
Scenario 4	£0.036	£0.041	£0.032	£0.027
Scenario 5	£0.002	£0.002	£0.002	£0.002

Whole Life Cost of heat based on target IRR %				
Scenario	All	Hotel	Office	Residential
	[£/kWh]	[£/kWh]	[£/kWh]	[£/kWh]
Scenario 1	£0.053	£0.041	£0.169	£0.061
Scenario 2	£0.073	£0.052	£0.251	£0.086
Scenario 3	£0.065	£0.053	£0.261	£0.061
Scenario 4	£0.079	£0.065	£0.269	£0.080
Scenario 5	£0.055	£0.055	£0.055	£0.055

Table 16 Calculated Cost of Heat Production 2013

year	2016

Cost of Heat (FUELEX, OPEX, REPEX, REVEX)				
Scenario	All/Average	Hotel	Office	Residential
	[£/kWh]	[£/kWh]	[£/kWh]	[£/kWh]
Scenario[11] 1				
Scenario 2	£0.036	£0.033	£0.048	£0.039
Scenario 3	£0.022	£0.026	£0.051	£0.012
Scenario 4	£0.035	£0.041	£0.032	£0.025
Scenario 5	£0.001	£0.001	£0.001	£0.001

Whole Life Cost of heat based on target IRR %				
Scenario	All/Average	Hotel	Office	Residential
	[£/kWh]	[£/kWh]	[£/kWh]	[£/kWh]
Scenario 1				
Scenario 2	£0.064	£0.046	£0.251	£0.076
Scenario 3	£0.064	£0.053	£0.304	£0.056
Scenario 4	£0.080	£0.065	£0.317	£0.079
Scenario 5	£0.064	£0.064	£0.064	£0.064

Table 17 Calculated Cost of Heat Production 2016

Refer to Appendix 3 for relevant assumptions.

In the tables above, costs are presented only for scenarios 1 to 5. The results are used as the basis for Scenario 6 to inform the decentralised energy analysis presented in Section 5, in order to ensure market competitive heat under this scenario.

Costs of heat production vary between compliance year. This reflects both varying plant investment costs and varying heat supply requirements. The simple cost of heat varies less than the whole life cost of heat, indicating a greater impact due to lower heat sales with increasing building efficiency and compliance requirements.

The simple cost of heat for gas CHP scenarios is low relative to other scenarios. This reflects the value of electricity sales which, in effect, subsidise heat production costs.

Table 15, Table 16 and Table 17 has been used to calculate the market price of heat for Scenario 6, the decentralised energy opportunity. The basis for pricing under scenario 6 is set out below.

[11] Based on 2013 scenario run, since 2016 option not modelled

For developments being constructed in advance of the heat network, scenario 5 is considered to be the most likely alternative case, since planning policy places a requirement to adopt community heat networks if feasible and since, based on the modelling assumptions in this report, it delivers the lowest average heat price to the notional developments. The whole life cost of heat this scenario is taken to be the average for 2010 and 2013 regulations, calculated to be 5.0 p/kWh based on achieving a 10% IRR. However, it is noted that having invested in the LZC heat production assets the ongoing cost of heat production would be far lower and equal to the simple cost of heat production which, under scenario 5, approaching zero due to the impact of electricity sales from the scheme. Connection to a heat network would only then become an option at the time of future asset replacement within the energy centre, at which time the avoided replacement costs could be factored in to the heat price calculations. For this reason, interim energy centres employing gas CHP could delay uptake of the heat network and are not recommended. Subject to compliance under future building regulations, temporary energy centres consisting of temporary gas boilers would be the appropriate interim solution, with an agreement to connect to the heat network in due course or retrofit LZC technologies in the event that the heat network is not forthcoming.

For new developments being constructed once the heat network is in place, the logical alternative to connection to the heat network would be a block based solution under scenario 2, 3 or 4.

For residential, student accommodation and hotel developments, block based gas CHP is likely to be the favoured option (scenario 3). Assuming that an Energy Services Company would install and operate the CHP and associated heating assets and, since this investment could be avoided at the time of potential connection to the heat network, the value of the heat can be considered to be equal to the heat price associated with delivering a 10% IRR for each development.

For new office developments, the most likely scenario is considered to be heat pumps. Due to the very low space heating and domestic hot water demands in relation to the plant investment costs, this scenario delivers extremely high prices necessary to deliver an IRR of 10%. However, based on a combined delivery of heating and cooling, the unit price would be much lower and therefore acceptable to the developer[12]. For the purposes of this study, the effective heat price under this option is taken to be the cost of heat based on fuel, operation and maintenance and asset replacement, assuming that the payback of the assets is absorbed in the cooling supply (which provides the larger demand for the office). It is also consistent with an assumption that under this option, investment in the heating assets by an ESCO would not be an appropriate route.

The market price for heat for new developments being constructed once the heat network is in place is taken to be equal to the relevant alternative scenario options described above, averaged over 2010, 2013 and 2016 and with a 5% reduction on price to ensure market competitive heat and to provide customers with an incentive to connect. These prices are summarised in Table 18.

Heat Selling Prices £/kWh		
Case	avoided Heat Cost	Incentivised Heat Price
hotel	£0.0527	£0.0500
residential	£0.0560	£0.0532
office	£0.0463	£0.0440

Table 18 Assumed heat prices for Scenario 6 as new customers to district heating network

3.4.2 Carbon Content of Heat delivered

The calculated carbon content of the heat delivered for space heating and domestic hot water for 2016 are presented in Table 19. These are not repeated for other years, since differences are marginal.

year	2016

[12] This has not been modelled

Carbon Content of Heat Delivered			
Scenario	Hotel	Office	Residential
	[kg Co2/kWh]	[kg Co2/kWh]	[kg Co2/kWh]
Scenario 1	0.215	0.215	0.215
Scenario 2	0.214	0.194	0.211
Scenario 3 gas CHP	0.085	0.185	0.135
Scenario 3 biofuel CHP	<0.000	0.108	<0.000
Scenario 4	0.046	0.173	0.117
Scenario 5	0.074	0.074	0.074
Scenario 6 Gas CHP	0.068	0.068	0.068
Scenario 6 Seneca	0.048	0.048	0.048

Table 19 Carbon Content of Heat Delivered for 2016

The calculation methodology assumes fuel emission factors as described in Appendix 3 and uses the methodology consistent with the Part L of the Building regulations in which, for scenarios 3, 5 and 6, the electricity generated through the CHP offsets grid emissions and is attributed to the heat.

The carbon content of the heat delivered varies significantly between the hotel, office and residential developments for a given scenario, for scenarios 2, 3 and 4 This reflects the differing contributions from the LZC and top up (condensing gas boiler) technologies under these options. Refer to Appendix 3 for assumptions around sizing and contributions from these technologies.

Similarly, differences appear between carbon factors between successive years due to differing contributions from the LZC and top up (condensing gas boiler) resulting from reducing space heating requirements with improving building fabric assumptions in going from 2010 to 2016.

For Scenario 3, a biofuel option has been presented. The carbon content of the heat delivered under this option is negative.

Scenario 6 includes two options. The first option covers the case that a gas fired CHP energy centre supplies the heat network. The second option (Seneca option) refers to the case that the heat network is supplied from a 2.5 MW biomass facility for which SENECA has achieved planning application at Hannah Close. Refer to Section 5 for further details.

The carbon content for the heat delivered under Option 6 is based on the analysis presented in Section 5. Refer to this section for further details of the approach taken.

3.5 Conclusions and Recommendations

The evidence base modelling has compared a number of development level, developer led LZC scenarios with a decentralised energy opportunity based on heat delivered through a heat network.

For each development level, developer led LZC scenario, carbon compliance levels, LZC technology investment costs, heat production costs and residual carbon compliance costs have been calculated. These have been compared to the equivalent costs arising under the decentralised energy opportunity presented in Section 5 of this report, assuming that the Seneca option is taken forward Option A.

It is recognised that any business case for developing a decentralised energy opportunity would require the project to deliver market competitive heat to both existing and new developments intending to connect to the scheme. The presumption is carrying out this case comparison has been that heat would need to be delivered at a minimum of 5% below the lowest alternative price based on alternative (business as usual) heat production costs.

The analysis has shown that the scenario 6, the decentralised energy opportunity, provides a number of potential economic benefits over the alternative options. These as follows:-

The identified decentralised energy opportunity offers the potential to deliver lower carbon content heat than can be generated at development level through the developer led LZC scenarios modelled in this report.

If the decentralised energy opportunity is taken forward, developments being planned and constructed after construction of the network, could potentially benefit from reduced costs of compliance with building regulations, BREEAM and Zero Carbon Homes and Zero Carbon Buildings Policy. The value of these savings depends on development type and on the compliance targets, which are themselves a function of standards set out in the current and future building regulations.

For developments being planned and constructed after construction of the identified decentralised energy opportunity, a number of potential additional benefits arise for developers. These include avoided capital investment costs in LZC technologies, the liberation of plantroom and roof level space associated with LZC technologies and solar PV, each of which can potentially generate additional leasable income or sales value to developers. It is likely to be difficult to argue that these costs are attributable to the project opportunity, although developers will recognise these benefits and should therefore see them as reasons to support the connection opportunity.

From 2016 (and from 2019 for Zero Carbon buildings), a proportion of the value of compliance savings could potentially be captured by the project in the form of Allowable Solutions payments by developers, subject to the implementation of the proposed Zero Carbon Homes Policy in legislation and subject to the project provider being able to gain access to the funds[13]. These developer 'contributions' could potentially cover or exceed the cost of routing pipework from the main heat network to the individual buildings[14].

Prior to 2016, there is no formal mechanism to require developers to offset carbon and therefore no firm basis on which to require developers to contribute to the network. However, the savings offered in respect of reduced compliance through on site PV measures could potentially be negotiated as a contribution to the project for these cases.

For developments being planned and constructed ahead of the identified decentralised energy opportunity, compliance through Allowable Solutions is unlikely to be necessary, based on the identified timing of the heat network opportunity and given the phase shift between incoming policy and projects adopting relevant standards passing through the planning process. However, for these developments, savings in LZC technology investment costs would potentially apply, subject to developers being permitted to install temporary boilers in lieu of LZC plants through building regulations. Temporary energy centres employing gas boilers would be the appropriate interim solution in this case, with an agreement to connect to the heat network in due course or retrofit LZC technologies in the event that the heat network is not forthcoming. For these developments a proportion of the value of the avoided investment in LZC technologies could potentially be collected retrospectively and invested in the heat network.

[13] This could happen through LBB, if it becomes an Allowable Solutions Provider and if it chooses to take a stake in the project opportunity. Equally, a private sector organisation or consortium could provide this role.

[14] associated with running service pipes from the network to the development plots and with installing heat exchanger stations

4. ENERGY FROM WASTE ANALYSIS

4.1 Introduction

Waste generated in the London Borough of Brent is a resource that could be used for production of heat and electricity. This section contains an appraisal of the waste resource in the London Borough of Brent, the availability of this resource for use within energy from waste (EfW) plants and a high level review of EfW technology options. The conclusion of this section contains a recommendation regarding suitable opportunities that should be considered further within the future energy Masterplan for the Wembley Regeneration Area.

4.2 Resource Appraisal

Three different waste arising scenarios have been considered, these are outlined below and are based on consultation with LBB and the West London Waste Authority and with reference to the Worchester Polytechnic Institute report "Energy from Waste in Brent" and the GLA's London Plan.

The scenarios modelled are summarised below. Refer to Appendix 4 for further details of the analysis undertaken.

Scenario 1

Scenario 1 considers waste arisings within the Wembley Regeneration Area only. Possible waste sources included in this analysis are:-

1. MSW arisings from existing, planned and potential developments that is collectable by London Borough of Brent
2. waste arisings from large commercial facilities in the locality such as Ikea, Tesco and Asda
3. waste arisings from the existing and planned ENVAC systems installed in the Wembley Regeneration Area
4. SRF sourced from the Seneca Materials Recovery Facility.

Based on discussions with the WLWA and SENECA, the opportunity for diversion of SRF from the SENECA facility is understood to be negligible in the short and medium term, since the contract waste volumes are locked into long term contracts with major European Customers. The potential for SRF as a waste stream is therefore excluded from further consideration in this scenario. Similarly, Tesco and Asda have declined to participate in this study and therefore the potential for these sources as a as a waste stream are not included in this scenario.

Scenario 2

For Scenario 2, the geographical area under consideration has been extended to the entire Borough of Brent. All available residual waste within the borough boundary, both MSW and C&IW are assumed available to a potential EfW scheme under this scenario.

The total tonnage of projected waste arisings and the composition of these arisings as presented in the Worcester Polytechnic Report (WPI report) prepared for Brent Borough are taken as the basis of the waste streams over the next 18 years to 2031. The waste arising projections for Brent Borough presented in the WPI report are based on figures from Chapter 5 of the London Plan, reduced to account for an overestimate of the 2011 MSW figures in the London Plan. C&IW figures from the London Plan remained unaltered as this is the best information available at this time

Scenario 3

Based on discussions with LBB, it is considered unlikely that the entire borough could be available as a catchment for feedstock for a potential energy from waste scheme serving the Wembley Regeneration Area. Therefore, the waste arisings from the only immediate Wembley area have been considered under this scenario.

Given the absence of specific waste arisings data for this catchment area, it has been assumed that 50% of the waste arisings identified under Scenario 2 are representative for Scenario 3. This is based on an equivalent breakdown of the areas by population density based on an analysis of Census data for LBB and through discussions with London Borough of Brent.

The results of the analysis are presented in Figure 19. A detailed methodology and waste composition breakdown are contained in Appendix 4 of this report. All scenarios include both MSW and C&I waste within the results. These are separated into MSW and C&I waste streams as indicated in the Figure below. The tabulated results are also presented in Appendix 4.

In the subsequent technology appraisal presented under Section 4.3, each technology is evaluated on the basis of both MSW and C&I waste streams being available to the plant. This implies that a necessary precondition for the development of an EfW plant would rest on securing both C&I and MSW fractions within the relevant catchment areas.

It is recognised that the C&I fraction of the available waste stream is currently collected and disposed of through the private sector and is therefore not under the direct control of LBB or WLWA. This adds a considerable degree of uncertainty to any plans for an EfW plant and would likely constitute an unacceptable level of commercial risk to a potential plant developers and investors.

On the other hand, although currently locked in to existing contracts with WLWA the MSW portion can be considered to be a relatively secure EfW feedstock since it is collected by LBB and disposed of by the West London Waste Authority. The calculated MSW fractions under each scenario could therefore potentially become available in future, when the existing contracts are due for renewal. Since LBB is responsible for collection of MSW, these waste fractions can be considered to be reasonably secure future sources of feedstock and therefore of low commercial risk.

The calculated waste arisings under scenario 3 are also representative a situation whereby only the MSW portion of scenario 2's waste arisings are available to scheme. This is due to the fact that approximately 50% of the waste in the entire Borough is from residential sources. The overall tonnage of available waste can therefore be assumed to be approximately equivalent, though the actual composition may differ slightly.

This would represent a lower risk, more commercially secure position on which to base a potential opportunity, given the logistics and uncertainty around securing long term contracts for the collection of C&I waste through private sector providers.

The feedstock calculated under this scenario can therefore be considered to be potentially available if LBB were to divert the entire borough's waste arisings under their control in the future, once existing contracts expire and are re-negotiated.

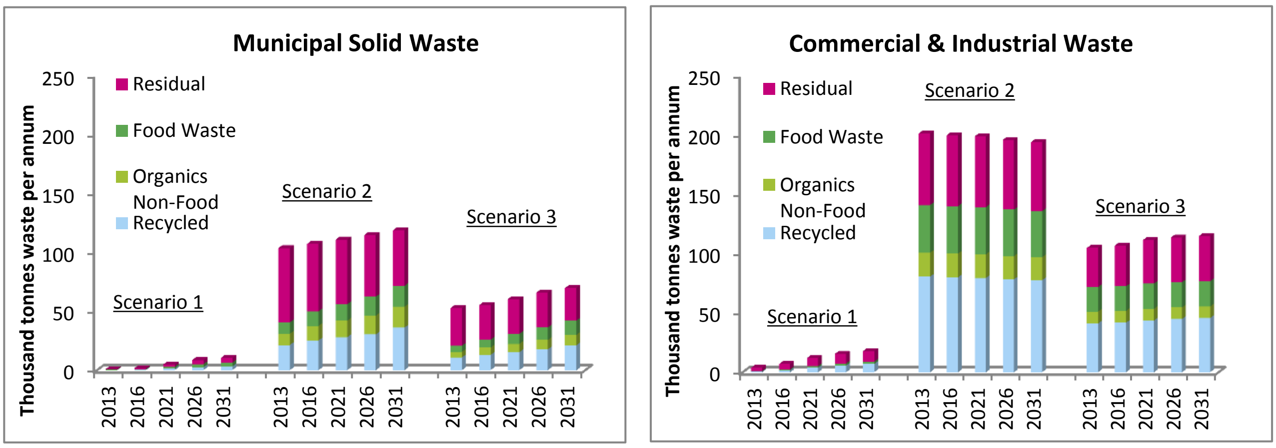

Figure 19 Projected Waste Arisings for each Scenario

4.3 Technology Appraisal

Based on the waste streams identified under the previous section of this report, opportunities for merchant facilities processing waste from the above waste streams have been investigated. Wider strategic opportunities based on importing waste outside of London Borough of Brent into the borough have not been investigated.

The technology review has evaluated current commercially available energy from waste technologies. The technologies under consideration have included anaerobic digestion, advanced thermal treatment and grate fired thermal treatment (incineration).

Feasible technologies and locations have been identified in the context of potential opportunities for supplying a decentralised energy network. The review has considered:

1. Technical aspects such as operating track record, reference facilities, expected plant performance, potential waste pre-treatment requirements and environmental performance.

2. Commercial aspects such as technology bankability, commercial viability at the identified scale and commercial risks.

3. Other factors such as space requirements within the strategic industrial area and logistics.

Potential site location analysis has focused on the industrial area (east of Forth Way) in the vicinity of the existing Seneca facility which is understood to remain as a Strategic Industrial location within Wembley Regeneration Area.

The technology options appraisal has been informed by a combination of sources including:-
1. Worchester Polytechnic Institute report "Energy from Waste in Brent".
2. the Joint Waste DPD for West London,
3. Ramboll Energy's experience and knowledge of the industry and the available technologies
4. consultation with technology providers
5. consultation with SENECA and review of SENECA planning application for 2.5 MW biomass facility at Hannah Close
6. LBB's Policy WEM 33 on Energy from Waste

The sections below give an overview of the commercially available technologies to recover energy from waste – ranging from technologies that are in development to well-proven technologies with numerous reference facilities.

Section 4.6 presents a summary of the technology options in the context of the calculated waste arisings. Appendix 5 gives further technical background information for each of the technology options assessed.

4.3.1 Anaerobic Digestion

The readily biodegradable part of food and other organic wastes is converted through an anaerobic process into an energy-rich methane-based biogas which can then be used in either a traditional gas boiler or a gas-fired CHP plant to produce heat (and electricity).

The typical feedstock for this technology is source-separated food waste which may be supplemented by some industrial streams such as dairy waste products.

Technology assessment – Anaerobic Digestion	
Historical background:	In the 1920s the first anaerobic digesters were built for sewage sludge. In the late 1970s anaerobic digesters were built to handle manure from farmers. The first plants for treatment of organic waste from households were developed in the 1990s.

Technology development:		The technology is well-proven. However, some facilities are/have been experiencing operational problems handling e.g. organic household waste. UK status /1/: - 54 existing AD plants (excluding sewage sludge treatment facilities) annually treating a total of 1,000,000 tonnes organic waste. The treated waste is mainly derived from commercial waste and from food and drink manufacturing. Actual electricity output is 35 MWe. - 50 planned AD plants with an anticipated installed power capacity of approximately 70MWe.
Feedstock Requirements:		Depends on the technical concept and the output requirements: - Use of digestate on agriculture land requires separated organic waste with very limited content of metal and plastic pieces. - Non pumpable concepts may allow a significant fraction of a non-biological waste.
Plant performance	Energy usage and consumables	Depends on technical concepts: - Electricity to pumps, agitators, centrifuges etc. - Heat to the pasteurisation process and maintaining correct temperature in digester. - Diesel to mobile equipment e.g. front-loader etc.
	Energy production	Depends on chemicals composition and biodegradability of feedstock. Typical biogas yield for source separated organic material at households (mainly kitchen waste): 40 - 70Nm^3 biogas (60% methane)/tonne material.
	Environmental emissions	Odour (level depends on technical concept for handling incoming waste and digestate) NOx emitted from combustion in gas-engines or in boiler system. Methane (typical 0.5-2% escapes to atmosphere from process) Nitrous oxide (a powerful greenhouse gas - may be produced in the bio-filter used to reduce ammonia and odour from the process air prior to emission through stack).
Technical operating track record	Typical plant capacity	Around 30,000 – 50,000 tpa
	Typical size range (min-max)	Capacity range - Typical range: 5,000 – 150,000 tpa.
	Commercial availability	Numerous suppliers such as Haase, Kompogas, OWS, Ros Roca, Scmack and Valorga.
Commercial issues	Bankability	High – well-proven technology with numerous reference facilities. (However, this assumes that the feedstock waste is of an acceptable quality with regard to the type of organic waste and the plastic/metal contamination.)
	Commercial viability	Minimum commercial scale of anaerobic facilities is – by the market – in general considered to be around 30,000 – 40,000 tpa. However, this is dependent on local conditions, such as alternative disposal routes for the organic waste and the potential income from heat sale.
	Risks	Technical issues: Odour problems - Wembley area will be sensitive to even temporary increased odour emissions. Contamination of waste – It may be difficult to achieve the aimed output quality (e.g. PAS 100) due to plastic and metal pieces in the household sorted organic fraction. Waste flow – Reject of waste due to contamination may reduce waste

		flow Digestate – Handling option and cost of digestate are uncertain. <u>Financial issues:</u> Waste amount - Uncertainty of waste amount that can be contracted locally. Heat sale – Uncertainty of potential heat sale and income

Table 20 – Assessment of Anaerobic Digestion Technology

4.3.2 Thermal treatment by combustion technology

The energy within the fuel is released as thermal energy through complete combustion in an excess of oxygen environment. The typical feedstock for this type of technology is residual waste.

Technology assessment – Combustion technology (grate fired incineration)		
Historical background:		Grate fired thermal treatment was developed in the 1930's. It is by far the most common technology to recover energy from residual municipal waste.
Technology development:		The technology is well-proven. Over 450 grate fired lines (>8 t/h) have been installed in Europe. UK status: - Around 23 existing grate fired incineration facility (Annually treating a total of 3.5 mio tonnes waste). Based on 2009 values /3/ Europe status: - Around 350 operating plants in Europe. Energy data from 314 European WtE plants (treating 59.4 mio. tpa. waste) is summarised within a report by CEWEP, publish 2012. /3/
Feedstock Requirements:		Residual municipal, commercial and industry waste is acceptable. No pre-treatment is normally required.
Plant performance	Energy usage and consumables	Depends on flue gas treatment system. The figures below are based on a medium sized facility with the common semi-dry flue gas treated system: - Around 80 kWh/ tonne waste treated - Around 5 kg 25% NH_3/ tonne waste treated - Around 15 kg hydrated lime/ tonne waste treated - Around 0.5 kg activated carbon/ tonne waste treated
	Energy production	Around 85-90% of the energy in the waste is transferred to the boiler system. The electricity production is dependent on steam parameter and whether the plant operates in 'Electricity only mode' or 'CHP mode'. - 'Electricity-only mode': Around 23-26% net electricity efficiency for new plants - 'CHP mode': Around 18-22% net electricity efficiency and 40-65% district heating efficiency, depending on the temperature/pressure requirement of the off-take heat.
	Environmental emissions	In accordance with requirements in 'Industrial Emission Directive'. However, actual emissions of e.g. dust, heavy metal and dioxin/furans are typical minimum a factor 10 lower than the requirements.
Technical operating track record	Typical plant capacity (one line)	Around 80,000 – 200,000 tpa
	Typical size range (min-max)	Capacity range - Range: 20,000 – 500,000 tpa. However, one incineration line can treat up to around 250,000 tpa – dependent on supplier.

	Commercial availability	Numerous commercial suppliers such as Babcock Wilcox Volund (Denmark), Fisia Babcock (Germany), Martin GmhB (Germany), Hitachi Zosen Inova (Japan), Vinci (France) and Keppel Seghers (Switzerland).
Commercial issues	Bankability	High – Well proven technology with numerous reference facilities in Europe.
	Commercial viability	The minimum commercial viable plant is normally around 80,000 to 100,000 tonnes per year. However, the minimum commercial viable plant capacity plant may be reduced in an area where there is a local market for heat, as the heat sale generates an additional revenue stream.
	Risks	Technical issues: Waste flow - The plant should be operated on continuous basis. This typically requires a waste load corresponding to 70% of the design capacity. Non-continuous operation will greatly increase wear and tear of the plant. Increased recycling rates in the future – this may lower the amount of waste in the local area. Increased recycling of plastics and paper - this may lower the calorific value, but this normally technical acceptable. Financial issues: Long term contracts are required to secure funding. Reduced negotiation position, if only locally generated waste is allowed treated within the plant.

Table 21 – Assessment of Combustion Technology

4.3.3 Thermal treatment by gasification technology

The main part of the fuel's energy content is released as combustible gases (syngas) in a reduced oxygen process (mainly hydrogen and carbon-monoxide). The remaining energy is released as thermal energy. The typical feedstock for this process is pre-treated residual waste.

Technology assessment – thermal gasification	
Historical background:	Thermal gasification was invented in the 1800's to produce town-gas from coal. The technology is now commonly used in areas with large coal deposits to convert coal into a gas that can be used to produce diesel and oil. Gasification is common technology in Japan and the high operational temperature (up to 1600 - 2000°C) makes it possible to melt the bottom ash and fly ash into a clinker, which often has been a requirement in the typical Japanese environmental permit. A number of plants are currently in operation in Japan. A couple of large gasification plants for treatment of municipal waste were built in the 1990's in Europe. Plants experienced operational problems and ceased operations. An example is the Thermoselect plant in Karlsruhe which was shut down in 2004 after 6 years of difficult operation.
Technology development:	The technology is well-proven for some concepts. However, there is limited long term experience with facilities designed with focus on energy optimisation. UK status: - Energos, operational facility since 2010, Isle of Wight, 30,000 toa (funded as part of Defra's New Technologies Demonstrator Programme - Energos, contract awarded, Milton Keynes Recovery facility, 90,000 tpa

		- Energos, contract awarded, Glasgow Recovery facility, around 90,000 tpa - Energos, granted planning permission, Knowsley Energy Recovery Facility, 96,000 tpa - Biossence, Granted planning permission, Hooton Park (Core technology to be supplied by the Canadian company Enerkem). - Biossence, Contract awarded, East London Sustainable Facility, 130,000 tpa RDF (core technology to be supplied by Metso. The Canadian company Enerkem was originally to supply core technology) World status: - Around 90 commercial gasification and pyrolysis plants - mainly in Japan - Energos have 8 plants in Europe
Feedstock Requirements:		Residual waste – it is often a requirement to shred to particle size of around 15 cm. Restrictions on input variation for e.g. calorific value, ash content and moisture.
Plant performance	Energy usage and consumables	Depends on technical concepts: - Electricity to waste shredding and general operation - Electricity to enrichment of the oxygen content of process air - Chemical to flue gas treatment can be expected to be somewhat lower than grate fired technology as the thermal concept is likely to produce less NOx and since less chloride is released from the waste to flue gas.
	Energy production	Many Japanese gasification facilities only have limited net electricity or even negative electricity production. The purposes of these facilities are to treat waste not to produce energy. In additional these plants have limited heat recovery due to the remote locations. Nippon Steel promotes a concept with a net electricity efficiency of 16-18%, which is considerable lower than grate technology. The net electricity efficiency the Energos technology can in principle be similar to grate technology as the overall technology concept is comparable. However, the net efficiency will e.g. be reduced due to requirement of shredding the waste prior to feeding into the thermal process.
	Environmental emissions	In accordance with requirements in 'Industrial Emission Directive'. However, actual clean gas emissions can be expected to be a similar level as 'grate fired' technology.
Technical operating track record	Typical plant capacity (per line)	30,000 –100,000 tpa
	Typical size range (min-max)	Energos (8 facilities): 30,000 – 39,000 tpa per line Nippon Steel (38 facilities): 13,000 – 80,000 tpa per line Ebara, Doosan Babcock and Thermo Select and others (around 50 facilities): 10,000 - 100,000 tpa per line
	Commercial availability	Yes, there are a number of suppliers.
Commercial issues	Bankability	Medium
	Commercial viability	Energos has been awarded a number of contracts recently in UK. Other gasification technologies seem to have limited presence in UK.

		The main reason for the competitive edge of Energos in UK is the relatively low investment cost (typically lower steam parameters than traditional grate technology) in combination with the financial benefit of the ROC scheme.
	Risks	Technical issues: Limited long term operation experience – Typically the Japanese gasification facilities have focused on the waste treatment process, not the combination of treatment and energy recovery. Waste flow - The plant should be operated on continuous basis. This typically requires a waste load corresponding to 70% of the design capacity. Non-continuous operation will greatly increase wear and tear of the plant. Pre-treatment – The process often requires pre-treatment. Changes in waste composition – The technology is less flexible to changes compared to grate technology. Financial issues: Dependency on ROCs - ROCs may not be available in entire project period, due to potential changes in the current scheme. Long term contracts are required to secure funding. Reduced negotiation position if only locally produced waste is allowed treated within the plant.

Table 22 Assessment of gasification Technology

4.4 Review of Small Scale Technologies

A number of companies promote small scale thermal treatment and anaerobic digestion plants (typically up to a few thousand tonnes per year). It is Ramboll's experience that small scale facilities tend to be less robust than larger facilities. They are more sensitive to changes in feedstock due to limited mixing capacity and have significant problems coping with residual plastics and metals that are present even in source separated organic waste.

These companies only have limited operational experience with their reference facilities and these often treat other types of fuels/wastes (such as brewery waste which produces high-yield, high-quality biogas when treated by anaerobic digestion). There is generally insufficient data available to estimate overall energy and mass balance for a these technologies. It is unlikely that these small scale facilities could demonstrate a good operational track record for the treatment of municipal solid waste for the previous 10 years within a commercially viable facility.

For these reasons a private investor is unlikely to consider investing in these technologies, therefore these small scale plants are not reviewed further in this study.

4.5 SENECA Facility

A potential alternative heat supplier for any district heating network opportunity in the Wembley Regeneration Area is the nearby SENECA material recovery (MRF) facility located in Hannah Close.

As indicated in Section 4.1 the possibility of sourcing SRF from this facility to support an EfW plant at a commercially viable scale is negligible. The existing WLWA contract with Seneca will end on 31st March 2015, and each year until then WLWA will be sending 70,000 tonnes of mixed residual waste to SENECA. From 1st April 2015 this tonnage will be absorbed into WLWA residual waste treatment contract which is currently being procured and it is planned that this contract will be 25 years in length. Equally, SENECA is locked into long term contracts with major European partners and although additional volumes of SRF may be available in future (outside of these contracts), the quantities are currently unknown and not likely to be sufficient to support an EfW plant at a commercially viable scale as noted above.

However, the facility has recently received planning permission for a 2.5MW_e biomass plant to process waste timber available to Careys (the operator) through its supply chain of C&I waste across London. This is understood to be a secure waste stream upon which a business case has been made.

The technical proposal as set out in the planning application is for a gasification plant using waste wood as a feedstock for the production of syngas for combustion in a CHP plant primarily to provide power for the Seneca facility's electricity requirements. It is unclear whether the recovered timber is classified as a biomass or waste however, in the environmental statement, it is stated that lime and ammonia-water is required for the biomass CHP plant. This indicates that the plant will operate under the waste regulations and means that there are additional technical requirements to be considered such as minimum combustion temperature, gas retention time and flue gas treatment compared to a facility treating biomass from a non-waste source. For this reason SENECA's proposed plant has been considered to be an EfW plant in this report.

Despite the specification of gasification in the planning application it has come to Ramboll Energy's attention that the supplier of the chosen technology has recently gone out of business. In light of this and for the purposes of energy modelling in this project an alternative thermal treatment technology has been considered.
In Ramboll Energy's experience, the most common thermal treatment technology for wood waste is a moving grate (similar grate as for treatment of residual waste) or a vibrating grate (a cheaper grate concept developed for wood chips). Under this technology, the energy released from the combustion process is recovered in a steam-boiler and expanded through a steam turbine to deliver electricity. The plant is capable of being configured as a combined heat and power plant, with heat recovery through steam extraction and/or through the steam condensers at the back end of the plant.

Ramboll Energy has modelled the process on the basis of the technology described above. On this basis, the potential heat production from the plant running in combined heat-and-power (CHP) mode is estimated be to around $7MW_{th}$, based on the assumption that the thermal input of biomass to the plant is around $11MW_{th}$ as per the terms of the planning application. All further calculations have been made on the basis of this assumption.

Seneca's on-site heat requirements are estimated to be quite low (heat used to dry incoming materials), on this basis it has been assumed that the heat requirement on-site is approximately $1MW_{th}$ and thus approximately $6MW_{th}$ of heat could be available for a District Heating Scheme. Based on this $6MW_{th}$ output, the annual potential energy production is estimated to be approximately 50,000MWh. This figure represents the heat energy remaining after the facility's heat requirements have been met and could potentially meet 65% of the proposed scheme's energy needs in 2030 and almost 100% in the first year of the District Heating scheme's commissioning.

Selling heat to the district heating scheme would bring greater benefit to Seneca through increased revenues and the fact that by selling to the scheme the heat produced by SENECA would qualify for the Renewable Heat Incentive. Initial discussions with Carey indicate significant appetite for exploring the opportunity further[15].

Ramboll Energy's modelling has assumed a turbine configuration in which heat extraction would take place at the low pressure outlet of the turbine in lieu of condensation through air cooled condensers. The associated district heating network temperatures are assumed to be 40 C on entry to the heat exchanger and 90 C on exit.

As noted above, it is also possible to extract higher temperature steam through a turbine extraction port that could be specifically designed for this purpose. This remains an option that could be further appraised if the opportunity is taken forward but hasn't been considered further at this stage. Steam Extraction for heat production would have a penalty in electricity production which would need to be compensated for through heat sales to the heat network operator.

Alternately heat recovery through the condensers might require an alternative, suboptimal set of design parameters if heat is to be delivered into the network as useful temperatures. This would also have an economic impact on the electrical efficiency and therefore on the net present value of the investment. Such considerations would need to be resolved in due course but for the present study a values of 0, 0.5, 1 and 2 p/kWh have been attributed to the cost of heat production to test the impact of this variable on the business case for the heat network.

[15] It is noted that economic impact of heat extraction to SENECA' operation would need to be established at the next stage if the project is taken forward.

A summary of the technology opportunity in the context of the calculated waste arisings is presented under Section 4.6.

4.6 Technology Review In relation to Calculated Waste Arisings

		Tech Options Summary		
		Scenario 1	**Scenario 2**	**Scenario 3**
Description of option		**Waste arisings within regeneration area only**	**Available Waste arisings within entire Brent, assuming both MSW and C&I available for processing.**	**Available residual waste within Wembley area, assuming both MSW and C&I available for processing.**
Source separated organic waste arisings				
Arisings 2018	[t.p.a]	2,069	53,089	28,614
Arisings 2031	[t.p.a]	5,202	56,550	33,478
Assumed design capacity of facility (100% nominal load)	[t.p.a]	3,000	50,000	30,000
Suitable technology at given facility scale				
Technology type (based on proven technology at given scale and likely commercial attractive project)	-	Anaerobic digestion is not commercial viable	Anaerobic digestion	Anaerobic digestion (but normally around 40,000 tpa is considered minimum commercial size)
Commercial preconditions	-		Long term contract for handling of organic waste to be investigated District heating potential and sale to be investigated	Long term contract for handling of organic waste to be investigated District heating potential and sale to be investigated
Planning considerations	-		Potential odour emissions from e.g. handling digestate a major issue	Potential odour emissions from e.g. handling digestate a major issue

Key barriers/risks	-		Risk of unacceptable odour emissions from tanks and handling of digestate Process can be difficult to control optimally Metal and plastic may cause technical problems within the plant Metal and plastic pieces may results in lower grade compost derived from the digestate	Risk of unacceptable odour emissions from tanks and handling of digestate Process can be difficult to control optimally Metal and plastic may cause technical problems within the plant Metal and plastic pieces may results in lower grade compost derived from the digestate
Technical overview				
Plant dimensions	[Ha]		≈ 1.2 - 1.5	≈ 0.8 - 1
Plant location				
Net electricity production of biogas facility	[MWh/y]		11,900	7,100
Net heat production available into heat network	[MWh/y]		13,700	8,200
Grade of heat assumed supplied	[^{o}C]		90	90
Direct fossil carbon emission from plant	[t CO_2/year]		≈ 0	≈ 0
ROC/RHI?	[£/MWh]			
Viability Scoring (high/medium/low)				
Financability/bankability	-		Medium Technical risks due to e.g. potential plastic/metal contamination in waste and potential problems with process control of anaerobic digester and odour problems.	Medium Technical risks due to e.g. potential plastic/metal contamination in waste and potential problems with process control of anaerobic digester and odour problems.
Planning approval ('High' indicates a relatively low risk of non-approval)	-		Medium	Medium
Commercial viability/market appetite	-		High Dependent on long term contracts for organic waste Dependent on guaranteed heat sale	Medium Dependent on long term contracts for organic waste Dependent on guaranteed heat sale

Table 23 Technology Options Summary for Anaerobic Digestion Plant Option to treat Organic Waste

Tech Options Summary					
		Scenario 1	**Scenario 2**	**Scenario 3**	**Option SEN1**
Description of option		**Waste arisings within regeneration area only**	**Available Waste arisings within entire Brent, assuming both MSW and C&I available for processing.**	**Available residual waste within Wembley area, assuming both MSW and C&I available for processing.**	**Excess heat from the potential biomass (wood waste) plant located at the SENECA MRF facility at Wembley**
Source separated organic waste arisings					
Arisings 2018	[t.p.a]	5,427	116,350	58,175	Unknown
Arisings 2031	[t.p.a]	13,046	105,965	52,983	Unknown
Assumed design capacity of facility (100% nominal load)	[t.p.a]	6,500	100,000	50,000	18,000
Suitable technology at given facility scale					
Technology type (based on proven technology at given scale and likely commercial attractive project)	-	Thermal treatment is not commercial viable	Grate technology (Energos technology - classified as gasification - to be evaluated further)	Grate technology (Energos technology - classified as gasification - to be evaluated further)	Not clear from planning application, but normally grate technology is used for this purpose
Commercial preconditions	-		Long term contract for handling of residual waste to be investigated District heating potential and sale to be investigated	Long term contract for handling of residual waste to be investigated District heating potential and sale to be investigated	Uncertainty about whether the required amount of wood waste is available within the waste stream SENECA actually will be receiving.

Planning considerations	-		Public opinion against thermal treatment of waste. Increase truck movements in local area		Public opinion against thermal treatment of waste. Increase truck movements in local area		Planning application submitted - Permission Granted - No further information
Key barriers/risks	-		Planning risks Lack of commercial appetite for project if long term contract for waste treatment and heat sale is not secured.		Planning risks Lack of commercial appetite for project if long term contract for waste treatment and heat sale is not secured.		Dialogue with SENECA is required to determine the feasibility of the project.
Technical overview							
			Grate technology	Energos	Grate technology	Energos	Biomass facility (wood waste)
Plant dimensions	[Ha]		≈ 1.4	≈ 1.4	≈ 1.2	≈ 1.2	≈ 0.8
Plant location							Seneca - Planned Facility
Net electricity production of facility	[MWh/y]		50,600	41,900	25,300	26,900	14,700
Net heat output from facility	[MWh/y]						61,300
Net heat production available into heat network	[MWh/y]		173,100	179,700	86,500	89,900	52,534
Grade of heat assumed supplied	[°C]		90	90	90	90	90
Steam parameters assumed	[bar/°C]		40 / 400	23 / 360	40 / 400	23 / 360	23 / 360
Direct fossil carbon emission from plant	[t CO_2/year]		35,000	35,000	17,500	17,500	0
ROC/RHI?	[£/MWh]		0		0		
Viability Scoring (high/medium/low)							

Financability/bankability	-		High (assuming long term contracts for waste and heat sale)	High (assuming long term contracts for waste and heat sale)	High (assuming long term contracts for waste and heat sale)	High (assuming long term contracts for waste and heat sale)	High (assuming that wood waste is available and long term contract for heat sale)
Planning approval (low score means high risks)	-		Medium	Medium	Medium	Medium	High
Commercial viability/market appetite	-		High (assuming long term contracts for waste and heat sale)	High (assuming long term contracts for waste and heat sale)	Medium Gate-fee may not competitive of this plant capacity.	High (assuming long term contracts for waste and heat sale)	High

Table 24 Technology Options Summary for Thermal Treatment Options to treat Non Organic Waste Streams

4.7 Summary of Conclusions for Waste Volumes and Timescales

Residual Waste

Two different technologies (gasification and grate technology) have been considered for the thermal treatment of residual waste and energy production for the Wembley Regeneration Area.

The volume of waste arisings from the regeneration area only (scenario 1) is not sufficient to support either of these technologies and as such this scenario has been ruled out at this stage.

Whilst it is difficult to state categorically the minimum size of a grate-fired Waste to Energy plant that can be considered commercially viable, the minimum capacity of existing WtE facilities in the UK is around 80,000 t.p.a. The variation in minimum capacity is dependent on gate fees and project financing.

Based on these reference capacities it appears that a commercially viable WtE plant cannot be supported from waste arisings from the Wembley catchment area alone (Scenario 2). However, the plant would potentially be viable if the waste arisings (both MSW and C&IW) from the entire LBB catchment could be made available for use. The difficulty in securing commercial waste is noted, as explained in the previous section of this report.

A gasification plant could potentially be supported under and of the following scenarios:

- Scenario 2 – All MSW and C&I waste arisings from entire Borough
- Scenario 3 – All MSW and C&I waste arisings from the Wembley Area
- Scenario 2a - All MSW waste arisings from entire Borough

It is important to note that this technology does not currently have a proven track-record and is therefore considered to be a significant commercial risk to investors in the short term[16].

The grate fired technology (100,000tpa) and gasification plants (50,000 and 100,000tpa) could provide all of the annual energy requirements for the lifetime of the District Heating Scheme.

However it should be noted that planning permission for these technologies may be difficult to obtain given the low public appetite for energy from waste plants, particularly those that treat residual waste.

Organic Waste

The minimum feedstock generally required for a viable Anaerobic Digestion (AD) plant is of the order of 40,000tpa of organic waste. This immediately rules out the possibility of an AD plant fed solely from Wembley Regeneration Area (Scenario 1) as the available organic waste from this area is approximately 10% of this value. The situation is more favourable when the Wembley catchment area is considered (Scenario 3) though the estimated available tonnage is still 10,000 t.p.a. lower than the minimum requirements for commercial viability. Similarly Scenario 2a also fails to meet the minimum feedstock requirements

There is a potential future opportunity to implement AD based on MSW and C&IW segregated food waste arisings waste arisings for the entire LBB (Scenario 2)[17]. The commercial viability of such a plant would depend on C&I waste streams also being secured, since current and future predicted MSW waste streams are not likely to be sufficient.

WLWA has contracts in place for green waste only, mixed food and green waste and food waste only from MSW sources. WLWA anticipate re-tendering these contracts during 2013/14 and expect future contract periods to be of the order of 3 years. This waste is considered available for treatment in an AD plant on the condition that the necessary contracts can be negotiated.

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[16] Gasification at this scale is currently economically viable due to its favourable classification under ROC guidelines and eligibility for the same. There is a risk that the ROC scheme will be altered in 2017 and that this benefit may no longer be available to operators and developers of facilities using this technology.

[17] The organic waste arising figures for the Wembley and LBB areas are based on the assumption that a limited amount of the source separated organic waste will be rejected due to contamination from plastics and metals.

Separate contracts would need to be negotiated and entered into for C&IW source separated food waste, this process involves engagement with individual businesses and may prove to be a long and difficult process. Both sets of contracts would need to be secured for the lifetime of the plant.

4.8 Conclusion and Recommendations

The planned Seneca biomass facility is considered to represent the most attractive near term opportunity for an EfW plant within the Wembley Regeneration Area, particularly as planning permission has already been granted, Seneca have already made a business case for this plant and as such it is assumed that there is a secure waste wood stream available to the plant and Seneca themselves have expressed interest in exploring the opportunity further.

This option can potentially provide a significant proportion of the future heat demands of the Wembley Regeneration Area, whilst also delivering this heat at low cost and with low carbon content, both of which are likely to represent an attractive proposition to developers within the Wembley Regeneration Area.

Heat extraction from this plant will potentially have an economic impact on the business case and the net present value of the investment. Providing that the impact is neutral or positive, there is a strong case for taking this opportunity forward on the basis of its existing business case. Further analysis should be undertaken at the next stage to assess the economic impact of proposed heat extraction. For the purpose of the present study the cost of heat production has been taken to be between 0.5 and 2 p/kWh.

In the event that this opportunity does not come forward, other potential EfW opportunities as identified in this report are worthy of further exploration. However, the issue of securing the MSW and C&IW waste streams is likely to prove to be the deciding factor in determining the commercial viability of these opportunities.

Potential short to medium term opportunities would require merchant facilities to set up in the area, and for these to source C&I waste from further afield than the London Borough of Brent. LBB needs to consider its appetite for this and whether it wishes to engage with the market and foster the necessary conditions to attract such providers into the area.

Any scheme supported directly through MSW sourced waste within LBB is only likely to materialise once existing LBB waste collection / treatment contracts with WLWA can be unlocked. Existing residual waste contracts with WLWA are currently being renegotiated for the next 25 year period. Whilst details haven't been finalised, it is considered highly unlikely that these contracts could be renegotiated at this stage and even if they could be, whether sufficient volumes of waste could be unlocked to deliver a viable opportunity. Equally this would require almost immediate action and contractual commitment by LBB and it is too early in the process of the DH scheme consultation process to pursue this. In this sense, the opportunity for an EfW plant has at this time been missed, and the earliest opportunity for a plant to come forward (based on sourcing MSW as a feedstock) is therefore likely to be circa 2040, when the new WLWA contracts are re-negotiated.

Organic waste collection contracts are negotiated on a 3-4 year basis and, as such the required waste streams could be secured with relative ease. However, it is noted that such short term contracts would also represent a significant risk to potential providers, who be likely to require long term contracts in place to invest.

Of the options considered, the 50,000 tpa gasification plant may represent the most viable option. The necessary waste stream for this plant would be more easily secured than an incineration plant requiring twice the volume of waste material. The waste arisings under scenario 3 or Scenario 2a (MSW only waste arisings from LBB) could theoretically supply the scheme. Additionally, in the event that this opportunity were developed on the back of an initial scheme developed around natural gas CHP, the transition to a gasification plant using syngas to operate internal combustion engines (as the Energos plant does) would potentially be easier and less costly to implement than changing the entire plant type as would be necessary for grate incineration or gasification plants operating under a steam cycle.

This opportunity should certainly be kept under review, particularly given the possibility of commercialisation and uptake of gasification technology over the period to 2042. However a brief should be maintained and due diligence assessments should ultimately be commissioned if this technology is to be taken forward.

The identified AD opportunity is considered to be less attractive (from an energy yield point of view) although its benefits in terms of future treatment of organic waste will increase the value of this option to LBB. This option is only truly viable as an energy generation scheme under scenario 2 (all waste from LBB). However additional analysis of scenarios 2a and 3 (MSW from LBB and all waste from Wembley Area) would be required if the value of waste treatment were to be considered.

Grate incineration technology is considered to be the least commercially viable option due to the scale of available waste arising within the catchment areas considered.

5. DECENTRALISED ENERGY OPPORTUNITY

5.1 Introduction

5.2 Identification of Indicated Buildings to be connected to the Decentralised Energy Opportunity

Decentralised energy schemes require high development (building) density (and associated high heat load density) to maximise the internal rate of return on investments and thereby make the project attractive to investors.

Projected future heat demands within the Wembley Regeneration Area are significant. This is centred around the area immediately adjacent to Wembley Stadium, bounded by North End Road to the north-east, Empire way to the west and the Chiltern rail line to the south. This area is currently undergoing major development with plans for further regeneration over the next 15 – 20 years. Suitable connection opportunities have been identified using linear heat density (that is MWh/m of network) as a proxy for IRR on investment.

This has led to the following conclusions in relation to identifying opportunities for developing a heat network within Wembley Regeneration Area.

- All existing anchor heat loads and development opportunities in the areas immediately to the North, East and West of Wembley Stadium have been included in the identified opportunity.

- Existing anchor loads and development opportunities outside of this area (i.e. to the east of Forth Way and in Wembley Central area) have been excluded as linear heat density falls significantly in these areas and, as such, the viability of extending the proposed heat network into these areas would significantly reduce IRR with little overall benefit in CO_2 savings.

The total cumulative heat demand and relevant phasing for developments within the Wembley Regeneration Area identified for potential connection to a heat network is shown in Figure 3.

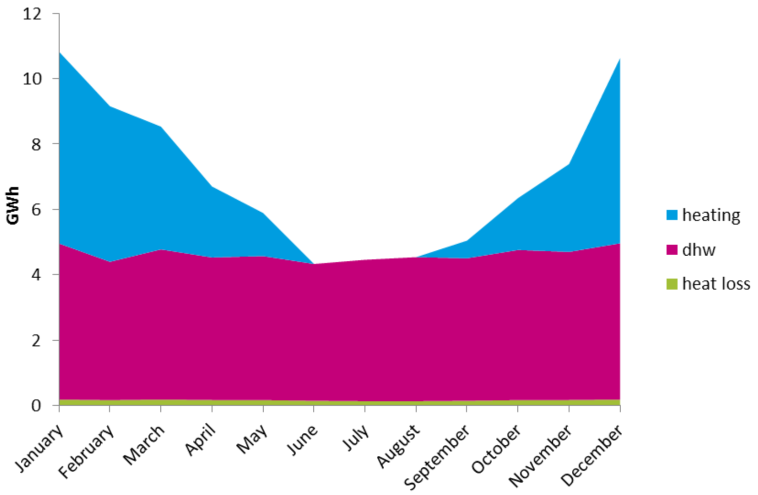

Figure 20 Heat Demand over the Final Year of the Project

As can be seen from Figure 20, the proportion of hot water demand (project base-load) to total demand is relatively high and represents 64% of the total. This high base load is very beneficial for CHP/ district heating schemes since heat production plants are generally sized to meet a proportion of this baseload (to allow them to operate for a high number of hours at high load factor and at optimum efficiency) and therefore will allow the heat production plants to provide a high proportion of the total system demand, thereby increasing total efficiency of supply and reducing reliance on more carbon intensive energy generation technologies such as gas boilers.

The heat demand map in Figure 8 shows the relative size of heat demands in the Wembley Regeneration Area at full build out from 2030 to the end of the project lifetime. This was carried out for the entire area and based on this and in conjunction with the estimated linear heat densities in the network as discussed in Section 2 the developments shown below were identified as suitable for connection.

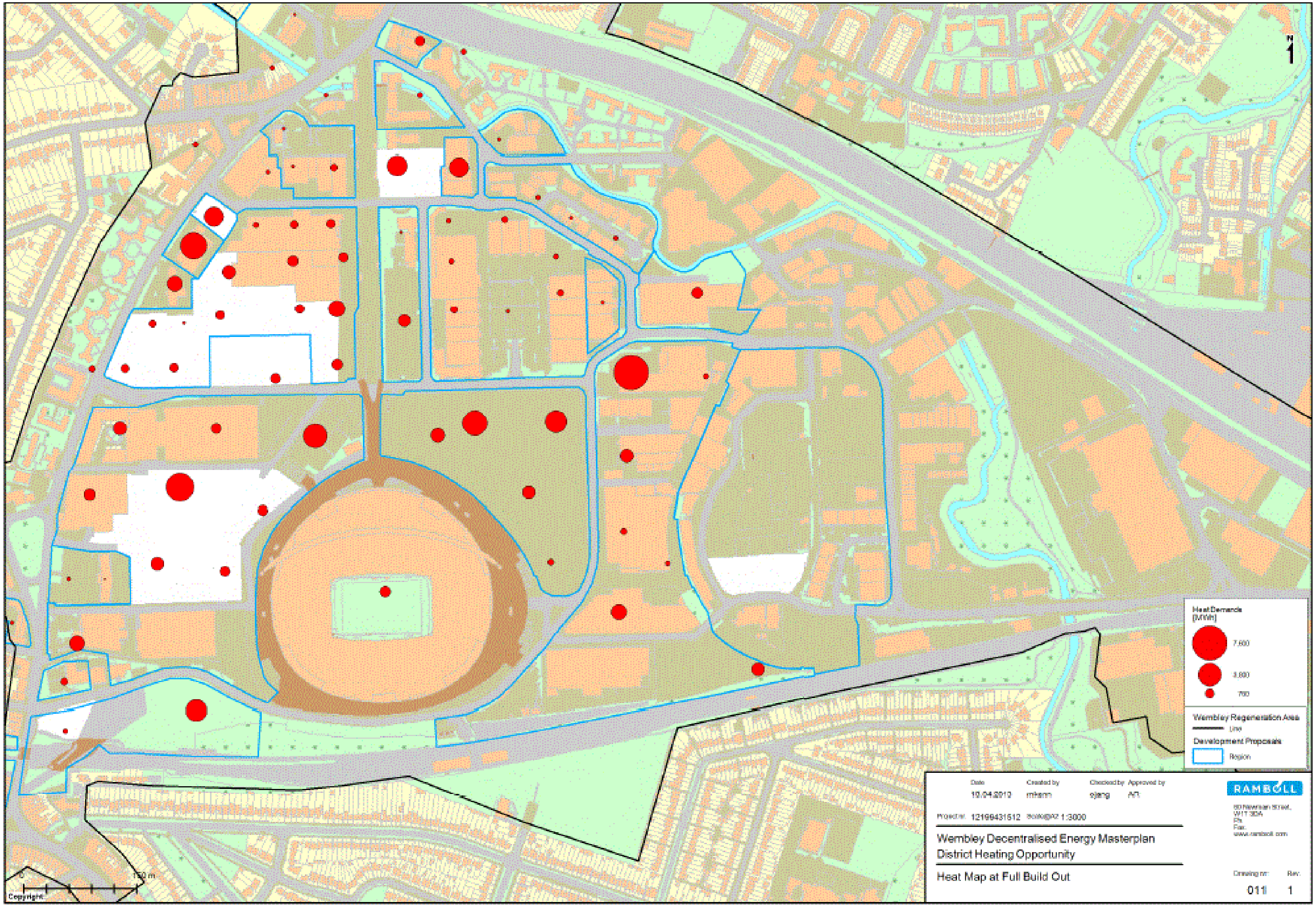

Figure 21 Wembley Regeneration Area Heat Map

5.3 Supply Side Technology Proposals

The basic technical supply requirements to be met by the proposed project are as follows:-

- Total annual demand of 83.9 GWh by 2030
- Peak diversified load[18] of 27 MW by 2030
- Network delivery temperatures to heat customers as identified in DH Manual for London

Three energy supply options within the Wembley Regeneration Area have been considered to meet these supply requirements:-

Option A – Primary Supply via waste Heat from Seneca
Option B – Gas fired CHP supplying base demand
Option C – Supply from an EfW plant located in the Wembley Regeneration Area

Within these options there are a number of sensitivities and sub-options to be considered, however Options A to C above represent the overall energy supply routes under consideration and are listed according to project preference, that is Option A is considered the most viable and attractive option and Option C the least.

Option A is considered to be the most attractive option for a number of reasons that have been discussed in Section 4 of this report and are summarised briefly here. These include the ability to deliver low cost, low carbon heat, the fact that the plant has planning permission already in place and the opportunity to collocate the energy for the heat network at the Seneca facility in Hannah Close.

Option B is considered to be alternative development scenario in the event that Option A cannot be taken forward for commercial reasons.

Whole life cost and carbon appraisals have been developed for Options A and B. These are presented in subsequent sections of this chapter. On the basis of the findings of Chapter 4, Option C has not been modelled at this stage.

5.3.1 Option A – Primary supply via waste heat from 2.5 MWe Seneca Biomass Facility

Option A considers the scenario in which the proposed 2.5 MW_e Biomass Facility at the Seneca MRF facility acts as the primary low carbon heat source for the heat network. This is supplemented by peaking boilers and thermal storage, together with an additional 2.4MW_e / 3 MW_{th} of gas CHP introduced under a 2^{nd} development phase.

The supply capacity required from the energy centre is based on detailed modelling of the project's baseload, peak and redundancy requirements, incorporating the expected demand phasing as described in Section 2.3 of this report. The modelled solution proposes a two phase implementation plan. This involves an initial phase of 6MW_{th} of waste heat from the Seneca Plant, in conjunction with a 470m^3 thermal store with a peak capacity of 18MW_{th}. This system is backed-up by a 21MW_{th} of gas boilers, providing both peaking and redundancy.

The second phase would become operational in 2023 following a significant increase in the heat load. 2.4MW_e / 3 MW_{th} of gas-fired CHP would be installed at this stage to meet the increase in base load for the scheme and an additional 11MW_{th} of gas boilers would be installed to provide the necessary additional peaking capacity and to ensure that required system redundancies are maintained[19].

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[18] The opportunity has been based on an assumption of 20 % redundancy, giving a required peak capacity of 32MW at full build out.

[19] The level of redundancy modelled assumes that, in the event that neither the waste heat, gas CHP nor thermal storage is available the peak heat demand in the scheme can be met by the back-up boilers.

An energy centre of approximately 1,500m^2 will be required to accommodate the plant under this option. This 1,500m^2 represents a space saving over Option B as the heat exchanger station required for this option would have a smaller footprint than the additional two gas-fired required otherwise. This represents an additional capital cost saving over and above the savings in plant and ancillary equipment.

Figure 22 presents the calculated contribution from each of the heat production units[20] at full build out of the scheme, together with calculated heat demands and heat losses for the scheme. As can be seen, in the final year of the project the DH demand can be met almost exclusively through the waste heat from Seneca and the 2.4MW$_e$ / 3 MW$_{th}$ gas-fired CHP.

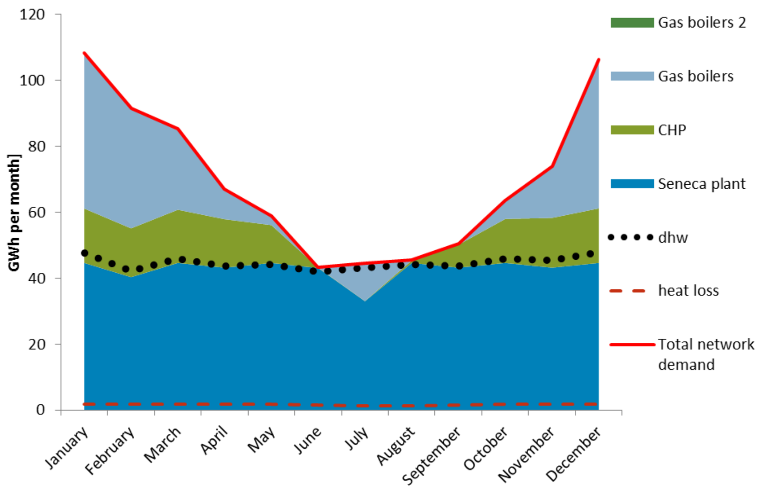

Figure 22 Supply Characteristic for Option A – Seneca Facility

5.3.2 Option B – Gas-Fired CHP

Option B considers the scenario in which gas fired CHP acts as the primary low carbon heat source for the heat network. This is supplemented by peaking boilers and thermal storage, and is developed in two phases, as per Option A.

The modelled solution is similar to that for the Seneca option and involves 4.8 MW$_e$ / 6MW$_{th}$ of gas fired CHP together with 21MW of gas fired boilers for peaking and back-up purposes to be installed in 2018.

An additional 3.2 MW$_e$ / 4MW$_{th}$ of gas fired CHP and 11MW of gas fired boilers would be installed in 2023 as per Option A. The thermal store under this option is sized based on the total planned CHP capacity and is 850m^3, that is it has a capacity of 32MW.

Figure 23 presents the calculated contribution from each of the heat production units[21] at full build out of the scheme, together with calculated heat demands and heat losses for the scheme.

[20] The contribution from the thermal store is not shown in this figure.

[21] The contribution from the thermal store is not shown in this figure.

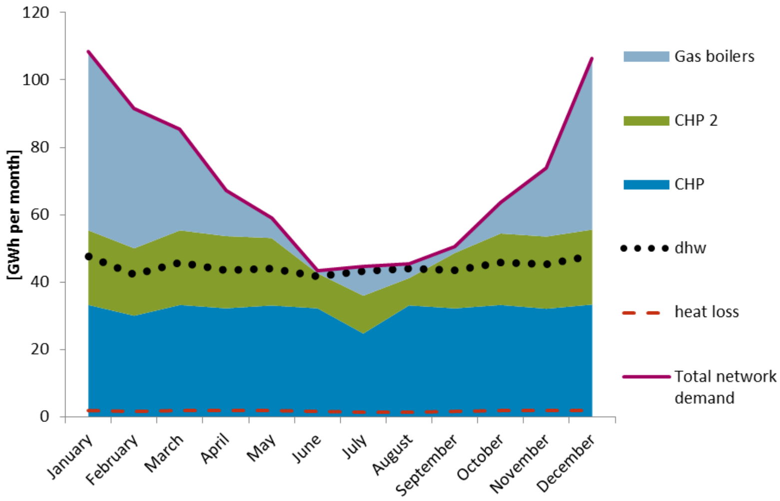

Figure 23 Supply Characteristic for Option B – Gas CHP Option

An energy centre of approximately 1,650m^2 will be required to accommodate the plant under this option.

Option C – EfW Plant

As has been discussed in Section 4 none of the options identified for an EfW facility within Wembley Regeneration area are considered to be realistic for development over the short to medium term. For this reason, Option C has been excluded from further consideration in this study and economic and carbon appraisal modelling has not been carried out.

If it transpires that the DH scheme is initially based on a Gas CHP (Option B) arrangement for the first 25 years it may be that switching to and EfW plant at the end of the initial project lifetime in may be beneficial to the scheme in relation to emissions targets, offsetting of the probable increase in natural gas prices and meeting relevant waste and energy regulations that are in place at the time

5.4 Energy centre location options

When considering the siting of any energy centre, the distance of the heat generating plant from the heat network is an important consideration as the cost of pipework can significantly add to the overall CAPEX and OPEX costs. Longer network lengths also lead to greater network heat losses over the scheme's lifetime, which has an additional financial penalty for the project. District heating schemes are therefore generally best served by locating the energy supply as close as possible to the demand.

Land availability and land value act as constraining factors in site selection and for projects such as this can prove to be the overarching decision factor. Site availability in the Wembley Regeneration Area is particularly constrained due to the intensity of the redevelopment proposals. An additional constraint in Wembley is the fact that much of the land identified as potential energy centre locations are in the vicinity of major development plots within the existing Masterplan, these sites have high intrinsic value and are therefore problematic to secure at acceptable cost to the project.

Three potential locations have been identified for consideration as potential sites to host an energy centre for the heat network. These are marked as Site A, Site B and Site C in Figure 24.

Site A is owned by Quintain and is intended for future redevelopment as a retail outlet. Site B is currently occupied by L&B Haulage and Civil Engineering Contractors, primarily for the storage of building aggregates and Machinery, with some office space on-site. Site C is owned by Seneca/Carey and is the site of the existing SMRF facility operated by Carey.

Each of these sites is located within the designated light industrial portion of the Wembley regeneration area Masterplan and therefore has relatively low associated land values and would not displace possible high value developments. All three sites are potentially big enough in terms of footprint area requirements and all three have adequate access for construction and operation of the energy centre. In relation to air quality[22] requirements none of the sites (and the respective technologies to be implemented thereon) is likely to incur prohibitively stringent constraints in the planning and licensing process. In relation to sites A and B, emissions will relate primarily to NO_X associated with gas-fired CHP and gas fired boilers. Depending on local air quality requirements, low NO_x variants of each technology can potentially be specified. In relation to site C similar issues will apply in relation to gas fired CHP and boilers whilst additional emissions from the biomass facility would need to be considered. However, it is assumed that filters and air scrubbers can be specified for this facility as necessary, further reducing the impact on the local environment. It is worth noting that in the event that the decentralised energy option is not pursued, it is likely that the majority of developments would have individual gas CHP plants with a greater combined effect on air quality in a much higher risk location (residential, hotel etc.)

Each of the site location options were discussed with stakeholders (Quintain Estates for site A) LBB for site B and Seneca for site C). These discussions have led to the following conclusions:-

Site C represents an attractive proposition due to the strong synergy between Seneca's planned 2.5 MWe biomass facility the proposed heat network, since space already exists on this site for development of the planned 2.5 MWe biomass facility and since additional space could be made available and given over to development of an energy centre if the two plots currently owned by Carey and leased to third parties were to be liberated. In addition, Carey also owns a portion of the railway sidings running North West from their land at Hannah Close, through which pipework could conceivably be routed with minimal disruption and associated cost.

Site A is unlikely to be available to host a future energy centre, since Quintain have existing development plans for this site and would not be in a position to liberate the land in the short to medium term.

Site B, remains an option for consideration, subject to negotiations with the landowner for the sale of the site.

For the purposes of the study, Site C has been taken forward for further analysis. A fourth possible location was identified at the council-owned Brent River Park, but this option has been ruled out in discussion with London Borough of Brent due to recent significant investment in environmental protection measures for this area.

The alternative of a modular approach for constructing energy centres has been considered based on locating a series of smaller energy centres located within some of the major developments. However this hasn't been costed as an alternative to the cases presented here. This approach would deliver lower efficiencies, is likely to be more expensive in overall cost terms (both because of plant costs and land value issues) and would miss the opportunity for connecting to the SENECA facility, which we believe is the primary opportunity for this area. This option is also likely to be unpopular with developers and London Borough of Brent planning department, given the increased use of prime development land and increased numbers of stacks, air quality impact and noise impact issues to resolve.

[22] Air Quality here does relates to NO_x, SO_x and particulate emissions and do not relate specifically to CO_2 emissions as these are considered separately in Section 5.10

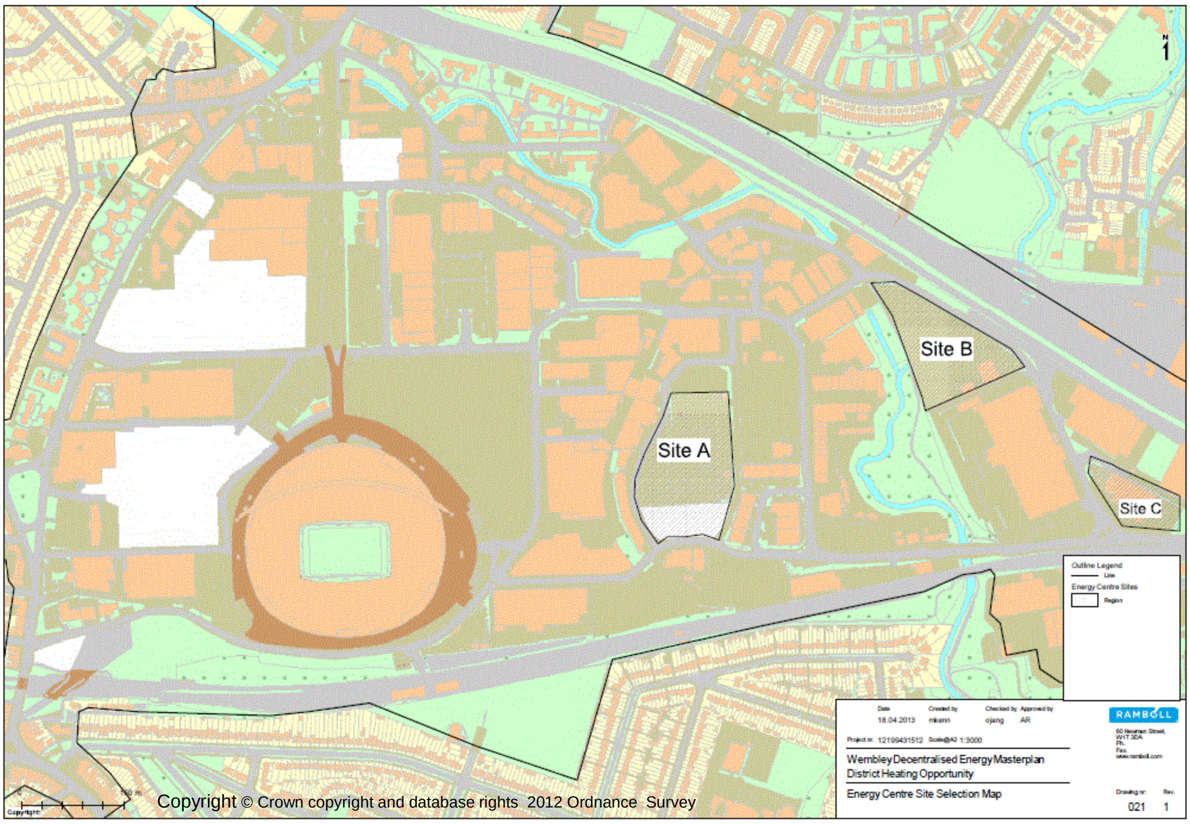

Figure 24 Energy Centre Options

In considering the suitability of each site for location for an energy centre, the choice of location is also dependent on which of the identified heat generation scenarios are pursued.

Under Option A the space requirement for the energy centre building would be approximately 1,500m^2, to include for the main plant assets as detailed in Section 5.3.1 together with balance of plant equipment and a heat exchanger station to connect the planned biomass facility to the energy centre. Under Option B, the space requirement for the energy centre building would be approximately 1,650 m^2, to include for the main plant assets as described in Section 5.3.2. In each case, an additional 15% - 20% of external space would be required for access, electrical substation, gas intake and car parking.

5.5 Network Phasing Strategy

Based on the projected pace of development within the Wembley Regeneration Area between 2013 and 2023, the earliest date for a heat network to be operational is considered to be 2018. On this basis construction of the heat network and energy centre would be required to start in 2017.

The development timescale for the heat network will ultimately depend on the phasing and volume of heat customers available to connect to the heat network at a given time. The timescales identified in Section 5.3 and 5.5 assumes that the developments would be available according to the development construction timescales identified in Appendix 1. If this timescale were to change, the viability of the identified heat network opportunity and the timescale for development of the heat network would change. For the purposes of this study only one development scenario has been modelled and the economic implications of an alternative development timescale have not been considered at this time.

Based on these assumptions, the development progression of the identified heat network opportunity is shown in Figure 25 to Figure 33.

5.5.1 Development Progression Prior to Heat Network

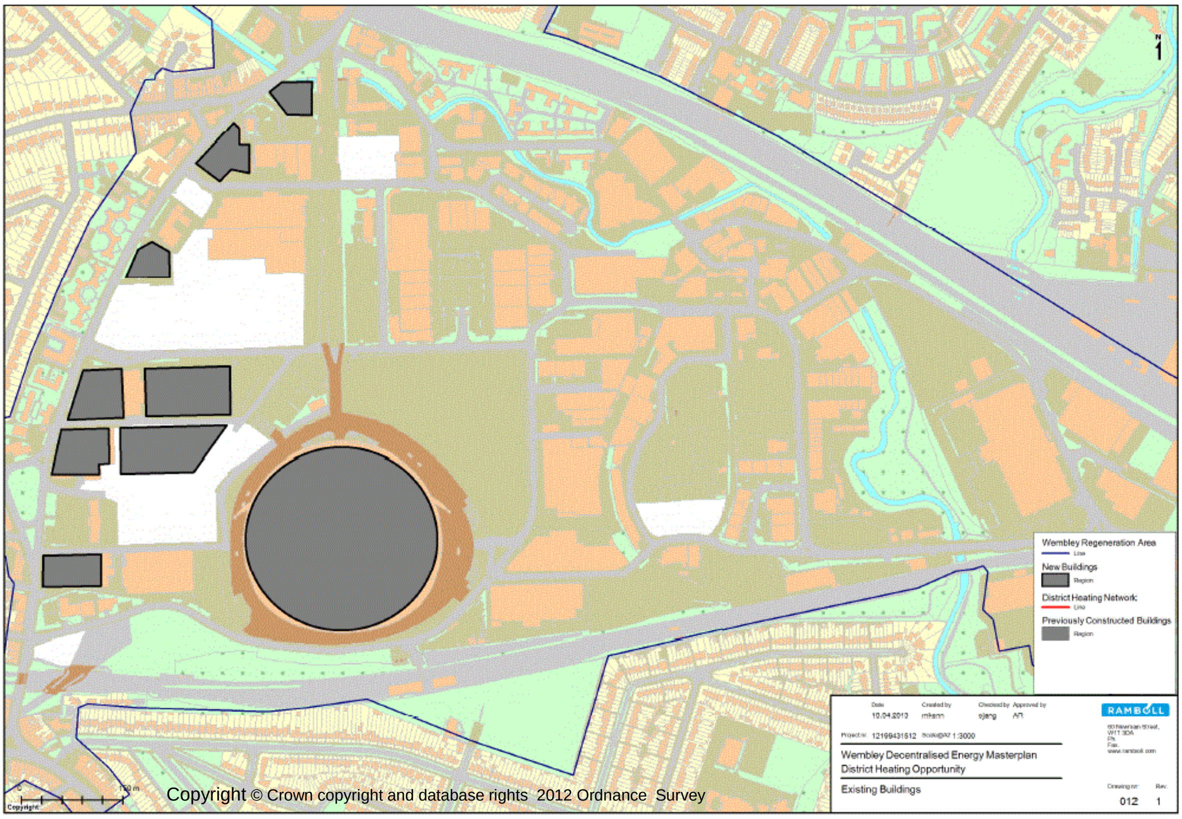

Figure 25 Existing Developments

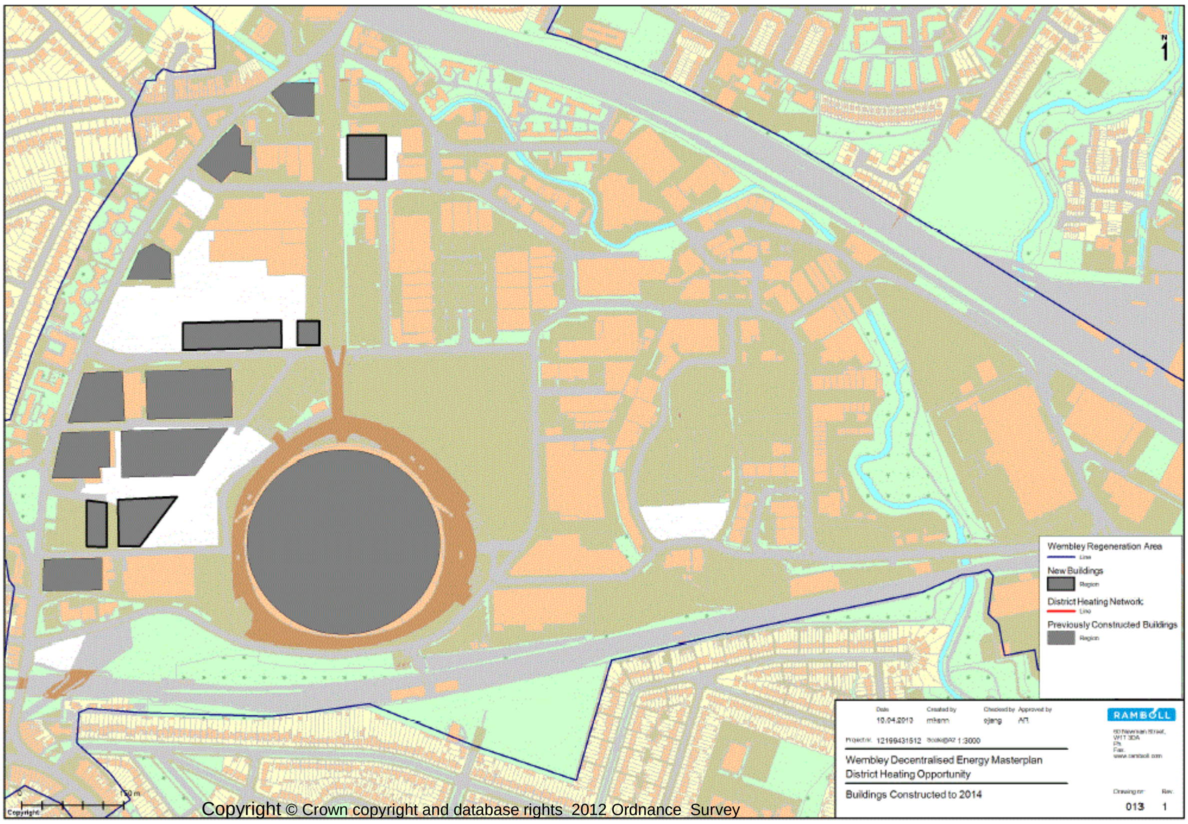

Figure 26 2014 Development Build-Out

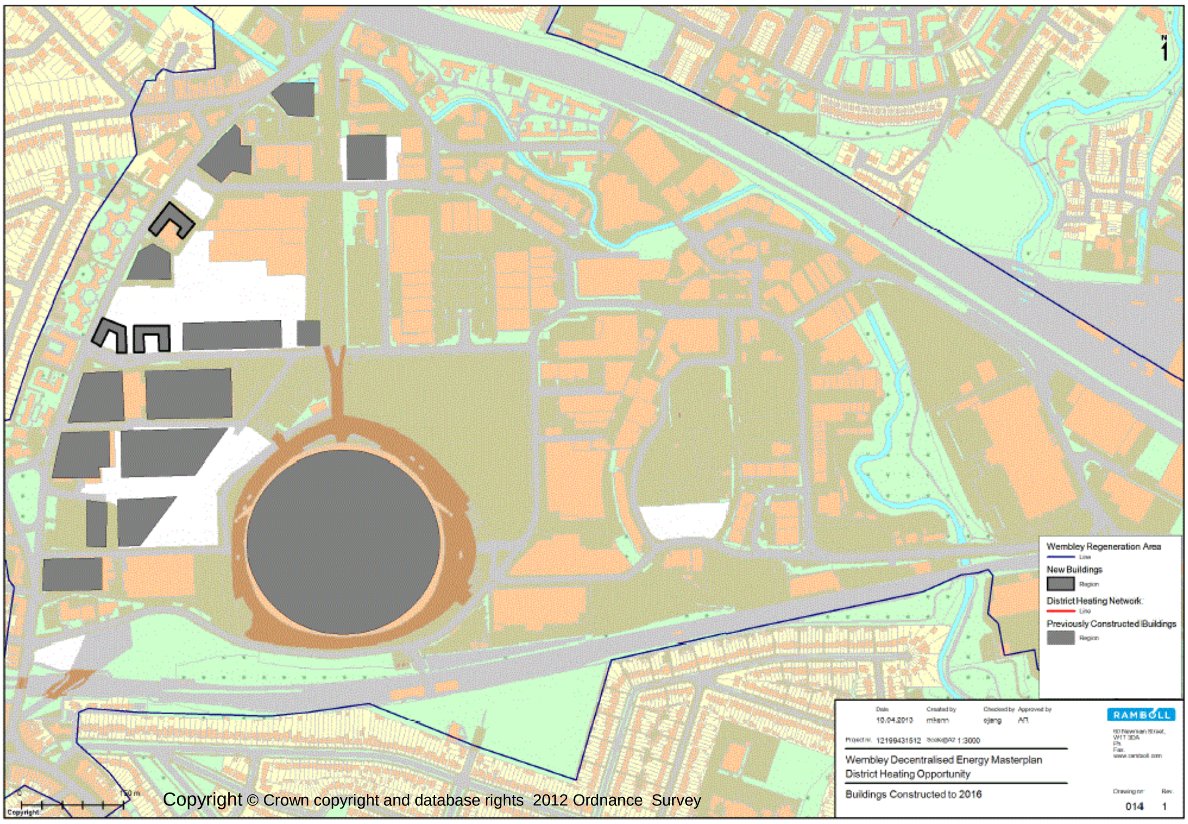

Figure 27 2016 Development Build-Out

5.5.2 Development Progression and Heat Network Build-Out

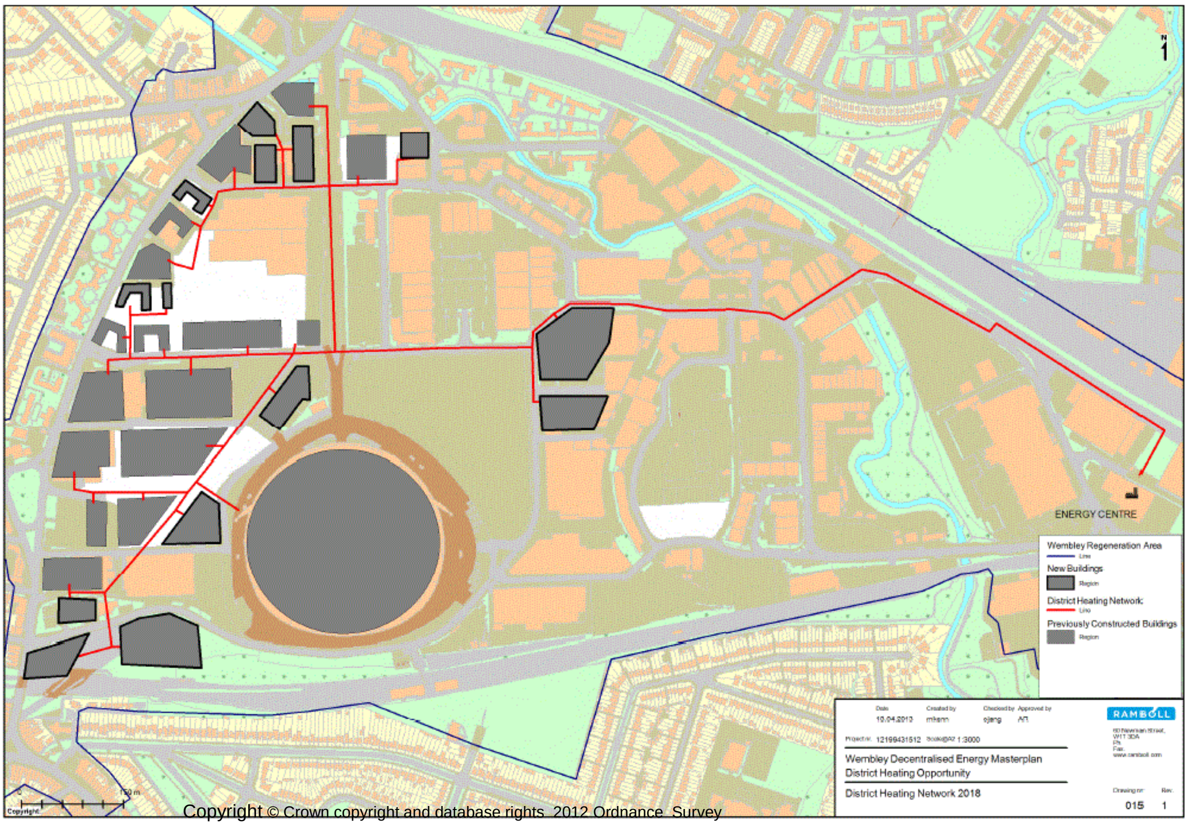

Figure 28 2018 Heat Network and Development Build-Out

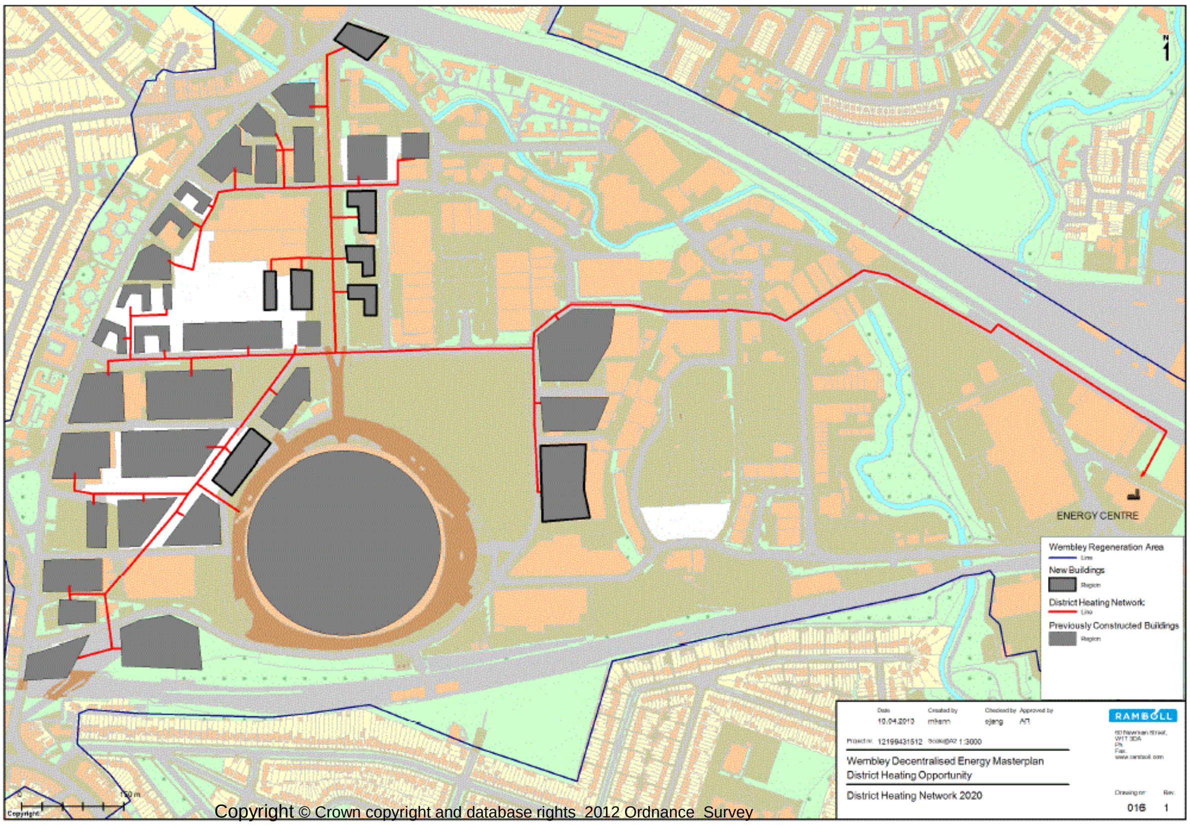

Figure 29 2020 Heat Network and Development Build-Out

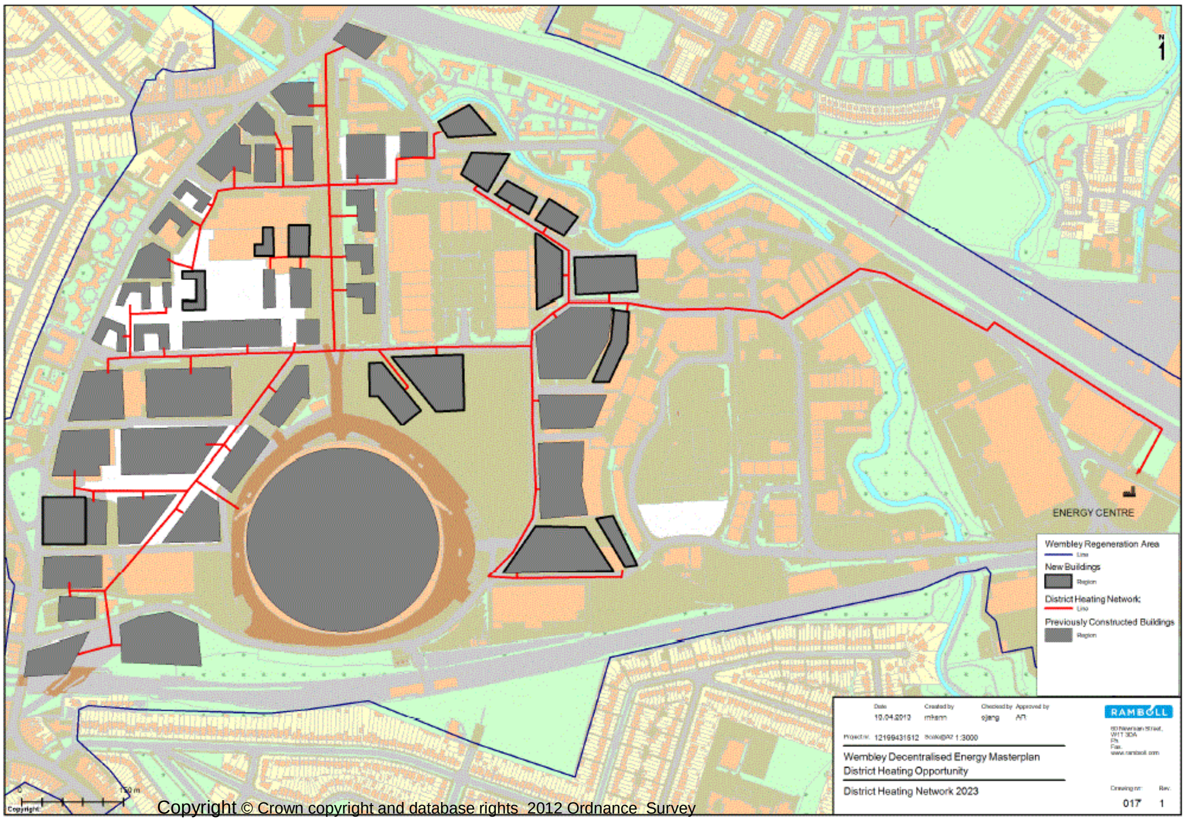

Figure 30 2023 Heat Network and Development Build-Out

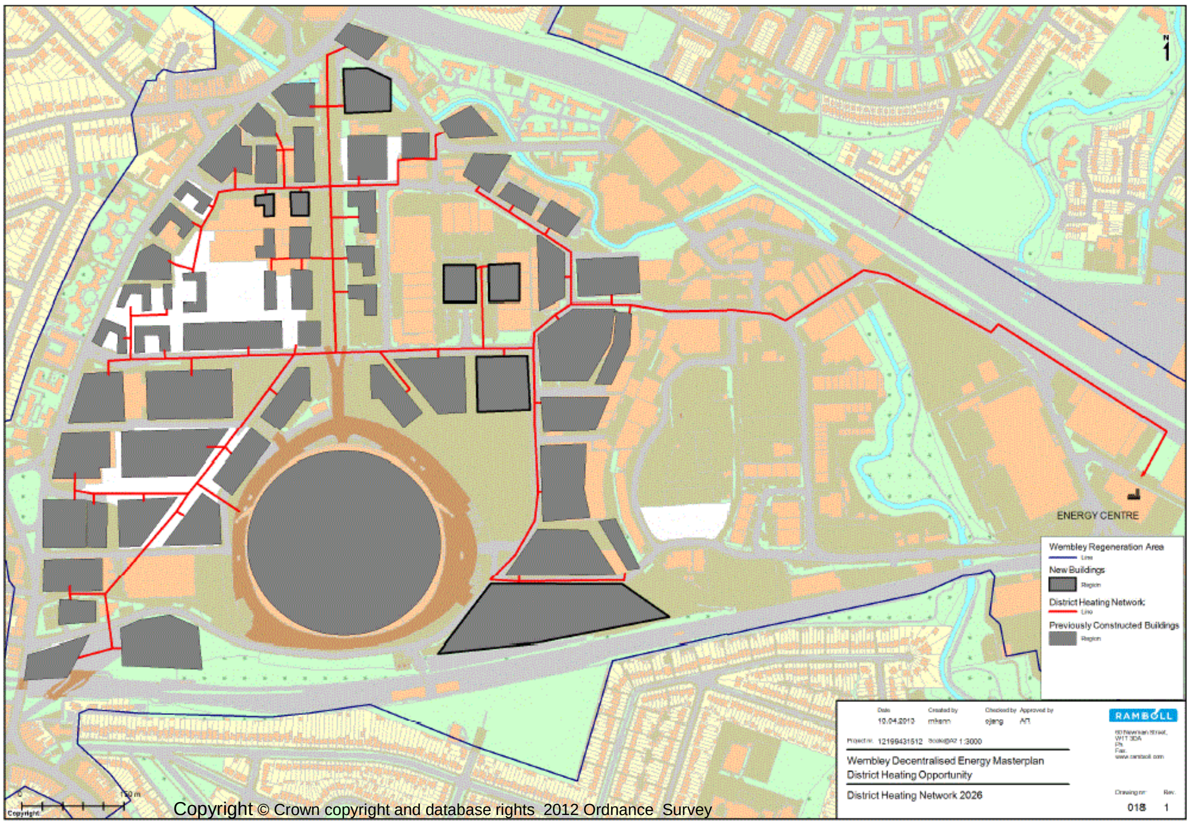

Figure 31 2026 Heat Network and Development Build-Out

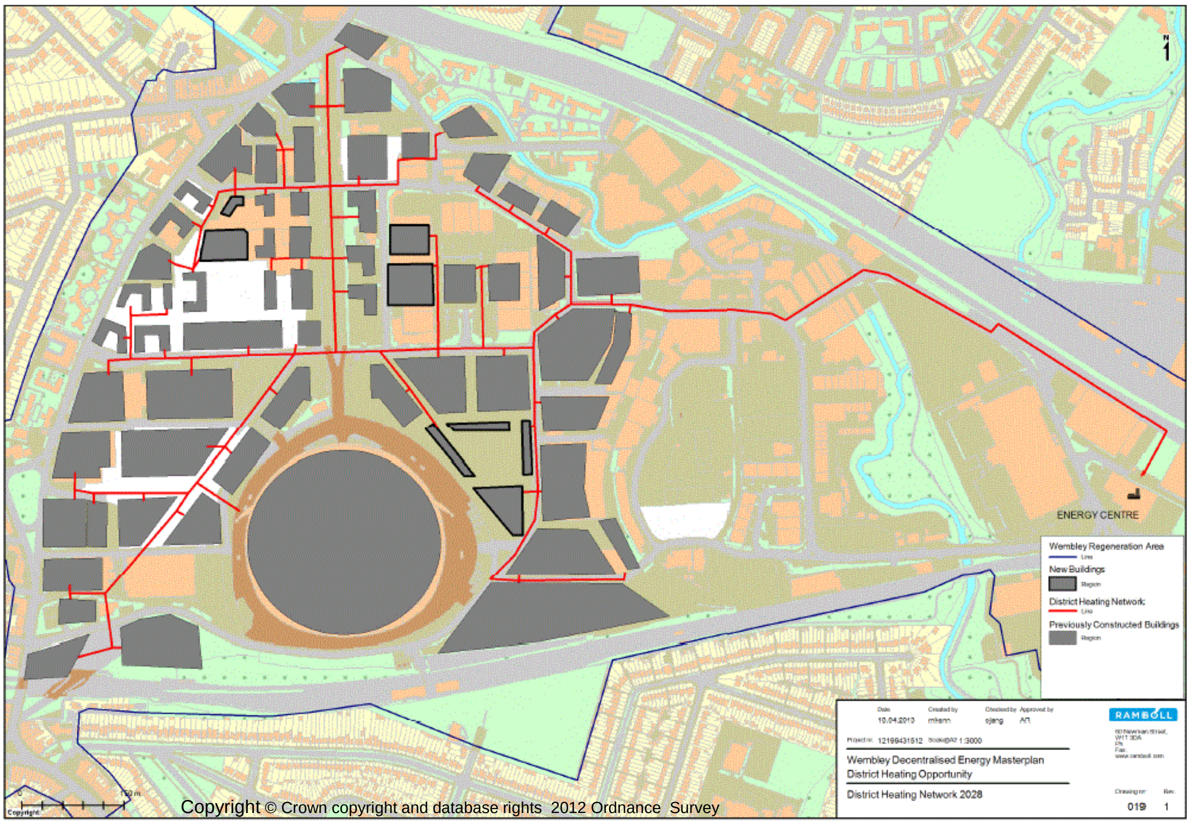

Figure 32 2028 Heat Network and Development Build-Out

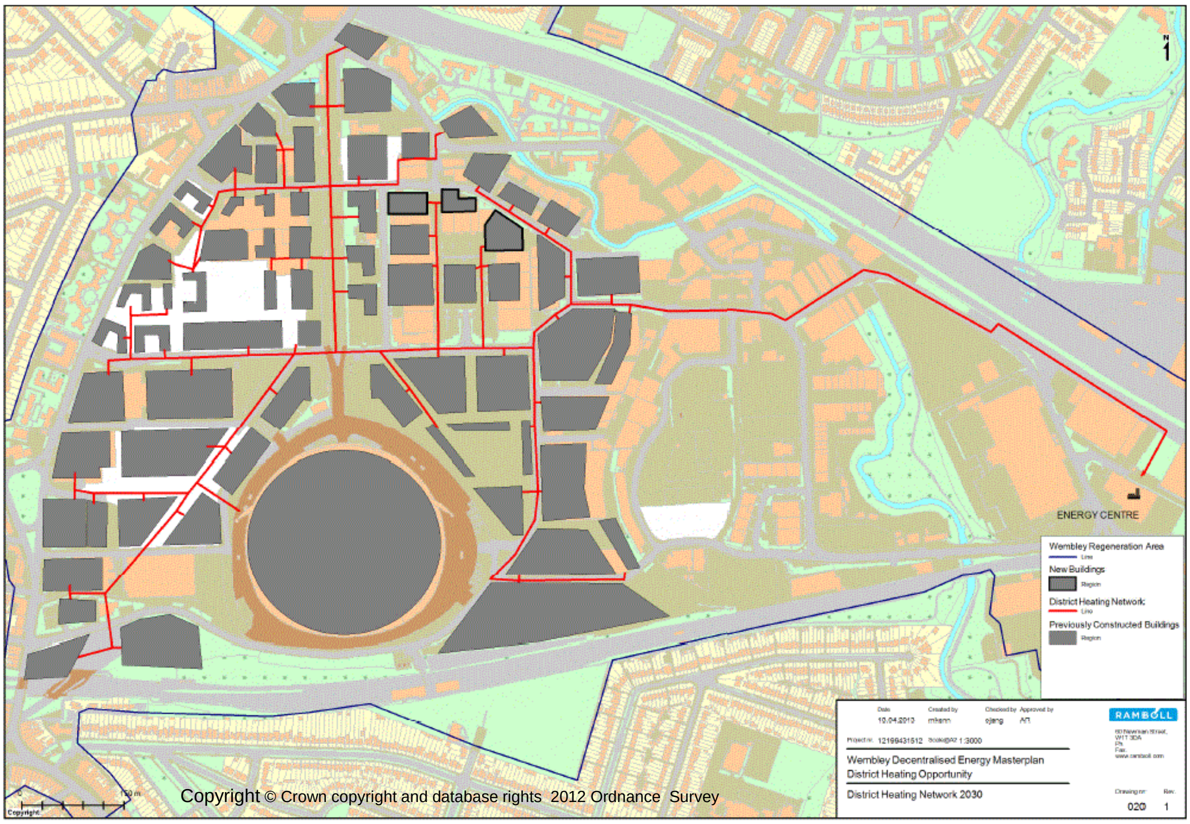

Figure 33 2030 Heat Network and Development Build-Out

5.6 Economic and Carbon Appraisal of Identified Opportunities

Economic and carbon appraisals of the identified opportunities have been carried out for technology supply Options A and B (Seneca and gas CHP options) as described in Sections 5.3 and 5.4 and for the heat network opportunity presented in Section 5.5. In both cases, Site C is assumed for the location of the energy centre.

The opportunities have been analysed in terms of their economic viability and carbon reduction potential using Internal Rate of Return (IRR)[23], Net Present Value (NPV)[24] and CO_2 abatement[25] as key indicators. The basis of the economic evaluation is presented in Appendix 6.

The network opportunities have been assessed over a 25 year operational period from 2018 to the final year of the project's lifetime in 2042. As noted in Section 5.5, investment in the necessary assets is assumed to occur at the start of 2017 for an anticipated operational start date of 2018.

Viability has been assessed on the basis of minimum required Internal Rates of Return for a fully private sector and fully public sector (i.e. London Borough of Brent) based procurement models. Accordingly nominal hurdle rates of 10 % and 6 % respectively have been assumed in line with common industry practice[26].

Project viability has been tested on the basis of a fully built out network comprising existing anchor demands, known developments within the planning process and future planned developments based on LBB's development schedule.

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[23] IRR is the discount rate at which the present value of all project cashflows are zero

[24] NPV is the difference of the present value of cash in and cash out throughout the project lifetime

[25] CO_2 abatement indicator is a measure of the CO_2 emission reductions attributed to the scheme compared to the business as usual alternative case for the buildings connecting to the scheme.

[26] It is noted that under current market conditions, and where increased risk is associated with a project, higher hurdle rates are typically currently required by the private sector

Electricity Licence Lite[27] has been taken to be the electricity selling arrangement for the project opportunities. A private wire network is considered to be an unlikely option for the project and a sell and buy back arrangement would require participation by LBB, which we understand is not under active consideration at this stage. A sensitivity of the IRR under each opportunity based on electricity wholesaling has also been considered, as can be seen wholesaling electricity to the grid has a greater effect on the IRR of the project for Option B than Option A due to the greater reliance of the business case for a gas CHP on revenue for electricity sales. Under this scenario, the IRR for option B reduces considerably from its value under Licence Lite and the project is no longer likely to be attractive to the private sector.

The key economic indicators for Options A and B are presented in Table 25 as a function of the assumed electricity selling arrangements for a project term of 25 years.

Refer to Appendix 6 for further details of the relevant assumptions around electricity selling arrangements.

		Option A	Option B
Total Investment CAPEX	[£ K]	20,951	26,145
Energy Centre CAPEX	[£ K]	7,646	11,031
Length of Heat Network	[m]	6,978	6,978
Cost of Heat Network	[£ K]	6,932	6,932
Connection CAPEX	[£ K]	1,222	1,222
Project Development Costs[28]	[£ K]	1,370	1,560
Annual Operating Costs	[£ K]	1,687	4,724
Annual Revenues from Heat Sales	[£ K]	3,990	3,990
Licence Lite			
IRR % over 25 years	[%]	14.7	14.9
NPV at 6% discount factor	[£ K]	17,342	21,707
Electricity Wholesale			
IRR % over 25 years	[%]	13.35	5.34
NPV at 6% discount factor	[£ K]	13,774	-1,355

Table 25 Economic Indicators

Discounted cashflow forecasts for the initial cluster project and the fully built out project options A and B are presented in Figure 34 and Figure 35 respectively. These are based on an Electricity Licence Lite arrangement. The presented cash flows shown illustrate the cumulative cash flows at various discount rates. The resulting value after 25 years indicates the NPV for the corresponding discount rate. Where the graph crosses the x-axis is the corresponding year when break-even occurs.

[27] A simplified electricity licence that would enable the licence holder to retail electricity to domestic and non-domestic customers
[28] Project Development Costs cover Planning, Legal, Architectural and Engineering Services and Contractor Preliminaries

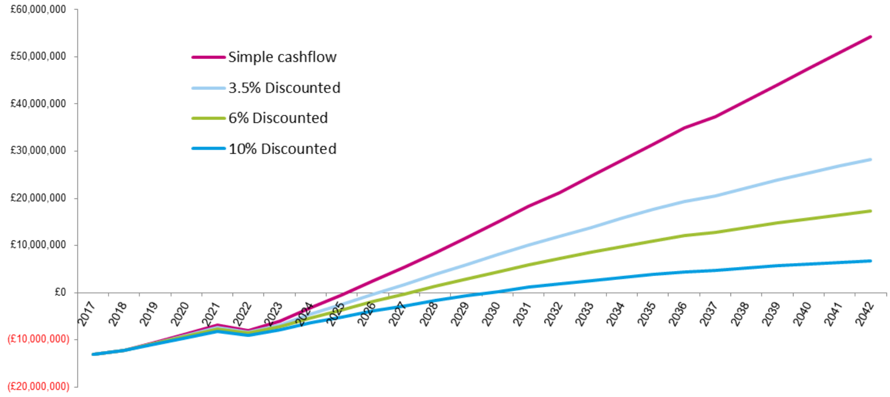

Figure 34 Discounted Cashflow Forecast under Option A assuming electricity retailing under Electricity Licence Lite

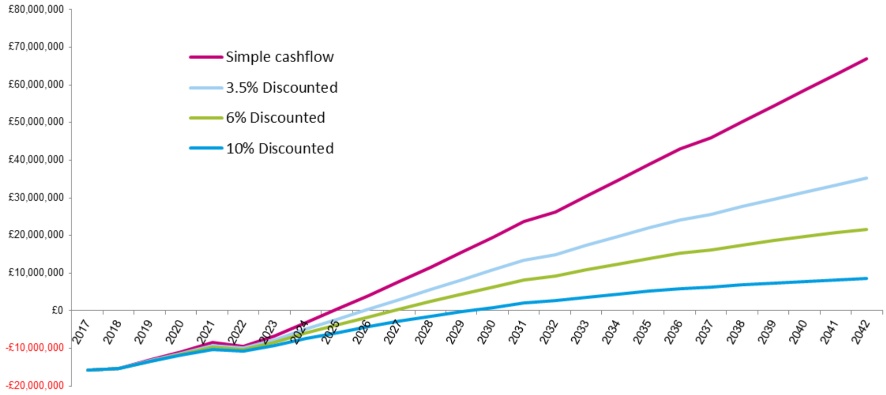

Figure 35 Discounted Cashflow Forecast under Option B assuming electricity retailing under Electricity Licence Lite

Figure 36 and Figure 37 below present the Net present value of each of the project options for varying discount rates. These NPVs are presented for the Licence Lite Electricity retailing scenario based on the central reference values used in the economic modelling and detailed in Appendix 6. Similar to Figure 34 and Figure 35, the net present values are given for discount rates of 3.5%, 6%, and 10%, additionally the estimated project IRR is shown here. That is the discount rate at which the NPV of the project is 0.

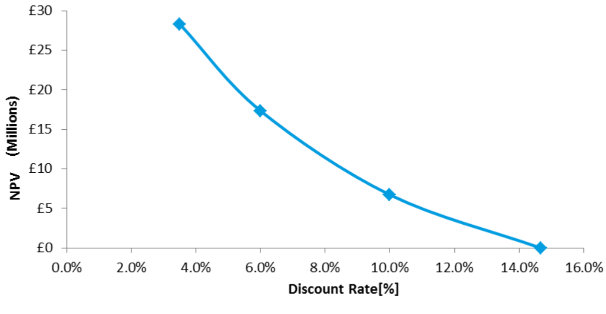

Figure 36 Net Present Value for Varying Project Discount Rates Option A

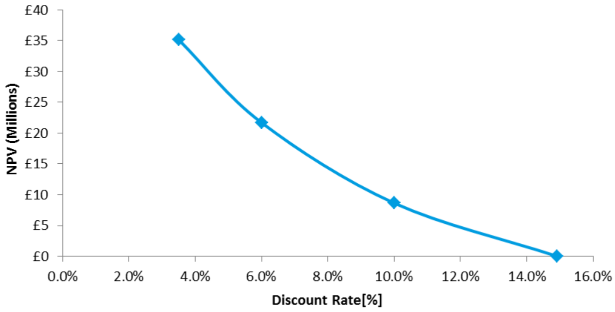

Figure 37 Net Present Value for Varying Project Discount Rates Option B

5.7 Sensitivity Analysis for Economic Parameters

A sensitivity analysis has been carried out around the key variables that influence the IRR for the project. The results of the sensitivity analysis are presented in Figure 38 and Figure 40 below for the fully built out project under the Electricity Licence Lite scenario.

The blue line shown in the graph represents the central estimate of the project IRR, based on the central assumptions for the listed variable along the x-axis which were used to produce the economic indicators presented in Appendix 6.

The bars in the graphs show the change in project IRR due to a change in a single variable, with all other variables being held constant. The magenta bars denote a 10% increase in the listed variable whilst green bars denote a 10% reduction. Exceptions to this are variables such as Developer Contributions which are modelled at 100% and 200% from a reference scenario of 0% (i.e. no contribution), connection costs, which are modelled as 100% (reference case), 50% or removed from the project and electricity sell prices which are additionally modelled for an electricity wholesaling situation. Further information on the methodology, the interpretation of the graphs and the values attributed to each variable is presented in Appendix 6.

The key conclusions for the project are that:-

1. Cost of heat from the Seneca plant, Electricity selling price, gas purchase price, project capital cost, and heat selling price are the major drivers in uncertainty around IRR.
2. Variations in these indicated variables could increase the IRR to over 15 %.
3. An unfavourable variation in the cost of waste heat from Seneca could reduce the IRR to under 9.0 %.

For the fully built out project an unfavourable variation in any of the indicated variables except for the cost of the waste heat from Seneca will still deliver an IRR of around 12.5 % to 13 %, which is still considered to be attractive to London Borough of Brent.

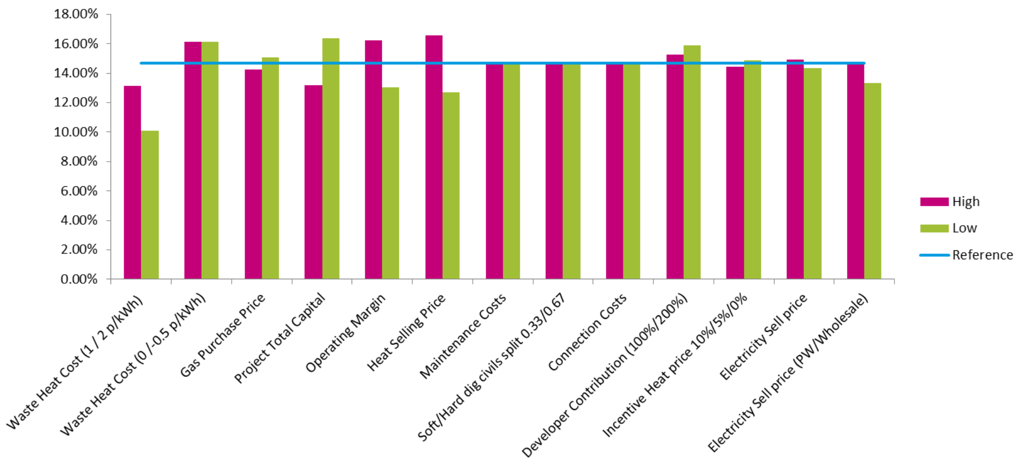

Figure 38: Economic Sensitivity Analysis – Option A

Figure 39 and Figure 41 show in greater detail the relative effect of variations in the indicated variables.

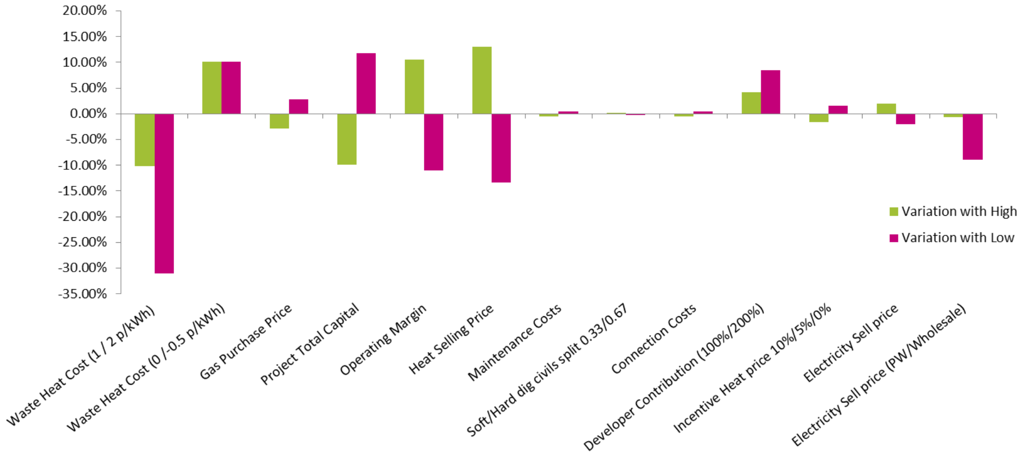

Figure 39 Variation in IRR with Sensitivity Analysis – Option A

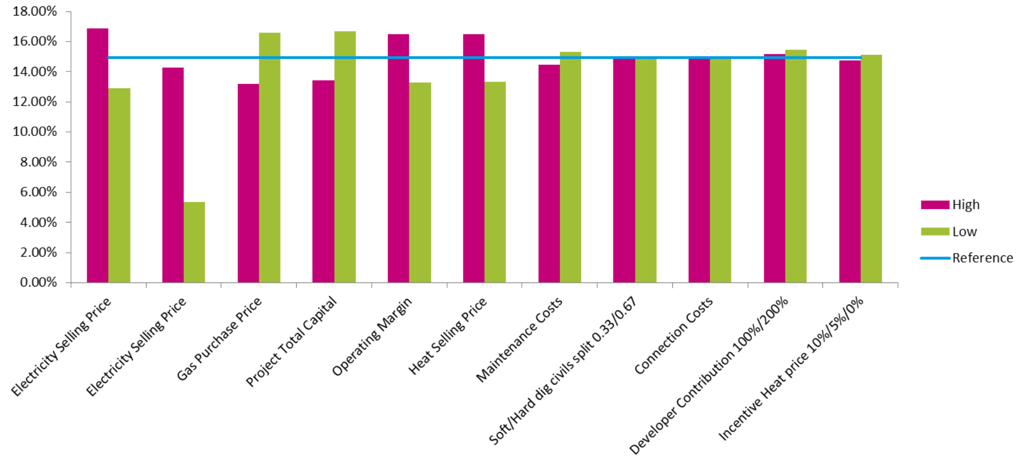

Figure 40: Economic Sensitivity Analysis – Option B

Figure 41 Variation in IRR with Sensitivity Analysis – Option B

5.8 Carbon Appraisal

Projected carbon savings for the project Options A and B over 25 years are presented in Table 26. Reference to the calculation methodology is provided in Appendix 6.

Carbon Appraisal for Decentralised Energy Options compared to Business as Usual			
		Option A	Option B
Business as Usual CO_2 over life of project	[TCO_2]	287,641	287,641
Heat Network Carbon Emissions	[TCO_2]	91,841	129,868
CO_2 Savings over life of project	[TCO_2]	195,854	157,827
% reduction in CO_2 Savings over life of project	[%]	68	55
Average Carbon Content of Heat Delivered over lifetime of project	Kg CO_2/kWh	0.048	0.068

Table 26: Carbon Emission for Decentralised Energy Options compared to Business as Usual

5.9 Network Route Appraisal

The initial network route has been designed based on assumptions outlined in Section 2 thus the heat demand to be met by the network comprises existing anchor demands, known developments currently in the planning process and future planned developments (as yet conceptual) based on LBB's masterplan and development schedule. A detailed description of the network design method and modelling software used is contained in Appendix 6.

The network route proposal is shown in Figure 42 .

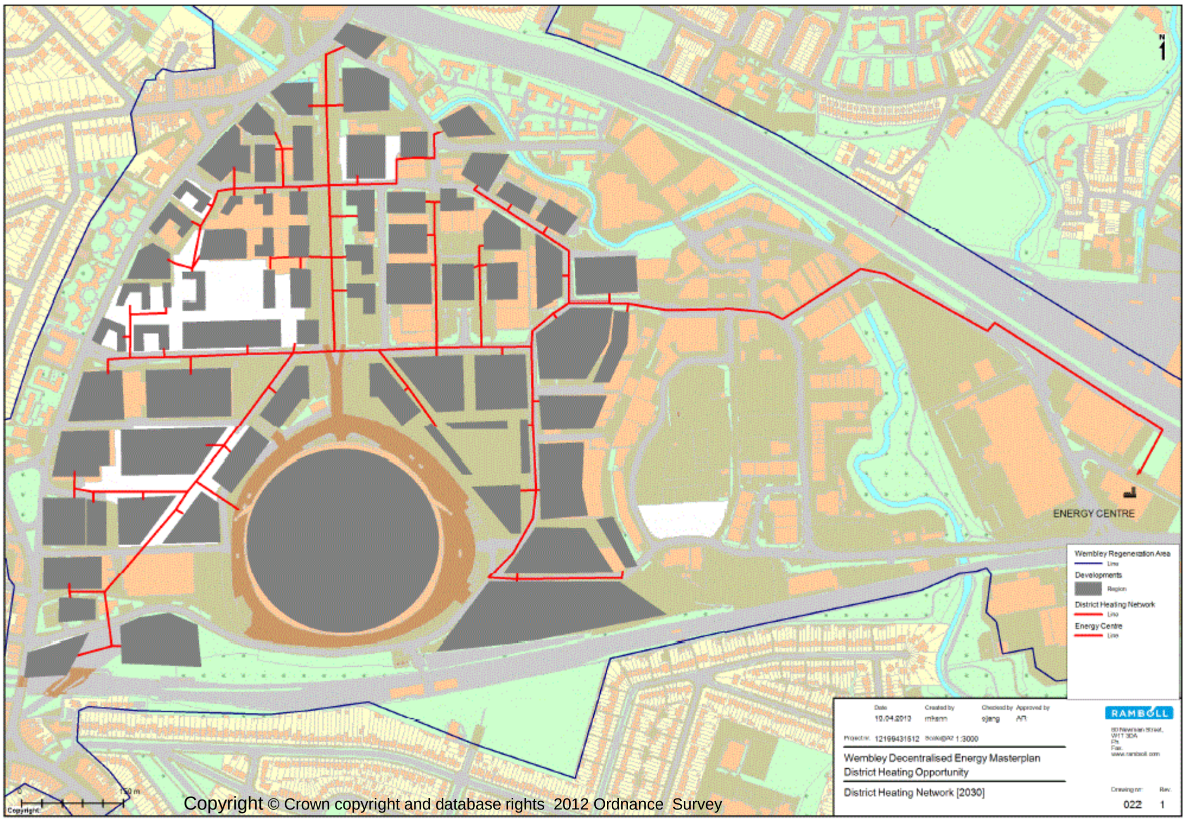

Figure 42 Fully Built-Out Heat Network

The indicated route is based on supplying all identified existing and proposed demands within the serviceable area from an Energy Centre at the Seneca facility and has been chosen based on an assessment of the phasing of heat loads within in Wembley Regeneration Area (and their suitability for connection to the proposed network) together with a high-level appraisal of major infrastructure barriers and opportunities including:-

1. Existing highways and other traffic routes
2. Rail lines
3. Known development plot boundaries
4. Considerations of land ownership and opportunities to route pipework through key stakeholder (e.g. SENCA and Local Authority) owned land.

The route as shown above has been designed based on the development phasing map published by LBB as part of their Core Strategy document. The primary trunk of the network follows the main roadways in the Wembley Regeneration Area, Fifth Way and Engineer's Way; both of these are established roads that are expected to be retained for the lifetime of the project. Whilst installation of district heating pipes along these routes may cause some traffic disruption to the Wembley area, these are not the primary entrance routes to the central Wembley area and diversions of minimal length can be provided for all routes. Both of these network sections could be installed at the same time at the project's outset and as such would be considered to be one-off disruptions.

Another existing route of significance that is to be utilised is Olympic way, which is a pedestrianized route running from Wembley stadium to the northern boundary of the Wembley Regeneration area. There would be some disruption to businesses and other stakeholders in this area however, given the pedestrian nature of the route and the large route width, it is anticipated that pipework installation could be managed without undue risk or cost to the project. It is recommended that this section be installed at the project's outset to avoid multiple disruptions to local stakeholders.

Developments in the Quintain West lands will be serviced by a distribution main branching off from Engineer's Way via the new roadway intended to run diagonally from just north of Wembley Stadium to the Wembley South Way Site. This route is currently under development and is progressing in parallel with the Quintain developments in the area. Additional road works to install district heating pipes would require road-closures however, as with the main routes, diversions are available and disruption to traffic could therefore be managed.

Branches from the distribution main into individual developments or multi-development clusters are not expected to pose an issue as these are expected to come forward at the same time as the developments are constructed. As such there would already be significant unavoidable earthworks underway associated with other utilities such as electricity, water supply etc. This represents a further opportunity to the project and to individual developments to investigate co-location of services in the same trench. Indicative trench construction methods and details are presented in Appendix 6.

A decision was taken early on to exclude any loads that would require crossing the major arterial roads within the Wembley Regeneration area as it is unlikely that the disruption and cost of supplying these areas would result in added value for the scheme given the low number of buildings affected and their (relatively) low heat demand. There is one road major crossing at North Road to Arena house. Whilst North road is not a major arterial route this does represent a barrier for connection for this particular development. The decision to connect this development would need to be taken in consultation with the developers and will be a decision based on the cost of crossing the road (either through traditional excavation or directional drilling methods).

There are no proposed crossings of bridges or railways and the network route avoids private property external to the project. If the project is taken forward, detailed route appraisals will need to be carried out. Network routing within individual developments would take place in consultation with relevant developers.

As discussed in Section 4 Seneca own a portion of railway sidings running alongside Hannah Close and there may be an opportunity for the project to utilise this space for some of the network route to the Seneca facility.

5.10 Conclusions

The scale and density of consented and planned development coming forward in the Wembley Regeneration Area over the coming decades suggest a significant commercial opportunity to develop a strategic district heating network in Wembley Regeneration area.

The network could supply affordable market competitive heat to both new and existing properties, creating significant investment and job opportunities and maximising the area’s true potential for efficient low carbon local energy generation.

Based on delivering market competitive heat[29] to existing and new developments in the Wembley Regeneration area, the indicated IRRs for the project are likely to be attractive to private sector energy providers, providing that the planning process is used to require developments to safeguard to connect to the heat network.

Such an opportunity could feasibly be developed with a newly constructed gas fired CHP energy centre or in conjunction with the proposed 2.5 MW_e biomass CHP facility at Seneca’s SMRF facility that has planning approval. In the longer term, and in the event that the Seneca biomass CHP opportunity does not materialise, a local EfW facility could potentially be constructed to supply the network.

During a meeting held between SENECA, Ramboll and London Borough of Brent SENECA indicated that they are confident that they can secure sufficient feedstock in the long term to fuel the proposed plant and would be interested in pursuing negotiations around selling heat to the proposed district heating scheme. We have not assessed the security of the supply chain to the proposed SENECA opportunity but the business case for the plant is understood to be based on SENECA’s ability to secure a feedstock from its construction waste collection business in what would therefore essentially be a vertically integrated supply chain arrangement. In the longer term SENECA also have the potential to exploit some of the steady feedstock available from the

[29] The presumption is that heat would need to be delivered at a minimum of 5% below the lowest alternative price based on alternative (business as usual) heat production costs

MRF plant, albeit that in the short term this is fully contracted to existing customers in mainland Europe. Further work should be undertaken to evaluate the security of the supply chain at feasibility stage.

A heat network based on an energy supply from this facility is considered to be the preferred option. This option will deliver lower carbon heat than the gas CHP option, provide greater support to developers in delivering against their compliance targets and reduce the local community's reliance on natural gas (therefore helping to protect the local community from fuel price volatility and increasing energy costs). It will also capture low grade heat energy that would otherwise be wasted at the Seneca plant and increase the total efficiency of production at that plant.

Depending on how the plant is designed, heat offtake may incur a penalty in on-going electricity production and/or may require modification to the design that would reduce total efficiency of electricity production. The impact of the heat extraction on the business case for the Seneca biomass facility as a power only production plant hasn't been modelled in this report. Initial discussions with Carey indicate that providing that the business case for the proposed biomass plant remains neutral or positive under the proposal to extract heat. The company is likely to view the opportunity in a positive light and would be interested to explore the option in greater detail at the next stage. Given also that the SENECA site could potentially be used to host the energy centre for the heat network and provide Carey an opportunity to generate a return on invest on their land, it is recommended that discussions are pursued with Carey at the next stage. In order to test the impact of variation in heat production cost from the Seneca plant, a sensitivity analysis has been carried out. Based on variations in the heat purchase price from 0 p/kWh to 2 p/kWh, the IRR can be expected to vary from 16.2% to 10.1%, assuming electricity sales[30] from the supplementary gas engines installed at the energy centre under a Licence Lite/Junior Licence.

Under this option (Option A in the report), the identified heat network opportunity is expected to deliver an IRR of around 14.7% based on a heat selling price 5% below the business as usual alternative for existing and future heat customers, electricity retailing under an Electricity Licence Lite / Junior Licence and heat purchase price from the SENECA facility of 0.5 p/kWh. Under the alternative scenario of wholesaling electricity at 5 p/kWh, the IRR would be approximately 13.35%, which is not as attractive to potential providers. The relatively small reduction in IRR is due to the fact that under Option A the actual revenue from electricity production is quite low relative to Option B.

Projected carbon emissions savings relative to the Business as Usual scenario amount to 68% over 25 years. This equates to 195,854TCO_2 at full build out in 2042 over the lifetime of the project.

In the event that the Seneca biomass CHP opportunity does not materialise, a heat network supplied from a natural gas fired CHP energy centre under a Licence Lite electricity selling arrangement still appears to represent an attractive investment proposition to the private sector and is therefore considered to be capable of being delivered through the market. This is not the case for a natural gas fired CHP energy centre under a wholesaling arrangement where the IRR is found to reduce to 5.34% indicating that the project is no longer likely to be attractive to the private sector.

Whilst the value of such a scheme in carbon terms would be lower than one based on renewable or EfW derived CHP heat, its construction would facilitate a future transition to renewable or EfW derived CHP heat and is therefore considered to be of value to the Wembley Regeneration Area.

Under this option (Option B in the report) the identified heat network opportunity is expected to deliver an IRR of around 14.9%. This assumes heat selling prices at 5% below the business as usual alternatives for existing and future heat customers electricity retailing under an Electricity Licence Lite / Junior Licence and no developer contributions to the heat network construction. Under the alternative scenario in which electricity generated from the CHP would be sold at

[30] The value of electricity sales from the Seneca plant is not attributed to the project. Forfeited electricity production in lieu of heat production is compensated for in the assumed cost of heat production.

wholesale prices[31], the IRR would be approximately 5.34%, which is not considered to be attractive to potential providers.

Projected carbon emissions savings relative to the Business as Usual scenario amount to 55% over 25 years. This equates to 157,827 TCO_2 at full build out in 2042 over the lifetime of the project.

For Option A the impact of developer contributions on project IRR has been tested. Developer Contributions totalling £1.18M would increase project IRR to 15.27% based on electricity retailing under an Electricity Licence Lite / Junior Licence. This value represents the estimated cost of service pipes and heat exchanger stations to each identified development. Developer contributions totalling £2.34M would increase project IRR to 15.9%. The evidence base modelling presented in Section 3 of this report has identified a potential basis on which to capture contributions from developers to the project opportunity.

The timescales for development of the identified heat network opportunity are likely to be 5 to 10 years, with an earliest likely heat on date of 2018. In order to safeguard the opportunity, it is crucial that new developments being constructed in the interim period prior to construction of the heat network are designed to facilitate future connection to such a network. This includes physical safeguarding measures as well as design of internal systems in accordance with appropriate design temperature standards to ensure compatibility with these networks.

Where appropriate, the presumption should be that new developments constructed in advance of the heat network should install community heating networks with temporary energy centres, fuelled by high efficiency gas boilers, combined heat and power plants and/or renewable heating systems, subject to local air quality assessments and economic viability appraisals. Where this is not the case, they should expect to contribute towards a decentralised energy system unless it can be demonstrated that such provision is not feasible or the proposed heating system is 100% renewable.

The identified decentralised energy opportunities are likely to be attractive to London Borough of Brent since it will support in the delivery of LBB's CO_2 emissions reduction targets, it will provide an opportunity to address fuel poverty within the area and it will place LBB at the forefront of delivery of DE in London. It also avoids piecemeal approach to compliance for new developments stands to reduce the environmental impact of heat supply through on development level solutions and is likely to attract green business/inward investment into the area. In the longer term, the opportunity offers a potential synergy to link waste collection and waste treatment with LBB with the opportunity to generate revenue from low carbon heat production.

Of the identified project opportunities, no insurmountable technical barriers have been identified. Further work will be required for projects taken forward in relation to more detailed network route planning.

[31] Assumed to be 5 p/kWh

6. DISTRICT COOLING

6.1 Introduction to District Cooling

The main opportunity with district cooling is to make use of two fundamental ideas; economy of scale and the use of thermal store.

Economy of scale makes the large scale chillers cheaper than many small scale chillers and in addition higher efficiencies can be achieved with more advanced technology, such as centrifugal chillers. Counting against these benefits is the cost of the pipework required to connect the loads with the large scale equipment.

The second idea is using thermal storage for two reasons;

1. Main reason is to reduce the size of the installed equipment. The thermal store costs less initially and is also cheaper to maintain compared to avoided capacity chillers. The reduction in size is possible when the thermal store is discharged in a controlled manner right over the maximum demand peaks during the day.
2. As a synergetic effect the electricity is cheaper during night time and as the store can be charged with lower cost electricity the project becomes more financially viable.

Carbon dioxide emissions can be reduced due to increased efficiencies of the larger more advanced chillers.

There are also other benefits such as the freeing up space in buildings and roof space as there is no need to locate dry air coolers on the roof. This could potentially be quite valuable but has been excluded from this analysis.

6.2 Summary of Opportunity

The network would have the same catchment area as the heat network albeit not all the heat load buildings are assumed to have cooling demands. The district cooling network is therefore less extensive compared to the district heating network. Based on linear coolth density, which is the cooling demand per metre of network route required, some areas are excluded from supply. The phasing of the cooling network follows the same strategy as the heat network, starting delivery of chilled water in 2018.

It has been assumed that developments constructed 2016 and 2017 would have temporary chillers before connecting to the network and thus avoiding the CAPEX associated with their own full installation of equipment.

Just as for the heat network opportunity the district cooling opportunity has been modelled using our in-house developed modelling tool EPEM. The model allows for hour by hour modelling of every hour of the project lifetime and is coupled with the cashflow analysis which allows for optimisation of the technology proposals.

The network would have the following main characteristics:

- Peak demand 23 MW,
- Annual demand 13.8 GWh
- Network losses (heat gain) are estimated to 127 MWh per annum. See section 2.5 for more information on the cooling demands.

The annual profile is shown in Figure 44 (daily resolution) and Figure 45 (monthly resolution). The chiller operation has been split into day and night time operation in order to investigate how much is produced when. Night time operation is considered to start at 22.00 hrs and day time operation takes over at 08.00 in the morning. The thermal store was only allowed to discharge from 08.00 to midnight. The difference in operation is due to the ability to charge an empty store midnight to morning. Some limitations were set for the peak output of thermal store i.e. during summer months, June to August, it could not discharge at full capacity during hours; 13-18 and not at all in the morning before this. This allowed a smoother output required from electric chillers and thus their capacity could be smaller.

In terms of profiling the annual cooling demand it has been assumed that process coolth, i.e. cooling demands independent of cooling degree days profile, are minimal. There could be some process coolth and this would make the project more financially viable as it smooths the monthly profile.

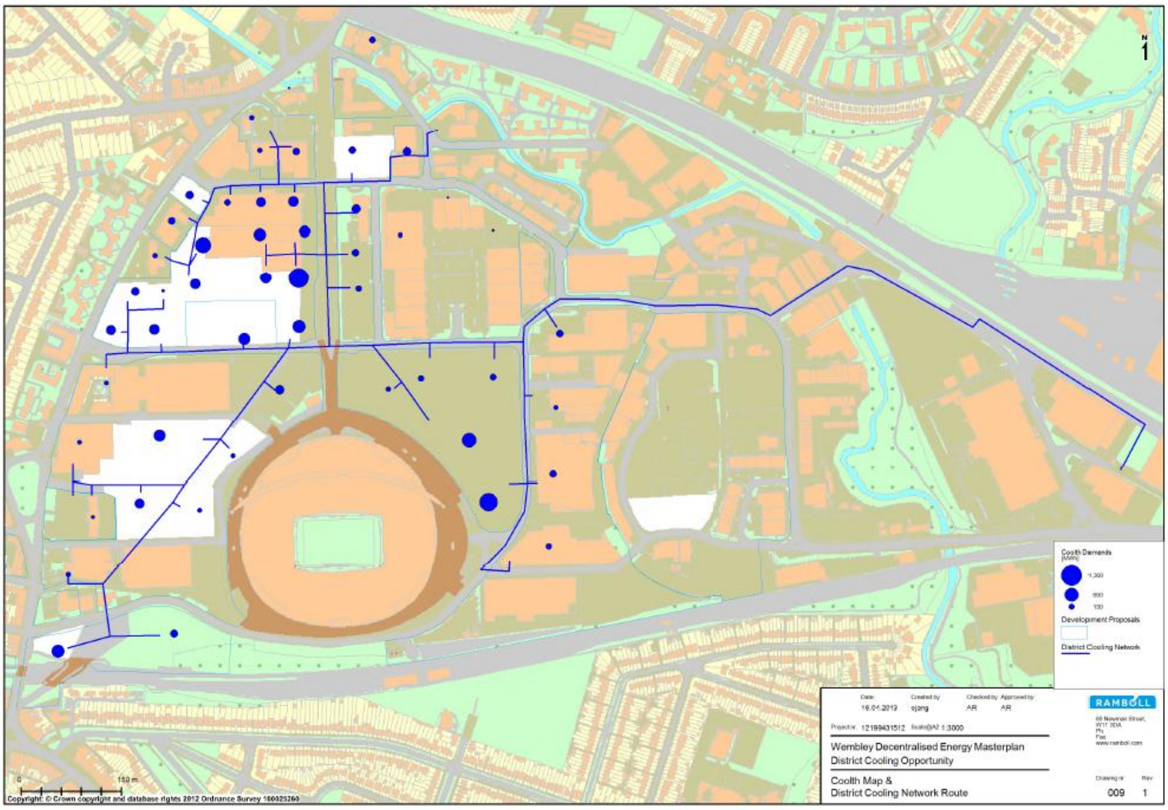

Figure 43 Coolth map identifying the district cooling opportunity including demands and network

It can be seen in the map in Figure 43 that the network does not extend to all the buildings connected to the heat network. Particularly the north east corner and the northern part of the Olympic way are not connected to the cooling network.

6.3 Technology Proposals

The main chillers at the energy centre are proposed as centrifugal chillers combined with wet cooling towers to enable good efficiencies. The installed capacity of the chillers would be 12 MW thermal cooling capacity. Connections would be made through either a direct connection or indirect connection. Indirect connections through plate heat exchangers have been assumed.

It has been assumed that by utilising free cooling during night time the COP of the chillers would be 7.5 during night and 5.5 during the day. Following the optimisation of the thermal store below the contribution from night time operation of the chillers would be about 75%.

Whole life cost and carbon appraisals have been developed for this approach. These are presented in subsequent sections of this chapter.

Following a thermal store optimisation exercise the best IRR was achieved for a thermal store size of 11,500 m^3.

This could be a thermal store cylinder 23m high and 23m in diameter. It is assumed that 85% of the store would the effective volume and that the differential temperature is 7 °C.

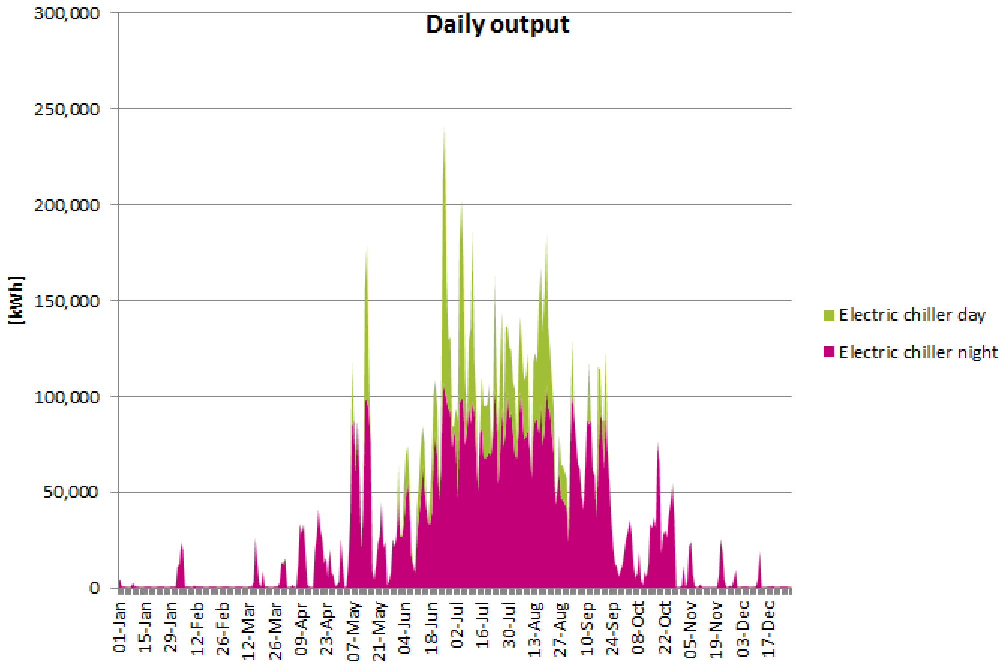

Figure 44 The daily sum of outputs from the chiller split into day and night operation

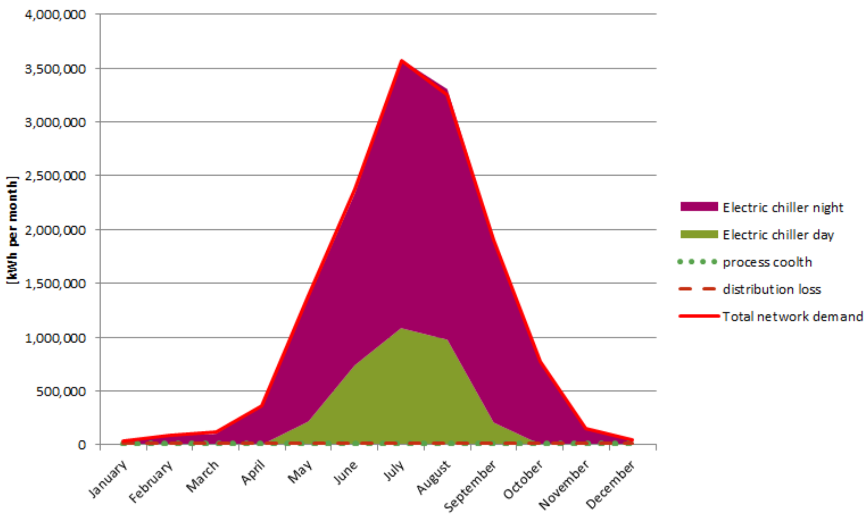

Figure 45 Annual Monthly Supply

6.3.1 Absorption Chiller

The investigation into surplus heat from potential WtE plant at Seneca shows there will be little if any surplus heat available for use in absorption chillers. Ramboll's experience from other projects shows that using absorption chillers fed from gas fired CHP is very sensitive in terms of carbon dioxide balance and it is not certain this would lead to carbon dioxide savings. The opportunity for absorption cooling is therefore considered to be limited based on the scenarios identified in this report.

6.4 Energy Centre Location

The energy centre location is assumed to be in the vicinity of or co-located with the heat network energy centre. Refer to the section 5.4 for more details on the energy centre location options.

We have allowed for the cost of a bespoke energy centre for the cooling network equipment and that the network would start at the Seneca plant with a DN500 pipe main connecting to the consumer area. The estimated floor area required for the cooling energy centre building is 637 m^2. The thermal storage area would be in addition to the energy centre and is estimated as circular 470 m^2.

6.5 Network Route and Phasing

See Figure 43 for the cooling network map.

The route is assumed to be the same as for the heat network and similarly for the phasing as it follows the same build out schedule and development schedule.

6.6 Economic Appraisal of Opportunity

6.6.1 Modelling concept

The avoided running costs of buildings are the input for the revenues of the project less an incentive (5%) to add to the other benefits of connecting. Included in the running costs are fuel, O&M and re-investment in chiller equipment.

At the time of connection, and when the development can avoid investment in chillers and dry air coolers, the development instead contributes the equivalent amount to the project.

The cost of the purchased electricity has been based on UKPN wholesale prices for 2011 divided up on 28 tariffs and averaged per hour per month (24x12) for both weekdays and weekend days. The distribution use of system (DUoS) charges are added to the whole sale as well as the capacity charge and a daily connection cost. See Appendix 6 for more details on the electrical tariffs used for the district cooling project. A summary of the economic headline figures are presented in Table 27.

Item	Unit	Qty
Total Investment CAPEX	[£ K]	16,221
Energy Centre CAPEX	[£ K]	8,023
Length of Heat Network	[m]	5,114
Cost of Heat Network	[£ K]	6,991
Connection CAPEX	[£ K]	811
Annual Operating Costs	[£ K]	199
Annual Revenues from coolth sales, incl capacity charge	[£ K]	1,448
Weighted Average Electricity Price	[£ /MWh]	43.2 in 2018 and 44.1 in 2042
Annual Operating Margin at full build out	[£ K]	1,249
IRR % over 25 years	[%]	12.4%
NPV at 6% discount factor	[£ K]	15,269

Table 27 Economic headline summary

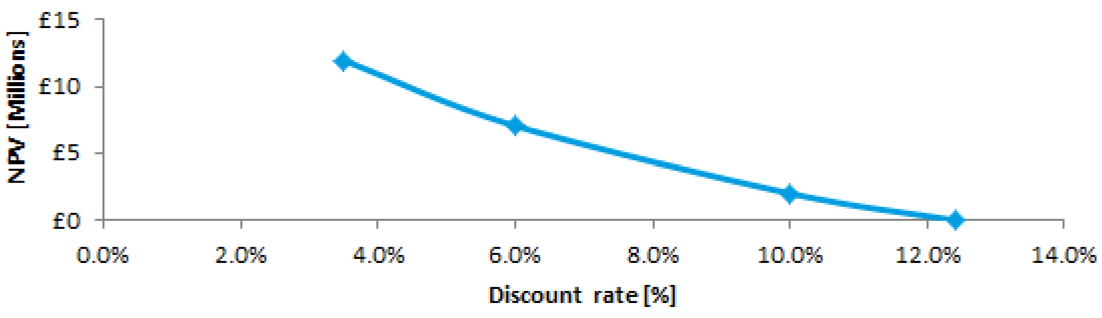

Figure 46 Net Present Value (NPV) against the various discount factors

Figure 46 shows the Net Present Value of the project at the end of the financial lifetime calculated for 4 different discount factors; 3.5%, 6%, 10% and 10.4% (IRR).

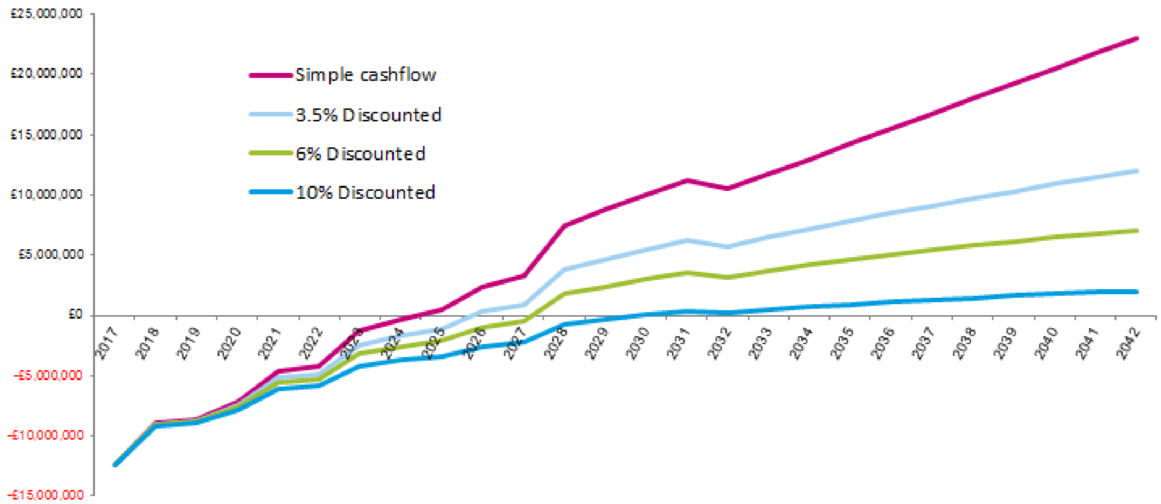

Figure 47 Discounted cash flow for 4 levels of discount factor, 0% (Simple cash flow), 3.5%, 6% and 10%

The discounted cash flow curves in Figure 47 are not as smooth as curves produced for projects with clear initial investment followed by steady fixed revenues typically are. The reason for this is that developer contributions and re-investment in central plant comes as and when they would happen. There is a clear dip in 2031 explained by re-investment in chiller equipment and thermal store.

6.6.2 Developer contributions

Should the developers not contribute to the investment cost of the heat network, at a level of avoided cost of local chillers (assumed to be £690/kW), the project IRR is expected to decrease to around 5%.

There are other benefits that could potentially be quantified and added as a benefit, however not included here, such as benefit of not having cooling equipment on the roof and therefore freeing up space for rentable uses.

6.7 Sensitivity Analysis

A sensitivity analysis has been carried out around the key variables that influence the IRR for the project. The results of the sensitivity analysis are presented in Figure 48.

The blue line shown in the graph represents the central estimate of the project IRR, based on the central assumptions for the listed variable along the x-axis which were used to produce the economic indicators presented in Appendix 6.

The bars in the graphs show the change in project IRR due to a change in a single variable, with all other variables being held constant. The magenta bars denote a 10% increase in the listed variable whilst green bars denote a 10% reduction. Exceptions to this are variables such as connection costs which are modelled as half or none from a reference scenario of 100% (i.e. full cost), capital contribution, which are modelled as 0 (reference case), £500k or £1,000k.

It can be seen that capital cost and operational margin are the two most sensitive variables followed by developer contribution. Changing the two aforementioned variables by 10% results in IRR change of more than 10%. The developer contribution variable changes the IRR 10% for a 10% increase or decrease in the variable.

The key conclusions for the project are that:-

1. Capital costs and operating margin are the major drivers in uncertainty around IRR.
2. The purchase price for electricity does not have a major impact; a 10% change makes less than 1% change in IRR.

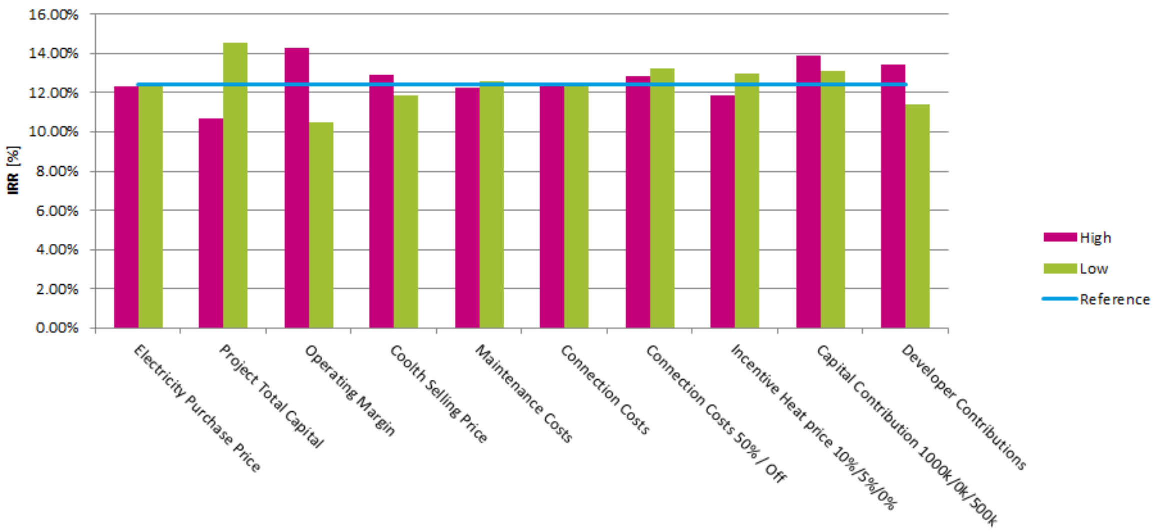

Figure 48 IRR with developers contribution equal to avoided cost of installation

Figure 49 shows the relative change in IRR for the change in variable. More details are set out in Appendix 6.

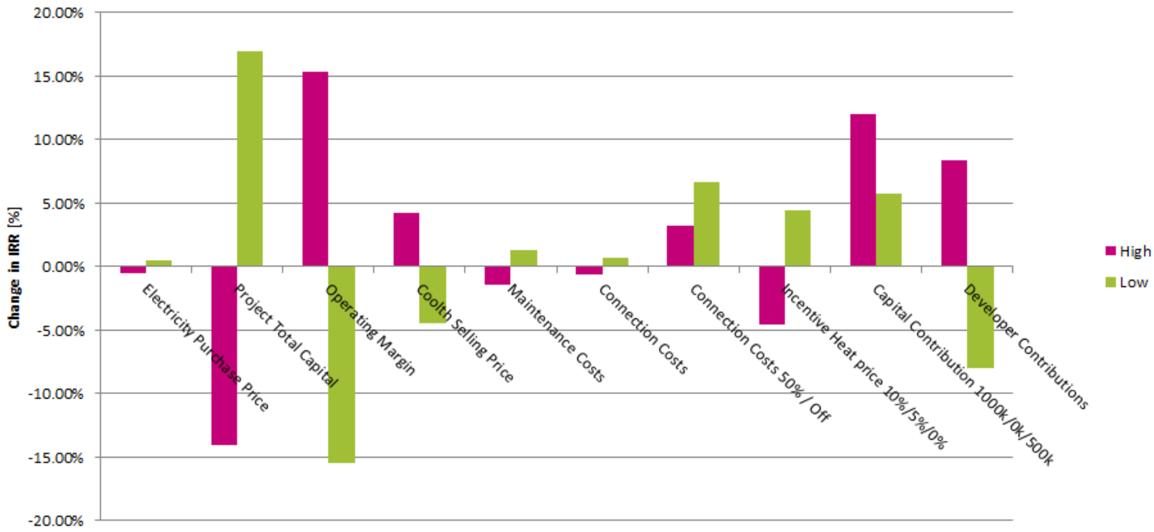

Figure 49 The per cent change in IRR when changing the variable indicates the sensitivity of individual variables

6.8 Carbon Appraisal

Table 28 shows the carbon performance of the proposed scheme. The savings are attributed to the efficiency gains possible with a larger central plant. Electricity for pumping has been taken into account as well as the losses in network. The carbon intensity of the electricity used in energy centre and alternative local options was considered equal although it can be argued that if connected at a higher voltage there would be fewer losses for the electricity and thus less carbon dioxide intensity for the electricity used for central chillers.

Item	Unit	Qty
Business as Usual CO2 over life of scheme	[TCO2]	38,853
CO2 Savings over life of scheme	[TCO2]	15,269
% reduction in CO2 Savings over life of scheme	[%]	39.3%

Table 28 Carbon Dioxide Summary

6.9 Network Route Appraisal

The network route is shown in Figure 43 has been assumed to follow the heat network with exclusions for legs with little demand. Refer to section 5.9 for details of the routing.

The total coolth sold per meter of route is 2.73 MWh.

6.10 Conclusions and Recommendations

The scale and density of consented and planned development coming forward in the Wembley Regeneration Area over the coming decades suggests a commercial opportunity exists to develop a strategic district cooling network in Wembley Regeneration area.

The network could supply affordable market competitive coolth to both new and existing properties, creating significant investment and job opportunities and maximising the area's true potential for efficient low carbon local energy generation.

Based on delivering market competitive cooling to existing and new developments in the Wembley Regeneration area, the indicated IRRs for the project are likely to be attractive to a mix of private energy providers and public sector, providing that the planning process is used to require developments to safeguard to connect to the heat network.

Such an opportunity could feasibly be developed with a newly constructed energy centre or in conjunction with the district heating network energy centre discussed in Section 5.

Based on purchasing electricity on the spot market wholesale, the indicative IRR is 12.4%.

Projected carbon emissions savings relative to the Business as Usual scenario amount to 39.3% over 25 years. This equates to 706 TCO_2 per annum at full build out in 2042.

The impact of developer contributions on project IRR has been tested. Developer contributions totalling £12.8M paid as and when the developments connect is included in the central assumptions. Changing these contributions by 10% up or down changes the IRR by 8% i.e. 13.5% IRR and 11.4% IRR as the high and low scenario respectively.

This value represents the estimated cost of avoided chiller equipment to each identified development. Capital contributions totalling £1M would increase project IRR to 13.9% if paid into the project in the first year.

The timescales for development of the identified heat network opportunity are likely to be 5 to 10 years, with an earliest likely coolth on date of 2018, as per the identified heat network opportunity. In order to safeguard the opportunity, it would be necessary for new developments being constructed in the interim period prior to construction to be designed to facilitate future connection to such a network. This includes physical safeguarding measures as well as design of internal systems in accordance with appropriate design temperature standards to ensure compatibility with these networks.

Where appropriate, the presumption should be that new developments constructed in advance of the cooling network should install chilled water networks with temporary equipment.

The investigation into surplus heat from potential WtE plant at Seneca shows there will be little if any surplus heat available for use in absorption chillers. Ramboll's experience from other projects shows that using absorption chillers fed from gas fired CHP is very sensitive in terms of carbon dioxide balance and it is not certain this would lead to carbon dioxide savings. The opportunity for absorption cooling is therefore considered to be limited based on the scenarios identified in this report.

Considering that much of the economic opportunity is embedded in the avoidance of capital costs, paying for chillers would nullify this benefit and thus render the project less viable. Therefore it would be key to sign up or otherwise de-risk the connection of future buildings. Where one developer is in control of many of the future buildings it should in principle be easier to de-risk.

Of the identified project opportunities, no insurmountable technical barriers have been identified. However, the district cooling opportunity has been analysed without detailed consideration of its impact on the district heating opportunity and vice versa. It will be important to consider the mutual impact of these networks when de-risking the route and considering pursuing a district cooling network. The larger pipes will require slightly larger trenches than for the district heating network. Together these networks will take up a significant trench width. Further work will be required for projects taken forward in relation to more detailed network route planning.

Equally, potential savings in investment may arise through shared construction costs, which have not been taken into account in this report.

7. NEXT STEPS AND IMPLEMENTATION PLAN

As discussed in Section 5 of this report, the scale and density of consented and planned development coming forward over the coming decades suggest a significant commercial opportunity to develop a strategic district heating network in Wembley Regeneration area. Such an opportunity could potentially be developed in conjunction with an EfW plant, the 2.5 MW biomass CHP facility at Seneca's SMRF facility that has planning approval or a newly constructed gas fired CHP energy centre.

If the identified opportunity is to be taken forward, a series of steps will need to be implemented and London Borough of Brent has a key role to play in supporting the development opportunity. These next steps are outlined in the subsequent section of this Chapter. London Borough of Brent's role might include securing a stake in the infrastructure assets or it may involve London Borough of Brent taking a facilitation role and ensuring that its local planning framework supports the future development of a heat network whilst leaving the construction of the heat network to the market to deliver.

In the absence of the opportunity materialising, new developments within the Wembley Regeneration area will come forward with individualised piecemeal solutions involving a range of low carbon technologies. This approach risks missing the opportunity to capitalise on the advantages highlighted through the Evidence Base modelling as set out in Section 3.5 of this report.

As a minimum, London Borough of Brent should implement the planning policy recommendations set out in Sections 7.1, 7.2 and 7.3 below. London Borough of Brent may also choose to take an active role in developing the identified project opportunities in which case, it is recommended that some or all of the actions highlighted in Section 7.4 are pursued.

7.1 Planning Policy Recommendations

7.1.1 Policy and Strategy Documents

a. London Borough of Brent's Core Strategy document should be updated to reflect the heat network opportunities identified in this report.

b. The proposals should be disseminated to relevant departments within the Council to raise awareness of the planned infrastructure proposals.

c. Recommendations set forward in the GLA's District Heating Manual for London (final draft to be published in October 2013) for recommended design principles of Secondary Side Heating Systems should be adopted. This manual has been used in this report and the recommendations set out for future safeguarding reflect those in the guide.

7.1.2 Safeguarding Connection of New Developments

d. London Borough of Brent should use its planning powers to require identified developments to safeguard for future connection into a heat network by implementing a series of future proofing measures where feasible. The indicated developments are identified on the vision maps in Appendix 2.

e. Future proofing measures that should be included in planning policy where appropriate and/or planning conditions, where identified to be feasible, are:

   i. Requiring 'wet' heating systems to be installed and prohibiting electrical heating systems.
   ii. Requiring the incorporation of communal heating systems instead of individual boilers. Communal heating systems should be fed from plant rooms producing low temperature hot water for space heating and domestic hot water. Future proofing should include for providing 'tees' and isolation valves to facilitate future connection of heat exchangers. Space should be reserved for heat exchangers, or it should be planned for heat exchangers to replace heat-only boilers at time of connecting to the heat network.

iii. Ensuring internal heating systems are designed so that they can be connected to supply a DE network with minimum retrofit. This should be achieved through measures such as built-in penetrations allowing pipes to be pushed through into plantrooms without structural alterations or significant works, designing heating systems to minimise return water temperatures, allowing provision in the building fabric to facilitate the installation of district heating pipework at a later time.
iv. External buried pipework routes should be safeguarded to the boundary of the plot where connection to the heat network will be made.

f. Under current building regulations, developments can achieve compliance using gas only boilers. However, future updates of the building regulations are set to adopt the compliance targets set out under the government's zero carbon homes policy. This will require developments to install compliant technologies in order to meet the building regulations and may not include provision to defer installation of such technologies in lieu of connecting to a heat network in the future.

g. There may be an opportunity for London Borough of Brent to allow developers to defer installation of alternative compliant technologies in lieu of making a provision to connect to a heat network. This will depend on provisions under future updates to the building regulations, which London Borough of Brent will need to be mindful of in policy setting terms. In such circumstances London Borough of Brent could place a requirement on developments to retrofit compliant technologies within a fixed period, in the event that a heat network is not taken forward.

h. Developments of a relevant scale where CHP would be considered that are being planned with a horizon of 5 years from the point at which the heat network is intended to be constructed in the vicinity of the development:

   i. The development should be designed on the basis of their own CHP with standby boilers and 'future-proofed' to connect into the heat network in the future.
   ii. Allowance should be made to defer investment (installation) in the CHP plant for five years to allow time for the heat network to be constructed and connected to the network. Once the network connection is made, the requirement to install CHP should fall away.
   iii. If the heat network connection is not made within five years and there is no reasonable prospect of doing so, then the development should be required to install a CHP plant. A section 106 obligation could be employed from the outset to ensure the CHP installation is carried out retrospectively.
   iv. During the five year period, the development will be supplied with heat from its own heat-only boilers, noting that the environmental benefits will not accrue until either the heat network connection is made or CHP installed.
   v. The developer could be given a planning condition to allow any 'freed-up' plant space resulting from the heat network connection to be used for more profitable purposes.

   These recommendations are subject to acceptable provisions under future updates to the building regulations.

i. For developments coming forward over a horizon of beyond 5 years from the date of construction of a heat network opportunity , provisions should be made for developments as follows:-

   i. For developments of a relevant scale where CHP would be considered that are being planned with a horizon of 10 years from the point at which the heat network is intended to be constructed in the vicinity of the development, the development should be required to safeguard to connect to the heat network at the end of the economic life of the CHP plant.

   ii. For developments of a relevant scale where CHP would be considered that may in future be planned to come forward beyond 10 years and at locations where they could connect into the heat network, these developments should be designed for a district heating connection from the outset. This would entail a smaller plant room to accommodate the interfacing district heating heat exchanger and displace the requirement for heat-only boiler and CHP plant.

7.1.3 Aligning Waste and Energy Policy

j. London Borough of Brent should coordinate its energy and waste policies in order to create appropriate conditions to attract waste to energy facility providers in the future.
k. London Borough of Brent should use its planning powers to require potential waste to energy providers to implement CHP and place a requirement on them to commit to connecting to the heat network as part of any planning approval.

7.1.4 Allowable Solutions Policy

Brent doesn't currently have an Allowable Solutions policy. In terms of off-setting CO2 through off-site measures, to date this has been done on an ad-hoc basis where they haven't been able to achieve the on-site reductions. Brent has been requiring 100 % of the reduction to be achieved on-site, but have sought contributions towards off-site measures where they have run into difficulties in on-site provision (post consent).

Section 106 agreements are structured so that they can propose alternative on-site measures (i.e. different from those originally approved), measures on land near the site but within the owners control, or payment for the Council to implement off-site measures. This is seen as a hierarchy where the presumption is that the CO2 reductions will be implemented through on-site measures unless this is not feasible. This policy is likely to change as the targets become more onerous the use of Allowable Solutions makes sense where achieving compliance with targets becomes more and more expensive.

The government's proposed Allowable Solutions framework will require developers of zero carbon homes to meet on-site requirements for Carbon Compliance whilst also accounting for the carbon emissions that are not achievable on site through Allowable Solutions. Under the proposals set out in the Zero Carbon Hub report dated July 2011 there are two routes that developers can take under the proposed allowable solutions framework. Under Delivery Route A, where approved Local authority policies are in place, developers will be able to pay into a local Community Energy Fund or via a Private contract with a third party supplier. In the absence of an established policy, developers will pay into Private Energy Fund, under Route B, without any geographical constraint over where the carbon-savings are realised. London Borough of Brent should therefore develop Allowable Solutions policies within its local plan in time for adoption by 2016 in order to be able to offer developers a local Community Energy Fund delivery route and thereby capture the benefit of Allowable solutions.

Delivery Route A is a proposal for channelling investment into locally prescribed Allowable Solutions for the benefit of local communities. It provides the opportunity for Local Planning Authorities to position themselves so that they are able to specify the particular Allowable Solutions projects which best align with their strategic energy and climate change mitigation vision for their area, as determined within their local plan. Under proposed Route A, developers will be able to see a prescribed list of Allowable Solutions and a local guide price (in £ per tonne for carbon to be abated via the Local Planning Authority).

Determination of this price may be informed by the price guide set for a possible National list of Allowable Solutions. The choice will then be either to contract with a Third Party provider who will deliver carbon savings from a list of Allowable Solutions projects prescribed by the Local Planning Authority (an Allowable Solutions provider or a specific project identified from the National Allowable Solutions Database) or to pay into a Community Energy Fund, giving responsibility to the Local Planning Authority to deliver carbon savings from its list of Allowable Solutions projects.

To achieve this position, Local Planning Authorities will need to have developed an Allowable Solutions policy, which should include:

1. A mechanism for approving particular Allowable Solutions within the overall local plan
2. Evidence that Allowable Solutions included in the local plan represent the most cost effective ways of delivering carbon emissions reduction in the Local Planning Authority area.
3. A clearly stated pricing policy for Allowable Solutions (Local Planning Authorities should not be able to charge any more than the national price ceiling for carbon).

It is noted that the proposals set out above are not yet adopted government policy.

Therefore any local planning authority without a plan in place will receive no Allowable Solutions money. Developers will be able to contract with a private energy fund to deliver carbon savings.

Allowable Solutions could be a future source of funding for the heat network and potentially for other projects in Brent. Brent should therefore consider becoming a provider and forming a robust policy in the Development Management Policies DPD accordingly.

7.2 Adoption of Local Development Order

a. London Borough of Brent should consider adopting a Local Development Order (LDO) to facilitate deployment of the heat network. This would allow the Council to create a blanket planning permission to a future Project Company for constructing heat networks without the need for specific planning applications at each stage of development of the heat network.

7.3 Ensuring Correct Design Standards are adopted

a. The design of customer connections and internal heating systems for new developments will have a significant impact on the operational capacity and efficiency of the heat network.

b. Developers should be required to implement appropriate internal heating system designs to ensure flow and return temperatures are compatible with the heat network. London Borough of Brent, through its planning department should ensure that systems are being designed, installed and commissioned appropriately.

c. Recommendations contained in the GLA's technical standards for district heating 0 should be adopted and disseminated to developers to ensure that heating systems are designed to a common standard, capable of future integration into the proposed heat network.

d. London Borough of Brent should also require new developments involving office, retail and residential to examine and consider as part of any viability assessment, opportunities for district energy balancing at development scale.

7.4 Proactive Involvement in the Identified District Heating Opportunity

If London Borough of Brent choses to play a proactive role in bringing forward the identified opportunity it should consider the following measures:-

a. Working with potential stakeholders to establish a Steering Group and a project delivery group to take forward the recommendations of this report. Key stakeholders include potential commercial ESCOs, Quintain, SENECA and West London Waste Authority.

b. Conduct feasibility analysis to further evaluate the technical options identified and investigate its options for ownership in the infrastructure.

c. Subject to the outcome of b, engage with commercial ESCos around possible joint development opportunities for the heat network. A local delivery vehicle could potentially be established being led by the private sector but with London Borough of Brent having a stake in the project company. This will bring the advantages of opportunities for funding and low cost borrowing through PWLB, CIL/S106, allowable solutions and the London Energy Efficiency Fund, which has recently opened to DE projects and is likely to be very interested in investing in publicly backed opportunities of this nature. It will also enable London Borough of Brent to establish a project vehicle on which to gain experience and form a platform for the delivery of other low carbon project opportunities over the longer term. Such an approach is also likely to be favourable to larger scale developers investing in the area, who will thereby avoid the need to procure an ESCo separately to deliver on their commitments.

d. Building internal political support and commitment, oversee the development of strategies and policies to develop the project opportunities and to obtain budget commitment to take forward the project through feasibility, planning, design and procurement.

e. Carry out business planning, drawing on support from GLA through the Decentralised Energy Programme Delivery Unit (DEPDU), to establish the London Borough of Brent's role in the identified project opportunities and the commercial basis on which the future strategic opportunities could be delivered.

a. Maintain a watching brief around developments under Electricity Licence Lite and establish a vehicle for setting up such an arrangement when the opportunity arises and/or for collaborating with other bodies such as GLA to pool operating costs and thereby reduce overheads.

b. Guarantee existing buildings within its control to connect to any heat network that comes forward and require new developments to safeguard for future connection through the planning process.

c. For energy centre locations and safeguard the most appropriate site(s).

d. To establish the appetite and technical viability amongst major stakeholders to engage in the project and establish the commercial basis on which this could be achieved. The steering group should work with stakeholders to commission feasibility studies to identify and de-risk technical and commercial barriers to implementation and establish a route to delivery.

7.5 Safeguarding for Waste to Energy Opportunities

l. London Borough of Brent should aim to encourage and attract future waste to energy providers to Wembley Regeneration Area. This would support London Borough of Brent's aspirations for delivering low carbon, affordable heat to the area.

m. London Borough of Brent should engage with potential providers of waste to energy facilities and work to de-risk opportunities for potential providers to allow opportunities to come forward.

n. London Borough of Brent should consider identifying, allocating and safeguarding land within the Wembley Regeneration Area to maximise opportunities for bringing forward waste to energy facilities in the medium to long term.

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APPENDIX 1 ENERGY DEMAND APPRAISAL

Development	Annual Heat Demand	First Year of Operation	Annual Coolth Demand	Annual Electricity Demand	Peak Heat Demand	Peak Coolth Demand
	MWh/y		**MWh/y**	**MWh/y**	**kW**	**kW**
Brent Civic Centre	841	2013	470	4,099	684	784
Dexion House	4,744	2016	183	3,598	3,514	306
Apex/Karma House	2,787	2018	228	587	2,064	380
Malcolm House/Fulton House	2,787	2018	228	587	2,064	380
Quintain NW Lands 1	588	2016	322	1,070	435	537
Quintain NW Lands 2	685	2016	375	1,248	507	625
Quintain NW Lands 4	1,036	2013	568	1,887	767	946
Quintain NW Lands 5	467	2018	256	851	346	427
Quintain NW Lands 6	90	2018	49	165	67	82
Quintain NW Lands 7	730	2023	400	1,330	541	667
Quintain NW Lands 8	825	2020	452	1,503	611	753
Quintain NW Lands 9	2,196	2020	1,203	4,001	1,633	2,005
Quintain NW Lands 11	1,492	2028	818	2,719	1,105	1,363
Quintain NW Lands 12	942	2023	516	1,716	698	860
Quintain NW Lands 13	818	2023	452	1,503	611	753
Quintain NW Lands 16	314	2028	172	572	232	287
Quintain NW Lands 17	583	2026	319	1,061	432	532
Quintain NW Lands 18	689	2026	377	1,255	510	629
Quintain Stage 1 - W03 (Power League)	4,061	2014	304	977	3,028	507
Quintain Stage 1 - W04 (Quadrant Court)	1,092	Existing	80	1,154	861	133
Quintain Stage 1 - W05	5,294	Existing	474	2,214	4,020	790
Quintain Stage 1 - W07	1,389	2014	327	1,219	1,029	545
Quintain Stage 1 - WO6	856	2020	88	1,181	665	147
Quintain Stage 1 - WO8	851	2018	95	1,183	665	159
Quintain Stage 1 - York House Basement	46	2013	70	206	50	117
Quintain Stage 1 East - QE01	1,684	2023	108	2,183	1,279	180

Quintain Stage 1 East - QE03	3,381	2026	165	4,279	2,508	275
Quintain Stage 1 East - QE05	383	2028	1,013	2,409	283	1,688
Quintain Stage 1 East - QE02	4,184	2023	159	5,212	3,123	265
Quintain Stage 1 East - QE04	1,396	2028	707	1,923	1,113	1,178
Quintain Stage 1 - W01 Forum House	1,381	Existing	78	536	1,148	130
Shubette House	2,970	2014	217	1,544	2,200	362
Kelaty House	7,529	2018	217	2,105	5,577	362
First Way (44)	1,434	2018	97	540	1,062	161
First Way (45)	374	2020	183	802	277	306
First Way (46)	1,882	2023	147	628	1,394	244
First Way (47)	1,326	2026	0	1,553	982	0
First Way (48)	261	2023	0	306	193	0
First Way (50)	226	2023	0	264	167	0
Wembley Link/South Way Site (West)	268	2018	542	1,390	198	903
Wembley Link/South Way Site (East)	3,229	2018	220	2,821	2,477	366
Mahatma Gandhi House	471	2018	0	544	349	0
York House	166	2023	0	194	123	0
1 Olympic Way	277	2026	0	324	205	0
Olympic Way Office Site - 28	124	2020	264	671	92	439
Olympic Way Office Site - 31	96	2020	203	516	71	338
Olympic Way Office Site - 34	1,216	2020	144	368	934	239
Amex House	124	2023	0	146	92	0
Watkin Road (39)	224	2018	0	259	166	0
Watkin Road (40)	222	2023	0	177	165	0
Watkin Road (41)	128	2023	0	150	95	0
Euro Car Parts	996	2023	0	1,166	737	0
Wembley Retail Park -29	243	2030	0	285	180	0
Wembley Retail Park -30	358	2030	28	473	308	46
Wembley Retail Park -32	313	2028	90	542	257	150
Wembley Retail Park -33	261	2029	35	374	234	58

Wembley Retail Park -35	482	2028	0	564	357	0
Wembley Retail Park -36	154	2026	0	180	114	0
Wembley Retail Park -37	400	2026	0	469	296	0
Stadium Retail Park - 19	153	2018	101	379	128	169
Stadium Retail Park - 20	484	2018	173	906	359	289
Stadium Retail Park - 21	131	2018	106	363	110	176
Arena House	816	2020	167	660	610	279
Quality Hotel	1,823	Existing	119	363	1,372	198
Holiday Inn	1,823	Existing	119	363	1,372	198
Future School	136	2021	0	117	108	0
Wembley Arena	813	Existing	0	0	658	0
Wembley Stadium	1,029	Existing	0	0	833	0
Crescent House	147	Existing	22	528	111	36
Fountain Studios	163	Existing	0	0	132	0
0	0	Existing	0	0	0	0

Table 29 Energy Demand and Consumption Values for Identified Developments and Existing Buildings

APPENDIX 2 MULTIFACTOR ANALYSIS FOR TECHNOLOGY OPTIONS APPRAISAL

Long list of Options

The table below shows the results of long list options appraisal.

	Technology Long List Summary
Solar Photovoltaic Collectors	Solar PV has widespread application in new high density developments due to its ability to contribute towards compliance under current and future Building Regulations. With reducing costs, it is expected to continue to play a continuing role in energy strategies for new developments within the Wembley Regeneration Area. Solar PV's potential for CO2 reduction is limited in high density developments where roof area space is relatively low. However, the technology is expected to continue to play and important role in delivery of compliance under the government's Zero Carbon Homes policy. This option is shortlisted for further consideration.
Solar thermal Collectors	Solar thermal collectors are not common in new high density developments. Solar thermal competes for high value roof space with other technologies (PV, cooling plant) and with other amenity uses and is invariably loses out to PV, which delivers far higher carbon savings per m2 of occupied roof space. Their effectiveness in delivering against compliance targets is low and for this reason, their role within Wembley Regeneration Area is likely to be minimal over the coming years. This technology has not been considered further.
Gas engine CHP	Gas engine CHP has widespread application in new build high density developments, particularly in the residential sector and for hotels and leisure uses, where there are significant base load hot water demands. Larger mixed use developments (typically in the range 300 to 500 apartments of which there are only a few in the area) are likely to be required by GLA to investigate the use of gas fired CHP. Those with resulting CHP capacities in the range 100 kWe to 500 kWe are likely to implement this technology ([1]) in conjunction with solar PV. The technology is a popular option amongst developers due to low capital cost, proven track record, and financeability due to low development risk. Gas CHP is able to deliver against compliance targets and expected to continue to do so under the 2013 building regulations as well as the government's Zero Carbon Homes policy within the proposed Allowable Solutions framework.

	For this reason it is expected to continue to play a significant role in energy strategies for new developments within Wembley Regeneration Area. This option is shortlisted for further consideration.
Ground source heat pump	Ground source energy is potentially well suited to new commercial and office developments, where balanced heating and cooling demands exist. Due to the development density, open loop systems are likely to be favourable, giving greater yields and better SEER's than closed loop options. Geological conditions in Wembley Regeneration Area are likely to be suitable, although a number of external factors influence cost and viability and complicate installation including the presence of existing utilities, Mixed use developments and individual buildings with complimentary heating and cooling demands are likely to be suited to use of ground energy to provide shared heating and cooling. Inter seasonal heat/coolth storage can be implemented to balance demands over winter / summer and minimise the need for external energy input. In such scenarios, top up heat would typically be provided through condensing gas boilers or through a connection to a heat network although any other form of heat generation is also technically feasible (e.g. biomass heating, gas or biofuel CHP) However, in Ramboll Energy's experience, developers are likely to find ground source heating applications high risk and we do not foresee developers taking up these options on a significant scale. This option has not been taken forward for further consideration.
Air source heat pump	Air source heat pump systems are significantly less expensive and lower risk option for developers than ground source heat pump systems. For this reason they are more likely to be favoured by developers in Ramboll's Experience. Applications could include high density developments and low density low rise retail / community type uses. Systems are likely to be installed as hybrids involving heat pumps together with top up gas boilers for heating and top up chillers for cooling. This approach reduces investment capacity and costs, minimises space requirements for heat rejection and avoids low operational efficiencies during extremes of ambient conditions. Systems are typically sized on upto 60% of the peak demand for heating or cooling, whichever is smaller, with the remainder being met by top up plant. Evidence from GLA (GLA, 2011) indicates that uptake has been low and has been limited to a small number of residential developments, usually in lower density areas where heat networks would not be applicable. In these cases, ASHP have proposed individually for each dwelling. This technology has been shortlisted for further consideration.

Biomass heating	Although biomass heating is an established, reliable technology it has seen reasonably low uptake in new high density developments in London due to a combination of commercial and planning and policy related factors. Evidence from GLA (GLA, 2011) indicates that air quality considerations have stifled the widespread uptake and this can be expected to continue within urban settings, albeit that that Exempt Appliances are available for use in Air Quality Management Areas such as Wembley Regeneration Area. From a planning perspective, air quality mitigation and transportation will be important considerations if the technology uptake is significant, due to the cumulative effect of large numbers of small appliances both in terms of emissions and fuel deliveries. In operational terms, there is a perceived risk around fuel prices and security of supply, and although the technology is fully automated in operation, maintenance requirements are relatively high. However, the technology delivers compliance under current building regulations and is expected to do so under 2013 Building regulations and the Governments Zero Carbon Homes policy from 2016. In addition there is precedent for this technology in the Wembley Regeneration Area. For these reasons, biomass heating is taken forward as a shortlisted option. Biomass heating at building or local community scale is shortlisted for further consideration.
Bio liquid boilers and CHP	Bio liquid CHP is a currently established technology with a proven operating track record. The technology is essentially based on an internal combustion engine operating on a diesel cycle and is therefore a relatively low capital cost approach to delivering against compliance targets. However, the availability and price of biofuels heavily determine economic payback and the cost of heat delivered to customers and its sustainability credentials determine whether the scheme is eligible for ROCs. This, coupled with operational complexities related to storage and transportation of fuel are presently considered to be a barrier to uptake of the technology. Evidence from GLA indicates that uptake of biofuel CHP has been relatively low to date within London. This is thought to be due to relatively high fuel prices and difficulties in sourcing fuel sustainably as discussed above. Where options have been taken up, these are usually linked to local sources of biofuel. Uptake within the Wembley Regeneration will ultimately depend on fuel costs and sustainability in the coming years. There are a number of hotels and student accommodation blocks within the regeneration proposals that could collectively generate a local fuel source for

	building scale solutions. To the extent that fuel can be sourced locally and sustainably, with secure long term contracts, bioliquid CHP is likely to represent an attractive solution to developers in Ramboll Energy's view. Bio liquid CHP at building or local community scale has been shortlisted for further consideration.
Biogas and biomass CHP	Biogas CHP is a proven technology which can potentially be deployed at community scale. However, sourcing of bio methane is not considered to be a realistic option for a number of years since there is no existing bio methane grid and the area and no realistic opportunity to generate biogas locally from a new facility. Timescales for widespread bio methane injection into the national grid are uncertain but are expected to be very long in the context of the development opportunity. Transportation of biomethane by road or rail is expected to remain expensive and logistically complicated for the foreseeable future. Evidence from GLA (GLA, 2011) indicates that uptake of Biogas based schemes have been limited to a few small scale locations where biogas is generated locally. Biogas CHP is considered to be an unrealistic option and not been considered further. The potential for biomass CHP at building or community scale is considered to be low, predominantly due to commercial viability and space requirements at the required scale of application. Available technologies include steam and organic Rankine cycle turbines, in which combustion of biomass is carried out in a boiler to raise steam and gasification plants which produce syngas for combustion in internal combustion engines. Evidence from GLA (GLA, 2011) indicates that a small number of large biomass schemes have proposed the possible use of biomass as the fuel for CHP in the future. Biomass CHP at building or local community scale is considered to be an unrealistic option and not been considered further.
Micro wind/ Mini Wind Horizontal or Vertical Axis Wind Turbines	The local wind resource, together with the available roof areas due to the scale and density of development does not lend itself to wind turbines. This technology has not been considered further.

Micro CHP based on Stirling Engine or Fuel Cells	Micro CHP is a domestic scale technology geared at individual dwellings, with installations typically at the 1 kWe scale and high total efficiencies[32] and attractive power to heat ratios. These technologies are currently available on the market although have so far been deployed in the UK in the 100's rather than in the 1000's. Although they have demonstrable operating track records they remain expensive and offer inadequate payback under current levels of RHI, FIT support. Depending on government financial support proposals under residential RHI, proposed support levels may increase which would have the effect of stimulating the market. If such technologies emerge, they can be expected to have applications at in the residential sector. However, in high density developments with block level or community level solutions, they are unlikely to be applicable, since costs will far exceed larger communal heating based alternatives. Additionally, under the Mayor's hierarchy, which calls for communal heating and cooling in advance of solutions at dwelling level, this technology is unlikely to gain planning approval. The technology has not been considered further.
Fuel Cell CHP	Fuel cell CHP has the potential for deployment at block level and community scale, particularly in hotels and residential applications where there is a significant domestic hot water load. Fuel cell CHPs have high total efficiencies, low maintenance costs and good power to heat ratios, making them attractive options in technical terms. However, their very high capital costs make fuel cells non market competitive at the present time and operational problems have been experienced in a number of pre commercial applications, creating a risk perception amongst investors and developers. Few installations are in place across the UK and the market base is very low at the present time. The technology is still in a pre-commercial phase. Fuel Cell CHP is likely to play a greater role in the future and may emerge as a market competitive technology in the coming decade. However its market share is likely to remain relatively low, particularly over the development timescales for the Wembley Regeneration area and it is not expected to be a popular choice amongst developers over the coming ten year timeframe. The technology has not been considered further.

Table 30 Shortlisting of Technology Options

Shortlisted Options Appraisal

The tables below show the results of the multifactor analysis of the short listed options.

[32] Up to 85% as reported by a leading example of such technologies BlueGen.

	Solar PV
Applicable Scale	Block Level
Technical Considerations	There are a range of technologies available on the market. Rigid mono or polycrystalline panels are in widespread use in high density developments due to their relatively high specific yield but building integrated applications using thin film PV may also be proposed where they can be integrated into fabric and glazing to provide solar shading for example. Crystalline technology requires largely un-shaded roof space and should face predominantly south to ensure adequate yield and therefore payback. Thin film technologies are less sensitive to direct component of solar irradiation and can therefore be mounted on horizontal and vertical facades. Maintenance requirements and costs are low (typically well under £1000 per year), although cleaning is required periodically and panels degrade over time reducing their output/yield.
Commercial Factors and Route to Market	Solar PV is a commercially well proven technology and represents a low risk to Developers and Investors. Solar PV has widespread application in new high density developments due to its ability to contribute towards compliance under current and future Building Regulations. With reducing costs, it is expected to continue to play a continuing role in energy strategies for new developments within the Wembley Regeneration Area. Solar PV's potential for carbon compliance under Zero Carbon homes and buildings is limited in high density developments where roof area space is insufficient in relation to building height. Solar PV is a developer led technology and the role of the Local Authority in implementation of this technology is negligible beyond the planning phase. The installation of Solar PV takes up valuable roof space and thereby has an impact on leasable value of the development. Reductions in required PV that can be achieved through other LZC technology options are likely to be welcomed by developers since it will provide additional sales of leasable income value for the site. Capital costs have reduced significantly since the revision of the Feed In Tariff and installed costs currently range from around £300 to £450/m^2 for thin film BIPV and from £850 to £1300/ m^2 for solid crystalline technology. Solar PV generates a guaranteed, low risk income through the Feed in Tariff and also displaces the need to purchase grid electricity.

	In principle this protects tenants from electricity price volatility. Tenants may or may not benefit directly from this through savings on electricity bills depending on how energy supply is structured and procured in each particular situation. Evidence from suggests a typical developer contribution cost of around £7,160/unit based on an 878 unit urban development.
Environmental, Planning Issues Constraints	There are no local environmental impact issues or specific planning related barriers to deployment in the Wembley Regeneration area.
Policy Support Measures	Eligible for Feed in Tariff support. The Government recently reduced the rate of FITs (1st April 2012) which has made PV panels less economically attractive, although a corresponding reduction in capital cost has also occurred.
Uptake in Similar Developments	Evidence from GLA (GLA, 2011) indicates that uptake has been very high, with two thirds of new developments in 2010 proposing to use energy supplied by CHP also planning to install PV panel arrays. This reflects the complementary nature of the two technologies.

Table 31: Solar PV

	Biomass Heating
Applicable Scale	Block level and Development Plot level
Technical Considerations	Biomass boilers are an established and reliable technology. The main biomass technology is solid fuel combustion. This is available in many sizes across the applicable range from 50 kW to 500 kW. Boilers can be condensing or non-condensing, depending on the application and are generally fully automated in operation. Biomass boilers can be located in containers externally or internally or can be installed within a plantroom space as part of an energy centre for a building or group of buildings. In the latter case, a dedicated enclosure may be provided. Since biomass boilers do not modulate very efficiently in relation to typical demand patterns, thermal storage is usually provided in order to maximise operating efficiencies. It is also usually most cost effective to size the boiler on a proportion of the total load and to use gas boilers for topping up to meet the peak load. Fuel stores need to be physically isolated from the boiler and the rest of the energy centre and building in order to minimize fire risk.

	Design of storage to protect against fire risk is very important and a fire suppression system will be required. Fuel stores typically need to be sized to allow for intermittency of supply. Fuel costs can be reduced if stores are designed to accommodate larger delivery vehicles since the price per tonne generally reduces with delivery volumes. This will reduce the cost of heat supplied to building occupiers. The space taken up by storage and the need for delivery access may impact on other aspects of the site planning. The boilers will require separate flue stacks to those for the gas boilers. Fuels selection will either be wood chip or wood pellet. Some suppliers provide boilers capable of running on both fuels. Pellets are likely to be the most appropriate option (both amongst developers and planners) within the Wembley Regeneration Area for a number of reasons including:- 1. lower fuel storage and transportation requirements due to higher energy density 2. More predictable and controllable emission levels due to tolerances and standards to which they are manufactured.
Commercial Factors and Route to Market	Biomass heating has a low capital cost compared to other renewable energy technologies. Capital costs are in the region of £400/kW - 500/kW at the relevant scale for buildings with the Wembley Regeneration Area. This is likely to make it a relatively attractive option to Developers. Biomass heating systems are commercially well proven with a long operating track record. Although modern appliances are fully automatic, maintenance requirements are more onerous than for natural gas boilers. Nevertheless, operation of Biomass is not particularly complex and facilities management companies will generally be able to handle this technology without the need for specialist energy companies to become involved. Whilst the footprint of biomass boilers is comparable to that of gas engine CHP on a per kW installed basis, additional fuel storage requirements take up valuable basement or external space. This represents an additional capital cost to the Developer and potentially a forfeited leasable value associated with the space. However, buried storage solutions are common and are likely to be attractive in high density developments such as the Wembley Regeneration Area. Biomass heating technology represents a low risk to developers and investors and raising finance is not a concern. However fuel price risk remains an issue since the biomass fuel supply chain is still an emerging sector. The majority of suppliers are small and there remains a level of risk associated with securing reliable sources of biomass at competitive prices over the long term.

	Commercial viability will be highly dependent on a number of factors and correct design at the outset will be vital to deliver cost effective solutions. These include plant sizing strategy, which dictates level of RHI support, plant utilisation and running costs, 1) local fuel price, which is affected by local supply chain and fuel storage volume on site and Emission abatement requirements. Current fuel prices for wood pellet are typically 3 to 4.5p/kWh. These are comparable to current gas prices. Biomass heating is a developer led technology and the role of the Local Authority in implementation of this technology is negligible beyond the planning phase. Biomass heating can potentially be installed as part of a community heat network. This will potentially improve operational efficiencies, reduce installation and running costs and reduce the impact of local emissions. Biomass heating can also be integrated with a community based gas CHP scheme, although the economics of this approach will need to be carefully evaluated to ensure sufficient full load running hours are available.
Environmental, Planning Issues Constraints	The Wembley Regeneration area is an Air Quality Management Area. Biomass appliances will therefore need to qualify as Exempt Appliances under the Clean Air Act to be authorised. Depending on local air quality, the impact from a few dispersed exempt appliances may not therefore be a concern. However, the cumulative impact from multiple developments is likely to be detrimental to local air quality. From this perspective, any scheme involving biomass heating would be better located centrally so that emissions can be better controlled and be done more cost effectively and at lower visual impact (by avoiding multiple stacks). Pellets are likely to be more acceptable than chips due to tighter control over fuel quality, leading to lower variations / uncertainty in emissions. Transportation of fuel will have an adverse impact on the local environment in terms of number of fuel deliveries and associated noise emissions. With appropriate design it should be possible to mitigate against these factors and meet compliance levels in the area, although this will have cost implications which will be unfavourable to developers.
Policy Support Measures	Biomass heating for qualifying appliances receives tiered support under RHI. • For small (<200 kW) sized boilers the support is 7.6 p/kWh for the first 1314 Hours of operation and 1.9p/kWh thereafter. • For medium (200 kW to 1 MW) sized boilers the support is 4.7 p/kWh for the first 1314 Hours of operation and 1.9p/kWh thereafter. • For large (1 MW+) sized boilers the support is 1.0 p/kWh.
Uptake in	Biomass heating systems have been proposed for a number of major developments in London. However, the proportion of

Similar Developments	developments proposing biomass was reported to have dropped compared to previous years, with air quality considerations and ability to achieve planning often cited as a reason for not pursuing this option.

Table 32: Biomass Heating

	Air and Ground Source Heat Pumps
Applicable Scale	Block level, and Development Plot level
Technology description and Application	Closed loop ground source water to water heat pump systems comprise a continuous pipework loop buried in the ground. Water circulates in the pipework and provides the means of heat transfer with the ground. Open loop ground source water to water heat pump systems generally involve the direct abstraction and use of ground water, typically from aquifers (porous water bearing rock). Water is abstracted via one or more boreholes and passed through heat exchanger and is returned via a separate borehole or boreholes, discharged to foul water drainage or released into a suitable available source such as a river. Typical ground water supply temperatures are in the range 6–10°C and typical re-injection temperatures 12–18°C (subject to the requirements of the abstraction licence).

	Open loop systems fed by groundwater at 8°C, can typically cool water to 12°C on the secondary side of the heat exchanger to serve conventional cooling systems. Subject to building height constraints, systems are typically sized to deliver up to 60% of the peak cooling or heating load (whichever is smaller), delivering around 90% of the corresponding heat requirements. Top up heat is required from other sources. Air to water heat pumps involve the exchange of rejected heat with the atmosphere. These of Hybrid systems are available, which integrate operation with gas
Commercial Factors and Route to Market	Commercial viability as a solution in high density developments is dependent on building height, costs of establishing boreholes, impact on internal heating and cooling system designs. Drilling costs are significant factor, as specific ground conditions can be variable, and there are potential problems in drilling through sand layers, pebble beds, gravels and clay. Major source of risk to developers, making them unflavoured option in many cases. In the given location, costs and risks may escalate, particularly if factors such as buried utilities and other infrastructure create complications in construction. Ground source systems require low temperature heating systems and high temperature cooling systems to maintain acceptable efficiencies. This will increase investment costs and space take in relation to HVAC equipment and systems. On the other hand, a move to underfloor heating will reduce space take for heat emitters within occupied areas. Interseasonal aquifer and borehole storage concepts are increasingly common in parts of Europe and are now appearing in UK as well. However development timescales for multi property plots presents a risk / barrier to employing such concepts, since there is no requirement for future developers to connect to such systems and there is uncertainty around future operating costs. Air source heat pumps deliver lower efficiencies but at significantly lower costs and are therefore generally favoured by developers. Developer led route to market. No requirement for Local Authority involvement.
Capital Cost	Borehole costs typically in the range £350 to 390K per borehole for large systems (~400kW). Heat pump per unit costs typically in the range £160K for large systems (~400kW). Evidence from X suggests a typical developer contribution cost of around £6,800/unit based on an 878 unit urban development using vertical boreholes.
Operating Costs	Fuel (electricity) costs determined by achievable Seasonal energy efficiency ratio (SEER). Typically, SEER's of between 3 and 4 can be expected for air and ground source systems, depending on operating temperatures. Variations in coefficient of performance are more marked for air source heat pump systems (due to greater variations in ambient temperature which acts as the sink to which heat is

	rejected). Annual maintenance costs are typically low and in line with conventional boiler plantroom maintenance costs.
Environmental, Planning and Policy Issues Constraints	Open loop systems require an abstraction licence from the Environment Agency. With open loop systems there can be risks in terms of operation in that the user is not in control of the quantity or quality of the water being taken out of the ground, this being dependent on the local ground conditions. Reduced performance due to blockage (silting etc.) may lead to the system not delivering the design duties whilst bacteriological contamination may lead to the expensive water treatment or the system being taken temporarily out of operation. For abstraction and disposal of the water for open loop systems, there are risks associated with the future availability and cost of the necessary licenses; For commercial buildings the risks tend to mean that closed loop applications are the system of choice. Ability to reduce carbon emissions limited by depth and area of collector field. The Mayor's hierarchy requires consideration of communal heating prior to adoption of ground or air source energy systems. Where significant heating demands are present, ground source systems have generally given way to other solutions, since these require balanced loads for permitting and for economic viability reasons. In such cases, air source systems have been applied for cooling loads in conjunction with electric chillers.
Policy Support Measures	Ground source energy schemes area eligible for RHI, subject to minimum COP levels being achieved. Air source heat pump systems are not eligible for RHI.
Technical Considerations / Constraints Barriers	In the Wembley regeneration area, ground source schemes are likely to be perceived as being high risk solution, given the complexity, cost and uncertainty associated with drilling boreholes. Air source heat pump systems are likely to be the favoured option by developers for this reason. Whilst open loop systems ground source systems are thermally the most efficient option, over time they can also suffer from blockages caused by silt, and corrosion due to dissolved salts. As a result, additional cost may be incurred in having to provide filtration or water treatment, before the water can be used in the building. In order to mitigate these risks, additional means of heat rejection and heating by mechanical means as a back-up can be provided but this adds costs and prevents space being freed up for other uses. Abstraction licence and discharge consent needs to be obtained for each installation, and this together with the maintenance and durability issues can significantly affect whole life operating costs, making this system less attractive. Since ground water is not being directly used, closed loop systems suffer fewer of the operational problems of open loop systems, being designed to be virtually maintenance free, but do not contribute to the control of groundwater levels.

Financability, Operating track record,	Air source heat pump systems are commercially proven technology, with extensive operating track record. Financing such technology is not an issue.
Uptake in Similar Developments	Uptake of air source heat pump systems has been relatively common in large commercial developments to date, primarily due to low investment costs relative to ground source alternatives.

Table 33: Air and Ground Source Heating/Cooling

	Internal Combustion Engine CHP at Block Level and as Part of Community Wide Heat Networks
Applicable Scale	Block level, and Development Plot level
Technology description and Application	Internal combustion engine technology is the prevalent technology at the scale of application. Electricity is generated through grid connected asynchronous generators and heat is recovered from engine jacket and exhaust systems. Gas turbine applications are also …. The most common fuel source is natural gas, although biofuel is also a realistic option on the context of the Wembley Regeneration Area. Currently first generation technologies for biofuel production refer mainly to the fermentation of sugars to bioethanol and the trans-esterification of fats and oils to biodiesel. The most common bioethanol technologies use sugar beet or wheat in the UK and , The most common biodiesel processes in the UK use waste vegetable oil, waste fish oil (ethyl ester), or tallow as a feedstock, but biodiesel can also be made from rape seed oil, palm oil or soy oil. Second generation biofuels are less prevalent in the market at present. These include conversion of cellulosic biomass to ethanol or to biomethane using anaerobic digestion and thermochemical processing in which a combustion technology is used to produce chemicals that are then synthesised or refined into biofuels. The electrical and thermal efficiency and the power to heat ratio of internal combustion engine CHP improves with scale. Similarly the utilisation of CHP, which has an overriding impact on economics, is greatly improved where there is a collection of building with different daily and seasonal profiles connected. When implemented as community based schemes, CHP will deliver greater operating efficiencies and improved utilisation over the long term. For any particular development, the sizing strategy depends on the relative sizes of electrical and thermal loads for the site. Where the electrical load is greater than the thermal load, it is usual to size the CHP for the thermal load and vice versa. Electricity exporting is uncommon due to the economics of this approach. However, for community scale applications, private wire networks help to allow larger CHP installations based on sizing for heat demand, thereby improving returns through lower operating overheads and better

	plant utilisation. CHPs are often sized on a based load which typically equates the domestic hot water demand for the building. When sizing schemes for multiple buildings, thermal storage is generally a prerequisite in order to deliver economic solutions. Storage allows both CHP efficiency and income from electricity revenues to be optimised and minimises the investment required to deliver a given contribution towards total heat supply. For single building applications, thermal storage is not always required. CHP can containerised and located externally or can be integrated internally in a plantroom within an acoustic enclosure. Footprint requirements are modest for gas CHP, with a 200 kW installation requiring around X m2. For biofuel CHP, additional space is required for tankage (sometimes two for start-up), bunds and an interceptor. Other considerations include compliance with EA PPG2 Oil Storage Regulations and logistics of fuel deliveries/availability. Bio-fuels also require special handling (including trace heating) and in some cases, the provision for handling different fuel types. Fuel storage is an issue and fuel needs to be heated to keep viscosity down, which represents an additional parasitic load.
Commercial Factors and Route to Market	Gas engine CHP is a commercially proven technology, with an extensive operating track record. At block level, the technology is a popular option amongst developers due to its low capital cost, proven track record, ease of financability and ability to deliver on compliance targets. Gas engine CHP typically costs around £1100/ kW at 100kW scale, £750/kW at 500 kW scale, £710/kW at 1100 kW scale. Currently capital costs for biofuel CHP are comparable to natural gas CHP since the technology is essentially the same, but bio fuel CHP solutions are not as readily financeable since returns on investment or paybacks of under 10yrs are not achievable. This is partly due to high biofuel prices and fuel price risk associated with limited supply. Current operating costs for Biofuel CHP are generally around two to three times that of Natural Gas CHP. Gas engine and biofuel CHP technologies are developer led technologies and the role of the Local Authority in implementation of this technology is negligible beyond the planning phase. In multi-site mixed use developments, where construction phasing is an issue and where there is uncertainty over future plot uses, developers are likely to favour installing individual CHP systems within each individual building. However, as noted above and in [1], precedents are in place to support the encouragement of developers to adopt single energy centre solutions. Location of the central energy centre assets are not critical to the economics of the scheme, and this will usually be dictated by cost / leasable value of the land and or the construction phasing (for example, the first development in a series of developments logically being the site for the energy centre). However, where a community heat network is developed, the land disposal strategy for the developer is likely to be more complex, particularly where one or more landowners and/or more than 1 development partners are involved. For example the lease and/or transfer of assets for a separate energy centre and community heat network, including rights of access etc., will require negotiation and agreement.

	Evidence from 0 indicates a typical net developer contribution cost of around £4,490/unit based on an 878 unit urban development, assuming 25 to 35 year ESCo concessions. For gas engine CHP, gas costs are typically in the range ~ 2.5 to 3.5p/kWh at the block level scale. Annual maintenance costs are typically in the range 0.08p/kWh generated for 1160 kW scale and 0.11 p/kWh generated for 100 kW scale units. Community based options can expect lower per unit costs both in fuel and maintenance due to higher volumes of gas being purchased and lower maintenance contact costs per unit of electricity generated. Biofuel costs based on waste vegetable oil derived biodiesel prices are currently approximately 10 to 12 p/kWh, based on information obtained from a major supplier in London. Waste cooking oil from restaurants or the catering sector for the moment it is still quite cheap as it is regarded as a waste product. The current service regime for Bio-diesel engines is around twice that of gas CHP engines. Operation of gas CHP technology is not particularly complex and at block level, Facilities Management companies will generally be capable of maintaining and operating the assets, with fixed service level agreements in place with the CHP supplier as necessary. Under the community based approach, the involvement of an ESCo is more likely, due to the risks, design complexity and specialist billing services required. For these schemes are many Energy services companies in the market who are able to provide complete solutions for the developer, which can including financing, constructing and operating the scheme, in return for a concession to supply heat and electricity to the development over 10 to 25 year period. Under solution provides a significant benefit to the developer since it reduces the developer's risk. The ESCo will generally aim to sell electricity to the tenants via a private wire, since the project will be contingent on electricity sales to return an operating profit. However exposure to customer switching for electricity remains a risk for the ESCo (under the provision of the Electricity Act) and without on-going incentive, support or requirement to continue to operate CHP, future revenue cannot be guaranteed. The ESCo will generally aim to incentivise customers to remain connected through private wire by tracking a basket of electricity prices from the main suppliers. This will result in an electricity price reduction for these customers which is a benefit. The ESCo will effectively maintain a monopoly on heat supply to the tenants connected to the network. However, as for other block level scenarios, tenants will be protected by Landlord & Tenant Act compliant consumer contracts requiring a mixture of provisions including clauses for:- • tariff structuring and indexation, typically with linking to basket of fuel prices from the main suppliers in order pass on fuel price risk to the tenants • standing charges and indexation, • compensation for interruption to supply, • Maintenance of demand-side and network side assets.

Environmental, Planning and Policy Issues Constraints	Fuel combustion from gas and biofuel engine CHP gives rise to air pollutants, particularly oxides of nitrogen (NOx), which convert to nitrogen dioxide (NO2) in the air and, in the case of biofuel, particulate matter (PM10). In Air Quality Management Areas for nitrogen dioxide where concentrations do not meet health based standards, various options exist to mitigate the impact of emissions including type and design of the plant, use of emissions abatement equipment and stack height to maximise dispersion of emissions from the chimney. Emissions Abatement Equipment options include Selective Catalytic Reduction (SCR) or Selective Catalytic Non Reduction (SCNR) to control the exhaust emissions in terms of NOx and particulate matter (PM10) and/or DeNox Catalyst. Both require substantial capital outlay and can incur additional running costs.
Policy Support Measures	Gas engine CHP receives the following support:- • Exemption from the Climate Change Levy for all Good Quality CHP fuel inputs and electricity outputs • Eligibility for Enhanced Capital Allowances (ECAs) for Good Quality CHP plant and machinery • Preferential treatment under the Business Rates for certain Good Quality CHP schemes • Levy Exemption certificates no longer available under Electricity Market reform, although this is not relevant in any case if CHPs are not exporting. Biofuel CHP is ROCable, receiving 2 ROCs per MWh for Good Quality CHP installations. The fuel must be 100% waste product and the process of accreditation can be lengthy. There is no RHI support on biofuel CHP at present. Reporting to OFGEM for compliance under ROCs requires monthly sampling testing of fuel, which can be onerous.
Level of uptake in Similar Developments	Evidence from GLA (GLA, 2011) indicates that the uptake of gas CHP in block level solutions has been very high, with over 60 per cent of new developments proposing to use energy supplied by gas CHP in 2010. In relation to application at community scale, evidence from GLA (GLA, 2011) also indicates that, despite the potential difficulties arising from the phasing of large mixed use developments, implementation of the London Plan policies has meant that developers have become accustomed to committing to establishing site wide heat networks. This document reports that whilst negotiations occur regarding the timing by which a site heat network will be established, the principle of establishing a network is rarely disputed. In the case of larger mixed use developments, it has been reported that success has been achieved in persuading developers to minimise the number of energy centres and for a few of the larger developments, single energy centres with enough space to install plant to supply heat beyond the boundary of the specific development have also been secured through the planning process.

Table 34: Natural Gas CHP

	District Heating
Applicable Scale	Development Plot level
Technology description and Application	District heating involves the supply of low temperature heat to individual building developments through a buried, pre insulated piped network. The supply is typically delivered into ground or basement level plantrooms. The design of the connection varies according to the design of the internal heating and domestic hot water supply systems. Typically heat exchanger sub stations are located at the incoming building plantroom to provide a hydraulic break. This approach provides a suitable metering point and contractual boundary between the service provider and the customer, typically the tenant or a facilities management company acting on its behalf. Space heating is then either delivered directly to apartments or indirectly through heat exchangers, whilst domestic hot water is usually provided indirectly in either case. Alternative options involving direct connection into the building with subsequent distribution to apartments under network pressure are also possible and have been successfully implemented. The pros and cons of the various options should be considered for each development and should form the basis of the heat network strategy since the distribution strategy at building level informs the capacity and temperatures for which the network needs to be designed. The quantity of heat supplied is controlled automatically and metered at each heat exchanger interface to enable customer billing. For new developments constructed once a heat network is in place, the heat exchanger station usually acts as the only source of heat into the building. Where the network is installed after the building has been constructed, the heat exchanger station typically connects in parallel with existing boilers and any LZC technology that has been installed. A fuel supply for the district heating network is dependent on the source of primary energy at the energy centre. Likely fuel source options for the Wembley Regeneration Area include natural gas, biomass and, in the longer term, energy from locally sourced waste.
Fuel source	
Commercial Factors and Route to Market	Evidence from 0 suggests that the cost to the developer of developing district energy is similar to the cost of developing building integrated micro generation solutions and that developers will tend to choose based on their experience, perceived design and build complexity and ability to sell more homes or derive greater receipts for land-sales. According to 0 there isn't evidence to indicate that community energy homes are more (or less) marketable and house builders and

	other developers are reported to perceive a risk with this approach that if selling building on, there will be a reduction in market value due to a fear of the unknown, concerns over reliability and the perception amongst tenants of being locked into a monopoly supply. Connection costs for district heating include the cost of heat exchanger station and branch pipework to the distribution main. Total cost depends on connection capacity and linear distances to boundary of the plot. For new developments constructed once a heat network is in place, the heat network provider will typically finance the connection into the building. In this situation, the heat supply tariff will include for recovery of this investment through the heat selling price. Where a building is constructed ahead of a proposed network, the Developer can be required through planning to safeguard for connection into the network and can potentially be required to contribute towards the connection costs and the community heat network to the boundary of the plot as part of his development. The extent of this might reasonably be in lieu of the avoided costs associated with implementing alternative LZC solutions necessary to achieve compliance. This is subject to the timescales and provisions of future building regulations, which may not allow deferred to take place in this way. In this scenario, a lower heat cost can be expected, since the heat network provider will not have financed the connection. Similarly, the developer will realise a tangible saving in physical space within the building which constitutes a potential additional leasable income. Evidence from0 indicates a typical net developer contribution cost of around £4,490/unit based on an 878 unit urban development. A range of options exist for delivering the heat from the network to the end consumer. The heat supply company can supply directly to tenants and leaseholders or it can sell heat to a facilities management company who then supplies the tenants and leaseholders much in the way that it would do under a building/block level solution. Under the first approach, the heat network provider will then carry out billing and metering directly to customers. This approach is likely to deliver lower cost heat to the end consumer but is dependent on the heat network provider’s appetite for taking on the operating overhead and risks of bad debt associated with individual customer billing. The approach of selling heat to the interface of the building is considered to be the more common of two in developments such as for the Wembley Regeneration Area. A range of options exist to structure the heat tariff under the heat supply agreement. The heat network provider will typically look to apply an annual capacity charge to cover fixed operating overheads and interest repayments on any connection costs it may fund on behalf of the developer. A variable tariff will then also typically be applied on a kWhr basis. Depending on source of primary energy, variable tariffs may also be time dependent, according to opportunity cost of heat production and/or linked to customer return temperatures. Where the heat network provider is also involved in electricity generation as a by-product of heat production, this electricity can be retailed locally via a private wire or sold to the public through an Electricity Supplier. The Electricity Licence Lite will make provision for

	heat network providers to trade electricity in this way. Where such providers are also licenced electricity suppliers, retailing through their normal supply business will be the preferred approach since they can utilise their existing supply business to purchase the electricity generated without the additional operating overheads of setting up a licence lite or the risks associated with a private wire supply. Leaseholders and tenants will not be locked into long term electricity contracts and will be free to switch under the provisions of the Electricity Supply Act and the Citiworks ruling. Electricity supplied by the district heating company will therefore need to remain competitive and will typically track and aim to undercut the basket price of the top six Electricity Supply companies, Leaseholders and tenants will be locked into heat prices sold through the heat network, unless the developer installs (or retains in cases where the network connection occurs retrospectively) local heating assets. However, customers are protected under heat supply agreements, in which provision should be made to link heat price to market price of gas, for example a basket price of the top six gas Suppliers. Although heat is not a regulated business at present, the industry is making moves towards self-regulation and including as part of this a consumer protection charter and standard terms under heat supply agreements. The present lack of regulation adds to perceived risk among developers and leaseholders, although it is our view that the industry will become regulated in the future, thereby removing this risk perception. Unlike the other options considered, the district heating option requires active involvement by the Local Authority beyond the individual project planning phase. As a minimum this includes an additional planning role in establishing the heat network, the associated energy centre and developing planning policies to support safeguarding measures for developers to connect to the network, without which a future heat network is unlikely to be forthcoming. Depending on whole life costs and economic of the project and the Local Authority's appetite for involvement in developing a local heat network , the route to market will either be fully driven by the private sector or through a joint venture arrangement involving both the public and private sector. In this scenario, the Local Authority will need to take an active role in developing the project, which will require resource and capital funds. However, depending on the rates of return available the project may represent an attractive investment to the Local Authority and an opportunity to develop an income.
Capital Cost	
Operating Costs	Maintenance costs for district heating connection and heat exchanger station are usually borne by the district heating company. The cost of heat supplied to the development will include for the maintenance costs described above but will typically be linked to a basket price of the top six gas Suppliers, with an incentive reduction (of the order of 10%) to attract and retain customers.
Planning and Policy Issues	The London Plan 2011 places a requirement on developers to actively investigate the potential to connect to off-site heat networks at the planning stage. However, it has proved more challenging to obtain a guarantee that developments will connect. Where this is the

Constraints Policy Support Measures	case, Section 106 agreements, where appropriate, have been used to ensure the applicants continue to prioritise connection to offsite heat networks. Heat networks per –se are not directly supported through policy measures. However, associated supply technologies are supported through a combination of measures including FIT, ROCs, RHI ECA's and CCL exemption on gas for qualifying CHP. Whilst LECs have been abolished under Electricity Market Reform, the Government has previously indicated that it will adopt the favourable 'boiler displacement method' for determining CPS liability for gas-fired CHP. Positive progress has been made in the treatment of aggregated portfolios of plant but the treatment of the 2 MW threshold cliff edge looks increasingly unlikely to be changed. HMRC has also indicated an intention to implement flexible guidelines on definition of CHP operator to account for differing developer and operators' business models. The changes will be implemented in the Finance Bill 2013. The Government has also indicated that the case for on-going revenue support for gas-fired CHP remains to be established. Several support options for CHP have been considered; including FiTs, preferential treatment in the capacity mechanism, soft loans, and CPS relief and a proposal to be included in the Heat Strategy has been made to Ministers.
Technical Considerations / Constraints Barriers	Internal heating systems need to be designed for low return temperatures, which can potentially add cost relative to business as usual, design. It is unclear whether future building regulations updates will allow deferral of compliant technologies in lieu of an intention to make a connection to a future heat network. If not, then the incentive for future connection will reduce or be delayed until the time when future asset replacement is required. This in turn increases risk for the district heating company.
Financeability, Operating track record	District heating is established technology with low technical risk. However, financing remains a difficulty where there is no guaranteed customer base and development timescale are long. This is due principally due to large upfront costs associated with establishing the energy centre and network assets and uncertainties around future revenue streams. If IRRs are adequate, ESCo's can arrange finance and the scheme can be fully developed off the Local Authority's balance sheet. Where larger type schemes are involved or there is a lot of risk, a public private partnering approach is usually needed, in which the public sector guarantees heat loads, provides access to land and in some cases takes a stake in the project.
Level of uptake in Similar Developments	Evidence from GLA (GLA, 2011) indicates a substantial number of mixed use developments with site heat networks proceeding through planning in 2010. Although the majority are in a position to connect to existing off-site heat networks, they will be able to connect

	should networks expand to cover these areas in the future, at which point they will also be able to act as anchor loads in the establishment of new larger networks in the future.

Table 35: District Heating

GLA, 2011, Monitoring the Impact of London Plan Energy policies in 2010

APPENDIX 3 EVIDENCE BASE MODELLING ASSUMPTIONS

Building Floor Area Assumptions

Floor area assumptions for the non-residential buildings within the notional development are presented in Table 36.

Non Residential Areas		
Hotel Model		
Retail floor area	3,088	m2
Hotel floor area	11,268	m2
Total floor area	14,356	
Office Model:		
Retail floor area	1,995	m2
Office floor area	11,321	m2
Total floor area	13,316	

Table 36 Floor Area Assumptions – Non Residential Buildings

Floor area assumptions for residential buildings within the notional development are presented in Table 37 below. Floor areas for 1-, 2-, and 3-bed flats comply with London plan minimum floor area assumptions and have been cross referenced and based on information for typical developments in the regeneration area based on planning applications for recent developments.

Residential			
Flat Type	1 bed	1 bed floor	1 bed roof
No. of units	102	6	6
Floor Area (m2)	51	51	51
	2 bed	2 bed floor	2 bed roof
No. of units	151	8	8
Floor Area (m2)	72	72	72
	3 bed	3 bed floor	3 bed roof
No. of units	107	6	6
Floor Area (m2)	92	92	92

Table 37 Floor Area Assumptions – Residential Developments

Low and Zero Carbon Technology Sizing Assumptions

Low and Zero Carbon Technologies have been sized on the basis of the assumptions set out in Table 38 for the purposes of modelling their contributions in the IES and NHER models. It is recognised that optimisation of sizing strategies could potentially be carried out, although this has not been done in order to maintain a consistent basis for comparison between scenarios. In all scenarios, with the exception of scenario 6, high efficiency condensing gas boilers are assumed to provide the residual requirement.

Under scenario 6, the district heating system is served by a combination of technologies that include gas fired combined heat and power, condensing gas boilers and a biomass CHP plant. Refer to Section 5 for more information on this.

Low Zero Carbon Technology Option				
Scenario	LZC technology	office	Hotel	Residential
Scenario 1	condensing gas boilers	domestic hot water and space heating	domestic hot water and space heating	domestic hot water and space heating
Scenario 2	Air Source heat pump	space heating	space heating	space heating
Scenario 3	Gas CHP	domestic hot water	domestic hot water	domestic hot water
Scenario 4	Biomass boilers	domestic hot water	domestic hot water	domestic hot water
Scenario 5	Gas CHP Community scale	domestic hot water	domestic hot water	domestic hot water
Scenario 6	District heating	domestic hot water and space heating	domestic hot water and space heating	domestic hot water and space heating

Table 38 Low and Zero Carbon Technology Sizing assumptions

For the purposes of capital investment and operating costs, the relevant technologies have been sized on the following basis:-

- Gas boilers have been sized on the basis of 120% of the peak diversified demand for the building or development. This simulates two boilers at 60%
- biomass boilers have been sized on the basis of delivering their contribution within 1314 full load equivalent running hours
- gas CHP have been sized on the basis of delivering their contribution within 5000 full load equivalent running hours
- Air source heat pumps are sized on the basis of delivering their calculated contribution within 964 full load equivalent hours. This reflects provision of space heating demands on average 8 hours per day, continuously for 4 months of the year.

Assumptions around Heat Price Calculations

Gas and electricity prices associated with delivering heat under the various scenarios are taken from DECC quarterly prices statistics[33] and are based on the calculated demand quantities for each customer type. They are reflective of Small/medium customer types as presented in Table 39. It is noted that some developments could potentially purchase gas and electricity at lower rates (for example though a portfolio of buildings for large companies with multiple tenancies), but this has not been modelled.

	gas prices p/kWh	electricity prices p/kWh	
	bought	bought	sold
hotel	£0.029	£0.094	
residential	£0.029	£0.144	
office	£0.029	£0.094	
CHP export price (scenario 5)	£0.026		£0.050

Table 39 Energy Price Assumptions

[33] Table 3.4.2 Prices of fuels purchased by non-domestic consumers, based on 2nd quarter 2012 and averaged for 2012

Under scenario options 3 and 5, the revenue generated from electricity sales due to operation of the CHP plant is included as a benefit and is subtracted from the cost of heat production.

This electricity is assumed to be retailed within each development through a private wire arrangement, with any surplus being exported to the grid at a value of 5 p/kWh. A 10% discount against the business as usual alternative is assumed for the customers within the scheme. Business as usual retail electricity prices for residential customers are based on DECC quarterly statistics for domestic customers based on 3rd quarter for 2012. The impact of selling a proportion of the electricity under a landlord's supply is a modelling option, but has been set to zero under the results presented in the report.

Under Scenario 4 (biomass boiler option), the cost of biomass is assumed to be 4.16 p/kWh based on biomass pellets and taken from a pellet supplier quotation. The income from PV generation is not included as a benefit on heat sales.

Under the variant Scenario 3 for 2016, (biofuel CHP option), the cost of biofuel is assumed to be 11 p/kWr based on waste vegetable oil derived biodiesel prices and on quotations obtained from a major supplier in the London area.

The income from PV generation is not included as a benefit on heat sales.

Under option 5, the energy centre is assumed to be constructed at ground or basement level within an existing building. The space is leased with a leasable value equivalent to a Student Accommodation Block. A community heating network is also associated with this option, with an assumed length of 100 m and an annual heat loss of 10% of heat supplied from the development plot boundary. This heat loss is assumed to be captured as a cost to the ESCo that is passed on as a cost to customers through the heat price.

Low and Zero Carbon Technology Cost, Maintenance and Footprint Assumptions

The assumptions used in modelling the investment costs, O&M costs and footprint area requirements are presented in Table 40. These have been derived from a combination of sources including SPONS 44th Edition (2013), internal benchmarks and supplier information from a number of reference projects.

gas boiler installed costs			
kW	400	6450	12500
£/kW	45	35	25

gas boiler maintenance costs			
kWth	400	6450	12500
£/kWh	0.0025	0.0015	0.001

gas boiler option plant footprint			
kW	400	6450	12500
m2	19	44	58

	Heat Pump installed costs		
kW	50	225	400
£/kW all	1147	617	510

	Heat Pump O&M costs		
kWe	50	225	400
£/kWh	0.003	0.002	0.001

	Heat Pump plant footprint		
kW	50	225	400
m2	2	2	8

	CHP installed costs		
kWe	238	400	750
£/kWe	668	593	500
	660	*603*	*497*

	CHP maintenance costs		
kWe	238	400	750
£/kWh	0.0116	0.0105	0.01

	CHP footprint		
kWe	238	400	750
m2	11	14	20

	biomass installed costs		
kW	50	500	1000
£/kWe	500	250	150

	biomass maintenance costs		
kWe	50	500	1000
£/kWh	0.011	0.002	0.001

	biomass plant footprint		
kW	50	500	1000
m2	6	14	30

	DH substn installed costs		
kW	70	1000	5000
£	8,200	20,800	36,600

	DH maintenance costs		
kWe	70	1000	5000
£	500	750	1000

	DH plant footprint		
kW	70	1000	5000
m2	3	6	14

Table 40 LZC Technology Cost and Footprint Assumptions

Lease Value Assumptions

Lease value assumptions for calculating costs associated with forfeited leasable space are presented in Table 41. These are based on information contained in Appendix 4 Residential appraisal Results and Appendix 5 Commercial appraisal results of the CIL viability assessment report carried out by BNP Paribas Real Estate on behalf of London Borough of Brent (date unknown). Reductions of 50% and 25% on calculated lease values are applied to basement and roof areas respectively.

	Lease Value	
	basement	roof
Hotel	£1,413	£2,120
Office	£113	£170
Residential	£134	£201
Student Acc	£123	£184

Table 41 Lease Value Assumptions

Approach for the treatment of 2016 regulations, zero carbon homes (and non-domestic buildings) policy for use in Evidence base modelling

In December 2006 the Government pledged that all new homes would be 'zero carbon' from 2016 and introduced the Code for Sustainable Homes. It was then recognised that the cost of building to this definition (Code for Sustainable Homes, Level 6), and its impracticality on many sites meant that an alternative approach had to be sought.

In 2009, the concept of 'Allowable Solutions' was proposed by the Government. By paying into an Allowable Solutions fund to spend on near-site or off-site carbon abatement projects , a lower on-site emissions target could be set for house builders, while preserving the zero carbon policy goal. Then, an additional change occurred in the March 2011 budget when the unregulated emissions (associated with cooking and appliances) were removed from the definition/requirement for zero carbon compliance. Presently only 'regulated' emissions (from heating, cooling, ventilation and lighting) need to be accounted for in the future Zero Carbon Policy.

Under the Government's proposals, Zero Carbon compliance is therefore expected to require a combination of high energy efficiency and on, or near-site, renewables (and other LZC options) together with one or more additional 'allowable' of site solutions to offset the remaining carbon. There are three core requirements which must all be met for a home to qualify as zero carbon:

1. A high level of insulation and air tightness that together meet a certain minimum standard, known as the Fabric Energy Efficiency Standard (FEES)

2. Sufficiently low emissions generated by efficient heating, hot water and lighting, known as the Carbon Compliance Standard (CCS)

3. The remaining carbon emissions (after requirements 1 and 2 have been met) must be reduced to zero.

.

Requirement 3 may be met by 'over-performing' on requirements 1 and 2, or met by investing in "Allowable Solutions" or a combination of these.

The performance targets are not yet established for high rise developments or for non-residential developments and are only in draft/consultation stage for other types of building.

The Zero Carbon Hub has proposed Fabric Energy Efficiency Standards FEES of 39 kWh/m2/year and Carbon Compliance Standards (CCS = 14 kgCO2/m2/year) for apartment blocks of up to 4 storeys, which are expected to form part of the normal Part L 2016 consultation process and have also formed part of the Part L 2013 consultation process.

The definition of zero carbon homes (and zero carbon buildings from 2019) is taken to be a building that has to offset all of its regulated carbon emissions, requiring a 100% improvement over the Target Emission Rate (TER) that is generated through energy calculations stipulated in Part L of the UK (soon to be English only) Building Regulations. This compares to a London Plan (and BREEAM Excellent) requirement of a building achieving a 25% improvement in CO2 emissions over the TER in 2010 and a 40% improvement over the TER in 2013

What is less clear is the proportion of this 100% reduction in emissions that should be offset through on-site measures and what proportion can be offset through off-site 'allowable solutions'.

This uncertainty has been circumvented in the Evidence Base calculations by assuming that the 100% improvement over the TER required for zero carbon homes is completely met by a theoretical amount of PV. In effect the PV is used as a constant comparator with which to compare each of the options against one another.

On this basis, our approach for the treatment of compliance under Zero Carbon Homes policy from 2016 (for residential) and anticipated Zero Carbon Buildings policy from 2019 (non for non-residential buildings) calculates the following indicators:-

- Energy calculations calculate a Building Emission Rate (BER) based on passive measures and plant fuels and efficiencies.
- The residual carbon compliance (if any) needed to offset either 25%, 40% or 100% of the CO2 emissions represented by the TER.
- The theoretical amount of PV that would be needed to deliver this residual compliance at the site.
- The actual amount of PV that could be deployed on the site and the associated carbon reduction that it could deliver. We have used the proxy of PV cost to calculate the financial impact of this element of the residual compliance requirement
- The residual offsetting requirement that would need to be met through allowable solutions in order to deliver 100% of the required compliance on the site. We have used carbon price as a proxy to calculate the financial impact of this element of the residual compliance requirement. The price of carbon has been assumed to be £50/TCO_2

Taking this approach has avoided the need for interpretation of an unsettled debate surrounding proportions of onsite/offsite carbon abatement technologies and expenditure. It has also allowed us to remain consistent with our modelling of the 2010 and 2013 scenarios, for which we have also taken the approach of using PV as a proxy for residual emissions offsetting.

This constant comparator approach illustrates how much 'work' or 'effort' is required to allow the development to comply with the 25% and 40% London Plan requirements and with the 100% Zero Carbon Homes requirement.

The PV comparator could equally be a different one (e.g. fabric improvement). However the PV measurement is consistent with the Zero Carbon Hub's own analyses and it is a suitable metric that sets a level comparator across the options and is appropriate to use as a basis for discussion with developers.

It should be noted that the calculated PV values are theoretical and cannot be achieved in practice on site due to space limitations for some scenarios. In such cases, developers would need to adopt alternative measures (such as improved fabric) in order to meet BREEAM targets or in the case of 2016 regulations, access allowable solutions. However, these are more difficult to quantify reliably and are not modelled here.

The alternative to using a single comparator method described above (in this case PV) would be to develop a set of assumptions around compliance limits based on the work carried out by Zero Carbon Hub in 2011. Ramboll's view is that this less reliable as a way forward since the report did not cover high rise developments and since the topic is still in a state of flux.

Non domestic buildings have been treated in the same way, but with a zero carbon target brought forward in the modelling to the period commencing 2016. There are no firm building regulation commitments for the period 2016-2019, so rather than add an additional period of time with unknown energy and CO2 emissions standards, the zero carbon methodology was adopted. However, we are reasonably confident of the CO2 emission requirements for zero carbon (non-domestic) buildings based on the zero carbon homes assumptions that are described above.

Fabric Efficiency Standards

Under each of the periods covered by a different set of Building Regulations (2010, 2013, 2016) building fabric assumptions and thermal parameters are assumed to be consistent for each modelled LZC technology scenario.

For all buildings, U values for 2010 are based on the values defined in Part L 2010 building regulations. U values for 2013 are assumed to be the Full FEES specification under example 2 for an apartment block as defined in the Zero Carbon Hub document Fabric Energy Efficiency for Part L 2013, Worked Examples and Fabric Specifications[34]. U values for 2016 are assumed to be the Full FEES specification under example 1 of the same document.

However, these have also been compared to the more stringent values specified for the End of Terrace model and where appropriate values applicable to the latter have been used. In particular, this relates to air permeability and calculated thermal bridging. The basis for this is an assumption that, for high rise apartments, a tighter fabric specification than that for low rise apartments is likely to be defined in order to achieve a greater degree of carbon reduction through fabric measures. Window U Values for 2016 have been retained at the values specified for 2013.

A summary of the main fabric efficiency assumptions is presented in Table 42.

	2010	2013	2016
External Roof U-value (W/m2K)	0.25	0.16	0.13
External Floor U-value (W/m2K)	0.25	0.18	0.13
External wall U-value (W/m2K)	0.35	0.20	0.18
Internal/party wall U-value (W/m2K)	-	-	-
Windows U-value (W/m2K)	2.2	1.40	1.40
Air permeability (m3/hr/m2 @ 50Pa	5.00	5.00	5.00
Calculated thermal bridging (W/m2K)	0.04	0.04	0.04

Table 42 Fabric Efficiency Standard –Residential Buildings

For non-residential buildings the same parameters have been adopted as presented in Table 43.

	2010	2013	2016
External Roof U-value (W/m2K)	0.20	0.16	0.13
External Floor U-value (W/m2K)	0.25	0.18	0.13
External wall U-value (W/m2K)	0.30	0.20	0.18
Internal/party wall U-value (W/m2K)	-	-	-
Windows U-value (W/m2K)	2.0	1.40	1.40
Air permeability (m3/hr/m2 @ 50Pa	5.00	5.00	5.00
Calculated thermal bridging (W/m2K)	0.04	0.04	0.04

Table 43 Fabric Efficiency Assumptions for Non Residential Buildings

Non-Residential Modelling Methodology and Modelling Assumptions

Modelling has been carried out using IES Software.
The following assumptions have been applied:-

[34] http://www.zerocarbonhub.org/resourcefiles/Fabric_standards_for_2013_worked_examples.pdf

- Internal heating and cooling system designs are common for the given building type under each modelled LZC technology scenario.
- Target emission rates consider only regulated emissions
- Target emission rates for 2010 are calculated using the methodology as defined in the National Calculation Methodology (NCM) Guide 2010, which is referenced by Part L2A 2010.
- Target emission rates for 2013 building regulations are expected to improve on the 2010 TER by 20%, giving an equivalent direct improvement over the 2010 TER of 40%.
- Target emission rates for 2016 are set to zero.
- Thermal parameters of rooms are as per Part L2A 2010 including heating/cooling set points, internal gains, ventilation rates.
- Office glazing g-value is assumed to be 0.43
- Hotel/Retail glazing g-value is assumed to be 0.64
- Office/Retail building glazing area is assumed to be 37% of the total wall area
- Hotel/Retail building glazing area is assumed to be 27% of the total wall area
- BREEAM Excellent required emission rates in the 2013 period are assumed to be a 25% improvement on the prevailing building Regulations (TER) at the time.
- Solar thermal for domestic hot water is not included in any of the scenario options as dwellings are assumed to form part of a tower block with minimal roof space
- Domestic hot water delivery efficiency within buildings is 95%
- Ventilation Heat Recovery units are assumed to have 85% efficiency.
- Chiller seasonal energy efficiency ratio is 400%
- Heat pump seasonal energy efficiency ratio is 300%
- Specific fan power is assumed to be 0.5 W/l/s for ventilation systems
- Variable speed drives are assumed for circulation pumps with multiple pressure sensors in the system
- No Changeover Mixed Mode cooling, i.e. no free cooling
- Central BMS control through a timer with optimum start/stop functionality, weather compensation and zonal time and temperature control
- Buildings are classed as partially exposed for infiltration calculation purposes
- Electric power factor correction up to 90%
- Lighting systems have provision for metering and warn of out of range values
- Simple zonal lighting control is implemented in office and retail spaces
- Space conditioning is delivered by Fan Coil Units

<u>Residential Modelling Methodology and Modelling Assumptions</u>

Modelling has been carried out using the SAP 2009 methodology and NHER calculation tool.
The following assumptions have been applied:-

- Internal heating system designs are assumed to be common under each modelled LZC technology scenario. Space heating and domestic hot water is supplied from a basement level plantroom via a two pipe system running through the building delivering heating directly into apartments. There is no domestic hot water storage in the apartments.
- Target emission rates are based on regulated emissions only.
- Target emission rates for 2010 are calculated based on the SAP 2009 methodology as referenced in Part L1A 2010.
- Target emission rates for 2013 building regulations are expected to improve on the 2010 TER by 20%, giving an equivalent direct improvement over the 2010 TER of 40%.
- Target emission rates for 2016 are set to zero.
- All flats are modelled as single storey and are located in postcode HA0.
- 5% of flats are located on the ground floor, 5% of flats are located at roof level and the remainder are at mid level.
- Flats are modelled with 2 sheltered sides. All flats have one side 8m in length, with the other length varied to make up the agreed floor areas of 1, 2, and 3 bed flats (51m2, 72m2 and 92m2 respectively). The Living room area is set to 25 m2 for each flat
- Windows are assumed to face East and West and the party wall area is equal to half of the exposed wall area
- Flats are served by mechanical ventilation with heat recovery systems which are 92% efficient. Specific fan power is 0.56 W/l/s

- No secondary heating systems are applied.
- Low energy light fittings are assumed
- Windows can fully open to prevent overheating
- Domestic hot water storage assumption is based on 120 litre DHW tank in each flat.

Solar Photovoltaic Calculations

For all developments in the notional development, solar PV is modelled with an Azimuth of SE or SW, with no overshading and an inclination of 45 degrees to the horizontal.

PV area calculations to achieve compliance under BREEAM, zero carbon homes and building regulations are based on SAP 2009 methodology which is used for domestic energy calculations. A figure of 797.6 kWh/kwp produced per year for the UK, assuming the PV is not perfect, i.e. it's at SE or SW orientation, and 45 degree tilt are assumed. It is noted that this is not an optimum tilt or azimuth for the location, with 35degrees and due south being more appropriate).

A specific panel yield of 7 m^2/kWp is assumed for all scenarios.

The cost of solar PV is taken to be £1500/kW.

Fuel Emission Factors

For scenarios 1 to 5, a consistent set of fuel emission factors have been assumed for all scenarios across 2010, 2013 and 2016. These are taken from Table 12 in SAP 2009 (March 2010) and are summarised in Table 44 below.

Carbon Emission Factors		
natural gas	0.198	kg/kWh
biomass pellet	0.028	kg/kWh
electricity imported (all scenarios)	0.517	kg/kWh
electricity displaced due to CHP operation	0.529	kg/kWh

Table 44 Carbon Emission Factor Assumptions for Scenarios 1 to 5

The basis for assuming common fuel emission factor assumptions across all years is as follows:-

1. The basis for the comparative calculations across 2010, 2013 and 2016 is the London Plan which stipulates as a basis for 2013 and 2016 Target Emission Rate (TER) assumptions, an improvement over a particular building's Part L 2010 TER. Therefore, in order to stay consistent with improvements over the 2010 TER it is appropriate to use the same fuel CO2 emission rates.
2. Currently energy compliance modelling software, for both domestic and nondomestic developments, is geared towards the assessment of Part L 2010 compliance and prevents the use of alternative fuel emission rates for the assessment when attempting to model future scenarios.
3. The fuel emission factors for both 2013 and 2016 are not confirmed at the present time.

For scenario 6, the district heating scenario, carbon emission factors used in the modelling have been calculated from the results of the district heating analysis. The relevant emission factors are summarised below. These assume that the benefit of the electricity offset is attributed to the heat supplied to the buildings and represent the average emission factors for the heat as delivered over the life of the project.

Carbon Emission Factors for Scenario 6		
Gas CHP energy Centre Option	0.068	kg/kWh
Gas CHP energy Centre Option with Seneca Plant	0.048	kg/kWh

Table 45 Calculated Carbon Emission Factors for Scenario 6

APPENDIX 4 WASTE RESOURCE APPRAISAL

Background to WLWA MSW Waste Contracts

Residual waste

WLWA residual waste treatment contract which is currently being procured for next 25 years. Procurement is for all of the available residual waste including the MSW by or on behalf of LB Brent. The contract will lock in the available waste streams and although there may be some flexibility in tonnage, this won't be known until the volume of waste arisings at a particular time are known and we know who the preferred bidder is.

If WLWA wanted to consider an alternative to that contract we would need to satisfy the requirement of the Public Contract Regulations as well as the necessary notifications and negotiations under the GLA Acts relating to the Mayor of London.

When the residual waste contract is coming to an end WLWA will begin a new process to procure treatment options for the future that meet the needs at that time. At this stage, there may be opportunity to secure this waste stream although it is noted that the waste stream has changed significantly over the last 25 years, in the next 25 waste arisings and technologies are likely to change significantly again so we cannot predict what may happen at the end of this contract.

Organic Waste

WLWA already has contracts in place for green waste only, mixed food and green waste and food waste only. For segregated food waste only the current tonnage is approximately 12,000 tpa. WLWA are anticipating re-tendering all of these contracts during 2013/14. The timing of the OJEU notice will depend on progress with the residual waste contract so whilst they hope the notice will be placed in Spring/Summer with the award before December and commencement in 2014 exact timings are not yet known.

AD facilities with PAS110 compliance already in place or shortly to be achieved may want to express interest, if there is a local facility that meets all the requirements we decide upon then we would of course welcome them alongside other tenderers. Whilst the length of contract hasn't yet been decided it is likely to be 2 or 3 years with the option to extend, at the Authority's discretion, for a similar period.

Scenario 1

This considers the waste arisings within the bounds of the study area for waste that is considered collectable by LBB and also considers the possibility of accepting additional waste arisings from large commercial facilities in the locality such as Ikea, Tesco, Asda and ENVAC. Waste arisings from within the regeneration area are assumed to come from existing, planned and potential developments.

These future developments have been identified and defined using a combination of sources, these include but are not limited to the Wembley Area Action plan, current planning applications and discussions with Brent Council's planning department.

Once identified total waste production from each development is calculated based on waste arising benchmarks for different building use definitions. These benchmarks have been taken from the Buro Happold Report from 2010 entitled "North West Lands Wembley Operational Waste Strategy". The benchmarks in this report are based on waste arisings for similar size past developments.

Existing building operators within the study area have been contacted and asked to contribute to this study. Unfortunately there has been a very low response to enquiries; only Ikea and ENVAC have contributed to the study. Ikea have indicated that they have approximately 1,000 tonnes of waste wood per annum available for a waste to energy project and ENVAC have provided waste production data for Forum House. These figures have been incorporated into the final analysis.

The total waste figures are further broken down into source separated totals. This is achieved using waste composition ratios for Municipal Solid Waste (MSW) and Commercial and Industrial Waste (C&IW). These breakdowns have been taken from the Greater London Authority Waste Composition Scoping Study Report; these breakdowns are contained in Figure 50 below.

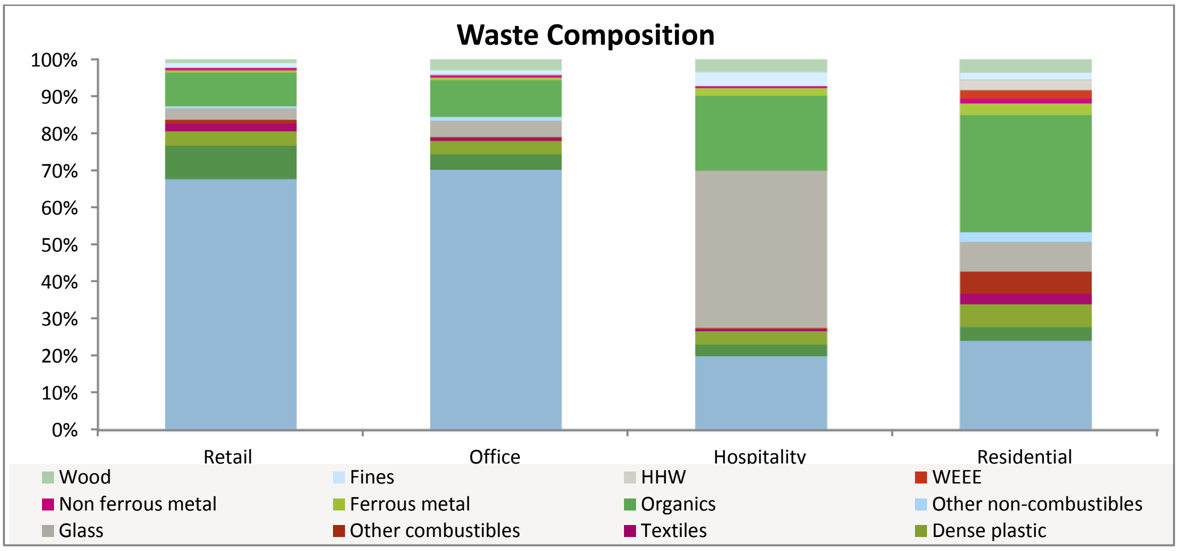


Figure 50 Waste Composition

Annual waste arising in the study area increase at varying rates between 2013 and 2031 as new developments are completed and begin producing waste. It is important to note that construction waste has not been considered in this report. The Mayor of London has set recycling rate targets for the next 20 years at 50% MSW by 2020 rising to 60% by 2030. 70% of all C&IW by 2020 is to be recycled, reused or composted; this level is to be maintained until 2030. These increased recycling rates and subsequent reduced residual waste available as EfW feedstock are taken into account in the final waste arising figures.

As a control exercise to validate the assumptions taken in the above analysis, the projected 2030 waste arisings for the study area were compared to those from the entire borough. The waste per head of population in the study area was found to be 1.04 tonnes/person/yr, compared to 1.05tonnes/person/yr for the borough. This favourable comparison allows us to be confident that the assumptions taken for the study area are in line with the standard established by the waste projections in the Mayor's London Plan and the subsequent Worchester report for Brent Borough

Scenario 2

For this scenario the area under consideration is extended to the entire Borough of Brent, that is, all available residual waste within the borough boundary, including only the portion of waste that is collectable by LBB. For the purposes of this study the projected waste arising figures as presented in the Worcester Polytechnic Report (WPI report) prepared for Brent Borough are assumed to be accurate estimates of the residual and organic waste streams over the next 20 years

The WPI report used waste arising projections for Brent Borough as presented in Chapter 5 of the London Plan. It is noted that WPI carried out a comparison exercise between the projected 2011 arisings in Brent with the actual amount of MSW collected in that year. This comparison showed that the London Plan had overestimated the MSW total tonnage by 30,000, the WPI report subsequently reduced the London Plan MSW estimates proportionally over the period 2016 to 2031 in order to more accurately represent the waste arisings expected in the Borough. C&IW figures from the London Plan remained unaltered as no comparison exercise was carried out, presumably due to the lack of dependable figures from the Borough for 2011. In the absence of any further information this report also assumes the London Plan C&IW figures are an accurate representation of the situation over the timeframe of this study.

This scenario assumes that both MSW and C&I waste are available, however it should be recognised that only the MSW portion can be considered to be a relatively secure EfW feedstock since it is collected by LBB and disposed of by the West London Waste Authority. This analysis is based on the presumption that a necessary precondition to the design and commissioning of an EfW plant would be to secure C&I waste in addition to MSW

Scenario 3

From discussions with the council it is considered unlikely that the entirety of the waste arisings from the Borough including both MSW and C&IW could be made available for and energy for waste scheme serving the regeneration area. More likely is that the waste from the immediate Wembley area may be used as a feedstock. Given the population density of the Wembley area and in the absence of specific waste arising data, it is assumed that 50% of the waste produced within the borough boundary arises in this area.

This 50% factor is applied to both MSW and C&IW, although once again it is assumed that this is only the portion collectable by LBB. As with scenario 2 though the MSW stream is the only possibly guaranteed waste source for the EfW plant the residual MSW waste in this scenario is too low to be the sole fuel source for a commercially viable EfW and as such this scenario is also based on the presumption that a necessary precondition to the design and commissioning of an EfW plant would be to secure C&I waste in addition to MSW.

This 50% scenario can also conveniently be used to consider the situation where only the MSW portion of the waste stream from the entire Brent area can be collected.

		2013			2016			2021			2026			2031		
		MSW tonnes/yr	C&IW tonnes/yr	Total tonnes/yr	MSW tonnes/yr	C&IW tonnes/yr	Total tonnes/yr	MSW tonnes/yr	C&IW tonnes/yr	Total tonnes/yr	MSW tonnes/yr	C&IW tonnes/yr	Total tonnes/yr	MSW tonnes/yr	C&IW tonnes/yr	Total tonnes/yr
Scenario 1 Wembley Regeneration Area	Recycled	163	661	824	372	1,740	2,112	1,277	3,871	5,148	2,441	5,698	8,139	3,118	6,930	10,048
	Organics Non-Food*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Organics Food	291	415	706	553	729	1,282	1,555	1,301	2,857	2,676	1,712	4,388	3,246	1,956	5,202
	Residual	448	2,760	3,208	788	4,456	5,244	2,079	6,838	8,917	3,358	8,217	11,574	3,969	9,008	12,977
	Total	902	3,836	4,738	1,712	6,926	8,638	4,911	12,011	16,922	8,474	15,627	24,101	10,333	17,895	28,227
Scenario 2 London Borough of Brent	Recycled	21,313	80,600	101,913	25,250	80,000	105,250	28,000	79,600	107,600	30,500	78,400	108,900	36,250	77,600	113,850
	Organics Non-Food	9,656	20,148	29,804	12,375	19,998	32,373	14,000	19,898	33,898	16,000	19,598	35,598	17,750	19,400	37,150
	Organics Food	9,656	40,300	49,956	12,375	40,002	52,377	14,000	39,802	53,802	16,000	39,202	55,202	17,750	38,800	56,550
	Residual	63,063	60,450	123,513	57,250	60,000	117,250	55,000	59,700	114,700	52,500	58,800	111,300	47,250	58,200	105,450
	Total	103,688	201,498	305,186	107,250	200,000	307,250	111,000	199,000	310,000	115,000	196,000	311,000	119,000	194,000	313,000
Scenario 3 Wembley Area	Recycled	10,820	41,061	51,880	12,997	41,740	54,737	15,277	43,671	58,948	17,691	44,898	62,589	21,243	45,730	66,973
	Organics Non-Food	4,828	10,099	14,927	6,188	9,999	16,187	7,000	9,949	16,949	8,000	9,799	17,799	8,875	9,699	18,574
	Organics Food	5,120	20,616	25,736	6,740	20,730	27,471	8,555	21,202	29,758	10,676	21,313	31,989	12,121	21,357	33,478
	Residual	31,979	33,060	65,039	29,413	34,456	63,869	29,579	36,688	66,267	29,608	37,617	67,224	27,594	38,108	65,702
	Total	52,746	104,836	157,582	55,337	106,926	162,263	60,411	111,511	171,922	65,974	113,627	179,601	69,833	114,895	184,727

Table 46 Tabulated Waste Resource Analysis

*** For the Developments in the Wembley Regeneration Area the proportion of organic waste that is non-food has been considered negligible given the nature of developments and the anticipated high level of recycling.**

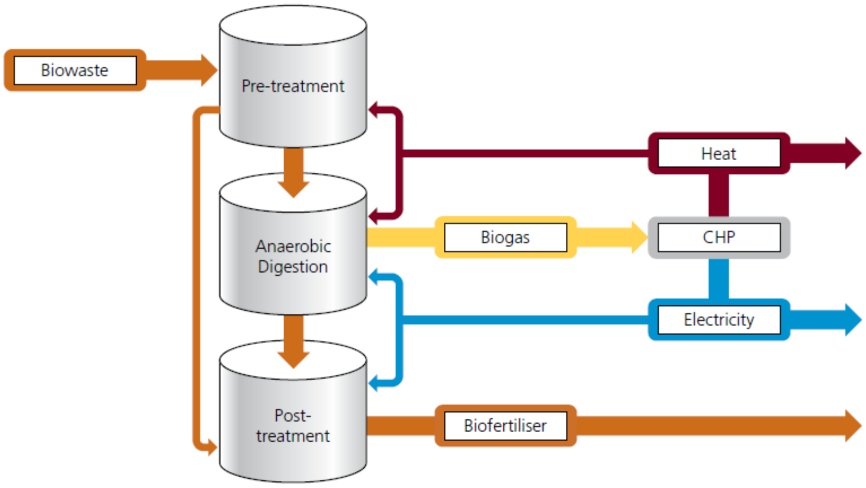
APPENDIX 5 WASTE TO ENERGY TECHNOLOGY APPRAISAL

<u>Anaerobic digestion</u>

The organic content of the waste is biologically converted - in an environment without oxygen - to the energy rich methane gas (CH_4) and the inert carbon dioxide gas (CO_2).

The process typically converts around 40-60% of the organic carbon in the waste. This means that around 40-60% of the energy content of the organic matter is realised to the gas phase. The actual conversion rate of the organic matter depends on process parameters and biodegradability of the organic matter. Typically garden waste is relatively difficult to biodegrade whereas fats and carbohydrates are easily biodegradable. The remaining organic matter ends up in the digestate from the process, which – depending on quality and market options - may be used as fertiliser or sent to landfill.

Figure 51 – Technical concept of anaerobic digestion /1/



The main advantage of anaerobic digestion - compared to thermal processes - is that no evaporation of the water in the waste is required to recover energy of the biodegradable material. The energy content of the biodegradable organic matter is released to the gas phase through production of biogas.

The produced biogas can be utilised in a number of ways such as:

- Combustion in a gas boiler for heat production
- Combustion in a reciprocating gas-engine for electricity and heat production
- Upgrading to natural gas grid quality and injection into gas grid.

The efficiency of a reciprocating engine is relatively high – typically around 38 to 42% - and it is possible to install a boiler to recover additional 30-50% energy from the hot exhaust gases.

However, the overall energy recovery efficiency of the organic matter through the anaerobic process is significantly lower as only part of the organic matter is transferred to the biogas phase and hence recovered.

There are a number of technical concepts for the anaerobic process. These can be divided into:

- Dry process (>30% dry matter)
- Wet process (<10% dry matter) where the organic matter is pumpable.

Dry systems may be used for organic waste from households, whereas the wet process often is used if the organic waste is mixed with sludge or other industrial waste streams. The biological process typically takes place at 37 °C (mesophilic) or 52 °C (thermophilic) to ensure optimal biological conditions. The latter process is the fastest process, but also more difficult to control potential ammonia inhibition of the process.

At this project stage it is considered feasible to evaluate 'Anaerobic digestion' as a general concept. No distinction will be made between the different technical concepts.

Thermal Treatment by Combustion Technology

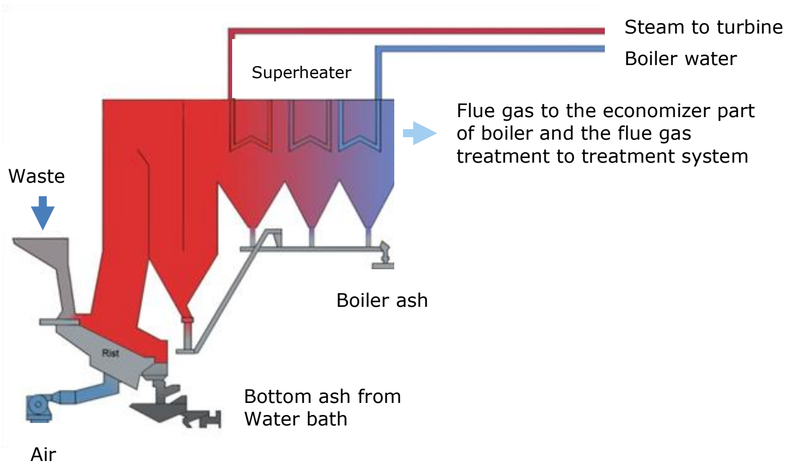
The traditional thermal treatment method is mass burn. Recovery of heat has been common for 60-70 years and electricity production for 30-40 years.

Continuous optimisation of the mass burn (also called grate-fired) concept has made it possible to transfer around 85-90% of the energy to the boiler and to convert around 30-35% of this energy into electricity by a steam-driven turbine. The reason that electricity efficiency from waste incineration is lower than electricity efficiency from coal power plants is due to limitation of the steam parameters in order to minimize corrosion.

The technical concept is illustrated in Figure 52. The residual waste is taken from the bunker by a crane and dropped into a chute. From the bottom of the chute the waste is mechanically pushed onto the grate. The waste is combusted on an inclined grate where air is injected from below. The waste is pushed forward on the grate and the bottom ash drops into a waterbath at the end of the grate.

Complete gas phase combustion is reached by injection of secondary air above the grate. Auxiliary oil/gas burners ensure that a minimum temperature of 850°C in minimum 2 seconds is reached (EU requirement) in the secondary combustion zone.

Figure 52 – Technical concept of grate fired waste incineration



Steam parameters of the boiler system are typically 40bar and 400°C when the steam is used in a turbine for electricity production. The steam parameters can be lowered for heat-only plant. Many facilities are now being developed with even higher steam parameters (e.g. 60 bars and 425°C).

The flue gas is typically treated in a dry system, where hydrated lime/sodium bicarbonate is injected upstream of a large filter in order to absorb the acidic gases (HCl, SO_2 and HF). Activated carbon is added to adsorb heavy metal compounds, and dioxins. The residue from the filter requires hazardous waste disposal. The NOx content is typically reduced by injection of ammonia water into the furnace, the so-called SNCR process.

The bottom ash is treated by removal of metals and oversize items, crushing, sorting into size based fractions and open air maturation of the sorted fractions. Bottom ash is in general classified as non-hazardous waste and can be used for construction projects, such a substitution of gravel for base-layer under roads.

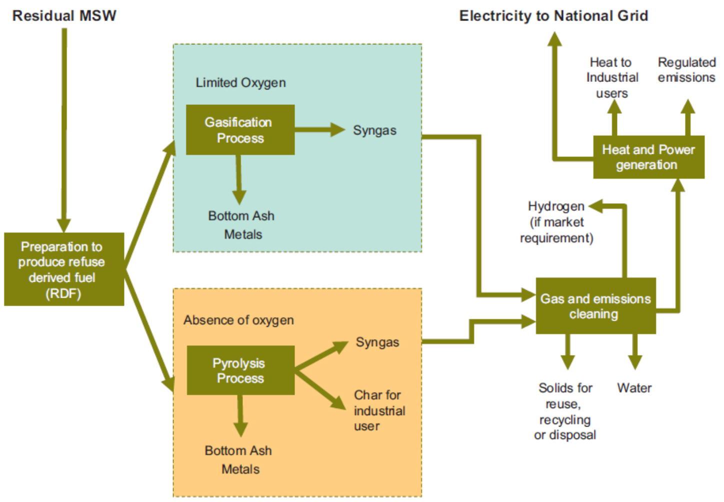
Thermal Treatment by Gasification Technology

During the last 20-30 years other thermal treatment technologies – such as pyrolysis and gasification - have been developed with vision of:

- Increasing energy efficiency compared to traditional grate technology
- Production of a storable fuel instead of electricity
- Reduction of potential environmental impacts from bottom ash and flue gas treatment residues.

The illustration in figure 3 shows that both gasification and pyrolysis processes produce an energy rich gas, the syngas. The syngas can be cleaned and fired in a reciprocating engine, which may have a significant higher electrical efficiency compared to a boiler system with steam turbine (reciprocating engines has an electricity efficiency around 38 - 42% compared to around 30% for steam turbine). However, in practice a steam cycle is often preferred over a reciprocating engine due to operational risks. Reciprocating engines are especially sensitive to the tar content of the syngas.

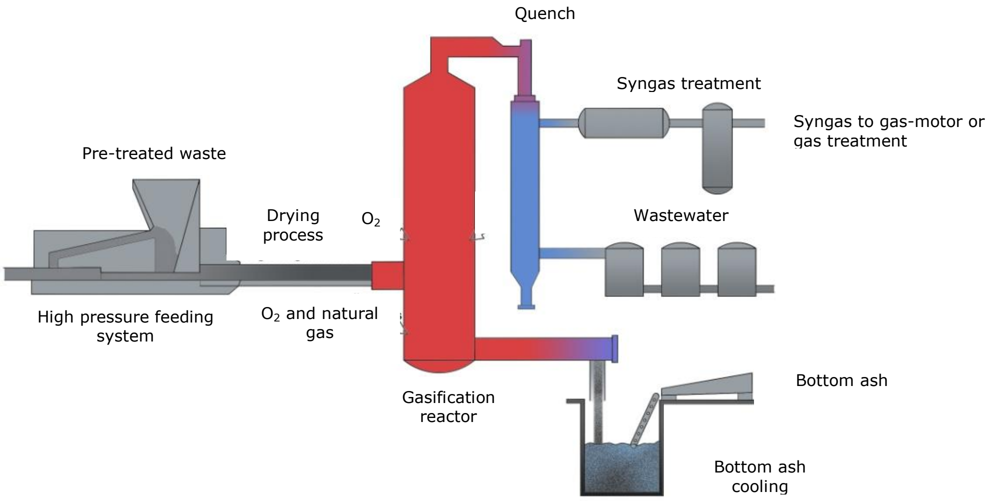
Figure 53 – Illustration of the main principles of thermal gasification



The technical concept varies significantly between the different suppliers such as Thermoselect, Ebara, Doosan Babcock, Metso and Nippon Steel.

The illustration in Figure 54 shows the concept of the Thermo Select concept which is installed at a number of Japanese facilities. The waste is indirectly exposed to a high temperature which causes the organic matter to crack and transfer into gases. Only limited oxygen is added to ensure that limited combustion takes place at this stage. The energy is therefore preserved in the syngas which may be used for energy recovery or other processes.

Figure 54 – Illustration of the main principles of thermal gasification (Thermo Select concept)



The hot flue gas is cooled by water injection in a quench prior to further gas treatment. The flue gas can be treated in a similar system as for grate fired facilities.

The inert fraction of the waste melts at the high temperature and the molten slag is subsequently cooled in a water bath. The cooled material is sorted with magnets and the remaining material can be used in construction. The material is often marketed by the suppliers as more environmental friendly than conventional bottom ash due to reduction of the potential leaching of heavy metals from the material. However, there is some uncertainty of the actual improvement of the leaching properties.

One technology supplier (Energos) has developed a two stage combustion process. The first stage is gasification with limited oxygen whereas the second stage is a combustion process with excess of oxygen. The boiler system, flue gas treatment and bottom ash system of the Energos concept is quite similar to a grate fired technology. Therefore, the Energos process bears strong resemblance to grate fired combustion technology. However, it is listed in this chapter since it is categorised as ‘advanced thermal treatment technology’ within the ROCs programme.

Two technology suppliers (AlterNRG and Plasco Energy Group) are promoting a variant of thermal gasification called plasma technology. The energy source for the cracking of the organic matter is an ionized gas produced by emitting gas through an electrical arc, where the gas reaches a temperature up to 3500°C. The high temperature vitrifies the bottom ash into a glassy clinker. The suppliers refer to three facilities, but the actual operational situation is unclear and no information seems to be publicly available. This technology is evaluated as not commercial ready for waste treatment and is therefore not discussed further in this report.

<u>Future perspective of technology – 10 years from now</u>

Numerous gasification plants have been established in Japan during the last 20 years. These plants have significantly lower energy efficiency compared to modern grate technology as the energy from the syngas is utilised in a conventional boiler and steam-turbine system. The lower energy efficiency is due to such issues as initial size reduction of the input waste and additional fuel/enriched O_2 air to reach the higher temperatures required to melt the bottom ash.

The usage of syngas for higher efficiency energy recovery such as fuel production or firing gas turbines has been undertaken for a number of years funded by research investments. However, a reduced level of research has been undertaken the last 10 years. The reasons are significant technical problems and financial unattractiveness compared with the conventional boiler concept.

Therefore, it is unlikely the potential efficiency of the gasification concepts will increase significantly within the next 10 years, unless this type of plant is significantly subsidised. However, the technical problems may not be solved in an acceptable way. The technology is in general not significantly subsidised - compared to grate technology - outside the UK.

Option C – EfW plant

The scale of plant required for a commercially viable installation for an EfW plant is significant and in most cases is too large to be accommodated in the space available anywhere other than site B. Air Quality is a major concern for EfW plants and the location of Site B in a heavy industrial area with no residential and commercial neighbours of significance is very important. Increased particle emissions associated with an EfW plant would most likely pose an issue for planning. Additionally increases in the size and volume of heavy vehicles bringing the EfW feedstock to site can be more easily accommodated at Site B where there is a history of such traffic movements associated with the Seneca facility and the aggregate storage facility currently located at the site. There would be a lesser impact on the roads and traffic closer to the central commercial and residential portion of the Wembley regeneration area.

With regard to Site A we would only recommend a small scale waste to energy plant of a type suitable for a residential area and even this may be constrained by planning objections and of course commercial viability factors. We recommend directing larger scale and more impactful plants further east to site B.

As has been discussed in detail in Section 4 it is not likely that a full scale commercially viable grate-fired plant could ever be developed in the Wembley regeneration are based on the available waste resource. The most likely option is a gasification plant and even this is unlikely to come forward prior to 2042 due to waste contract constraints on waste availability. It may be that in 2042, at the end of the proposed project lifetime that provided contracts could be negotiated in good time and a developer/operator could be found for such a plant, this could replace the 2018 to 2040 project proposal (Options A or B) and thus enable the scheme to fully separate itself from fossil fuels depending on the scale of plant constructed. Any such scheme is entirely dependent on the ability of a developer to secure contracts for the disposal of the necessary waste resource, planning regulations in place at the time and the local position on the plant.

An additional opportunity is that a medium scale anaerobic digestion plant could be constructed based on available organic waste volumes, the contracts for the disposal of this waste are re-negotiated every 3-4 years. This option could only provide just under one-fifth of the heat demand in 2030 and thus can only ever form part of a larger solution, though as a means of decarbonising the fuel and reducing the dependence of the project on natural gas, biogas from this plant does have some value.

Both of these options are considered unlikely to come forward due to the dependence on contract negotiations and the general lack of appetite of the public for energy from waste projects of this type.

APPENDIX 6 INVESTMENT AND CARBON MODELLING ASSUMPTIONS FOR DECENTRALISED ENERGY MODELLING

Economic Modelling Assumptions

Scheme economics have been calculated around required Internal Rates of Return of 10 %, 6 % and 3.5 % to reflect private sector, public sector led schemes and investment according to HM Treasury Green Book guidelines.

Project Term

The financial value of the project and the calculation period for Internal Rate of Return (IRR) and Net Present Value calculation (NPV) is taken to be 25 years on the basis of a scheme beginning operation in 2018 and with a nominal end date of 2042. Initial investment is assumed to take place in 2017.

Project Investment Costs

Construction cost estimates have been based on benchmarks from other projects. This includes reference to UK projects and Ramboll's experience of similar projects carried out in Denmark (translated to UK prices. Project specific evaluation and verification of costs data has not been carried out at this stage in the assessment process as this is outside the scope of this project. Heat network construction costs are based on previous quotations from district heating pipe system suppliers, corrected for 2013 prices based on inflation under the Retail Price Index. These costs cover the supply and installation of the pipe systems in both hard and soft dig. The proportion of hard to soft dig on this project has been assumed to be 70:30 due to the urban nature of the scheme. Costs of installing DH pipe systems in hard dig areas are taken to be 15% higher than for soft dig.

The economic modelling has assumed that a single Project Company would finance the investment in the heat network and associated infrastructure assets[35].

In the case of the Seneca option, these incudes costs for interfacing the biomass facility to the heat network, but not investment in the biomass facility itself, which would be financed under a separate business case. In order to capture the heat from the Seneca biomass facility for use in the proposed scheme, the plant would need to be configured for CHP and a heat exchanger station would be required to interface between the plant and the energy centre serving the heat network. The capital investment attributed to the project for this purpose is taken to be associated with the heat exchanger station only at this stage. It is recognised that there may be an additional cost associated with conversion of the facility to operation as a CHP plant, although this has not been captured, other than through assumptions around effective cost of heat production from the plant (refer to section below). The business case for investing in the biomass facility as a CHP plant as opposed to an electricity-only generation facility will need to be carried out at the next stage. The outcome of this would be a key determining factor in whether there is a case for taking the project forward.

Project planning, development, design and commissioning costs have been taken to be 14% of construction costs (5.5% development, planning and legal costs, 6% engineering and architectural design and 2% testing and commissioning). An additional 2% of initial CAPEX costs is included for Contractor's Preliminaries.

Reinvestment costs in the heating and cooling networks, including all associated network infrastructure assets, are based on assumed annual reinvestment and replacement rate of 0.25% of the cumulative network CAPEX costs. This figure is based on our previous experience on existing projects in Denmark and the UK. This has been included in the financial model as an annual set aside value.

Plant reinvestment costs have been calculated based on a 15 year reinvestment cycle at varying technology-dependent rates, 70% of initial capital investment for Gas CHP units, 20% for the thermal store, 50% for gas boilers and the heat exchanger substation at the SENECA biomass facility.

[35] , either private sector in the form of an ESCO, a publically driven vehicle headed by the London Borough of Brent or a public -private partnership between LBB and a local developer or LBB and an ESCO

The cost of financing this scheme has not been modelled here, this action should be taken at a later stage should the project proceed.

Land Values for the energy centre site have been based on commercial land evaluations carried out and reported on by BNP Paribas Real Estate. The calculations are based on an industrial site and incorporates a number of factors for similar sites such as:-

- Current land value,
- Gross development value of land at present,
- Development costs,
- Admin costs,
- Revenue in rental value
- Purchaser's Costs
- Existing Use Value
- Existing Use Area

This has resulted in a land valuation for industrial land in the Wembley Regeneration Area of £654 /m^2. An additional reduction in land value of 20% has been applied to simulate the land value at the Seneca plant (a more industrialised area within the Wembley Regeneration area presumed to have a lesser value). The resulting in a final land value is taken to be £523/m^2 at this location.

Developer Contributions

District Heating

In order to test the "worst case scenario" for the district heating scheme it has been assumed that no developer contributions would be available to the project. That is, the project is assumed to bear the cost of the distribution heat network, the energy generation plant and cost of connection for existing and new developments to the scheme, including service pipes to individual buildings and heat exchanger stations. In reality, new developments could potentially meet the cost of service pipes and heat exchanger stations themselves. If /when the Zero Carbon Homes Policy is adopted they might also be in a position to contribute more through the Allowable Solutions mechanism. The impact of developer contributions to cover the cost of service pipes and heat exchanger stations has therefore been tested and is reported in the main body of the report. A basis for levying developer contributions is also discussed in Section 3 of the report.

The costs associated with the internal infrastructure for individual developments (i.e. internal building DH pipework) are assumed to be borne by developers.

In order to ensure that new buildings are compatible with the proposed district heating network specific planning obligations will be required for all new planning applications within the scheme boundaries. The value associated with these networks is assumed to be realised by the developers through the selling and letting of the developments and is not therefore included in the project model.

District Cooling

Developer contributions have been included in the district cooling project for the developments constructed from 2016 and onwards with the cost of £690 / kW as and when the developments are connected to the network.

For the district cooling network the costs associated with the internal infrastructure for individual developments (secondary network) are assumed to be borne by the developers where necessary, with the scheme bearing the cost of the primary cooling network distribution mains and the heat exchanger costs. In order to ensure all schemes are compatible with the proposed scheme specific planning obligations will need to be applied to new planning applications within the scheme boundaries. The value associated with these networks is assumed to be realised by the developers through the selling and letting of the developments and is not therefore included in the project model.

Operating Revenues

Electricity Selling Arrangements

Two models for selling electricity from the gas fired CHP installed at the energy centre have been considered:-

1) Retailing electricity under a Electricity Licence Lite arrangement
2) Selling electricity directly into the wholesale market as spill[36] electricity

These are explained below in further detail. The options of entering into a sell and buy back arrangement with a Supplier (i.e. netting off) and supplying local customers under a private wire network have not been considered as explained in the main body of the report.

Electricity Licence Lite

In 2009, Ofgem introduced its Electricity Supply Licence Lite proposals, intended to make it easier for embedded generators, including decentralised energy projects, to operate as licensed suppliers across the public electricity network.

Under the proposed 'Licence Lite', the project could enter into a 'supplier services agreement' with a licensed third party supplier and benefit from being able to retail electricity generated to residential, commercial, retail and public sector consumers within the local distribution network[37], whilst also avoiding the many of the cost overheads associated with setting up and operating a full electricity supply licence. The electricity supply customer base would not necessarily need to be the same customer base receiving heat from the project and the customer base could therefore be matched to the export capacity of the project.

The value of the retailed electricity could be expected to be comparable to concurrent prices paid by customers under the project, with an incentive or discount to attract and retain them over an on-going period.

There are currently no junior electricity / Licence Lite projects in operation although GLA and Ofgem have been working together with selected London Boroughs to finalise project proposals and establish the first Licence Lite projects in London[38]. To that end, the GLA has recently applied to Ofgem for a junior electricity supply licence/Licence Lite licence to allow it to purchase the energy produced independently by local authorities and sell it directly onto other public sector buildings. Once the GLA has received its licence from Ofgem, it will go out to tender to the licensed third party suppliers to find a project partner. The scheme is expected to be up and running by 2014 at which time the GLA will be able to sell power from London boroughs to other public sector users. At present, the intention is that private businesses could only get involved by partnering with a local authority and selling the energy via the GLA's Licence Lite. However, in due course, it is intended that private companies will be able to sell and buy power via the Licence Lite arrangement independently of any local authority's involvement. It is anticipated that by 2015 the concept of Licence Lite will have been successfully proven and that local generators including Local Authorities and private commercial organisations would be able to operate under such licences at that time.

The cost of administrating the Licence Lite is unclear at the present time, since there are no operational projects against which to benchmark (the economic modelling in this study does not take into account set-up costs for a Licence Lite, although it does include an estimation of on-going administration costs). The GLA is currently conducting work in this area and, whilst early adopters are likely to incur relatively high setting up and running costs, the intention would ultimately be to pool the administrative burden of setting up and operating a Licence Lite across a number of projects so that the operating margins would be acceptable to small generators.

In the modelling carried out, it is assumed that the net value to the projects would be 8.8 p/kWhr, reflecting a mix of residential and commercial customers connecting to the project, a 10% incentive on their alternative prices to attract and retain them and an operating overhead

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[36] Spill electricity is a term normally used for CHP electricity surplus to local demand and therefore 'spilled' to grid at low value.

[37] Retailing into the strategic network would probably be un-economic due to the Transmission Use of System (TUoS) charges arising

[38] A group of six London supervisory councils (WF, Hackney, Haringey, Camden, and Islington) are currently working with GLA to establish Licence Lite.

payable on a p/kWhr basis. This assumption needs to be tested at the next stage, if the project opportunities are taken forward.

Electricity supply into the wholesale market

The simplest alternative arrangement for the project would be to sell electricity directly to the wholesale market. However, due to its intermittent nature and the small volumes involved, the value of the electricity generated would be low in market. For this reason, the wholesaling arrangement represents the least favourable option to the project and is considered to be worst case a viable arrangement under which any of the projects could operate.

In the modelling carried out, the value of electricity sold by the projects into the wholesale market is assumed to be 5 p/kWh.

Heat Sales (district heating scheme)

In the following sections the assumptions made in relation to the available revenues from scheme heat sales are presented. These assumptions have been used to inform the economic model developed for the scheme and the IRR and NPV values presented in the main body of this report are based on the information below.

As described previously, costs of connection to the heat network are modelled by assuming that these are borne by the Project, which would recover the costs through annual capacity charges and consumption charges.

It is likely that any operator's connection model will involve the following elements:

- Connection charge – a one-off payment for connection to the network for new customers, this is dependent on the cost to the scheme of providing connection assets and on the economic model pursued by the project developer.
- Capacity Charge - this is payable monthly and is dependent on the capacity of the connection. It is intended to cover fixed operating costs of the scheme (lifecycle replacement costs and fixed maintenance costs of the primary plant and heat network).
- Consumption Charge - payable monthly for metered heat supplied to the customer, there is also the possibility that this charge could be linked to development return temperatures to incentivise customers to make the most efficient use of the supplied heat and thus to return water at low temperatures.

For the purposes of this economic model, annual equivalent heat charges to consumers have been calculated on the basis of their avoided heat generation costs under the business as usual case.

For new developments this is as calculated in the evidence base for this project under Section 3 of this report. For these customers, the avoided cost of heat generation is taken to comprise avoided investment costs in the LZC plant, avoided fuel costs, avoided operation and maintenance costs and avoided plant reinvestment costs (assuming a 15 year replacement cycle). The calculated heat prices assume these schemes would develop through energy companies who would invest and require a 10% rate of return on this investment. For existing customers, the avoided cost of heat generation is taken to comprise avoided fuel costs, avoided operation and maintenance costs and avoided plant reinvestment costs (assuming a 15 year replacement cycle) on the basis that existing assets would be in place.

Customer heat prices for each customer type in the business as usual scenario are presented in Table 47. Also shown is the heat price to customers under the district heating scheme. This includes the variable tariff that would be paid to reflect avoided fuel costs along with a capacity charge to reflect avoided O&M costs and avoided annualised replacement/refurbishment costs.

	Effective Heat Price
Customer Type	p/kWh
Large Commercial - existing	3.6
Medium Commercial - existing	4.7
Hotel - Planned	5.0

Medium Office/Retail- Planned	4.4
London Borough of Brent	3.6
Residential - planned	5.3
Residential - existing	6.1
Light Industrial	3.6
Large Commercial (office/Retail) - planned	4.7
Community users	3.6

Table 47: Heat Tariff Assumptions

The impact of incentivising existing customers to connect to the scheme has been modelled as a 5% reduction in business as usual heat price. This is reflected in Table 47.

Where relevant it has been assumed that a proportion of the benefit of avoided CRC payments for existing customers would accrue to the project. A rate of 8 £/tonne CO_2 saved has been applied.

The 2011 Budget removed Climate Change Levy Exemption Certificate support[39] for new and existing CHP plants. This was subsequently confirmed in the 2012 Budget. There is uncertainty around what the impact of the government's Electricity Market Reform proposals will be on support for gas CHP (i.e. whether equivalent levels of support will be provided to replace the Climate Change Levy Exemption Certificates). Due to this uncertainty and in order to evaluate the project opportunities as "worst case scenarios" Carbon price support for CHPs has not been modelled.

Coolth Sales (District Cooling scheme)

The business as usual case for buildings within the Wembley Regeneration Area in the event that a district cooling network does not come forward is taken to be air cooled, electrical chiller systems with seasonal energy efficiency ratios of 4 and their respective electricity price based on the quarterly energy prices according to their respective demand.
Customer coolth prices for each customer type in the business as usual scenario are presented in Table 48; these figures are based on 2012 electricity values. Also shown is the coolth price to customers under the district cooling scheme. This includes the variable tariff that would be paid to reflect avoided fuel costs including avoided O&M costs along with a capacity charge for avoided annualised replacement/refurbishment costs. The rightmost column indicates the effective price per kWh.

	Alternative coolth price	Incentivised coolth price	cooling demand	Cooling demand	Capacity charge	Total cost per cooling demand
Customer Type	p/kWh	p/kWh	MWh	%	£	p/kWh
Large Commercial - existing	5.24	4.98	545	4%	35,212	11.44
Medium Commercial - existing	5.58	5.30	157	1%	10,177	11.76
Hotel - planned	5.24	4.98	1,653	12%	106,846	11.44
Medium Office/Retail - planned	5.58	5.30	3,124	22%	202,424	11.78
London Borough of Brent	5.24	4.98	470	3%	30,401	11.44
Residential - planned	6.01	5.71	4,062	29%	262,558	12.17
Large Office/Retail - planned	5.24	4.98	4,155	29%	268,556	11.44
Community users	6.01	5.71	60	0%	3,878	12.17
Other Public	5.24	4.98	22	0%	1,390	11.44

Table 48: Coolth Tariff Assumptions

[39] Climate Change Levy Exemption Certificates (LECs) are tradable certificates that enable electricity exported to the grid from combined heat and power (CHP) plants to be exempted from the Climate Change Levy.

Item	Unit	Qty	CAPEX	REPEX	REPEX after
		-	£k	£k	years
Thermal store	m3	11,500	1,517	303	15
Chillers and equipment	kW thermal	11,785	3,276	1,638	15
Substations	kW thermal	23,337	811	-	-
Network	m	5,114	6,991	-	-
Energy Centre and Land Value	m2	637	1,289	-	-
Development costs	%	2.5	396	-	-
Developer contributions	No.	36	12,853	-	-
Sub Total			**14,280**	**1,941**	
Total			**16,221**		

Table 49: Summary of the district cooling head line figures

Item	Unit	Qty	CAPEX	REPEX	REPEX after
		-	£k	£k	years
Alternative Scenario	kW thermal	18,628	12,853	15,206	during 15 years at 10% discount rate
Total			**22,629**		

Table 50: CAPEX for the alternative solution

Consumers have been modelled as having a 5% discount on the re-investment charge and coolth price in order to incentivise connections to the network. The re-investment, REPEX, assumption is based on 70% of the installation cost.

Operating Costs

Cost of Purchasing Heat from Heat Generators

The cost of purchasing heat from Seneca has been modelled from 0 p/kWh to 2 p/kWh, with a central estimate of 0.5 p/kWh.

Fuel Price Assumptions for District Cooling Opportunity

Energy prices are taken from DECC quarterly forecasts. Energy price variations/increases above inflation are not modelled.

Electricity prices for the Project have been modelled based on the UKPN Eastern wholesale costs for 2011. These were averaged for both weekdays and weekend days per hour per month and divided into 28 tariffs. The average prices are shown in figure XX below for weekdays. The Distribution Use of System (DUoS) charges are included as well as the losses addition to the metered energy. In addition to these a daily charge and a capacity charge has been added to the total costs.

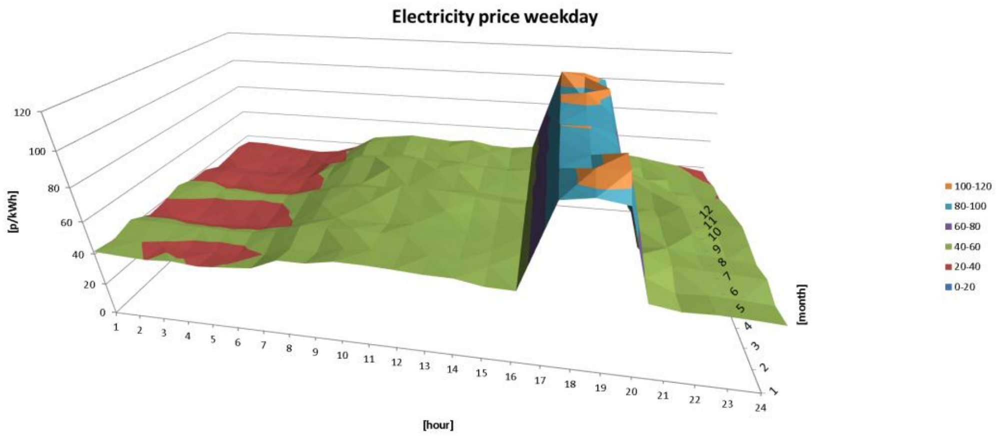


Figure 55 Electricity price assumption for weekday operation

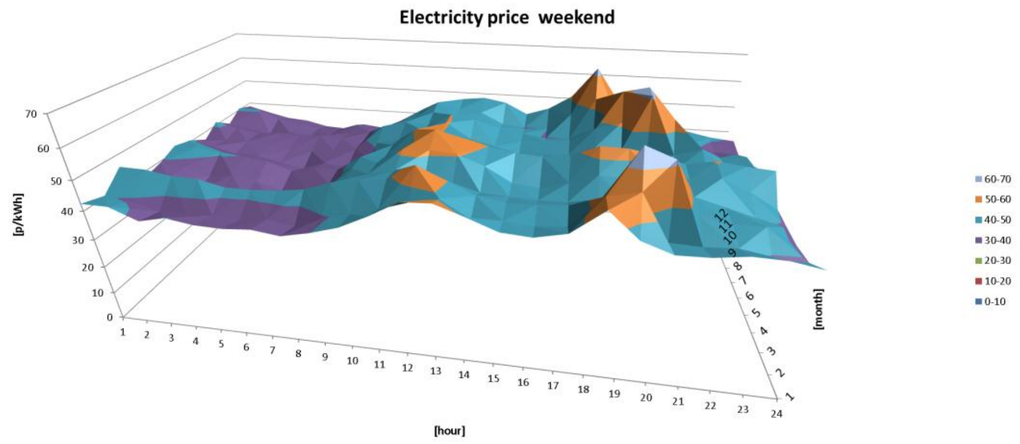


Figure 56 Electricity price assumption for weekend operation

The modelled average electricity price paid is 4.4 p/kWh which is due to most of the electricity being used at night time when the tariffs are lower. It should be pointed out that the economic performance is not sensitive to the electricity purchase price. A 10% change in electricity price changes the IRR by less than 1%.

Scheme Operation and Maintenance Overheads – District Heating Opportunity

Operation and maintenance costs are modelled as variable running costs accruing on per kWh basis and as fixed administration costs associated with operational and staff overheads. Staffing overheads assume an operating team consisting of a Plant Manager, Plant Engineers, and Administration Support.

Variable costs include operation and maintenance of specific heat production units as well those associated with general energy centre operating overheads (e.g. water treatment, general repair, consumables etc.).

Heat network pumping and heat loss costs are modelled from results of hydraulic calculations using System Rornet assuming variable volume, variable temperature operation. Heat losses are modelled in kW per unit length of network. Pumping losses assume a cubic relationship with demand.

Scheme Operation and Maintenance Overheads – District Cooling Opportunity

Operation and maintenance costs are modelled as fixed per year costs of 2.5% of investment costs for the thermal store and chillers.

Network maintenance and replacement cost is modelled as 0.25% of total so far spent capex per year.

Cooling network pumping and heat gain costs are modelled based on results of hydraulic calculations using System Rornet assuming variable volume operation. Heat gains are modelled in kW per unit length of network per pipe size. Pumping losses assume a cubic relationship with demand.

Carbon Emission Assumptions

The business as usual for each customer is based on carbon emission factors quoted in SAP 2009 methodology.

Carbon emission factor calculations for the decentralised energy opportunities are based on values reported in the SAP 2009 methodology, with the exception of waste heat from the Seneca plant, which is taken to be have a carbon intensity of zero.

Sensitivity Analysis around Internal Rate of Return Calculations

A sensitivity analysis has been carried out for each project opportunity around the key variables that influence the IRR for the project. The results of the sensitivity analysis are presented within the relevant sections of this report.

The blue lines in the graphs represent the central estimate of the project IRR, based on the central estimates for the listed variable along the x-axis which were used to produce the economic indicators for the project.

The bars in the graphs show the changes in project IRR due to changes in the relevant listed variable, with all other variables being held constant. Red bars generally denote a % increase in the listed variable whilst green bars generally denote a % reduction in the listed variable.

Exceptions to this are variables such as the Carbon Price Support for CHP and connection costs, which are treated as half / removed variables.

Further information on each variable is presented below.

Electricity Selling Price: Variation in electricity selling price have been modelled as +/- 10% on the central estimate under the Electricity Licence Lite model. An additional sensitivity factor investigating the wholesaling of electricity at 5p/kWh has also been modelled.

Heat Purchase Price from Seneca: Variations in the cost of heat purchased from SENECA are taken to be 0 p/kWh, 1 p/kWh and 2 p/kWh.

Gas Purchase Price: Variations in gas purchase price have been modelled as +/- 10% on the centrally estimated purchase price for each project.

Project Total Capital: The uncertainty in project development costs has been modelled as +/- 10% around the central estimate. Uncertainties around development costs (design, panning, procurement), which are likely to be less significant than the CAPEX related costs, are included in this variation.

Operating Margin: The impact of uncertainty for the operating margin modelled as a +/-10% variation on the central estimate.

Heat Selling Price: The impact of heat selling price is modelled as a +/-10% variation on the central estimate of heat selling price for each individual customer type. Separately, the impact of incentive discounts on heat prices is also modelled as 0%, 5% and 10% of the avoided cost.

Maintenance Costs: The uncertainty in project fixed and variable operating costs has been modelled as +/- 10% around the central estimate. This includes the variation in annual sinking funds for reinvestment in the heat network and energy centre.

Developer Funding Costs 200%/100%/Off: The default assumes that the project pays for the connection costs to developments. The impact of this assumption is tested by reducing simulating the scenario that developers 100% and 200% of the calculated substation and service pipe costs.

Network Sizing Methodology

Heat Network

The heat network has been designed in accordance with the design parameters set out in the District Heating Manual for London, prepared by GLA and published in March 2013.

Accordingly, the design parameters assumed in this report are as follows:-

Design Parameter	
Maximum design pressure	16 bar
Design flow temperature	110 °C
Design return temperature	55°C

Table 51: Heat Network Design Parameter

The necessary pipe dimensions are estimated using the software package SR developed by Ramboll Energy. SR is a simulation program developed by Ramboll Energy for the specific purpose of carrying out hydraulic and thermal analysis of district heating networks. This modelling package has been used successfully in Ramboll Energy for over 20 years and has a proven track record in accurately modelling both large and small scale district heating schemes. The benefits of this model are twofold, both enabling "day-one" modelling of DH networks and allowing interim changes to existing networks to be quickly assessed on an on-going basis for our clients, our SR model created by our Danish team for the city of Copenhagen is continuously updated as that network evolves.

Pipe design parameters are taken from information provided by pipe manufacturer's to ensure the most accurate information possible is incorporated into the design if the scheme. The pipe diameter calculations are based on analysis of temperature differential between flow and return system, pressure levels, costs for piping and pipe velocity constraints.

Cooling Network

The cooling network design parameters assumed in this report are as follows:

Design Parameter	
Maximum design pressure	10 bar
Design flow temperature	5 °C
Design return temperature	13 °C

Table 52: Heat Network Design Parameter

The main importance for the network cost is the difference between the flow and average return temperature. The network sizing has been carried out with an 8 °C differential temperature. It should be noted that in networks work on 10 °C in Denmark and considering most buildings would be new the possibility to increase the differential temperature exists.

As for the heat network, the necessary pipe dimensions are estimated using the software package SR. See District Heating section above for more information.

Network Control Concept for District Heating Opportunity

The operating concept of the heat network is likely to be based on a variable flow, variable temperature design, in accordance with the design parameters set out the District Heating Manual for London prepared by GLA.

The working pressure will be controlled within the system to ensure the pressure and flow characteristics are met at critical locations in the network at all times. This will be achieved through distribution pumps operating to maintain a minimum pressure difference between flow and return at each customer, controlling to maintain a minimum pressure difference across the index point of the circuit. This will guarantee the required flow of heat to customer substations and ensure that heat demand is met at all times.

In addition to volume control, heat network delivery temperature will also be controlled on the basis of ambient temperature in order to minimise heat losses throughout the year and maximise capacity and lowest investment cost. The delivery temperature from heat production units into the heat network will be controlled through local mixing circuits at the heat production plants.

The primary flow temperate into the heat network will typically be controlled between[40] 80 °C and 95 °C when outdoor temperature exceeds +5°C. The primary flow temperate will then be increased to a maximum of 110 °C when the outdoor temperature reaches the design temperature of -5°C.

[40] Dependent on requirements of existing buildings connected to the heat network.

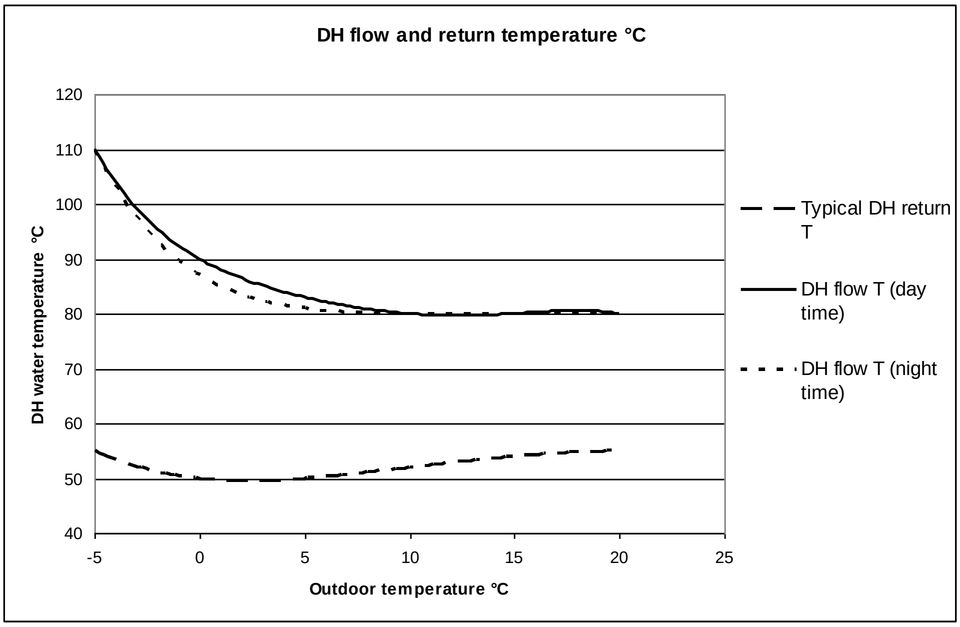


Figure 57: Typical Flow and Return Temperature Characteristics (image courtesy LDA/GLA)

The heat network will typically be pressurised at a single point. This should be located at the energy centre which will also house the primary distribution pumps, water treatment and pressurisation and expansion systems for the heat network.

Heat flow into customer substations will be controlled by 2-port control motorised valves so that customers can take all the heat they need at any moment in time.

Pipework Selection for District Heating Opportunity

District heating systems can employ a number of different pipe systems ranging from rigid steel pipes to flexible plastic produced as a pre-insulated bonded pipe system. Pipe systems have developed significantly over the last 30 years and now European standards for their construction (EN253) and installation (EN13941) are in place to ensure that the highest quality pipe systems are developed.

Pre-insulated bonded pipe systems are today by far the most commonly used system for heat networks. Insulated steel pipes in concrete ducts or outer steel casing are also be used for special applications or in systems with special requirements along the route (for example the railway bridge crossing in Ilford Town Centre, which is likely to be installed as steel in steel pipe. Pre-insulated pipes consist of the medium pipe that can be of steel, copper, plastic (PEX - cross linked polyethylene) or Aluminium PEX. Common to each is a layer of polyurethane foam insulation and an outer protective casing. The insulating foam thickness can vary to provide lower heat losses.

Rigid steel pipes are generally envisaged as the medium pipe for the projects identified in this report. These employ standard steel pipe, in standard pipe sizes, e.g. DN100, DN125 and are manufactured in straight lengths of 6m, 12m and 16m for general purpose use.

Different insulation options are available, providing varying levels of insulation thickness of the polyurethane foam. The increased foam thickness reduces the heat losses from the pipe system. The selection is usually made on the basis of a cost benefit analysis at the design stage, although Class 1 insulation is considered suitable for the projects identified in this report.

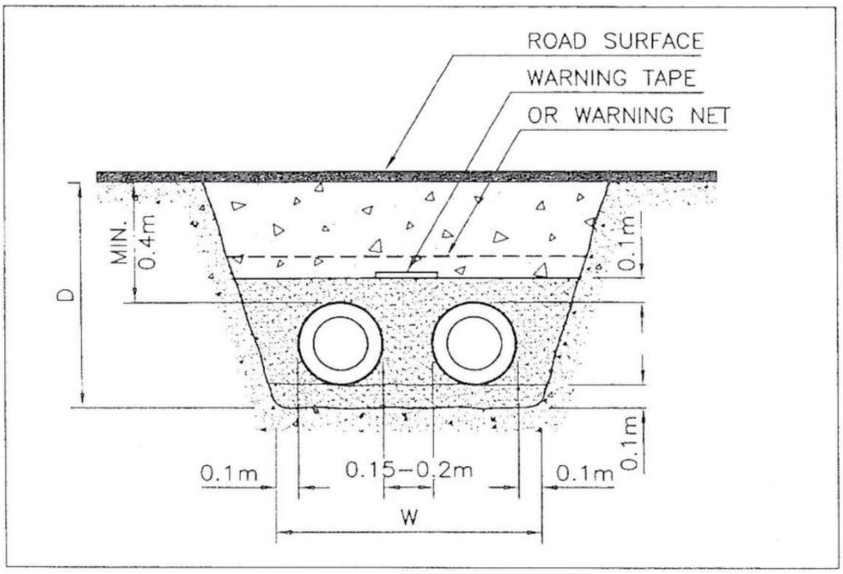
Figure 58: Rigid Steel pipes for District Heating (image courtesy of Ramboll)

Twin pipe options are available as an alternative to single pipe system. These are constructed using the same materials as single pipes but both flow and return pipes are contained within one outer casing. This design reduces heat losses and operational costs and can in some circumstances be cheaper to install. Due to production technology limitations, twin pipes are presently limited to a maximum pipe size of DN200, which limits their use in larger networks.

Twin pipes are best suited to long runs, where branch connections are minimised, since the complexity involved in welding twin pipes can be significant and ultimately can offset the cost savings arising from manufacturing. Considerable skill and expertise is needed for welding twin pipe systems. This may also influence the decision to adopt this pipe system. The choice of pipe system will ultimately also be dictated by route constraints, which is the subject of detailed route appraisal at the design feasibility stage.

Figure 59: Twin Pipes for District Heating (image courtesy of Ramboll)

Typical pipework dimensional requirements are shown below for various pipework diameters based on single pipe technology.



Nominal Diameter mm	Casing diameter mm	W_{min} m	D m
32	90	0.7	0.65
40	110	0.7	0.65
50	125	0.7	0.65
65	140	0.8	0.65
80	160	0.8	0.70
100	200	0.9	0.75
125	225	1.0	0.80
150	250	1.1	0.90
200	315	1.2	1.00
250	400	1.4	1.00
300	450	1.5	1.00
350	500	1.6	1.10
400	560	1.8	1.20

Figure 60: Pipework Trenching Details (image courtesy District Heating Handbook, EDHPMA)

Typical installation requirement details are shown in Figure 61.

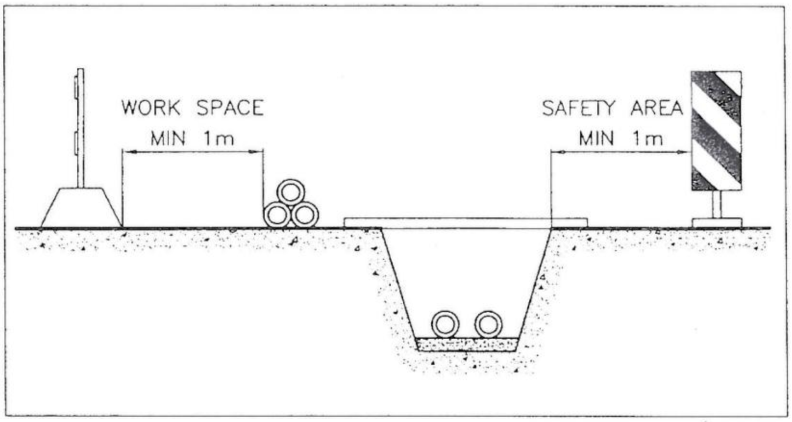


Figure 61: Pipework Installation Working Space (image courtesy image courtesy District Heating Handbook, EDHPMA)

Services pipes connecting buildings to the heat network can in principle be supplied as flexible pipes. The types of pipes available for service pipes are:

1) Flexible pre-insulated DH pipe with medium pipe of copper (cu-flex)
2) Flexible pre-insulated DH pipe with medium pipe of PEX or AluPEX material
3) Flexible pre-insulated DH pipe with medium pipe of steel (steelflex)
4) Traditional non-flexible pre-insulated DH pipes with medium pipe of steel

However, flexible pipes have operational limits in relation to maximum allowable pressure and temperatures. Depending on the final project design parameters they may or may not be unsuitable for use in the proposed heat network.

<u>Design Temperatures and Pressure Considerations</u>

The approach to designing the heat networks for the Wembley Regeneration Area has been to assume that variable volume, variable temperature control would be implemented. Design delivery temperature on the primary side would be 110 °C with design return temperatures of 75 °C and 55 °C for existing and new developments respectively, giving design temperature differences of 35 °C and 55 °C for existing and new developments respectively.

Primary design return temperatures of 75°C are expected to be the limiting value for existing buildings unless / until modifications to internal heating systems are carried out to permit lower return temperatures (e.g. through temperature compensation, increased thermal efficiency of building fabric insulation etc.). It is noted that return temperatures from existing buildings may be higher than this in many cases, particularly at off design temperatures.

Primary design return temperatures of 55°C should be achievable for new buildings based on underfloor heating concepts, with a presumption that developers would be required to design their heating systems to achieve this (with a secondary returns in the region of 45°C). Developers could be incentivised for designing to return heat at below these temperatures.

In relation to pressure, there are two design options of rigid steel pipes; one suitable for use in systems rated at 120°C; 16bar and one for use in systems rated at 120°C; 25bar. The 120°C; 16 bar option will be suitable for the projects identified in this report. Based on the hydraulic modelling carried out it is envisaged that a 10 bar g or 16 bar g design pressure can be specified for the network fittings and auxiliary equipment, with pressurisation on the system return and indirect connection to customers.

The scope for increasing future capacity and operating the network at lower operating temperatures to allow supply from lower grade heat sources in the future relies on being able to reduce return temperatures from existing buildings. The cost, viability and timescales for this approach will require detailed assessment at the next stage.

Methodology for Sizing of thermal storage for district cooling opportunity

In order to decide the size of thermal store an optimisation exercise was undertaken using our hour-by-hour modelling tool EPEM. The tool enables us to model each hour of operation throughout the project life time and do this for various sizes of thermal stores and electric chillers and hence the create a curve of IRR against the size of the thermal store. Figure 62 indicates 11,500 m3 as the most economic option for the project and this has therefore been chosen as the reference. Figure 63 illustrates the contribution that night time chilling can make to depending on the size of the thermal store.

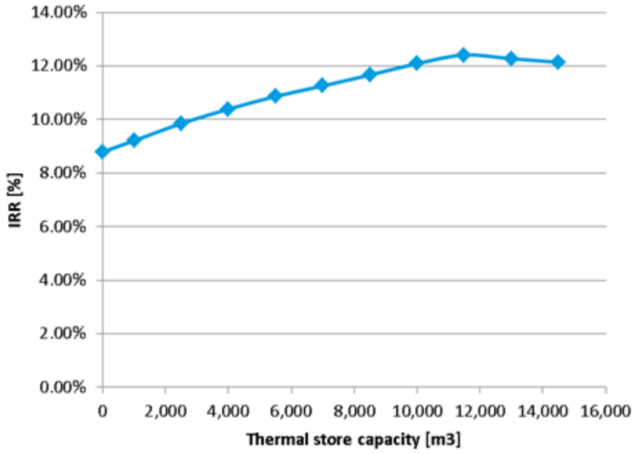


Figure 62: IRR plotted against a range of thermal store sizes

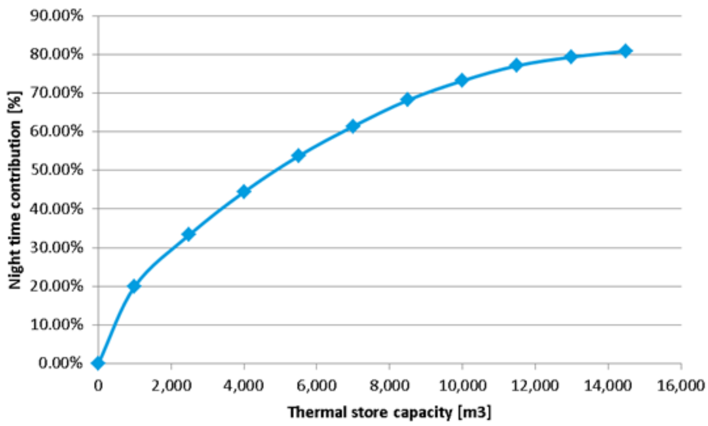


Figure 63: The contribution of night time, low electricity price cooling as proportion of total cooling supply