OPDC
OLD OAK AND PARK ROYAL DEVELOPMENT CORPORATION

Utilities Study

LOCAL PLAN SUPPORTING STUDY

June 2018

MAYOR OF LONDON

54. Utilities Study

Document Title	Utilities Study
Lead Author	AECOM
Purpose of the Study	To investigate options for delivering utilities in the core development area in Old Oak and identify potential preferred solutions.
Key outputs	• Decentralised energy strategy identifying the opportunities for district energy, heating and cooling. • Electricity and gas strategy, identifying the areas current capacity and the need arising from development and potential trigger years for upgrades to the network • Water supply and drainage strategy. Identifies approaches to water supply and reduction and surface water drainage. This summarises the recommendations in the Integrated Water Management Strategy (IWMS) and should be read in conjunction with this Strategy.

Key recommendations	• The preferred approach is for a strategic district heating network, centred around 5 clusters. This would require upfront funding however, so the Local Plan should continue to have a back-stop option requiring developers to deliver heating on-site where no strategic network exists. Priority should be given to zero and low carbon heat sources.
	• Electricity demand is estimated to be 120MW. There is currently 11MW spare capacity. Recommendations for the delivery of the new network are centred on:
	  • Engage with large developers and electricity users such as HS2 Ltd;
	  • Start competitive dialogue with potential independent distribution network operators (IDNOs); and
	  • Investment ahead of need may be required and funding sources for this should be explored.
	• The existing water supply network will be unable to provide sufficient capacity for the development Thames Water has undertaken a Network Impact Assessment, which defines the extent of network reinforcement works that are required to supply the proposed development.
	• There is no capacity within the network for surface water drainage. Development needs to achieve greenfield run-off rates. To achieve this, OPDC should adopt a sequential policy, looking to minimise and re-use water, , if feasible drain into the Grand Union Canal, use on-site SuDS and if on-site, prioritise vegetated SuDS and deliver and connect into strategic SuDs.
	• Recommendations from the study have been appropriately incorporated into the Infrastructure Delivery Plan (IDP).

Key changes made since Reg 19 (1)	NA

Relations to other studies	Interfaces with the Integrated Water Management Strategy (IWMS), Development Infrastructure Funding Study (DIFS), Environmental Standards Study, Waste Management Strategy, North Acton District Energy Network Study, Old Oak North Development Framework Principles and Public Realm, Walking and Cycling Strategy,
Relevant Local Plan Policies and Chapters	• Strategic Policies SP2 (Good Growth), SP10 (Integrated Delivery) • Environment and Utility Policies EU3 (Water), EU9 (Minimising carbon emissions and overheating) and EU10 (Energy systems)

Old Oak

Infrastructure Advisor – Stage 2 Report

Utilities Infrastructure

Old Oak and Park Royal Development Corporation

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Table of Contents

DRAFT

DRAFT

The below appendices are available separately.

DRAFT

Figures

DRAFT

Tables

DRAFT

1. Executive Summary

1.1 Context

The Development at Old Oak Common & Park Royal is set to be the UK's leading redevelopment and regeneration scheme. It will transform an inaccessible area in West London, into a modern, well-connected hub capable of supporting over 26,000 new homes, approximately 814,000m^2 of new office accommodation, and the creation of nearly 67,000 new jobs over the period up to 2062. The scale and timeframe of the overall development provides the opportunity to define and deliver an exemplary development that is sustainable, smart and resilient. With the Old Oak and Park Royal Development Corporation (OPDC) acting as the planning authority for the scheme, the development will promote innovation, as is consistent with the OPDC vision of London as a global city.

Development of this scale will require the provision of new and significantly upgraded infrastructure, including expanded utilities and energy provision. These provisions present an opportunity to utilise smart technologies and systems to build-in optimised solutions and provide a platform for building a smart city solution.

The primary objective of this study is to establish a robust plan for the scheme with options for staged configuration, enabling physical connectivity of the site and individual plots, by removing the enabling infrastructure from the overall critical path for the development.

1.2 Purpose of this Report

This report provides an assessment of the available capacity within the existing electricity, gas, potable water and combined sewer networks, and it identifies physical, commercial and environmental constraints that may form a barrier to network expansion. This report also identifies a series of strategies that are intended to enable the development to be delivered in a highly sustainable manner, by minimising demand and reinforcing the existing utility networks, taking account of potential development phasing.

The recommendations contained within this study have been developed though consultation with key stakeholders in order to define requirements for Local Plan Policy that will establish a framework for the delivery of decentralised energy systems, water recycling measures and reinforcements to the electricity, gas and potable water networks required to serve the Old Oak development. The recommendations also define the spatial allowance that will be required within the Old Oak masterplan in order to enable new utility networks to be extended through the highly constrained site in a co-ordinated manner.

The pace, timing and location of specific plots that are released for development, in addition to their intended mix, ownership and decision-making responsibility, creates a complex challenge for the overall configuration of essential enabling infrastructure, energy assets and utility systems. There is a progressive opportunity, which should be reviewed cyclically, to establish core assets and to optimise systems in order to deliver:

- Resource efficiencies
- Cost efficiencies (reducing the capital outlay for new infrastructure assets)
- Innovation and technology advancement (delivering an international exemplar of smart enabled development)

1.3 Key Findings & Recommendations

The key findings and recommendations of the Stage 2 Utility Infrastructure Appraisal are outlined below.

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1.3.1 Electricity

Significant reinforcement of the existing infrastructure that is owned by the Distribution Network Operators (DNOs), UK Power Networks (UKPN) and Scottish and Southern Energy (SSE), will be required to supply the proposed development. Reinforcement works are either likely to include providing several new secondary substations around the periphery of the site, or alternatively, providing a new primary substation near to the centre of the site and installing a smaller number of secondary substations to serve remote areas of the development.

Four strategic options for expansion of the supply infrastructure have been identified, ranging from a no intervention approach to public sector funding and invest ahead of need. These strategic options have been assessed against objectives that have been developed with OPDC and key stakeholders, to ensure that the power supply is reliable, flexible, affordable and available to suit the increasing power demand as the development proceeds.

The results of the assessments undertaken to date have identified that in the short-term an opportunity exists for OPDC to collaborate with HS2 Ltd, to establish whether the electricity infrastructure that will be installed for construction of the new rail line can supply the proposed development at Old Oak. In medium to longer term, consideration could be given to engaging potential IDNOs, to encourage private sector investment ahead of need, in order to remove potential capacity constraints that could delay development.

1.3.2 Decentralised Energy

London Plan policy currently promotes high efficiency standards to reduce energy demands, encourages the provision of district heating to enable the utilisation of waste and low carbon heat sources, and promotes the use of renewable energy sources.

For development sites of more than a few hundred homes, part of the current market response from developers to these energy policies is to provide communal heating systems, served by gas-fired Combined Heat and Power (CHP) engines serving each development plot. This has been the typical strategy for current planning applications for early development in the North Acton and Scrubs Lane areas of Old Oak. Such applications may also include a commitment to connect into a wider area heat network should there be a prospect of one being delivered in future.

Gas CHP has historically resulted in significant carbon savings as it generates electricity on site, which has displaced high carbon electricity that would otherwise have needed to be provided from the grid. However, as a result of the current and projected decarbonisation of grid supplied electricity, the carbon emissions associated with heat generated from gas CHP are expected to increase rapidly, while the carbon emissions associated with heat generated from electrical sources such as heat pumps are expected to decline.

The work has focussed on developing a decentralised energy strategy that has the flexibility to respond to grid decarbonisation and changing energy policy drivers and incentives, and which can meet OPDC's objectives of providing sustainable, low carbon, resilient and affordable heat supplies for the life of the development.

The analysis has in particular explored whether there are alternative low carbon heat sources which could replace gas CHP as sources of heat for heat networks as the CO_2 saving benefits of gas CHP decline. The analysis has also exploring whether district heat networks will continue to offer an effective means of meeting the OPDC's objectives compared with alternative dwelling or block based heating solutions.

Local low carbon heat sources have been identified that could meet the expected baseload heat demands of Old Oak for at least the first twenty years of development. These include the potential for heat offtake from a proposed Energy from Waste (EfW) facility being considered by Powerday for their commercial refuse recycling plant and the use of heat pumps to extract heat from sources including: the London Aquifer; the Grand Union Canal; and from existing and new sewerage networks.

Analysis of the carbon emissions associated with different heat sources at different time periods in the future build out has shown that heat from an EfW plant could provide an attractive low carbon heat source in particular in the early phases of development, from the mid 2020's heat supplied from heat pumps is expected to become the lowest carbon heat source. (See Table 4 and Table 7).

The EfW proposed by Powerday would potentially be one of the largest local low carbon heat sources and would require heat networks to exploit it. The ability to utilise this potential heat source would be subject to Powerday securing a successful planning application and permitting approvals for their proposed plant.

The heat demands at Old Oak are geographically dispersed and develop in a phased way. In the early phases the bulk of the heat demand will be at North Acton. In later phases development of the HS2 and Crossrail sites will create major heat demands at Old Oak North.

To deal with the expected phased delivery of development, and geographic separation of demand, the preferred technical strategy for the early phases of development would be to deliver an area wide heat network in each of the main geographic clusters of development (North Acton, Willesden Junction, Scrubs Lane, Old Oak North). Creating cluster-wide networks, rather than multiple small plot based heat networks such as those currently being delivered at North Acton. This would allow multiple heat sources to be utilised and supplied from a single energy centre. It would also enable the use of larger more efficient plant, and provide greater flexibility to update and change heat sources over time to ensure continued low carbon heat supply. If delivered at scale heat networks can offer greater potential for a proportion of delivery costs to be met through third party ESCO funding.

Each cluster wide network could be served from an energy centre located such that it is capable of utilising the local low carbon sources identified, as well as conventional heat generating plant such as gas CHP engines and gas boilers, which may be required to enable economic operation. Each of these cluster wide networks could potentially be linked to its neighbour. This would enable the capacity of low carbon energy sources to be shared more widely and create greater supply resilience.

This strategy would enable London Plan policy to be met along with OPDC's objectives for a sustainable low carbon, resilient and affordable energy supply.

After around 2030 the carbon intensity of heat supplied from alternative dwelling or block based solutions such as closed loop ground source heat pumps, is expected to have fallen to the point where they may offer a preferable solution to further expansion of heat networks. The total costs for users (energy bills, maintenance and replacement) is also expected to compare favourably with heat from heat networks. For the later clusters of development occurring after 2030 the preferred technical solution would need to be reviewed in light of how national and London plan policy has evolved in response to grid decarbonisation and in light of how the heat networks and their heat sources have evolved up to that point.

The preferred strategy of delivering interlinked area wide heat networks is in line with current London Plan policy and would also enable the strategic opportunity to utilise heat from the proposed EfW facility. The benefits of an area wide heat network would be less strong if an EfW plant does not come forward.

Section 3 of the main report summarises the preferred strategy, and highlights how it can be safeguarded through the masterplanning process and through Local Plan policy. Key considerations for the masterplan will be to identify and safeguard suitable sites for an energy centre to serve each of the main clusters of development and which can access the identified low carbon heat sources. Routes for the primary heat pipe network required to link energy centres from sources of supply to centres of demand will need to be planned and safeguarded in particular focussing on the integration of distribution infrastructure into upgraded roads and planned rail, road and canal crossings.

Local plan policy should support the delivery of strategically planned heat networks that can draw on the various low carbon heat sources. These networks should ideally be designed for low temperature operation to support the efficient use of heat pump technology as the electricity grid decarbonises.

1.3.3 Gas

National Grid (Gas) has advised that the existing gas infrastructure in the vicinity of Old Oak will need to be progressively reinforced to provide a flexible and resilient gas supply. Network reinforcements are likely to involve upgrading the existing low pressure mains that extend below Scrubs Lane,

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Victoria Road and Old Oak Common Lane to form medium pressure gas supplies, before extending new medium pressure gas connections to Energy Centres.

In order to ensure that the network may be reinforced in a cost effective and co-ordinated manner, it will be necessary to safeguard land within the masterplan for the extension of new gas supply networks and include passive provision within bridge decks for medium pressure gas mains. It will also be necessary to carefully plan new highway works to enable new corridors to be created for a new medium pressure gas supply to be extended across physical constraints to Energy Centres.

Regular dialogue with National Grid (Gas) should be established in order to allow proposed reinforcement works to be co-ordinated with other plant relocation works that are proposed for HS2 in order to ensure the optimal solution for all parties.

1.3.4 Water Supply

Thames Water has indicated that the Old Oak site extends across the Barrow Hill and Shoot Up Hill water supply zones, but that the existing water supply networks will not provide sufficient capacity to accommodate the anticipated demand from the proposed development, due to the significant increase in development density. Thames Water has also indicated that without intervention the water demand within Greater London is forecast to exceed the available water supply, as the demand is predicted to grow due to increasing population, and the rainfall yield is predicted to reduce due to climate change.

Thames Water is implementing multiple measures to reduce the water supply deficit, which include leakage reduction, installation of additional meters and water recycling. However, there is a risk that Thames Water may be required to use the desalination plant at Beckton to supply potable water in the event that other measures are not effective.

In the short term, it is likely to be necessary to reinforce the potable water supply network by installing a new 400mm main, which will extend across the site. It will also be necessary to install a new cross connection between mains in Barrow Hill Zone in order to adjust the boundary between the Barrow Hill and Shoot Up Hill water supply zones. In order to ensure that the network may be reinforced in a cost effective and co-ordinated manner, land should be safeguarded within the masterplan to accommodate new water supply networks and bridge decks should be designed to incorporate ducts for water mains. It will also be necessary to carefully plan new highway works to enable new corridors to be created for new water mains to be extended across physical constraints within the site.

The longer term impact on water resources should be minimised through the provision of demand reduction, visible metering and water recycling measures, which could include combined rainwater and greywater recycling systems within commercial tenures, and water efficient appliances and individual meters within residential and commercial tenures. This strategy is intended to minimise the demand for a centralised water supply, by encouraging changes in behaviour within residential dwellings, and by using recycled water for non-potable purposes within commercial units where behaviours are more difficult to influence.

1.3.5 Foul and Surface Water Drainage

Thames Water has indicated that there is no additional capacity within the existing combined sewers that extend adjacent to, and through the Old Oak Common site to accommodate the additional foul flows that will be generated by the development. It is therefore likely to be necessary to minimise the area of the site that discharges surface water to the existing combined sewer network, by encouraging Developers of parcels situated within the catchment of the Grand Union Canal to discharge surface water to the canal, and to provide Sustainable Drainage Systems (SuDS) to restrict the peak discharge from rainfall events with a return period of up to 1 in 100 years plus climate change to permissible rates defined by the Canal and River Trust. This approach will enhance sustainability by minimising the volume of surface water that is treated at the Beckton Sewage Treatment Works.

Where it is not practical to discharge surface water to the canal, it will be necessary to provide SuDS within the development to enable the peak surface water discharge rate from rainfall events with a return period of up to 1 in 100 years plus climate change to be restricted to the equivalent greenfield runoff rate and thereby create capacity for the increased foul flows. These systems will occupy space within development parcels and preliminary calculations have been prepared to determine the volume of storage that will be required within each parcel to allow adequate allowance to be included within the masterplan.

Physical constraints within the Old Oak site limit the ability to provide a single, fully integrated surface water drainage network that incorporates source control features on plot and site control features positioned strategically within the development, as it will not be practical to extend sewers across proposed bridges. However, opportunities for integrating a cascading system of features within the development should be maximised; firstly, by providing source control features on plot, potentially in the form of intensive green roofs, porous paving and geocelluar storage tanks; and secondly, by designing areas of public open space to form site control features that will accommodate excess surface water generated during extreme rainfall events, particularly when these areas are situated in close proximity to the receiving combined sewer network or Grand Union Canal.

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2. Introduction

2.1 Background

AECOM has been commissioned by Old Oak and Park Royal Development Corporation (OPDC) to provide infrastructure advice to support the proposed redevelopment of Old Oak.

The Old Oak site (the Site) is situated close to the intersection between the proposed Crossrail and HS2 rail lines and has been identified as a key growth area for London with the potential to deliver approximately 26,970 new homes, 814,000m^2 of new office accommodation, and 66,780 new jobs during the period 2016 to 2062.

Old Oak is predominantly occupied by industrial and commercial land uses, although there are also small pockets of residential development. The Site is dissected by the Grand Union Canal (Paddington Branch) and by a series of major transport links, including the Great Western Main Line, West Coast Main Line, London Overground and London Underground Lines. Significant highways are also situated in the locality, as the A40 extends close to the southern boundary of the Site, whilst Scrubs Lane and Old Oak Common Lane extend along the eastern and western boundary, respectively. This transport network will be further expanded through the planned development of Crossrail and the proposed HS2 rail line and station.

The total land area available for housing is expected to be approximately 57 hectares. Development densities are likely to be high, varying between 300 dwellings per hectare in more sensitive locations and 600 dwellings per hectare around key transport interchanges, with some buildings over 20 storeys.

The increase in development density and change in land use of development, combined with the presence of ageing infrastructure in the area, introduces a requirement for significant changes in utility and social infrastructure (Old Oak and Park Royal Development Capacity Study). The proposed redevelopment also provides an opportunity to create an exemplar sustainable development that minimises environmental impacts and maximises opportunities for social development and economic growth.

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2.2 Overview of Previous Work (Stage 1)

During the period between April and July 2016, AECOM was commissioned by OPDC to undertake a review of the existing strategic infrastructure and the anticipated services demands for the new facilities, in order to identify the improvement works that are likely to be required to support the proposed development. The key findings and recommendations of the Stage 1 Infrastructure Appraisal are outlined below:

- There is currently a shortage of capacity within the electricity infrastructure in the Old Oak area. UK Power Networks (UKPN) and Scottish and Southern Energy (SSE) should be commissioned to conclusively determine the extent of the available capacity within their respective supply areas. Based on the outcome of these studies, applications should be submitted to UKPN and SSE to reserve capacity within the existing electricity network and to obtain a quotation for a 66MVA electricity supply to the Old Oak area.
- National Grid (Gas) has indicated that the existing gas supply network is likely to require reinforcement to supply the proposed development. The gas demand for the redevelopment at Old Oak will be heavily influenced by the energy strategy; therefore there needs to be considerable flexibility in the strategy for the gas supply network.
- Consultation with Thames Water has revealed that the existing potable water supply network is likely to required reinforcement to accommodate the demand arising from the development. However, the Grand Union Canal extends through the site and there is therefore an opportunity to delay or reduce any off site reinforcement works to the existing supply network by abstracting and treating water from the canal and distributing this water throughout the proposed development, via a non-potable water supply network. Opportunities for integrating rainwater or greywater recycling measures on plot have also been identified.

- Thames Water has indicated that there is no additional capacity within the existing combined sewers that extend adjacent to, and through the Site to accommodate the additional foul flows that will be generated by the development. It will therefore be necessary to provide Sustainable Drainage Systems (SuDS) within the development, to enable the peak surface water discharge rate from rainfall events with a return period of up to 1 in 100 years plus climate change to be restricted to the equivalent greenfield runoff rate and thereby create capacity for the increased foul flows.
- Decentralised Energy may be employed to reduce the environmental impact of the development. An energy technology options appraisal should be undertaken to establish future energy requirements and to determine the carbon saving potential for different technologies, in order to establish the preferred decentralised energy strategy. A funding and delivery options appraisal should also be prepared to identify and evaluate alternative commercial frameworks.

2.3 Outline Scope of Work for Stage 2

The Stage 1 Infrastructure Appraisal highlighted significant constraints in the capacity of existing electricity, gas, potable water and sewerage infrastructure.

This Stage 2 Infrastructure Assessment has been undertaken between September 2016 and March 2017, in order to determine the key infrastructure improvements that will be required to support the proposed redevelopment of Old Oak, and thereby enable OPDC to prepare their Local Plan, determine planning applications and inform the Old Oak masterplan. This has comprised the following key activities:-

- Decentralised Energy - An energy technology options appraisal has been undertaken to establish future energy requirements and to determine the carbon saving potential for different technologies, in order to establish the preferred decentralised energy strategy. A funding and delivery options appraisal has also been prepared to identify and evaluate alternative commercial frameworks.
- Electricity – UKPN and Scottish and SSE have been consulted to obtain an improved understanding of the available capacity in the existing electricity network, and options have been identified to deliver appropriate network reinforcements, which consider alternative procurement models.
- Gas – National Grid (Gas) has been engaged to obtain an accurate estimate of the supply capacity within the existing gas distribution network, and to establish the extent of the reinforcement works that will be required to develop a resilient network that will provide flexibility for emerging energy technologies.
- Potable Water – Thames Water has been commissioned to prepare a Network Impact Assessment to establish the extent of reinforcement works that will be required to accommodate the additional water demand of the development. Water recycling options have been identified and appraised, in order to establish the preferred method of reducing the impact of the development on the existing water resources by reducing potable water demand.
- Foul and Surface Water Drainage – Thames Water has been consulted to verify the reduction in peak surface water discharge rate that will be required to create capacity with the existing combined sewer network, to accommodate additional foul flows generated by the development. Preliminary calculations have also been prepared to estimate the volume of attenuation storage that will be required within each sub-catchment of the site to achieve the required reduction in surface water runoff. The Canal and River Trust has been commissioned to produce a Discharge Assessment to establish the feasibility of discharging surface water to the Grand Union Canal, in order to reduce the volume of surface water entering the combined sewer system that will require treatment at the Beckton Sewage Treatment Works.

The key outputs from this Stage 2 Assessment are the identification of strategies for improvements to the strategic infrastructure at Old Oak, leading to a series of preferred options and recommendations for further work to deliver the required improvements.

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2.4 Baseline Information

This Stage 2 Assessment has been based upon the Draft Phasing Trajectory v7.11 - Early Scenario and the v7.12 - Late Scenario for Planning, which were issued by OPDC on 5 January 2017 and provide details of the anticipated delivery of new homes and office space to 2065. These two scenarios ultimately result in the same quantum of development and service demands and differ only in timing. However, since the v7.11 early trajectory results in the shortest lead times, this is considered to provide a worst case scenario for infrastructure reinforcement. This scenario has therefore been considered during this assessment. Refer to Figure 1 and Figure 2 below.

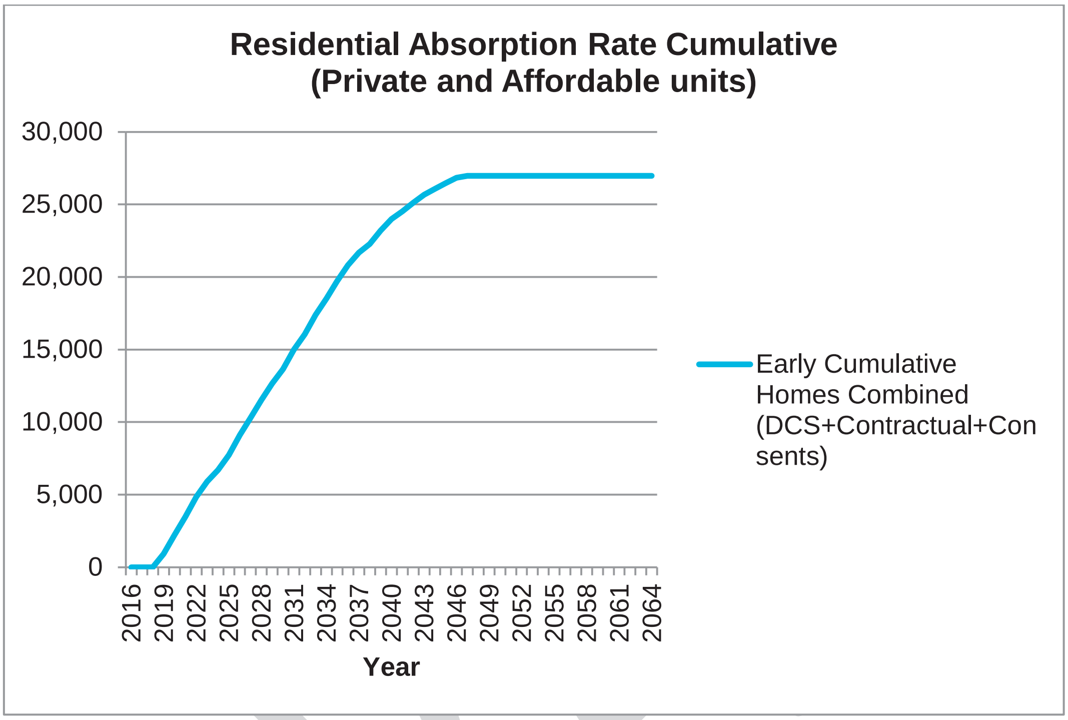

Figure 1. Anticipated Housing Growth (Draft Phasing Trajectory v7.11 - Early Scenario)

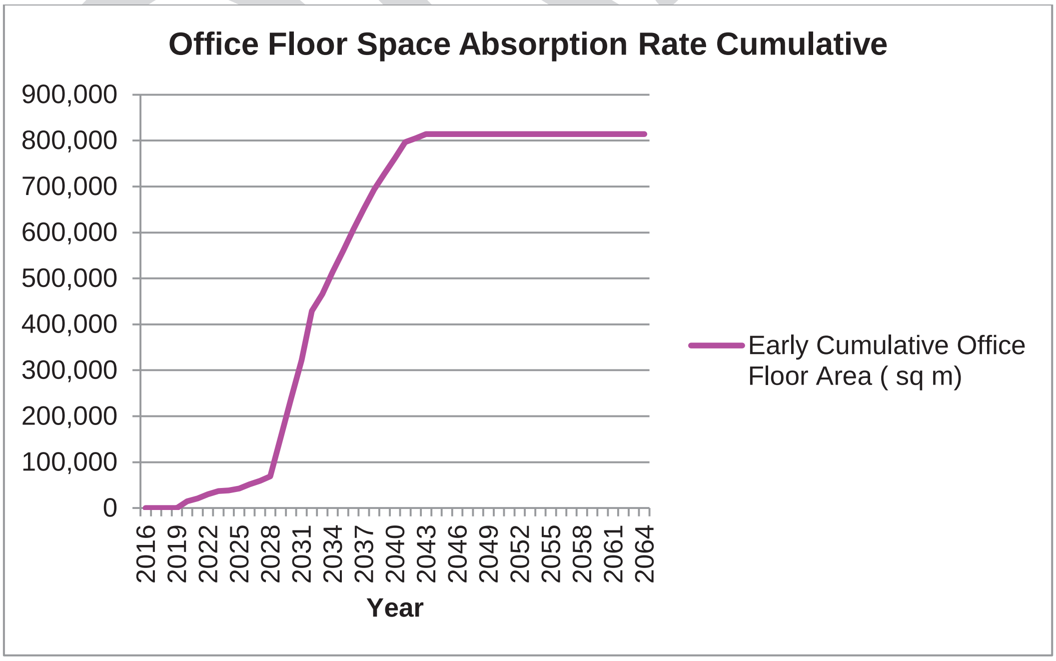

Figure 2. Anticipated Employment Growth (Draft Phasing Trajectory v7.11 - Early Scenario)

The redevelopment of the Old Oak site has been considered in terms of the following five geographical areas, which are illustrated in Figure 3 below:

- Old Oak North
- Old Oak South
- North Acton
- Scrubs Lane
- Willesden Junction

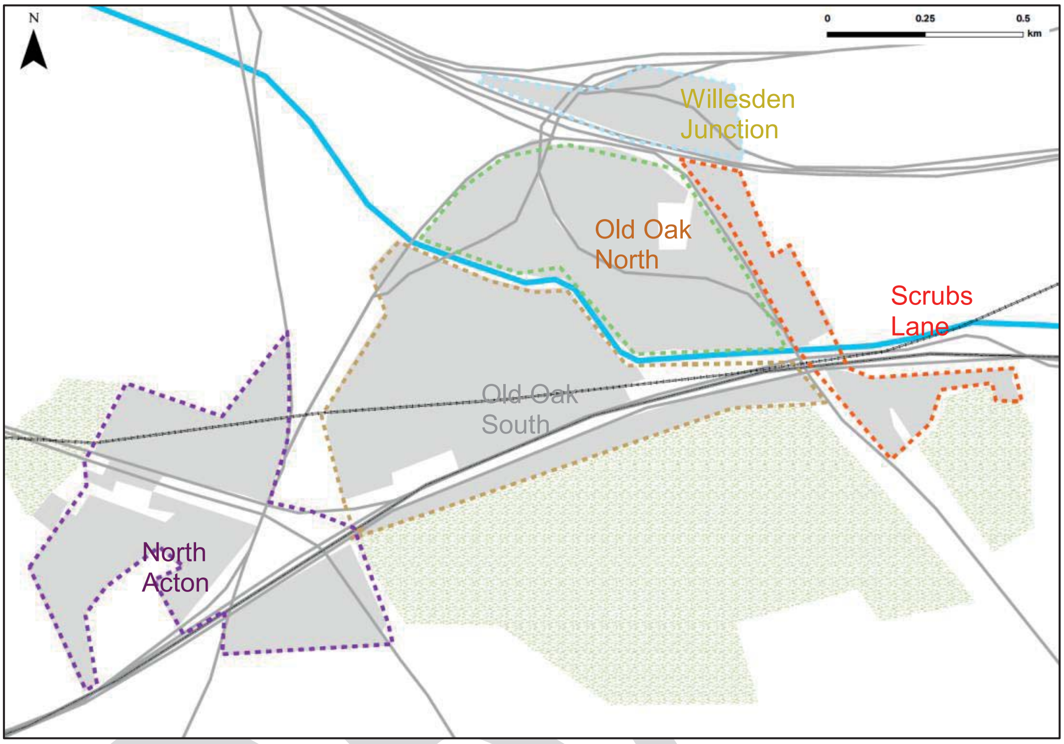

Figure 3. Old Oak Development Areas

This assessment also makes reference to information contained in the Development Infrastructure Funding Study (DIF Study) prepared by Peter Brett Associates (PBA) in March 2015 and the Integrated Water Management Strategy (IWMS) that was prepared by AECOM in January 2016.

2.5 Engagement with Key Stakeholders

Meetings have been held with the following Key Stakeholders and Statutory Undertakers during the period extending between September 2016 and March 2017, to verify constraints in the existing infrastructure, and to discuss potential mitigation measures that will minimise the environmental impact of the proposed development. These consultations have also been undertaken to ensure that these mitigation measures comply with the current, emerging and future requirements of planning policy:-

- Old Oak and Park Royal Development Corporation (OPDC);
- Greater London Authority (GLA);
- UK Power Networks (UKPN);
- Scottish and Southern Energy (SSE);
- National Grid (Gas) (NGG);
- Thames Water (TW);

- Canal and River Trust (CRT);
- HS2 Ltd;
- Representatives from Powerday Limited; and
- Promoters and operators of the Kings Cross Heat Network, Queen Elizabeth Olympic Park Heat Network, Bunhill Heat network and the planned Lea Valley Heat network;

2.6 Objectives for Infrastructure Improvements

A number of strategic objectives for improvements to the existing infrastructure have been identified through consultation with OPDC and key stakeholders. These objectives enable the relative benefits of alternative options to be assessed in order to allow the preferred strategy to be identified.

Individual objectives have been identified for each study, which are broadly based around the timely provision of new infrastructure to support the proposed development of Old Oak, whilst ensuring flexibility, reliability, resilience and being cost effective.

2.7 Structure of Report

This report provides a comprehensive assessment of strategies for utilities infrastructure improvements at Old Oak, and it provides recommendations on how these strategies are outlined and assessed within the following sections of the report:.

The report addresses these requirements as follows:

Section 3: Energy, including electricity, decentralised energy and gas

Section 4: Potable Water

Section 5: Foul and Surface Water Drainage

Further details and context are set out in a series of appendices, which follow Section 5.

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3. Energy

3.1 Introduction

Old Oak is expected to be developed over a number of decades. During this development period it is anticipated that there will be significant changes to the UK's energy system driven primarily by the need to cut carbon emissions, but also by the need to improve air quality in our cities, the changing costs of energy generation and the need for increased energy security. Corresponding changes to the associated policy framework and the fiscal incentives that underpin our energy system are also expected. The energy strategy and energy infrastructure developed for Old Oak will need to be designed with sufficient flexibility to respond to these changes.

In the absence of a national energy strategy it is difficult to predict with certainty exactly how the national energy system will evolve. However, there are a number of important general trends that have been considered.

3.1.1 Decarbonisation of the Energy System

There is widespread consensus from the international scientific community that man-made climate change poses a significant threat of disastrous climate change. As part of international efforts to address this, the UK Climate Change Act 2008 requires the UK to deliver an 80% space reduction in greenhouse gas emissions by 2050 compared to 1990 levels. The new Mayor of London has set the ambition that London should have net zero emissions by 2050.

As carbon emissions are largely related to energy use, the final energy consumption in the UK is often divided into four categories: industry, transport, domestic and other. For 2015, domestic uses accounted for 30% of all energy consumption, the second largest contributing sector after transport (see Figure 4).

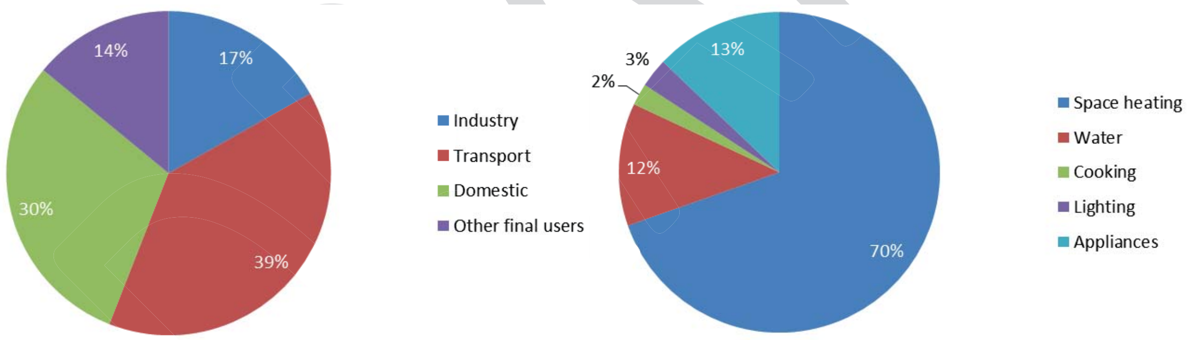

Figure 4. L – Final Energy Consumption by Sector; R – Domestic Final Energy Consumption by End Use (Existing Housing Stock)[1]

The overall carbon emissions generated in the UK have seen significant reductions since 1990. The latest data available from the Department for Business, Energy and Industrial Strategy (BEIS) indicates that CO_2 emissions have fallen by c.32% compared to the baseline 1990 year, and overall greenhouse gas emissions, which includes other greenhouse gases such as methane, nitrous oxides, have reduced by c.38%. Figure 5 shows the reduction in UK CO_2 emissions.

[1] Energy Consumption in the UK, BEIS, November 2016. [https://www.gov.uk/government/statistics/energy-consumption-in-the-uk]

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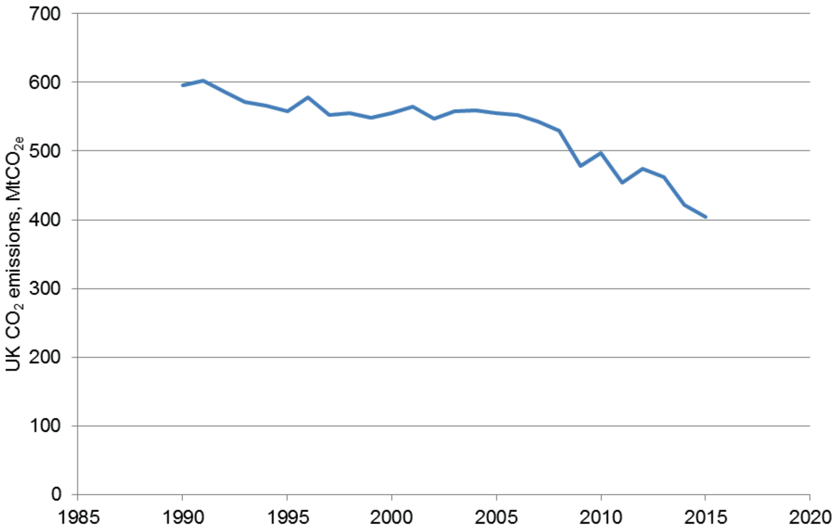

Figure 5. UK CO_2 Emissions, 1990 - 2015[2]

The key to maintaining this trend and delivering the required 80% reduction in CO_2 emission by 2050 will be to decarbonise national electricity supplies. A move away from large coal-fired power generation towards a much greater use of wind and solar energy has resulted in a rapid decarbonisation of the electricity grid. Government projections show this continuing into the future via further deployment of renewable and nuclear energy. The yellow line in Figure 6 shows the projected carbon intensity of UK grid electricity through to 2044, which represents the CO_2 emitted per kWh of electricity delivered. For further information on this chart and on electricity grid decarbonisation, please see Appendix F.

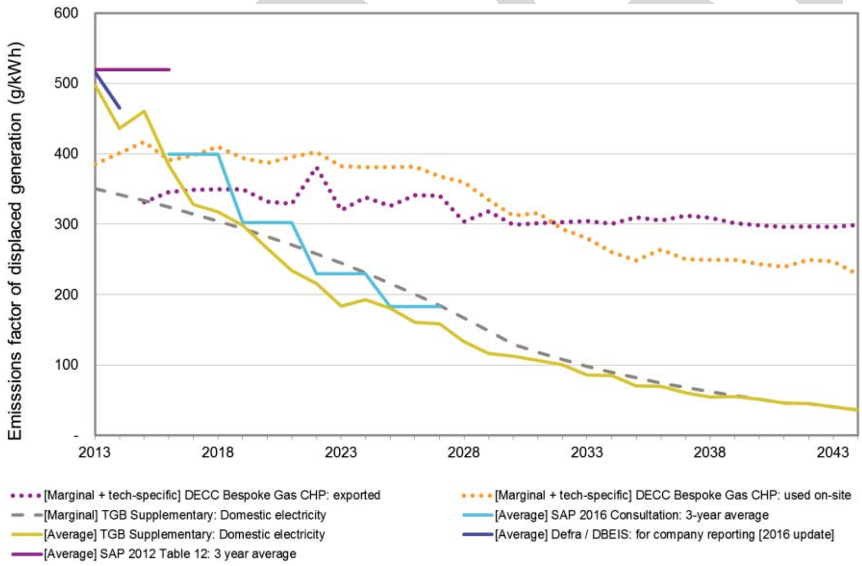

Figure 6. Projected Carbon Intensity of UK Grid Electricity

This rapid decarbonisation of the electricity grid will mean technologies such as heat pumps that use electricity to generate heat will see their carbon emissions decline, while technologies such as gas fired Combined Heat and Power engines (CHP), which derive their carbon saving benefits from displacing high carbon electricity from the grid, will see their calculated carbon saving benefits rapidly decline relative to other technologies.

[2] Final UK Greenhouse Gas Emissions National Statistics 1990 – 2015, BEIS, 2017 [https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015]

At present London Plan policy has promoted the use of heat networks served by gas fired CHP engines, as these would currently show a significant carbon saving. However, in the following sections of this report, if calculation methods are updated to reflect decarbonisation of the electricity grid and remain based on average grid emission factors, the calculated carbon emissions from gas CHP would rapidly become one of the highest options for delivering heat to new homes, compared to other heating sources.

3.1.2 Changing Demands for Electricity

Heat for water and space heating currently accounts for over 80% of all energy use in the existing domestic sector (Refer to Figure 4). For new well insulated homes this split reduces, but it remains the dominant demand and the one where there is the greatest opportunity to influence carbon emissions at the design stage. Figure 7 shows the energy demand spilt for homes designed to meet the target emission rate in Part L of the Building Regulations, the demands have been averaged for the dwelling size mix expected at Old Oak. Space heating and hot water makes up 62% of the energy demand. Cooking and appliance use does not form part of the energy use regulated by Building Regulations, as appliances are not always provided in new build properties and occupants can easily replace appliances following occupation, but these uses are included in Figure 7 to show the significant contribution that unregulated uses make to total energy demand.

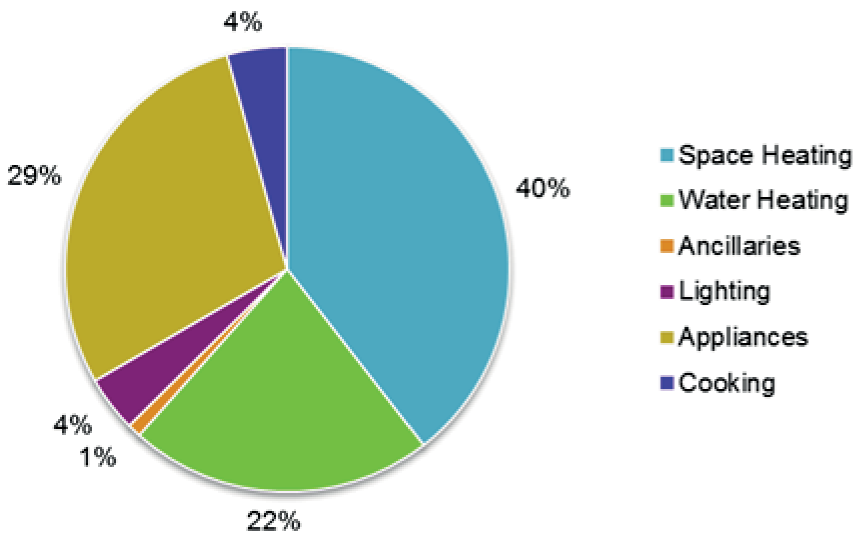

Figure 7. Energy Demand Spilt for Average Old Oak Home Complying with the Part L Target Emission Rate

With grid electricity emission factors falling, the expectation is that there will be a growth in the use of electricity for space and hot water heating in new buildings, driven by the desire to reduce carbon emissions. This is expected to be accompanied by an increase in the use of electric vehicles driven both by the need to reduce carbon emissions, but also the air quality impacts of diesel and petrol driven vehicles in urban areas.

3.1.3 Growth in Electric Vehicles

With transport representing the largest energy demand sector in the UK and with London and other major cities failing to meet EU air quality standards, decarbonising the transport system is another major focus for Government and the car industry. The issue of poor air quality is now a key concern for London, with London Plan Policy 7.14: Improving Air Quality, specifically targeting clean technologies and vehicles.

A large-scale rollout of electric vehicles, combined with the expected decarbonisation of the UK electricity grid, provides an opportunity for decarbonising the UK transport sector. It will also contribute significantly towards improving air quality in urban areas, but it will be accompanied by increased demand for electricity.

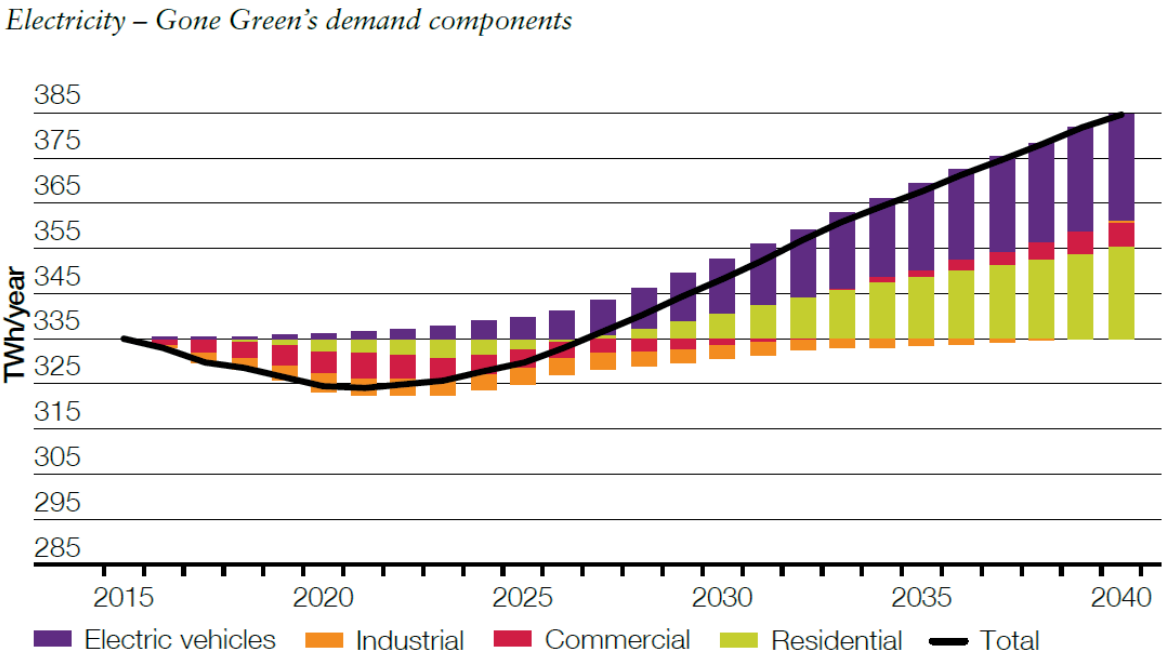

Figure 8. National Grid Projection of Growth in Transmission of Electricity for a Gone Green Scenario

National Grid have developed a number of scenarios for how electricity demands on the national transmission system may respond to the predicted growth in electric vehicles and increased use of electric heating.[3] Figure 8 shows the anticipated growth in demand for their "Gone Green" scenario which is one of four examined. This reflects growth at a national level, the impact on local demand for new development would clearly be more dramatic were there to be a wholesale switch to electric heating and electric vehicles.

3.1.4 Growing Requirements for Demand Management

The anticipated growth in electricity demand is expected to require investment in new generation capacity as well as upgrading of local distribution infrastructure. It is recognised that this will also have substantial costs. To reduce the costs of reinforcing existing electricity infrastructure or increasing the capacity of new infrastructure, there is a growing focus on the role that active demand management could play in reducing peak demands, assisted by the emergence of smarter control systems and the reducing costs for technologies such as battery storage.

Demand management can be used to increase the effectiveness of local generation assets, for example by linking battery storage to PV generation, so that a greater proportion of the generated energy can be utilised locally, or to shift flexible demands away from peak demand periods, for example by offering reduced tariffs for using electricity outside peak demand periods. There may also be opportunities to manage demands through a more integrated management of energy systems, for example thermal storage in heat networks could be used to store energy by running electric boilers during periods of high renewable electricity availability, or CHP engines forming part of heat networks could be operated during peak demand periods in response to high export tariff incentives.

[3] Future Energy Scenarios – GB gas and electric transmission. National Grid – July 2016

Smarter controls could also help manage demand, for example for district heating networks this might include the introduction of bypass functions on Heat Interface Units (HIUs) that ensure space heating and domestic hot water heating do not operate simultaneously. The effects of these smart demand management systems are varied, but they are expected to include a reduction in the capacity of peaking generation facilities and reducing the use of high carbon emitting reserve capacity.

3.1.5 Economic Impact of Heat Technology Choice

Running gas CHP engines on large scale networks is currently attractive from an economic perspective due to the difference in cost between electricity and gas. The capital cost and future revenue potential for alternative heat sources may be more or less attractive than gas CHP, and this may impact the commercial viability of networks served by sources other than gas CHP. The Department of Energy and Climate Change's (DECC) recent review of the potential for heat pumps in district heating has for example noted that while they will in future offer substantial carbon savings, they have relatively high capital and running costs with the study concluding that heat costs could increase by 35-74%[4].

3.2 Assumptions for Energy Infrastructure

With uncertainty on precisely how current energy trends will impact the future policy framework and incentives a number of assumptions have been made regarding likely energy infrastructure provision, which are set out below.

3.2.1 Role of Gas CHP

While the calculated carbon saving benefits of gas CHP are likely to diminish rapidly, gas CHP will remain an economically attractive option compared with some of the alternative heat sources (due to the generation of high-value electrical output). Gas CHP linked to heat networks may continue to offer value to the UK energy system in terms of helping to balance peaks in demand. Rather than being operated to maximise heat output and running hours (as would be the case now), gas CHP could be installed and operated to maximise revenue from electricity sales during peak demand periods. If operated in this way, the real impact on carbon emissions would be minimal, as it would likely be displacing gas-fired combined cycle gas turbine generating plant on the grid with equivalent or higher emissions. As long as gas CHP only contributed a small proportion of the total heat delivered, and the majority of heat was delivered by sources with lower calculated emission rates, networks could potentially maintain an acceptable calculated carbon emission rate as the grid decarbonises.

It is assumed that energy centres will benefit from having multiple heat sources (heat pumps and gas CHP) that could be operated to maximise revenues based on changing electricity market tariffs.

3.2.2 Requirements for Gas Infrastructure

It is assumed that Energy Centres serving district energy networks could potentially use gas CHP engines in early phases, or to improve economic viability in later phases, and that peak and standby gas boilers will continue to be utilised in early phases. As a result energy centres will need to be served by medium pressure gas mains.

It has been assumed that residential properties served by district heating mains or electric heating systems would not necessarily require gas supplies, as cooking could be provided by electric ovens and induction hobs, but that some commercial uses such as catering may require gas supplies which could be accommodated by extension of the medium pressure mains serving energy centres.

3.2.3 Local Electricity Generation Sources

The density of development is expected to prohibit the use of wind generation, due both to the disrupted wind regime and the safety issues associated with blade or ice shed in densely populated

4 Heat Pumps in District Heating, Final Report, DECC, 2016

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areas. Local electricity generation is likely to be restricted to generation from CHP engines including a possible waste to energy plant and to renewable energy generation from PV.

PV costs are expected to continue to fall and PV is likely to remain an attractive means of generating renewable electricity for Developers. However, areas for PV will be limited by building density and competing requirements for roof space, and carbon savings from PV will fall as the grid decarbonises, but PV will remain a renewable generation source with economic value to those who install it. Despite the limitation on roof space, a significant total capacity could be accommodated across the development, therefore electricity distribution network will need to be designed to accept high levels of PV generation.

It is assumed that as the cost of battery storage falls, there will be a growth in the market for home storage systems to improve the utilisation and economic returns from PV, but the degree in growth in the deployment of such systems will be dependent on the economics of the emerging technologies and these cannot be assumed at present.

3.2.4 Electricity Distribution

Local electricity generation from all available sources will not meet the electrical demands of the development and cannot be relied upon as a secure and resilient supply. Therefore, new local distribution infrastructure will be required to create robust and resilient supplies from the grid.

While smart technology may be able to help manage and reduce energy demands or shift demand to reduce peaks, it is assumed that until there has been greater demonstration of robust reductions in demand from smart technology and dynamic demand management, District Network Operators (DNOs) will wish to size their systems to reflect current experienced peak demand, with flexibility to increase capacity to deal with anticipated growth in demands due to electrification of heating and transport.

It is assumed that new electricity infrastructure will need to be designed with flexibility for additional loads to be accommodated over time and should consider a scenario where a large proportion of heat is being delivered electrically via heat pumps and in later phases by direct electricity. The degree to which such networks rely on smart technology such as battery storage to limit the capacity of systems installed will be dictated by the costs and revenues to the network operator.

3.3 Electricity

3.3.1 Stage 1 Overview of Previous Work

The Stage 1 Infrastructure Assessment prepared by AECOM in July 2016 identified that there is likely to be a shortage of electricity supply capacity to the Old Oak area with the available spare capacity likely to be in the order of 5MW. The peak electricity demand for the proposed redevelopment at Old Oak was estimated to be approximately 120MW and the increased electricity demand was anticipated to exceed the available spare capacity before the end of Phase 1 (2020).

Preliminary discussions held with UK Power Networks (UKPN) identified that the lead time for the installation and commissioning of new supply infrastructure could be 3 to 4 years. The anticipated shortage of electricity could therefore, constrain the Phase 1 development at Old Oak.

The planned development of the new high speed rail line HS2 is also likely to have a significant bearing on the available electricity supply in Old Oak, as approximately 70MW of additional capacity will be required during the construction period. The electricity demand for HS2 will significantly reduce following completion of the tunnel boring operations in 2023, which could release capacity to supply the proposed development at Old Oak.

In order to obtain a clearer understanding of the available electricity capacity in the Old Oak area and identify options for upgrading the existing infrastructure to supply the proposed development, the following actions were recommended:

- Commission feasibility studies from the two DNOs that supply the Old Oak area, to determine conclusively the extent of the available capacity within their respective supply areas.

- Request a quotation from UKPN for a 66MVA source of supply to the Old Oak area. However, it was recognised that this supply is likely to be available from 2020 onwards.
- Commence stakeholder engagement and competitive procurement activities for an alternative 66MVA source of supply.

3.3.2 Stage 2 Scope of Work

In August 2016, AECOM was commissioned by OPDC to provide further advice on the improvements that would be required to the existing electricity infrastructure at Old Oak, to reduce the risk of the proposed development being delayed by insufficient supply capacity. The main objectives for this second commission were to:

- Assess the future demand for alternative development scenarios/phasing.
- Research options and understand opportunities for early collaboration to help identify any safeguarding requirements.
- Provide further detail on the required infrastructure.
- Input fixes to the Masterplanning commission, commencing in early 2017.
- Highlight opportunities, activities and decisions that need to be progressed urgently, to provide additional electricity supply capacity for the proposed development.

In order to achieve the above objectives, the following activities have been undertaken:

- Liaising with the Statutory Undertakers to obtain a clearer understanding of their existing infrastructure and the improvements required to supply the proposed development.
- Preparation of a scope of work and requesting quotations for network impact assessments/feasibility studies from the Statutory Undertakers, to identify at a strategic level the current spare capacity, the trigger points for reinforcement of the existing infrastructure and options for upgrading the existing infrastructure.
- Undertaking a feasibility study to evaluate whether the provision of new secondary substations may provide a better option than one primary substation, given the infrastructure constraints on the site and the anticipated phasing of development.
- Estimation of the anticipated peak electricity demand, to reflect updated development scenarios and phasing.
- Identifying significant items of new electricity infrastructure that may be required and the likely effect on the development footprint/phasing.
- Identification and assessment of strategies and options for intervention to secure improvements to the electricity supply infrastructure.
- Liaising with HS2 Ltd. to obtain details of their proposed supply strategy and establish whether this could be suitable for supplying the proposed development.

3.3.3 Objectives for Old Oak Electricity Strategy

As outlined in Section 1, a number of strategic objectives have been developed with OPDC and key stakeholders for improvements to the existing services infrastructure. These objectives are based around the timely provision of new infrastructure to support the proposed development of Old Oak, whilst ensuring flexibility, reliability, resilience and being cost effective.

In order to assist with the identification and assessment of strategic options for improvements to the existing electricity supply infrastructure, seven high level objectives were developed, as shown in Figure 9 below.

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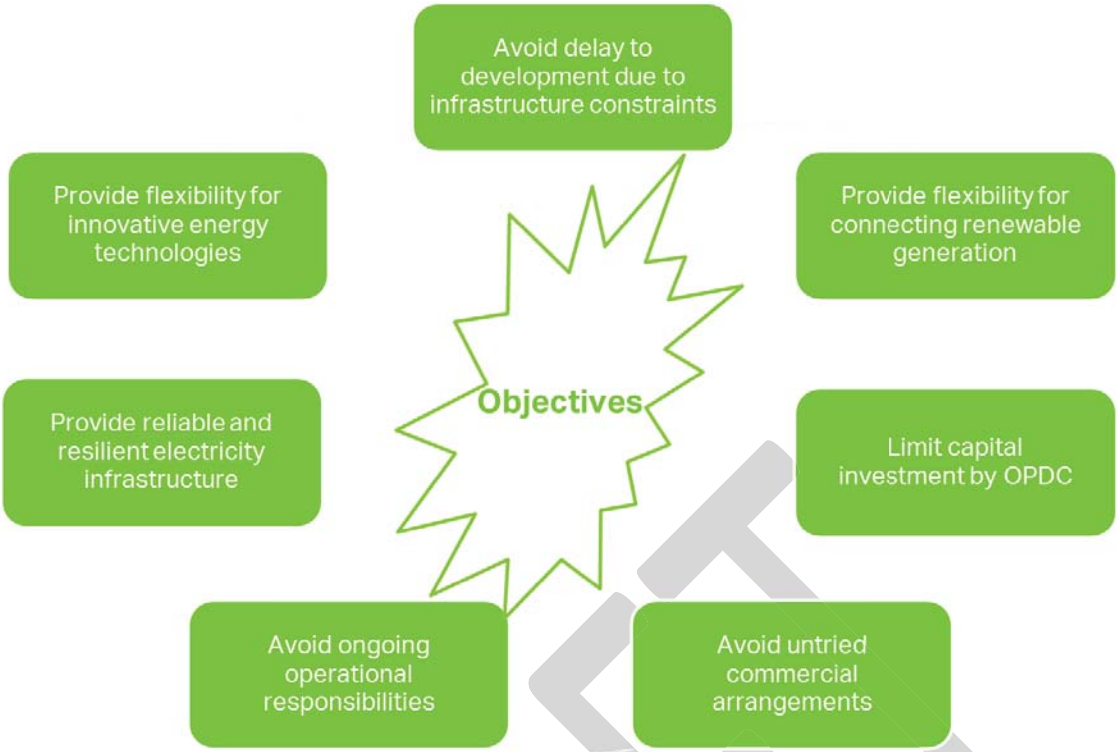

Figure 9. Electricity Strategy High Level Objectives

The high level objectives outlined above are focused on the provision of a resilient electricity supply, which does not require significant levels of early capital investment, incur high operational costs, is scalable to match the increasing demand from the development and is flexible to respond to changes in generation and/or usage patterns.

3.3.4 Network Architecture

Electricity is distributed throughout the UK via the National Grid, which is the high voltage power transmission network connecting power stations and major substations. Primary substations are connected to the high voltage transmission network at grid/bulk supply points, typically at voltages of 66kV or 132kV, and transform this electricity to a lower voltage for interconnection and supplying large consumers directly. Each primary substation feeds a network of secondary substations, which transform the electricity to lower voltages in order to supply cable ring-mains that feed developments and/or individual customers. Interconnections between the secondary substations typically operate at voltages of 22kV or 33kV, and the ring-main cables at 6.6kV or 11kV. Refer to Figure 10 below.

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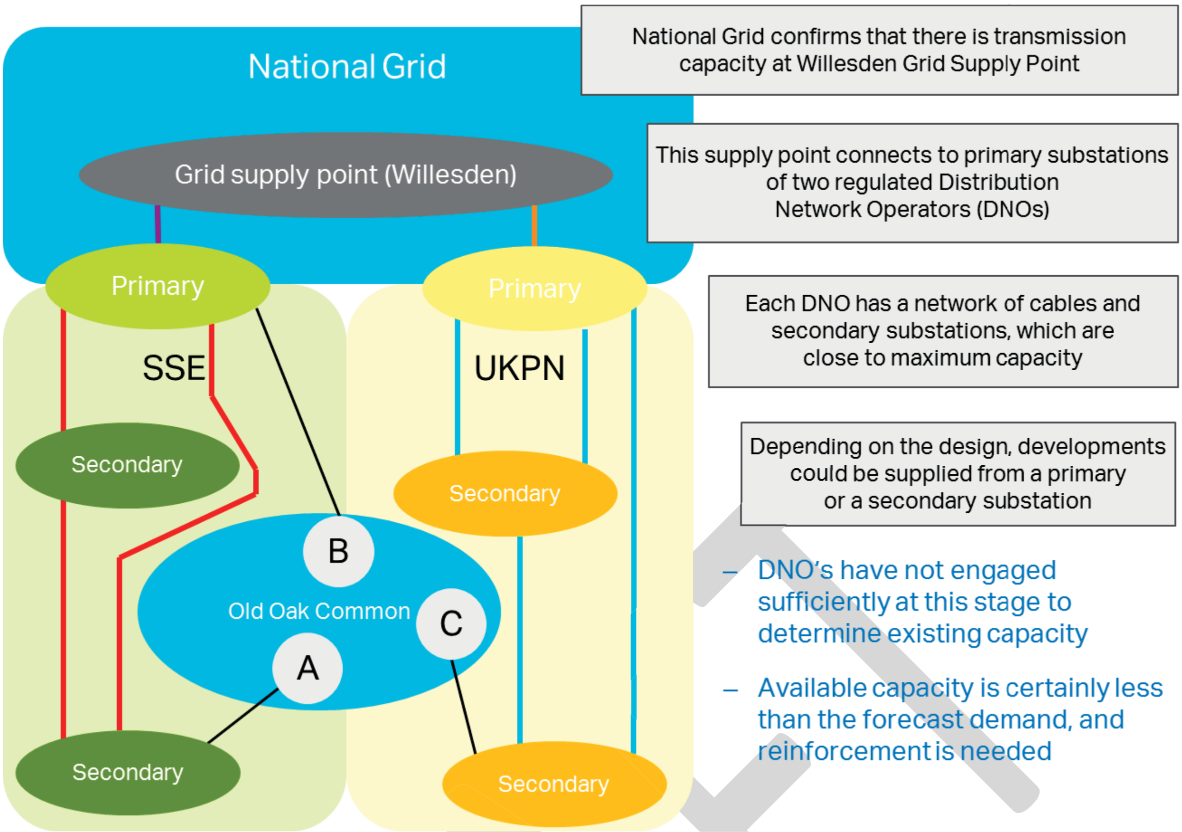

Figure 10. Current Electricity Distribution Responsibilities in Old Oak

Where there is available capacity in the transformers, switchgear and cables in a secondary substation, the cheapest and simplest response to a connection application is to extend a ring-main to supply the consumer premises.

3.3.5 Regulatory Environment

The electricity supply industry in the UK is relatively mature and has been operating as an open-access, government regulated market for many years. Under the current regulations, a number of companies are licensed to produce, transmit or distribute electrical power; these include three transmission system operators, multiple power producers and fourteen DNOs. Competition is encouraged in the generation and distribution segments, and mechanisms exist for both statutory and independent operators in both segments.

Across the UK and Ireland, there are ten electricity distribution franchise areas. Old Oak falls across the franchise boundary between the UKPN and Scottish and SSE networks. It is likely that most developments within the Old Oak area would take an electricity supply from one of these statutory DNOs, although a Developer could also take a supply from a licensed Independent Distribution Network Operator (IDNO) if desired.

3.3.6 Existing Infrastructure

Transmission System Operator (TSO) for England and Wales is National Grid. Both UKPN and SSE receive bulk electricity supplies from National Grid at the Willesden and Acton Lane supply points. Based on discussions with National Grid it is understood that there is adequate capacity at these supply points and in the underlying transmission network to supply the proposed development at Old Oak, even under the most onerous future scenarios.

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There are currently five substations in the vicinity of Old Oak, which form part of the UKPN network supplied from the Willesden Grid Supply Point and the Acton Lane Bulk Supply Point, namely Kimberly Road 11kV, Fulham Palace Road 11kV, Gibbons Road 11kV, Bulwer Street 11kV, and Townmead B 11kV (refer to Figure 11 below). Of these, Fulham Palace Road, Townmead B and Gibbons Road are unlikely to be suitable supply points for Old Oak due to distance and cable routing issues. The remaining two substations are within 2.5km of Old Oak and could conceivably supply the development, albeit with many relatively long cable runs.

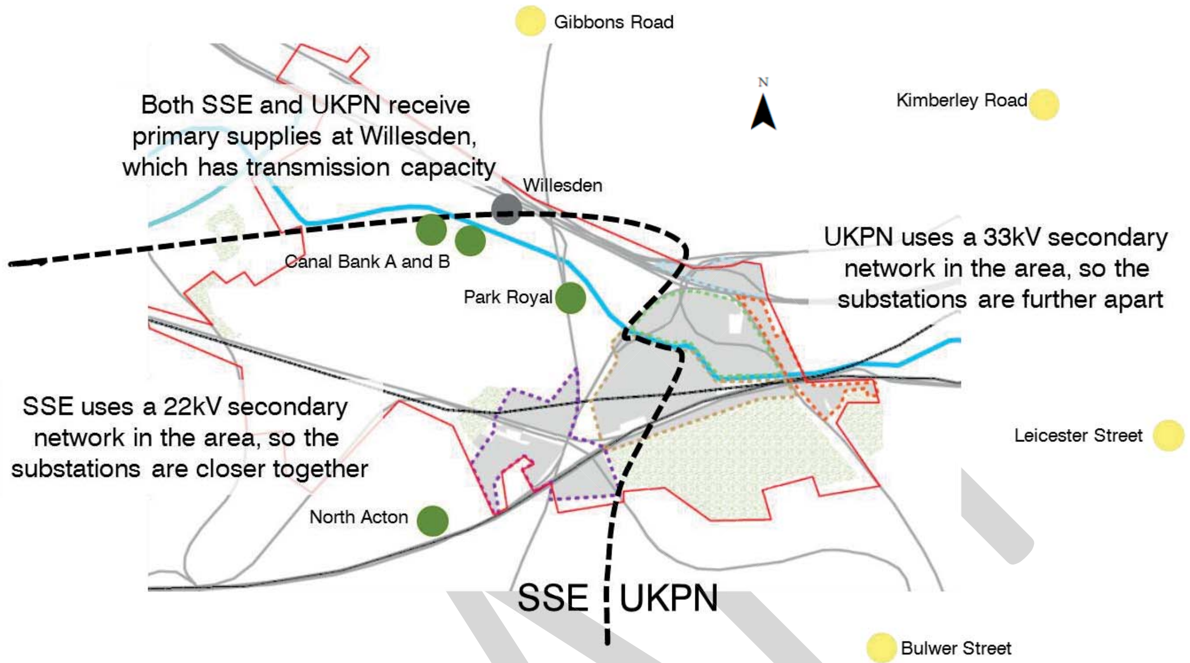

Figure 11. Current Electricity Infrastructure Supplying Old Oak

There are also five substations in the SSE network supplied from Willesden Grid and Acton Lane, which are Canal Bank 11kV, Canal Bank 6.6kV, Park Royal 6.6kV, Leamington Park 6.6kV and Goldsmiths 6.6kV. Of these, Leamington Park 6.6kV could supply developments in North Acton, but because the voltage is lower, it is unlikely to be suitable for supplying the new development in Old Oak South, Old Oak North, Willesden Junction and Scrubs Lane. The other substations are located too far from the development area to be feasible supply points.

The actual spare capacity at a substation depends on the transformer capacity, the electrical switchgear capacity and operational constraints within the distribution network. The DNO can assess the actual capacity, but the required studies are time-consuming, provide accurate data only at a particular point in time and were therefore not provided for this report. However, the spare transformer capacity is an upper bound and this can be determined from published data. Data for the three identified potential supply substations is provided in Table 1 below, which shows that the easily-accessible spare capacity in the existing distribution networks is at most 11MW.

Substation	Transformer configuration	Spare transformer capacity
Kimberley Road	4x15MVA, 22/11kV	1.4MW
Bulwer Street	4x15MVA, 66/11kV	6.1MW
Leamington Park	2x13MVA, 22/11kV	3.5MW
TOTAL		**11.0MW**

Table 1. Anticipated Spare Capacity at Existing UPKN and SSE Substations

3.3.7 Increased Electricity Demand from Proposed Development

3.3.7.1 Estimate of Future Electricity Demand

It is important to understand the differences between maximum and average electrical power demand and electrical energy consumption.

- Electrical power supply infrastructure is dimensioned on the basis of the maximum or peak power demand measured in kilowatts (kW) or megawatts (MW).
- Consumers of electricity are charged for the total electrical energy consumed over a period of time, measured in kilowatt-hours (kWh) or megawatt-hours (MWh).

However, electricity usage varies during the course of a day and from season to season, so the average power demand is less than the maximum (peak) power demand. For example, based on 2014 survey data, the maximum (peak) demand of an average UK household (without electric heating) is 10.6kW, but the annual electrical energy consumed by an average UK household is 4,400kWh, which translates to an average power demand of 0.5kW. This demonstrates that electrical energy consumption can increase substantially without increasing the maximum electrical power demand, provided that energy is consumed evenly during the course of a day and from season to season.

Consumers also use electricity in various ways, and this diversity of use causes the maximum power demand of an area to be less than the sum of the maximum demands of individual consumers. This gives rise to the concept of an average after-diversity maximum demand (ADMD), which is the generally accepted quantity used when dimensioning electricity distribution networks.

Modelling of the electrical power demand for the proposed development at Old Oak has been based upon two delivery scenarios, v7.11 Early Trajectory and v7.12 Late Trajectory, prepared by OPDC. These two scenarios ultimately have the same maximum electrical power demand and the same geographic spread, but differ in timing. Since the early trajectory v7.11 results in the shortest lead-times, it is considered the worst case scenario, and it has therefore been analysed in the most detail.

In keeping with the worst case scenario principle, it has been assumed that a particular Developer would conclude a supply agreement with a Network Operator for the full electricity demand at the start of construction. This is a low risk, long lead-time approach which many, but not all, Developers are likely to follow. Details of the estimated increase in the maximum (peak) electricity demand are shown in Figure 12 below.

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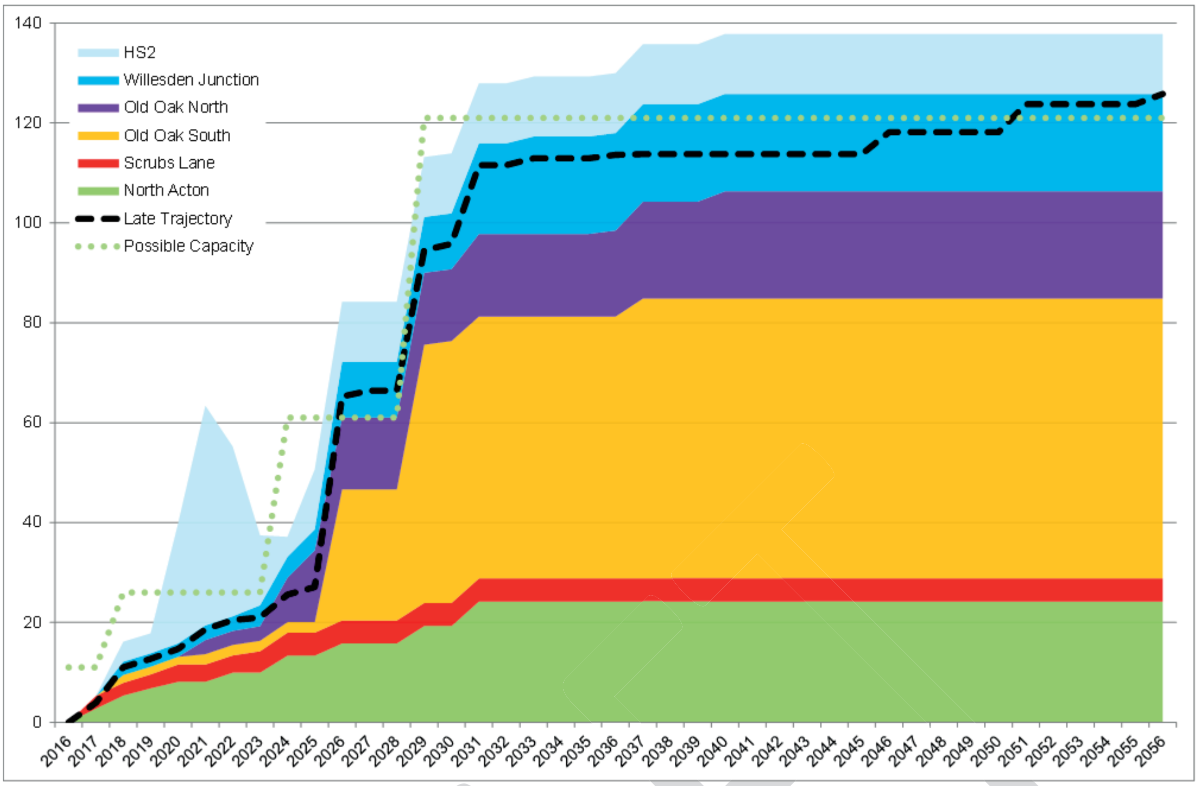

Figure 12. Build-up of Electricity Demand in Old Oak

Assuming the typical average after-diversity maximum demand (ADMD) estimates for various consumer categories shown in Table 2 below, the total electrical power demand for the Old Oak development is expected to be around 125MW.

	Basis	ADMD	Units	Demand
Private homes	kW/home	2.3	13,484	31 MW
Affordable homes	kW/home	1.8	13,484	24 MW
Shared ownership units	kW/unit	1.8	0	0 MW
Office/commercial premises	W/(1,000 sqm)	85	814,024	70 MW
TOTAL				**125 MW**

Table 2. Estimated Peak Electricity Demand for Old Oak Development

In addition, the HS2 railway development will be supplied with electrical power from the same underlying distribution networks. Based on discussions with HS2 Ltd., the additional electrical power demand for the new railway and the proposed station will be:

- 4MW construction start-up supply;
- 40MW tunnel-boring supply; and
- 12MW permanent load.

3.3.7.2 Geographic Spread of Future Electricity Demand

As shown in Figure 13, the Old Oak area is divided by existing infrastructure such as the Grand Union Canal, two existing mainline railways, the proposed HS2 railway, other minor railways (including London Overground, Central Line, and freight lines) and several major roads. Although these may complicate engineering designs for the proposed development, they are not insurmountable obstacles for an underground cable based electricity distribution network.

The future electrical power demand within Old Oak is dominated by two large individual consumers, which are the HS2 Over-Station Development and the Crossrail Depot Development. It is anticipated that the Crossrail Depot is unlikely to progress in the short to medium term, due to the current lease arrangements and the HS2 area development is likely to be less than shown in the present trajectories, but nevertheless these two developments account for approximately 50MW of the estimated future demand. Smaller developments are expected to require an additional supply capacity of circa 70MW, spread approximately equally over the UKPN and SSE franchise areas. These regulated DNOs are obliged to provide electricity to developments located in their franchise areas, if requested.

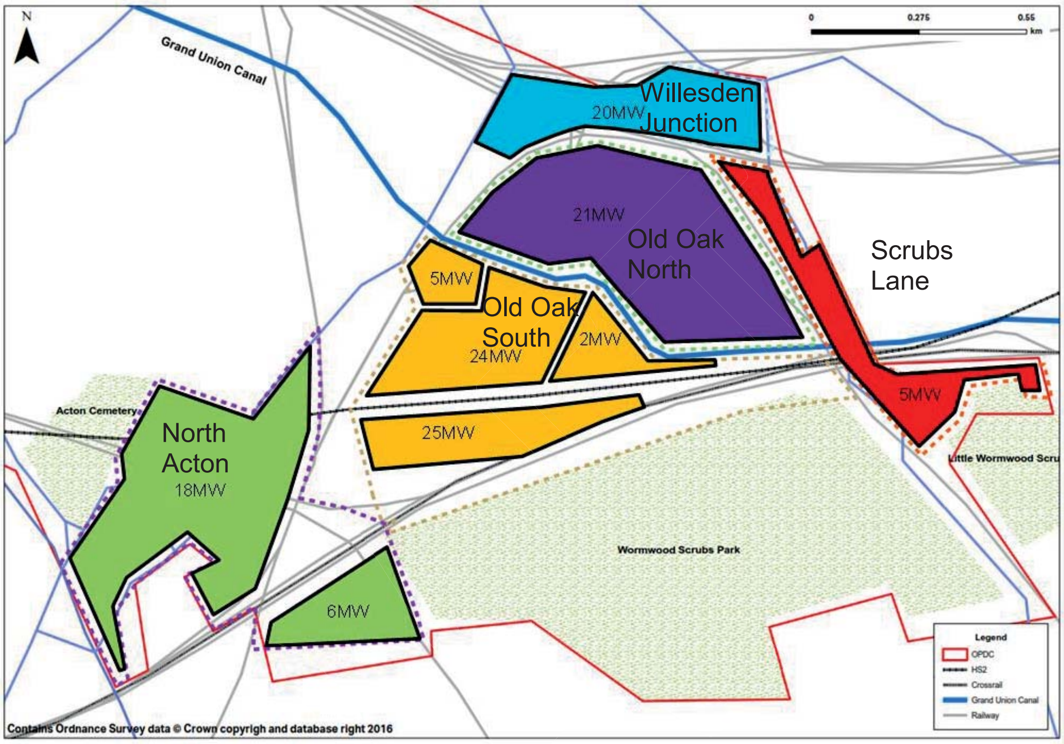

Figure 13. Estimated Peak Electricity Load by Area

The proposed development at Old Oak breaks down into five broad clusters, each with different phasing and landowner characteristics, as shown above.

3.3.7.3 Future scenarios for Electrical Power Supply

As outlined in Section 2.1, electrical energy consumption is expected to increase in the future due to changing demand and new technologies. The magnitude of the change will depend on improvements in the energy efficiency of appliances and buildings, the penetration of consumer electronics (home automation, air-conditioning, electronic entertainment, etc.) and the manner and degree of adoption of sustainable, low-carbon, technologies (heat-pumps, electric vehicles, battery storage, etc.). There is speculation that electrical energy consumption could increase by up to five times within the next few decades. However, a significant proportion of this energy is likely to come from distributed renewable generation embedded in distribution networks, requiring sophisticated demand-side management technologies for effective utilisation. The electricity infrastructure should be able to accommodate embedded generation and demand-side management from the outset, because it has little (if any) impact on the capital cost of the infrastructure, and retrofitting or upgrading in the future will be costly, if indeed possible.

The electrical power demand will also change in the future, but present technology scenarios suggest that in future, electricity will be used more evenly throughout the day and there is unlikely to be a significant increase in the maximum electrical power demand. In fact, if energy storage technologies become more common, there could even be a decrease in the electrical power demand. Due to the uncertainty in the changes in electrical power demand and consumption, it is considered unjustifiable to over-dimension infrastructure at the outset, to cater for possible increased demand in the future. However, where practical, it is recommended that space should be allowed for future expansion.

3.3.8 Constraints to Development

3.3.8.1 Architecture of a Distribution Network and Methods of Reinforcement

Where there is a constraint in a secondary substation or congestion of the ring-main cable routes, the distribution network can be expanded by adding a new secondary substation (provided that there is spare capacity in the primary substation). This is termed *secondary expansion*, and it adds a block of capacity to the distribution network. The size of the block depends on the engineering design practices of the network operator, but it is typically in the order of 15MW to 30MW. The cost of secondary expansion is, therefore, substantially higher than that of extending a ring-main.

Where there is a constraint in the primary substation or congestion of the interconnecting cable routes that cannot be resolved, provided that there is spare capacity in the transmission substation, the distribution network can be expanded by adding a new primary substation and possibly new secondary substations. This is termed *primary expansion*. The capacity block that is added will be larger than for secondary expansion, and the cost will be substantially higher. Again, the size of the block depends on the engineering design practices of the network operator, but it is typically in the order of 60MW to 120MW.

3.3.8.2 Impact on Proposed Development

The costs of reinforcing the distribution network can be significant, which in the context of the proposed development at Old Oak could delay a number of the smaller developments, as the DNO's will only reinforce their networks to meet the required demand.

3.3.8.3 Capacity Deficit

A regulated DNO only invests in new capacity when a Developer funds a full block of load (e.g. 30MW). However, a Developer with a small load demand (e.g. 0.5MW) is likely to struggle to fund a full block due to the relatively high cost.

In this case, the demand is suppressed and development is delayed until another Developer funds the full block.

3.3.8.4 Capacity Surplus

A Developer has funded a full block of load, but the increase in capacity has exceeded the demand (e.g. 10MW demand out of a 30MW block).

A Developer with a small electrical demand requires a new supply and must fund the portion of the block that is required. The Developer who funded the full block receives a rebate via the "second-comer rule"

In this case, the demand is serviced and development proceeds.

3.3.9 Opportunities for Reinforcement

3.3.9.1 Technical Opportunities

In order to supply electricity to the proposed development at Old Oak, the existing supply infrastructure will need to be upgraded to meet the anticipated demand of 125MW. Considering the geographical spread and build-up of power demand, it is apparent that there are essentially two options for reinforcing the networks supplying Old Oak.

- The first option is to construct several new secondary substations near the periphery of the area, which can each supply developments that are near to them. Construction could be timed to coincide with development in each of the clusters, and in the final configuration there would probably be four new substations, each with three 15MVA transformers, and space for a fourth. This provides flexibility for future expansion.

- The second, and more expensive option is a new primary substation near the middle of the area, supplying nearby developments directly, but also supplying secondary substations for developments that are further away. In the final configuration, there would probably be two 67MVA transformers in the primary substation, with space for a third, and three 15MVA transformers in each secondary substation, with space for a fourth.

The final number, ratings and positions of the substations in each option would be determined by the relevant DNO, based on the electrical power demand and the engineering policies and procedures documented in the DNO's Long Term Development Statement (LTDS).

3.3.9.2 HS2 Limited

It is understood that HS2 Ltd. is planning to start operating a new high-speed rail link into London by 2025. The electricity for construction and operation of a portion of this rail link will be supplied at Old Oak and will be sourced from the same underlying transmission and distribution networks as the planned development by OPDC. The electricity demand for HS2 can be characterised by three distinct phases.

- Normal construction and fit out requires a 4MW supply to the worksite at Atlas road by 2018. This is required until operation starts in around 2025.
- Tunnel boring will be an around-the-clock activity starting in 2019, that ramps up to 40MW when all tunnel drives are active in 2021, and then drops down as the individual tunnel drives are completed. The tunnel boring should be complete by 2023.
- From 2025 the tunnels will require a 12MW operating supply.

The magnitude of the tunnel boring supply is substantial, and the underlying networks cannot provide this supply without being reinforced. After tunnel boring is complete, this capacity can possibly be released back to the network operators, in order for them to supply other developments in the area however, this is contingent on the suitability of the infrastructure.

3.3.10 Delivery Model Options

Within the current regulations, there are essentially three delivery models for upgrading the existing electricity infrastructure within the Old Oak development area.

3.3.10.1 Statutory DNOs

The normal approach for individual Developers to obtain an electricity supply from a DNO is:

- Submit a connection application and the DNO will quote for the complete works, or alternatively for the non-contestable and contestable works[5] ; then
- If required, solicit alternative quotations for the contestable works from Independent Connection Providers (ICPs); and finally
- Select the preferred option, and the chosen service providers will install the required infrastructure to supply the electricity needs of the development (the power required for construction will be supplied using temporary generation or a temporary connection, in instances where sufficient capacity does not currently exist).

Due to the current regulations that control the DNOs, they are not incentivised to undertake strategic expansion of their networks, as this is perceived to be investment that is ultimately at the risk of the consumer. However, the DNOs are required to respond to connection applications at an operational level, and when capacity is exhausted, any Developers that make a connection application will be quoted the full network expansion cost for the step-change in capacity that is needed, albeit with the likelihood of receiving rebates via the second-comer rule for five years.

[5] *Non-contestable works must be executed by the DNO, but contestable works may be executed by an independent connection provider if the Developer decides that this is advantageous. Often, an independent connection provider can execute contestable works at a lower price or faster than the DNO.*

Where there is spare capacity, the quotations from DNOs will be commensurate with the connection applications. However, if capacity is exhausted, this will not be the case and development is likely to stall until a Developer is willing and able to fund the step-change in capacity. During this waiting period, smaller Developers may allow their quotations to lapse, because they have, or are unable to secure sufficient cash resources to fund the large additional investment, especially with uncertain rebates over a period of several years, which may not cover the full additional investment.

To ensure that sufficient electricity supply capacity is available for future expansion, Developers can contract for a significantly higher capacity than is needed initially. In this case, the assets are installed by the DNO to provide the contracted capacity and if the capacity is not used, the DNO charges a capacity reservation tariff. If the Developer reduces the contracted demand, the capacity which is released may then be resold by the DNO.

3.3.10.2 Independent DNO (IDNO)

Independent Distribution Network Operators (IDNOs) develop, operate and maintain local electricity distribution networks, which can be either connected directly to the infrastructure of a DNO, or indirectly via another IDNO. The IDNO networks typically supply housing and commercial developments, which fits well with the Old Oak opportunity.

There are currently nine IDNOs that are licensed to operate in Great Britain:

- Energetics Electricity Limited
- ESP Electricity Limited
- Harlaxton Energy Networks Limited
- Independent Power Networks Limited
- Peel Electricity Network Limited
- The Electricity Network Company Limited
- UK Power Distribution Limited
- Utility Assets Limited
- Utility Distribution Networks Ltd

IDNOs are regulated in the same way as DNOs, except that the IDNO licence does not have all the conditions of a DNO licence. Specifically, an IDNO is permitted to invest at risk and can therefore undertake strategic expansion. In this case, the IDNO will purchase a bulk supply from either the TSO or a DNO, and develop a downstream network to supply consumers. An IDNO does not pay a capacity reservation tariff to the DNO.

As the conditions of the IDNO licence are less onerous than those imposed on a DNO, the IDNO can offer more technically innovative and/or commercially attractive solutions to Developers. However, an IDNO cannot be designated as a “compulsory supplier”, and it must compete with DNOs and/or other IDNOs to provide the supplies to individual consumers. Typically, an IDNO would need to secure several consumers before building and operating a network, which may result in a start-up delay compared to a DNO connection.

3.3.10.3 Public Sector Investment

The Greater London Authority (GLA) has developed a procurement model where a public sector entity purchases a connection from a DNO to initiate network reinforcement, with the full cost of the improvement works funded by the public sector. This creates spare capacity within the electricity network, which can be purchased by Developers and a rebate issued to the public sector (original investor) via the second-comer rule. In the event that not all of the spare capacity is sold within the 5 year period that currently applies for the second-comer rule, the public sector entity would receive no further payments towards the outstanding amount.

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3.3.11 Emerging Intervention Options

Arising out of the analysis, four strategic options have emerged for upgrading the electricity infrastructure in the Old Oak area to supply the proposed development. The simplest option is to undertake no intervention, which is attractive in many respects, but which is associated with high levels of risk based on the objectives outlined in Section 3.3.3. To address these risks, three intervention options have been developed. Each option has advantages and disadvantages, and no option is unequivocally superior. The final decision on the electricity infrastructure strategy will therefore be a compromise based on a comparative evaluation against the objectives.

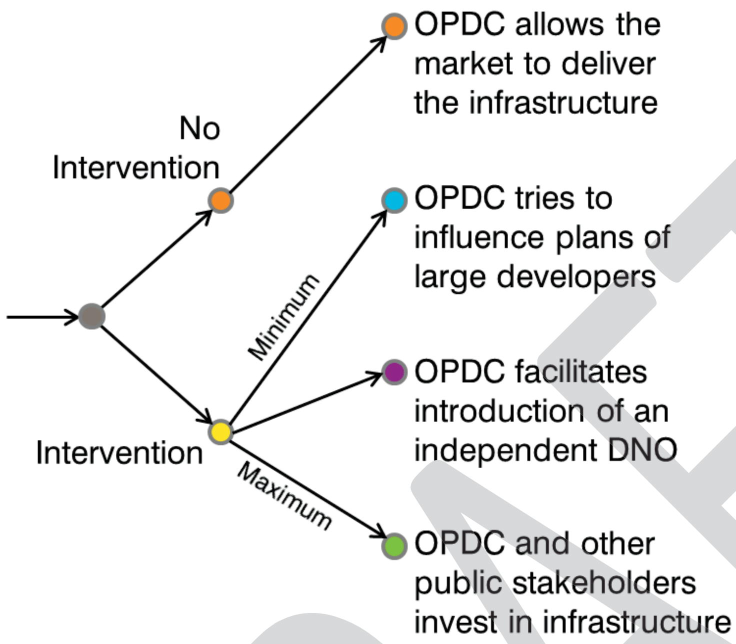

Figure 14: Varying Levels of Intervention for reinforcing the Electricity Network

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3.3.11.1 No Intervention

The network will be extended incrementally by the two DNOs in response to accepted quotations for connections, using the most cost-effective solution for each individual application. From an OPDC perspective, this is the simplest approach to delivering electricity infrastructure to Old Oak.

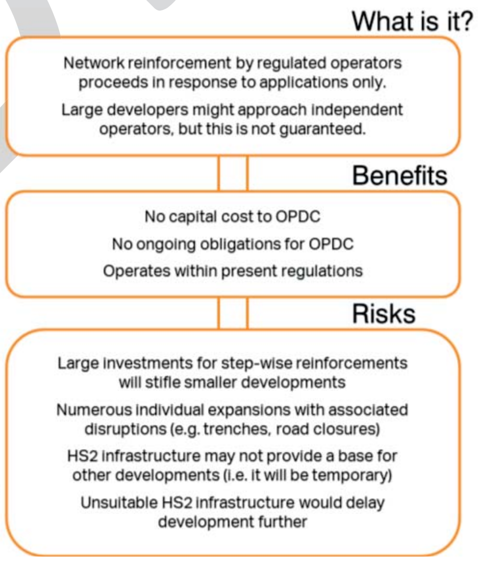

Figure 15. Anticipated Benefits & Risks Associated with No Intervention Approach

3.3.11.2 Technical Considerations

With a No Intervention approach, the network will expand incrementally at a ring-main level and fundamental secondary or primary reinforcement will be hard to justify. An application from a large Developer is one circumstance in which a new secondary substation could provide the most cost-effective solution. If this option is adopted, large single Developers might initiate some secondary expansion, but a new primary substation with its associated strategic optimisation benefits, is very unlikely. Other technical consequences are the likely congestion of ring-main cable routes and repeated disruption to road traffic during installation of new ring-main cables.

3.3.11.3 Delivery Model

For small Developers, extension of a ring-main or a new ring-main are likely to be affordable and provided there is existing capacity that the DNO can offer, the development will proceed. However, when existing capacity is exhausted, a new substation is likely to be the most cost-effective solution that a DNO can offer. This solution may be unaffordable to small Developers and in this case development will stall. Due to the significant costs that are involved, reinforcement of the underlying networks through the provision of a new substation typically relies on connection applications by large Developers that have sufficient financial resources. Battersea Nine Elms is a case study which clearly demonstrates these effects.

In Old Oak, there are envisaged to be several large Developers, with the proposed HS2 railway being the first and largest of these. As indicated in Section 3.3.9.2, it is understood that the proposed construction of HS2 requires a significant increase in the electricity supply capacity by 2019, which could initiate expansion of the power infrastructure required to support the initial phases of development at Old Oak. However, this is dependent on the detailed technical solution that HS2 decides to adopt. There is a risk that time and cost pressures to commence construction of HS2 result in contestable works being procured for the new railway, which do not provide a point of common connection that can supply other developments, or which are not to DNO adoptable standards.

Although the proposed development of HS2 could resolve the capacity shortfall and reduce the risk of early stage development at Old Oak stalling, the No Intervention approach is vulnerable to stalled development along the whole of the development trajectory. In later phases, development may stall again if a large Developer such as Car Giant, the Crossrail Depot Redevelopment or HS2 Over-Station Development does not apply for a connection in time to suit the smaller developments. Also, at each juncture, there is again the risk of contestable works being unsuitable.

3.3.11.4 Financial Considerations:

Using the No Intervention approach, there is no direct financial contribution needed from the public sector. However, awareness by Developers of the power supply constraints could be reflected in lower land valuations.

3.3.11.5 Large Developer Engagement

Since the timing and technical solutions that are offered to large Developers for the contestable works have a significant impact on progress along the development trajectory, attempting to influence these factors could provide an attractive high-impact, low-cost intervention approach. This is the Large Developer Engagement approach. In the present context, HS2 is the Developer that could be engaged, but there may be others in the future.

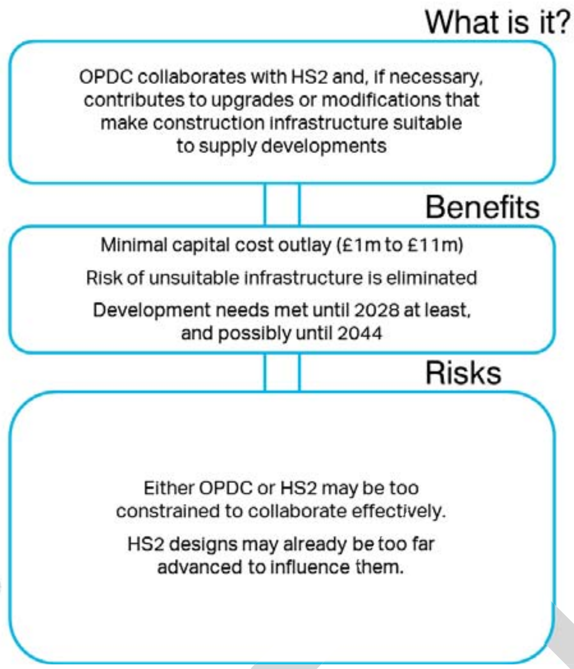

Figure 16. Anticipated Benefits & Risks Associated with Engaging Developers Controlling Large Landholdings

3.3.11.6 Technical Considerations

HS2 Ltd. has purchased a connection to supply its 4MW start up demand and has applied for a connection to supply its 40MW tunnel-boring demand. HS2 has not finalised the full technical details of the tunnel boring and permanent supplies, but in discussions the Developer has indicated that its present design concept involves:

- A point of connection at either 132kV or 66kV on the Atlas Road construction site;
- Temporary transformation to 11kV for supplying the tunnel boring machines, via cables rated for 33kV so that they can be reused to supply the permanent load; and
- Permanent transformation to 33kV for supplying the permanent load once tunnel boring has been completed.

For supplies to other developments, the temporary transformation to 11kV may be problematic. Siting the point of connection on the Atlas Road site may also be a sub-optimal use of potentially valuable development land. There are technical solutions that may provide better use of land and resources in the long term, but these will have short term time and cost implications that HS2 may not be willing to accept.

3.3.11.7 Delivery Model

In order to beneficially influence the technical decisions regarding the HS2 electricity supply connection, it is important to constructively engage both the HS2 Design and Engineering Team and the DNO Planning Team. Relocating the substation could affect the non-contestable works quotation, although the impact is expected to be small. Improving the temporary and permanent solutions will affect the contestable works. HS2 has indicated that any cost differential arising from changes to the current solutions would need to be funded by OPDC or another party. In addition to finalising the technical solution, quantifying the cost differential and identifying a funder are critically important activities to deliver an improved technical solution to the HS2 power supply.

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3.3.11.8 Financial Considerations:

As outlined above, quantifying the cost differential and identifying a funder are important activities for the Large Developer Engagement option. For HS2, it is expected that the cost differential will be relatively small, but an appropriate mechanism for recovering the cost must be found.

Improving the technical solution and securing a power supply for early developments may have a beneficial effect on land values, and releasing valuable land for future development when HS2 construction is completed is also likely to be financially advantageous.

3.3.11.9 IDNO Introduction

From a regulator (OFGEM) perspective, IDNO networks were envisaged mainly as extensions to the DNO networks serving new housing and commercial developments. This vision fits well with the nature of Old Oak, and it suggests that an IDNO network may be a good solution.

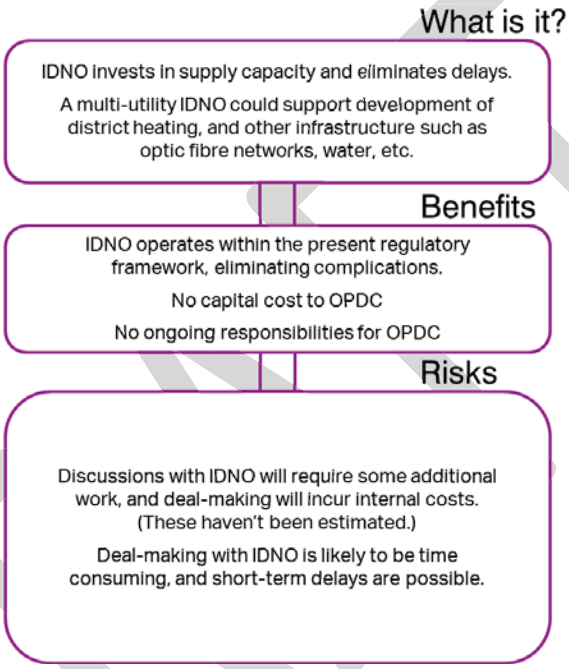

Figure 17. Anticipated Benefits & Risks Associated with Introduction of an IDNO

3.3.11.10 Technical Considerations

The architecture and technical details of the network would be determined by the IDNO, and it is expected that there would be significant primary and/or secondary reinforcement along the lines described in Section 3.3.9. Because the IDNO can invest strategically, the architecture would align with the masterplan, so the IDNO introduction option results in a more cost-effective and technically efficient solution compared with incremental reinforcement of the existing networks.

3.3.11.11 Delivery Model

Competitive selection of an IDNO should be undertaken and preferably follow the OJEU Competitive Dialogue process to ensure that the proposal provides best value for the development. Multi-utility proposals could be considered, which may support future implementation of sustainable, low-carbon initiatives such as electric vehicles and energy efficient street-lighting.

3.3.11.12 Financial Considerations

There would be no significant financial contribution needed from the public sector, and hence no need for a mechanism to recover up-front investment costs.

Resolving the power supply constraint may beneficially affect land valuations, and would ensure that the development is successful along the whole trajectory.

3.3.11.13 Investment Ahead of Need

In the case of the proposed development at Old Oak, significant optimisation and value enhancement opportunities may be lost as a result of the No Intervention approach being adopted. Investment Ahead of Need intervention by the public sector may be a viable alternative that captures some or all of these opportunities.

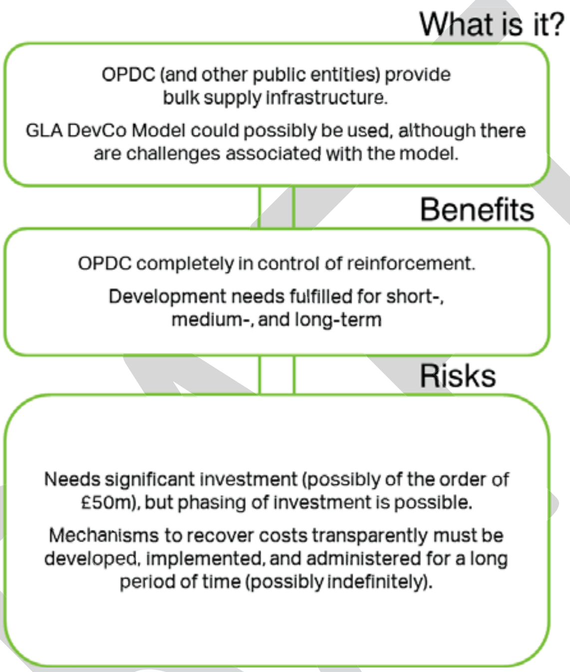

Figure 18. Anticipated Benefits & Risks Associated with Investment Ahead of Need

3.3.11.14 Technical Considerations

The network design would be undertaken by the DNOs in response to a connection application from a public sector entity. This application would need to be large enough to initiate primary and/or secondary reinforcement. By designating the connection point, the applicant would have some influence over the network configuration, but ultimately the DNO would determine the solution that it considers to provide the most cost-effective option. The network would still be designed reactively, albeit in response to a relatively large demand, which would give the DNO some latitude to pursue strategic objectives within the constraints of the least-cost requirement.

3.3.11.15 Delivery Model

Network reinforcement would be initiated by a public sector application for a power supply. The application should not be too large, because only subsequent applications within five years will attract a second-comer rebate, and this is the primary means of recovering the cost of the reinforcement. It is anticipated that there is likely to be a shortfall between second-comer rebates and the cost of reinforcement, and a method of recovering this shortfall must be developed and implemented.

3.3.11.16 Financial Considerations

Investment ahead of need is likely to require a substantial capital injection by the public sector. Some of this money will be recovered over the second-comer interval of five years.

In order to offset this investment, certainty surrounding the power supply may reflect in higher land valuations allowing Developers to pay higher capital contributions to OPDC.

3.3.11.17 Evaluation of Intervention Options

Objectives	No Intervention	Large Developer Engagement	Introduction of an IDNO	Investment Ahead of Need
Avoid delay to development due to infrastructure constraints	★	★★★	★★★	★★★
Provide flexibility for connecting renewable generation	★	★★	★★★	★★★
Provide flexibility for innovative energy techologies	★	★★	★★★	★★★
Provide reliable and resilient electricity infrastructure	★	★★	★★★	★★★
Limit capital Investment by OPDC	★★★	★★	★★★	★
Avoid untried commercial arrangements	★★★	★★★	★★★	★
Avoid ongoing operational responsibilities	★★★	★★★	★★★	★

Table 3. Assessment of Intervention Options

An assessment of the four intervention options has been undertaken based upon the objectives outlined in Section 3.3.3 and the results are shown in Table 3 above.

Based upon this assessment, the risks associated with adopting the No Intervention approach are considered to be unacceptable. It is possible that large developments will commence at points in time and select connection options that provide sufficient spare capacity for smaller Developers, but successful and timely development along the whole trajectory will be more a matter of chance than good management.

Investment Ahead of Need is an obvious and direct response to the risks of the No Intervention approach. In this case, the second-comer rule appears to be the primary mechanism for recovering the investment cost from Developers that benefit from the increased electrical capacity however, the relatively short duration for recovery of the initial investment is likely to encourage multiple small improvements. As such, this approach is unlikely to fully capitalise on optimisation opportunities that consider the whole trajectory. There is also likely to be some under-recovery of costs, and an additional mechanism must be developed and implemented to address this. The approach is also capital intensive for the public sector, which is considered undesirable.

Given that it is a relatively low cost, high effect intervention, Large Developer Engagement should be undertaken whenever practical. The engagement should focus on the timing of an individual development and the technical solution for the connection, with a view to maximising the benefit to the whole development area. There may be differential costs associated with changes to the optimum solution for the individual Developers, which would need to be funded by the public sector and recovered from the subsequent Developers who benefit from the changes. Although the capital contribution from the public sector is smaller than for the Investment Ahead of Need option, limited investment will still be required.

IDNO Introduction is an intervention that is well-suited to a large regeneration programmes such as that proposed at Old Oak. The IDNO can plan a network in close cooperation with the Development Masterplanner, and can capitalise on strategic optimisation opportunities. Since an IDNO is governed by the same price control mechanisms as a DNO, there are no cost penalties to Developers, and in many cases the IDNO can offer innovative packages that benefit Developers and consumers financially. In this case there is no requirement for capital contributions from the public sector, which is desirable however, since the IDNO must plan the network alongside the Masterplanner and they will seek to conclude supply agreements ahead of network construction, there is likely to be a time lag in the availability of any new infrastructure.

3.3.11.18 Recommended Intervention Option

Based upon the above assessment, the recommended approach for the provision of new electricity supply capacity at Old Oak is multi-faceted. In the longer term, introducing an IDNO is considered to be very desirable, and is therefore recommended.

Due to the anticipated time lag in the availability of the new infrastructure, it may be necessary to engage large Developers to mitigate the risk of stalled development in the short term. If Large Developer Engagement is unsuccessful, investment ahead of need may be required, but this should be limited to relatively small investments that can be recouped using the second-comer rule.

3.3.12 Conclusion and Next Steps

An assessment of the currently available electricity supply capacity has been undertaken for Old Oak, which has identified that significant reinforcement of the existing infrastructure that is owned by the Distribution Network Operators UKPN and SSE will be required to supply the proposed development.

Four strategic options for expansion of the supply infrastructure have been identified ranging from a no intervention approach to public sector funding, to invest ahead of need. These strategic options have been assessed against seven objectives which were developed with OPDC and key stakeholders, to ensure that the power supply is reliable, flexible, affordable (with limited capital investment by OPDC) and available to suit the increasing power demand as the development proceeds.

The results of the assessments undertaken to date have identified that collaborating with HS2 and other large Developers could avert some undesirable short-term effects of “Do Nothing” option and will require little capital expenditure.

In the short-term an opportunity exists for OPDC to collaborate with HS2 Ltd., to identify whether the electricity infrastructure that will be installed for construction of the new rail line can supply the proposed development at Old Oak.

In medium to longer term, there will be further constraints, which could delay development. These could be mitigated through engagement with potential IDNOs, to encourage private sector investment ahead of need.

Although probable, there is no guarantee that an IDNO can be established in the area therefore, models which could sensibly enable investment ahead of need by public entities should be investigated in parallel with the other activities.

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3.3.13 Fixes for Masterplan

It has been identified in Section 3.3.9 that there are two possible approaches to reinforcement of the electricity network. Given that there is significant uncertainty regarding future demand levels, it would be prudent to ensure that the most onerous land-take requirements for electrical infrastructure are accommodated within the masterplan. In this case, the following constraints should be considered, which are illustrated on the drawing contained within Appendix H:

- A possible primary substation, which could be located on the identified landlocked site adjacent to Old Oak Common Lane. The approximate size of the substation is expected to be 60m wide by 50m long.
- A secondary substation located on the Car Giant site. It is anticipated that the location and design of this substation will probably be undertaken by Car Giant to suit their proposed development.
- A secondary substation for the HS2 permanent infrastructure. It is anticipated that HS2 will undertake the siting and design of this infrastructure.
- A secondary substation in North Acton located near to (or on the same site as) the proposed energy centre. The area occupied by the substation site is expected to be approximately 40m wide by 50m long.
- A secondary substation to supply the proposed developments at Scrubs Lane and Willesden Junction, of similar size to the new infrastructure at North Acton.

In the land-take estimates above, conventional air-insulated open-terminal substations have been assumed. It is possible for secondary substations to be of indoor construction, although this increases the cost. Nevertheless, by using indoor switchgear, the size of a secondary substation could be reduced to around 40m wide by 15m long.

Heat energy and electricity are closely related therefore, it is recommended that if possible the masterplan should locate secondary substations, electrical energy storage and energy centres close together (ideally on the same site). Typically, it is expected that the siting of energy centres would be subject to greater constraints than siting of substations.

Since the precise substation locations are still to be determined, from a masterplan perspective it is important to ensure that physical support infrastructure to allow crossing of all major obstacles with heavy cables be implemented. From a design perspective, it is recommended that a minimum imposed load of 200kg/m should be considered for the electricity cables.

Provision should also be made below the pavements and/or verges of all major roads for large electricity cables to be installed, with a recommended service corridor of typical size 1.2m wide by 2.0m deep. These cables could be installed in dedicated service tunnels, which would eliminate the need for repeated excavations throughout the lifetime of the development. However, if this solution is adopted, it is recommended that the internal size of the tunnels be 50% greater than the service corridor dimensions detailed above, to allow for heat dissipation. On smaller roads, it is recommended that a service corridor of approximate size 0.6m wide by 0.9m deep be provided.

For the operation of a next-generation, smart distribution network, large volumes of data will need to be shared between consumers and the network operator. To facilitate this, the masterplan should incorporate measures to ensure that broadband telecommunication can be installed throughout the entire development.

3.4 Decentralised Energy

3.4.1 Overview

3.4.1.1 Stage 1 Overview of Previous Work

AECOM's Stage 1 work was commissioned in April 2016 and reported in July 2016. This set out the issues that a decentralised energy strategy for Old Oak would need to address, and set out a road map of the key tasks that would need to be undertaken to develop a preferred strategy for delivering low carbon, affordable and secure energy supplies at Old Oak.

One of the key questions identified in the Stage 1 work was whether district heating would remain an effective means of delivering low carbon heat, as electricity grid decarbonisation reduces the carbon savings from gas CHP, and whether there are appropriate low carbon technologies that could replace or be used in conjunction with gas CHP as sources of heat for heat networks.

A second related question was whether plot based solutions, combining high levels of fabric energy efficiency and on site low carbon technologies, could offer similar carbon savings to district heating solutions at lower cost, while meeting wider objectives including affordability to consumers.

It was recommended that prior to commencing the masterplanning work, a techno economic options appraisal should be undertaken to help provide answers to these two questions.

A further question identified in Stage 1 was around the delivery mechanisms open to OPDC for delivering low carbon district energy solutions at Old Oak, and their likely merits to OPDC in meeting its objectives for decentralised energy. It was recommended that an initial appraisal of the delivery options be undertaken, prior to further developing the preferred technical solution and delivery model alongside the masterplan. The assumption when preparing the Stage 1 roadmap was that all public sector land would be transferred to OPDC and this influenced the proposed steps in the roadmap.

3.4.1.2 Stage 2 Scope of Work

In September 2016 AECOM was commissioned to undertake a sub-set of the tasks that had been recommended as part of the Stage 1 Work. Those tasks commissioned included:

Technology Options Appraisal:

- Review the impact that smart technology could make on demand and the required capacity of installed systems;
- Review the capacity that local low carbon heat sources could provide as alternative heat sources to gas CHP;
- Review potential network routes that would enable heat sources to be utilised and their constraints; and
- Consider the potential for local heat sources to offer an alternative to gas CHP.

Delivery Options:

- Review lessons learned from the delivery of other existing large scale district heat networks, for different public and private sector delivery models, and assess the advantages and disadvantages of these different approaches;
- Review current private landowner energy strategies within the Old Oak area, to understand the implications for a decentralised energy strategy;
- Obtain initial market views from Energy Services Companies (ESCOs) and utility companies on their interest in delivering decentralised energy infrastructure at Old Oak.

In December 2016 AECOM's scope was extended to cover an assessment of the costs and carbon savings for alternative energy strategy options. The analysis compared dwelling or site based solutions to district heating solutions. The assessment explored the potential carbon savings of

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different options at different points in time over the development period, so it could be seen how preferred technical options may change over phases of delivery.

The extended scope also included providing support to OPDC in drafting an appropriate decentralised energy policy for the local plan.

The aim of the Stage 2 work was to identify a preferred energy strategy approach and in particular whether or not district heating is an appropriate long term solution for the proposed development at Old Oak. It was also to ensure that preferred energy strategy options could be safeguarded through the masterplanning process, and that appropriate local plan policy is put in place to support the delivery of the preferred strategy.

3.4.2 Vision and Objectives for Old Oak Energy Strategy

As part of the mayoral elections the current Mayor pledged that by 2050 London will be zero carbon and will run on 100% clean energy. As one of the largest development opportunities in London and with timescales that will see development being delivered beyond 2050, there will be an expectation for Old Oak to set an exemplar for how the Mayor's pledge can be delivered.

The Mayor's pledge is supported by existing policies in the London Plan. Some of the key policies to highlight in relation to decentralised energy are as follows:

3.4.2.1 Energy Efficiency

London Plan policy promotes the use of energy efficiency measures to reduce energy demands. Supporting guidance to the London Plan effectively requires that buildings meet the target emissions rates in Part L of the Building Regulations through efficiency measures alone, before savings from low carbon or renewable energy supplies are taken into account.

3.4.2.2 Carbon Reduction Targets

There are a number of specific targets for reducing CO_2 emissions compared to Building Regulations requirements:

- All new homes to have zero regulated CO_2 emissions from 2016;
- All new non-residential buildings to have zero regulated carbon emissions from 2019; and
- All homes and buildings to deliver a 35% reduction in regulated CO_2 emissions through on site measures.

Any shortfall in these targets not delivered on site must be addressed by offset payments to a ring-fenced carbon offsetting fund, to be administered and set up by the Local Planning Authority.

3.4.2.3 District Heating

The London Plan sets out the following preferred hierarchy for the provision of heat:

- Connection to existing heat networks;
- Creation of new heat networks on site, to be served by CHP; and
- Provision of building-scale communal heating systems.

The Mayor's ambition is that by 2025, 25% of London's energy needs should be met from decentralised energy sources, including heat networks utilising low carbon heat supplies.

3.4.2.4 Renewable Energy

- Utilise local renewable energy sources where feasible.

Supporting text to the London Plan policy sets an expectation for renewable energy to provide a 20% reduction in CO_2 emissions, but this is not part of the policy wording and is rarely achieved or enforced.

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3.4.2.5 Objectives for the Old Oak Energy Strategy

In developing the preferred energy strategy a set of strategic objectives were set out and agreed through meetings with OPDC and other stakeholders. These are summarised in Figure 19. The alternative decentralised energy options have been appraised against these objectives to arrive at a preferred strategy for decentralised energy.

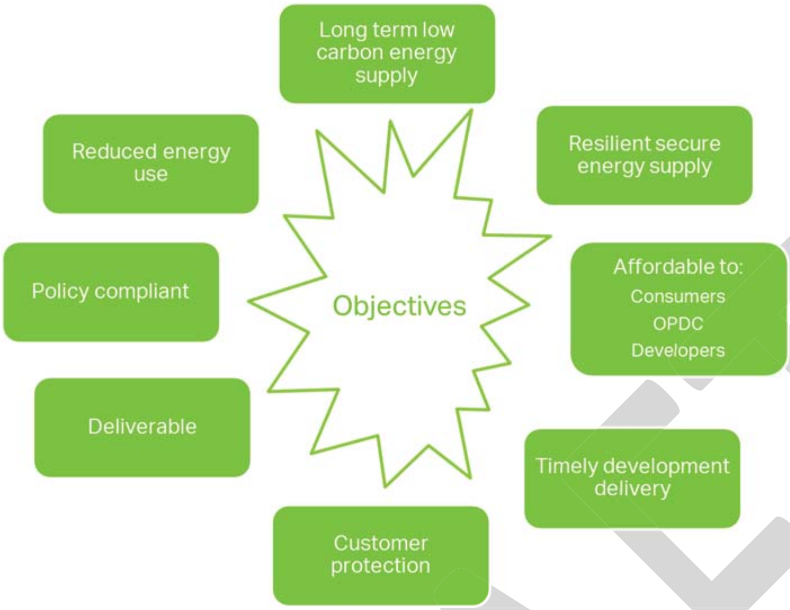

Figure 19. Objectives for the Decentralised Energy Strategy

The key objectives for the energy strategy are to:

- Reduce the development's demands for energy;
- To deliver low carbon, resilient, secure, sustainable energy supplies to consumers now and in the longer term; and
- To do this in a way that is resource efficient, affordable to OPDC, Developers and consumers and which is policy compliant.

The energy strategy and associated provision of energy infrastructure also needs to enable and not hinder the timely delivery of development.

As provision of heat through heat networks is currently an unregulated industry, it will also be important to ensure a reasonable level of consumer protection in terms of the prices consumers pay and the level of service they receive where heat networks form part of the strategy.

3.4.3 Current Market Response to London Energy Policy

The typical market response to meeting current London Plan policy for schemes of more than a few hundred homes is to install sufficient fabric and service efficiency improvements to meet or slightly improve on the Part L of Building Regulations requirements through efficiency alone. Developers typically provide communal heating systems in buildings, and supply these with heat from gas CHP engines in a central energy centre. Roof-mounted Photovoltaics (PV) on any unshaded roof areas are used to provide an additional CO_2 saving from renewable energy. The resulting energy performance is typically sufficient to enable the combined package of measures to deliver the required 35% CO_2 emissions reduction target on site. This is not the only approach, although it is a common approach deployed at present.

Where there is an existing heat network local to the site, or where there is the prospect of one being delivered, it is common for planning authorities to seek a commitment to connect to the network once it is available. This is normally subject to the network offering acceptable commercial terms.

A review of the planning applications that have recently come forward in the Old Oak area (see Section 3.4.4.3 and Appendix B) has confirmed that the strategy set out above is the typical energy solution put forward.

Since the 1st October 2016, Developers have been required to achieve zero regulated emissions for new homes. As this is usually not technically feasible to achieve on site, it is typical for the remaining 65% reduction in CO_2 emissions to be met by a Section 106 payment to a Local Planning Authority carbon offset fund. Some London boroughs have yet to establish the necessary framework for collecting and spending offset funds, so this money will not currently be collected in all cases in all boroughs. OPDC or neighbouring boroughs will need to consider how they will set up and administer carbon offset funds and recruit or develop carbon saving projects for future investment.

While gas CHP has been an effective strategy for reducing carbon emissions and meeting the policy targets in the past, decarbonisation of the electricity grid means this may not be the case in the future.

3.4.3.1 The Impact of Changing Grid Electricity Emissions

Current increases in the use of renewable generation, including wind and photovoltaics, and decommissioning of ageing coal-fired power stations, is leading to a significant reduction in the carbon intensity of electricity delivered from the grid.

Gas fired CHP generation has traditionally been a low carbon source of heat. Although the thermal efficiency of CHP engines is low, the electricity generated alongside the heat displaces high carbon electricity that would otherwise be imported from the grid. This has given a significant net carbon saving benefit compared to conventional gas boilers. However, as the grid decarbonises, this benefit is rapidly being lost.

The Government has recently consulted on proposed changes to the grid electricity emission factor used to underpin the Standard Assessment Procedure (SAP) calculations. SAP is used to underpin compliance calculations for homes in Part L of Building Regulations. If adopted, the proposed SAP 2016 change would reduce CO_2 emissions for grid supplied electricity from 0.519 kg/kWh delivered (as per Part L of the Building Regulations 2013) to 0.398 kg/kWh delivered. This change would more than double the calculated CO_2 emissions of a unit of heat delivered from gas CHP. Based on projected future average grid emission rates set out in the SAP consultation, in the medium to longer term gas CHP will cease to show any savings against alternative technologies and become increasingly carbon intensive.

Appendix F sets out a detailed assessment of published government trajectories for grid electricity emissions and the factors that have been used in the assessments that underpin this work. As the SAP calculations that underpin Building Regulations and London Plan CO_2 targets are based on average emission factors, these have been used to compare the carbon savings of different technologies in this report. If making investment decisions, Treasury Green Book Guidance would require the use of marginal carbon emissions factors for CHP calculations[6].

Figure 20 compares the carbon intensity of a unit of heat generated by a number of alternative heat supply technologies. In the case of Energy from Waste (EfW), heat pumps and gas fired CHP, the heat source is assumed to be serving a heat network and allowance is made for 10.6% heat losses in the primary network[7] and 15% heat losses in the secondary network[8]. The carbon intensity of all electrical-based systems (including heat pumps) are shown to decrease over time in line with the decarbonisation of the grid. Gas CHP however, is shown to increase significantly over time, as a result of the lower carbon emissions that the CHP displaces from the grid. In a theoretical scenario, where grid electricity is zero carbon, CHP effectively doesn't displace any carbon emissions from the grid – from a carbon emissions perspective, it effectively operates as a c.38% efficient[9] gas boiler.

[6] Marginal emissions factors reflect the plant that would likely be taken off grid with additional CHP plant generation. At a national level, this is assumed to be gas-fired combined cycle gas turbines (CCGT) plant, rather than an average blend of generation (as the grid average represents). This means that in national terms, gas CHP will offer benefits for longer than Building Regulations calculations would show (since it is more carbon efficient than the marginal CCGT plant).

[7] The primary heat network is the network of heat mains connecting the Energy Centre where heat generating plant is located to heat substations at the boundary of each development plot or building.

[8] The secondary network refers to the network of heat pipes connecting the heat substation at the plot boundary to the heating interface units serving each home or consumer.

It can be seen that by the early 2020s a unit of heat from gas CHP would have a higher carbon intensity than heat provided from any of the sources considered, including direct electricity (which is assumed to operate locally to the point of demand, without the need for a heat network). Heat provided by electrically driven heat pumps will become increasingly low carbon and heat from waste sources, such as the proposed EfW plant at Powerday, is expected to remain a relatively low carbon source. However, by the mid-2020s heat pumps will start to offer a lower carbon heat source than EfW, and by the early 2030's direct electric heating would be lower carbon than heat from EfW.

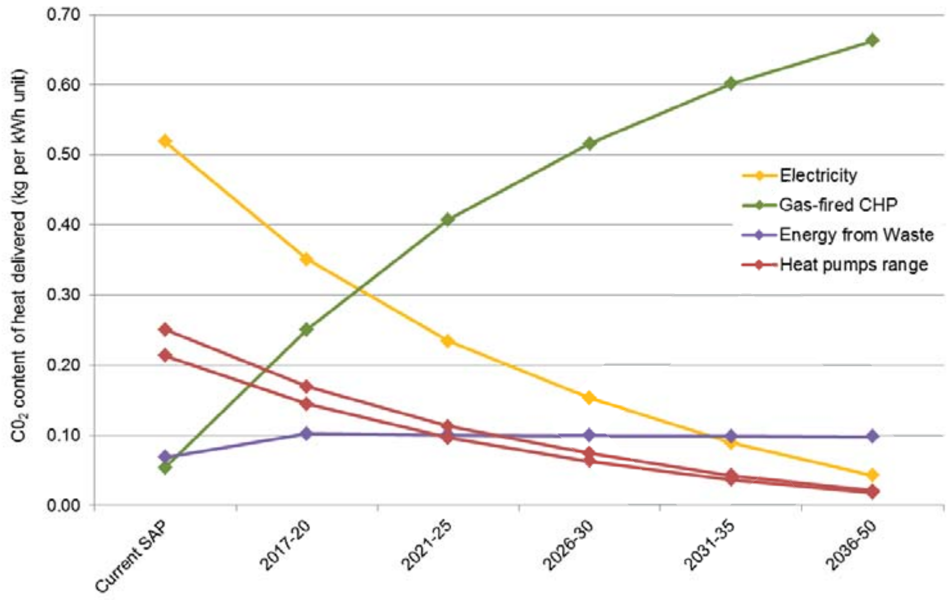

Figure 20. Carbon Intensity of Heat Generated from Different Sources[9]

This analysis highlights that the market response to current London Plan policy is not on its own going to ensure that heat supplied at Old Oak remains low carbon. It also shows that the calculated carbon emissions from solutions currently being delivered at North Acton will rapidly increase over time, showing a higher carbon outcome than if conventional gas boilers were installed.

3.4.3.2 A Continuing Role for Gas CHP?

It is important to note that the carbon trajectory used in the analysis above is based on average emission factors, as these currently form the basis of calculations carried out by Developers to demonstrate compliance with Building Regulations and London Plan policy. Average emissions factors have limitations and do not fully reflect the benefits of technologies that reduce demand for marginal electricity generation plant. Marginal generation plant is brought into service during peaks in electricity demand. BEIS's own analysis using bespoke marginal emissions factors suggests that gas CHP may in reality continue to offer carbon benefits until 2032. BEIS indicates that modelling of the interaction of additional gas CHP capacity with the electricity market throughout the 2020s will primarily displace electricity generated by gas fired Combined Cycle Gas Turbines[10]. However, it is expected that over time, gas CHP will increasingly displace low carbon generation, such that, from around 2032, operation of gas CHP will result in net increases in annual carbon emissions. However, the complexities associated with these dynamic interactions with the electricity market are not reflected in the calculations used to demonstrate compliance with Building Regulations or planning policy.

As the grid decarbonises the shift to electrically based heating is expected to increase demand for power, and rather than simply invest in new capacity to deal with this, there is an increasing focus on better demand management by using price signals and other mechanisms to shift or curtail demand

[9] Gas CHP parameters: Electrical efficiency, η_e = 39%; Thermal efficiency, η_{th} = 38%.
[10] Bespoke Gas CHP Policy: Summary of Analysis Results & Conclusions, Department of Energy & Climate Change, December 2014

during peak periods. This suggests that the financial incentives for demand management are likely to increase, for example heat network operators being offered high prices for the sale of electricity during peaks and being offered low supply tariffs to increase utilisation of electricity at periods of high supply and low demand. The latter would for example occur on windy days when there may be a surplus of electricity generated by wind power. This suggests there are likely to be economic benefits in having energy centres served by a combination of heat generation sources including both gas CHP and electrically based heating systems, and that, at least until 2032, gas CHP may still offer some carbon benefit even if this may not be reflected in the calculations that support planning applications. Large scale networks serving significant areas of development are likely to be able to benefit more from dynamic price signals, as they are likely to be able to deploy a greater range of heat generation and heat storage options than smaller plot based heat networks.

From an economic perspective, gas CHP offers revenue to the operator from the sale of both the electricity as well as heat. The greater the difference in price between gas and electricity (the "spark gap") the greater the revenue to the operator of the CHP engine. Some of the alternative low carbon sources, such as heat pumps, are likely to reduce the available revenue streams for operators (since they do not generate a high-price electrical commodity) which in turn will impact network viability or the benefits that can be offered to the consumer (heat prices or standing charges).

Discussions with the operators of existing or planned major heat networks in London have revealed that gas CHP has been fundamental to the business case (see Appendix D).

3.4.4 Development at Old Oak

The Old Oak area breaks down into five broad clusters of development, as shown in Figure 21, each of which are characterised by different phasing and land ownership.

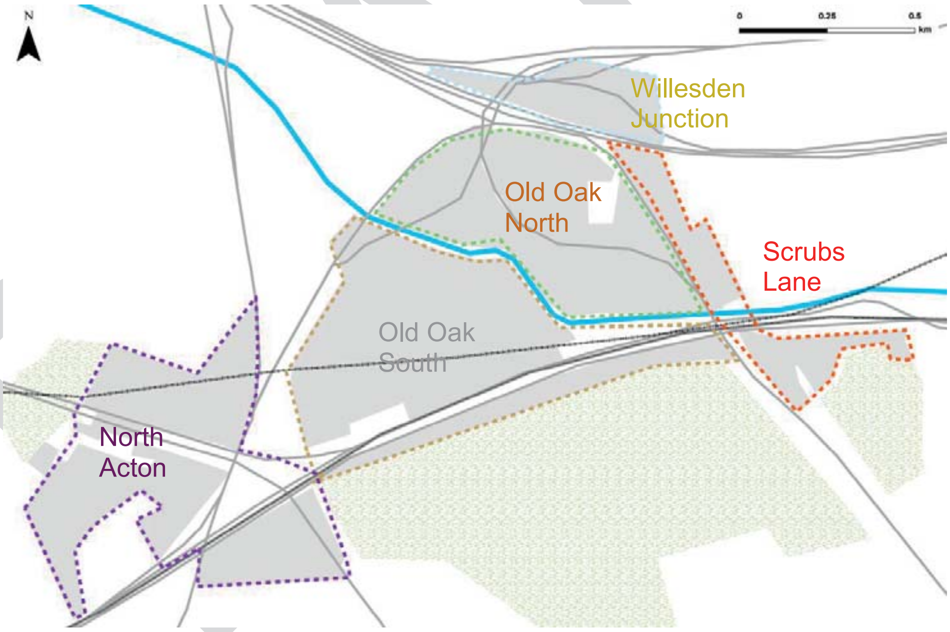

Figure 21. Five Development Clusters

3.4.4.1 Clusters Characterised by Multiple Small Land Ownership

Based upon the current trajectory, North Acton is one of the earliest areas to be developed and is made up of many smaller private land ownerships and many planning applications have already been submitted for development in this area (see Section 3.4.4.3). This multiple private sector land ownership makes delivering an area wide coordinated energy strategy in this area more challenging due to many separate land owners who will need to be engaged with and the varying timeframes for each scheme.

Scrubs Lane has similar characteristics to North Acton in terms of multiple land ownerships, but has a further challenge that the cluster of development is elongated, increasing the heat network length in relation to density of load. A number of planning applications are currently being submitted in the Scrubs Lane area.

Willesden Junction is also expected to be made up of multiple land ownerships.

The fact that many Developers have already developed and submitted energy strategies in these areas further complicates any future engagement.

3.4.4.2 Clusters Characterised by Larger Single Land Ownership

Old Oak North includes a number of much larger land ownerships including Car Giant who will provide around a quarter of the new homes at Old Oak. Old Oak South includes the relatively small privately owned Genesis site, but also the two major public sector land holdings of HS2 and Crossrail. These larger land ownerships provide greater potential to engage the private sector in delivering area wide district energy solutions as there will be fewer parties to reach heat connection agreements with. There are similar benefits for any public sector led delivery of district heating networks.

OPDC's future role in terms of land ownership is currently unclear and is likely to remain so until masterplanning work is complete. Should some or all the land currently in public ownership transfer to OPDC this will clearly allow OPDC to have greater influence on the energy strategy outcomes for sites that are in their ownership.

3.4.4.3 Existing Energy Strategies and Planning Applications

Appendix B sets out a high level review of the Energy Strategies for planning applications that had been submitted within the Old Oak area up to November 2016. A summary of the locations for submitted applications is shown in Figure 22.

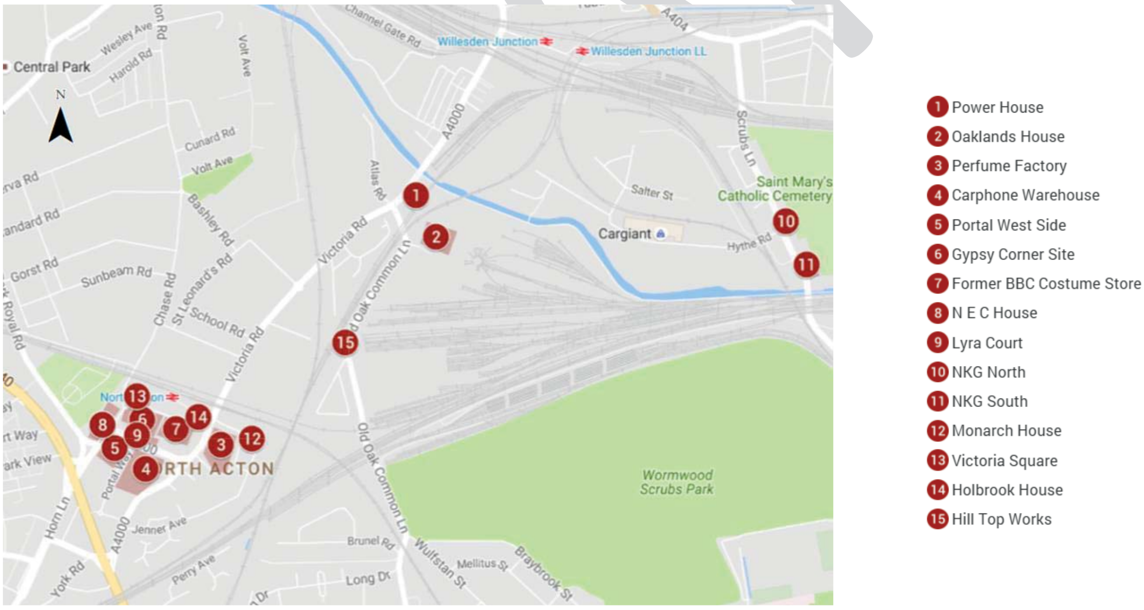

Figure 22. Existing Planning Applications

Ten separate planning applications were identified with separate energy strategies within the North Acton area. As outlined in Section 3.4.3, the typical energy strategy proposed for each of these developments is to promote efficiency standards sufficient to meet the Target Emission Rate (TER) in Part L of the Building Regulations, and then to deliver an on-site communal heating network served by gas CHP engines providing the base heat load and gas boilers providing peak and standby loads. CHP engine sizes proposed at North Acton range from 25kW to 500kW electrical (kWe), with many less than 300kWe in capacity. A number of schemes also include some provision of PV, or propose the use of air source heat pumps. These strategies have been driven by the London Plan policies for the provision of district heating networks and the need to meet calculated on site reductions in regulated CO_2 emission of 35%.

While these schemes meet the London Plan policy requirements, and currently would show a significant carbon saving using the current SAP calculation process, these savings will in reality reduce over time as grid electricity emissions fall. Smaller engines tend to be less economic to run, with proportionately higher maintenance costs for the energy being generated, while lower electrical efficiencies (compared to larger CHP engines) reduce the economic benefit from the electricity generated. For the smaller schemes there is a significant likelihood that maintenance and running costs associated with the CHP engines will mean that, after a period of time, the gas CHP engines will be switched off and heat will be supplied from the peak or standby gas boilers to reduce running costs. OPDC will have little leverage to encourage any switch from the current planned plant provision to lower carbon alternatives in future.

In a number of cases the proposed energy strategies include a commitment to connect to an area wide heat network, should this be developed. We understand from OPDC that, where this is the case, conditions are in place to require a connection should this be possible prior to basement plant rooms being constructed. London Borough of Ealing is currently responsible for determining planning applications in North Acton.

The planning applications coming forward in North Acton indicate that an area wide heat network is unlikely to be delivered in North Acton without intervention. It is also considered unlikely that a private ESCO will want to take on the risk of having to negotiate multiple relatively small heat connection agreements. They would also need to identify a site for and obtain planning permission for an energy centre to house central plant. Finding sites for Energy Centres when seeking to retrofit heat networks into existing areas can be a major challenge for heat network promoters. One of the ESCO's engaged with in the Phase 2 work described the characteristics of North Acton as their "worst nightmare" in the context of bringing forward a heat network.

3.4.4.4 Major Energy Strategies Coming Forward

Car Giant is the single largest private sector land holder within Old Oak. Discussions were held with Arup, who are the infrastructure advisor for the Car Giant site, to understand the energy strategy they are considering for their site. Car Giant's focus has been to develop a deliverable and policy compliant scheme, which aims to limit their reliance on third parties for delivery. Their strategy provides for a central energy centre at the north west corner of the site, adjacent to the boundary with the Powerday site. This will be designed to meet the energy demands of their masterplan possibly with some surplus capacity to enable expansion to serve wider sites. While Car Giant have considered the possibility of taking heat from Powerday, their preferred solution is to utilise gas CHP engines as a deliverable policy compliant technology. The earliest they are likely to require heat was expected to be 2023.

While Car Giant has made provision for on-site delivery of a district energy network and energy centre, their preference would be for offsite connection to a heat network if the heat was available at commercially attractive terms and delivered within required timeframes. This suggests there is potential to work with Car Giant to explore the delivery of a strategic area wide network, for which the Car Giant site could provide a key anchor load. Car Giant's proximity to the Powerday site provides an opportunity to explore heat provision from the EfW facility, although as noted in Section 3.4.5 it will take some time for Car Giant's heat loads to build up to the point where they could fully exploit the heat that could be available.

As discussed in Section 3.4.5, the other major land owners within Old Oak (namely HS2 and Crossrail) are not expected to be delivered until late in the delivery programme. As the majority of development on these plots is expected beyond 2030, no energy strategies have been developed for these sites at present.

3.4.5 Heat Demand Requirements

Although improvements in building fabric standards continue to reduce the demand for heating in new buildings, development of the scale anticipated in Old Oak will result in a significant demand for energy, in particular heat energy to service space heating and domestic hot water loads.

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3.4.5.1 Impact of Smart Technology

The widespread deployment of smart systems could however significantly reduce the expected peak heat loads, although it will have a lesser effect on overall (annual) demand for heat. Appendix E sets out the findings of a high level desk based review of the likely potential for smart technology to influence the future heat (and power) demands at Old Oak.

Previous studies have suggested smart metering and feedback to occupants on their energy use and energy costs can result in a modest 3% reduction in annual energy use in homes.

Initial estimates suggest that the peak demand for heat could be reduced by between 10-20% by the deployment of more effective control infrastructure that is not reliant on user intervention. Such controls could include hot water priority controls on Heat Interface Units (HIUs), which switch off space heating for the short period of time when domestic hot water is being drawn. The use of such a system means there is no coincident space heating / domestic hot water load in the dwelling unit, thereby significantly reducing the required size of the dwelling heat interface unit (HIU), while also reducing the peak load on the network, which in turn reduces the size requirements of the network piping, and the frequency of backup/peaking boiler operations.

Further examples include intelligent controls for heating and hot water services with learning algorithms that learn the behaviours of the occupants and can pre-empt and pre-heat buildings and/or thermal storage to optimise plant operation for expected patterns of use. Pre-heating of buildings and utilising the thermal mass of the building itself, can also lead to load flattening, thereby reducing the peak loading on the network. Enabling controls would need to be installed in buildings, and appropriate communication links to energy centre control systems would need to be provided, to ensure the network responds to forecasting, and maximises the operational efficiency of the energy centre plant thermal storage.

Planning policy and future decentralised energy procurement should seek to promote the use of these smarter control systems with the aim of reducing demand.

While not an exhaustive review, the initial study suggests there are likely to be opportunities to manage peaks in power demand by moving to more intelligent and dynamically operated local distribution networks that can more effectively take advantage of local generation, flexible demand in commercial and domestic buildings, and advances in power storage technology (e.g. battery storage increasing the effectiveness of PV and other onsite generation in meeting on site loads).

While the regulatory and commercial models that will fully enable this are still evolving, OPDC should seek to promote smart distribution infrastructure through supportive planning policy and through any involvement in infrastructure procurement.

3.4.5.2 Projected Heat Demand

OPDC has produced a number of trajectories to show how development is expected to proceed at Old Oak. Appendix A includes an assessment of the expected growth in heat demand. Figure 23 shows an estimate of the likely peak heat demand build up for each cluster for the early baseline trajectory (Early Trajectory Version 7.11). This provides a worst case for how quickly heat loads might build up. The dotted black line shows how this might vary for a trajectory that assumes later delivery of some plots (Late Trajectory Version 7.12). Note that the projected demand assumes the current and anticipated emerging London Plan compliant insulation standards are maintained, and that no smart systems for peak load shifting are installed on a large scale.

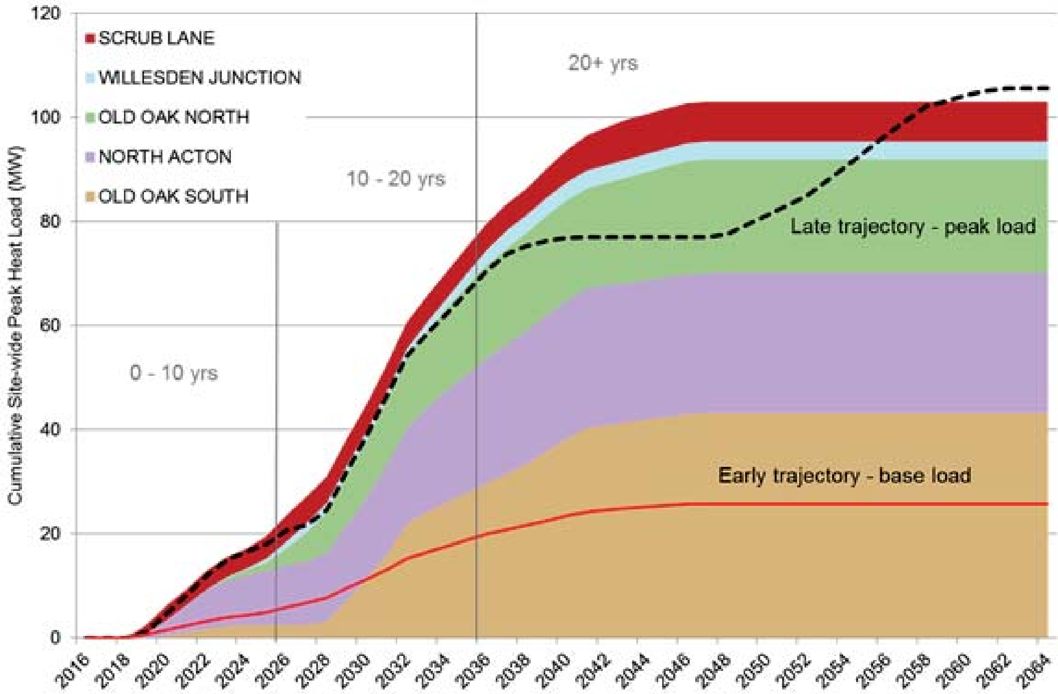

Figure 23. Heat demand build-up (at the end customer[11])

The peak heat demand build up includes homes and offices but does not include retail, schools and community buildings. Allowing for schools and community uses, the peak heat demand is estimated to exceed 100MW. This assumes typical current insulation standards and hot water demands and appropriate levels of diversity (see Appendix A for assumptions). Roughly half of the total c.100 MWth is expected to be required by 2030.

A key point to note from Figure 23 is that in the first ten years, the majority of the new heat demand will be in North Acton and that at full build out North Acton will represent around one quarter of the peak heat demand. Together with development scheduled for Scrubs Lane, North Acton is expected to account for approximately 65% of the total load within the first 10 years (i.e. by 2026).

In Old Oak North, Car Giant is expected to commence development in 2019, although significant development will not begin to come forward until the second half of the 2020s, with approximately half not being delivered until after 2030.

The largest heat demands will be for development associated with HS2 and Crossrail in Old Oak South, although the bulk of this development is expected to be later in the programme (mostly beyond 2030). Significantly, development during this time will coincide with substantial reductions in grid electricity emissions. It is expected that later phase development (beyond 2026) in Old Oak North and Old Oak South area will eventually account for almost 60 MWth, with c.45 MWth not coming forward in this area until after 2030.

The heat demand varies over the course of the year, increasing in winter but also varying diurnally with morning and evening peaks. An appropriate use of thermal storage allows loads to be shifted from times of high load to those where the load is much smaller (e.g. during the night). This allows for the prolonged use of low carbon and economically efficient technologies (of which gas CHP is the current default technology), and results in a reduction in higher baseload relative to the peak load, compared to what would otherwise be experienced. The concept of baseload and peak demands is illustrated in Figure 24.

[11] Additional heat losses in the distribution and transmission networks will increase the demand for heat generated by the energy centre/s

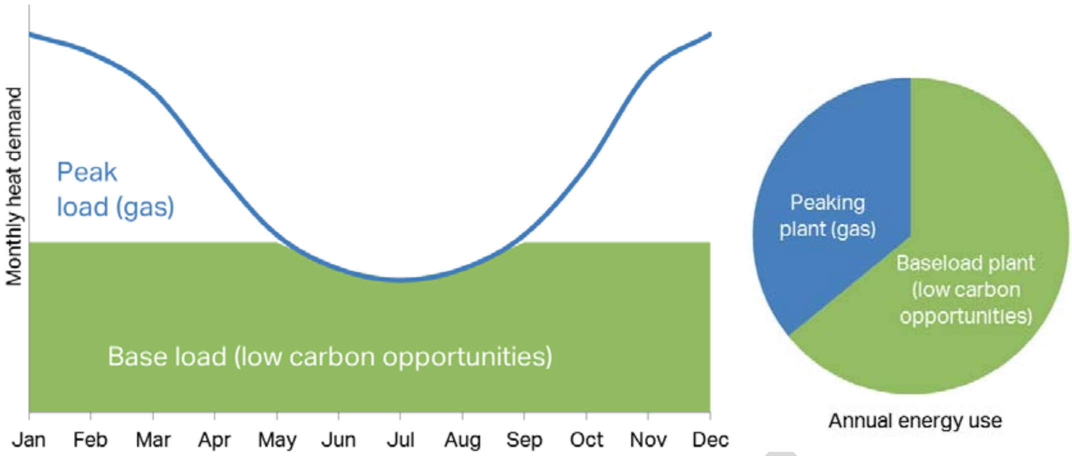

Figure 24. Relationship between Baseload and Peak Demand and Annual Energy Use

If seeking alternative low carbon heat sources to replace or to be used in conjunction with gas CHP, we would not expect these to need to meet the peak demand; although they can provide a significant proportion of the total annual energy use, even if they are only meeting the baseload.

Thermal profiling and appropriate levels of thermal storage indicate a base heating load of c.20 – 30 MWth at full build out. Baseload demand after 10 years is expected to be 5 – 7 MWth, and after 20 years it is expected to be around 17 – 23 MWth.

This spatial distribution of development, and the phased build-up of base heat load, is illustrated in Figure 25.

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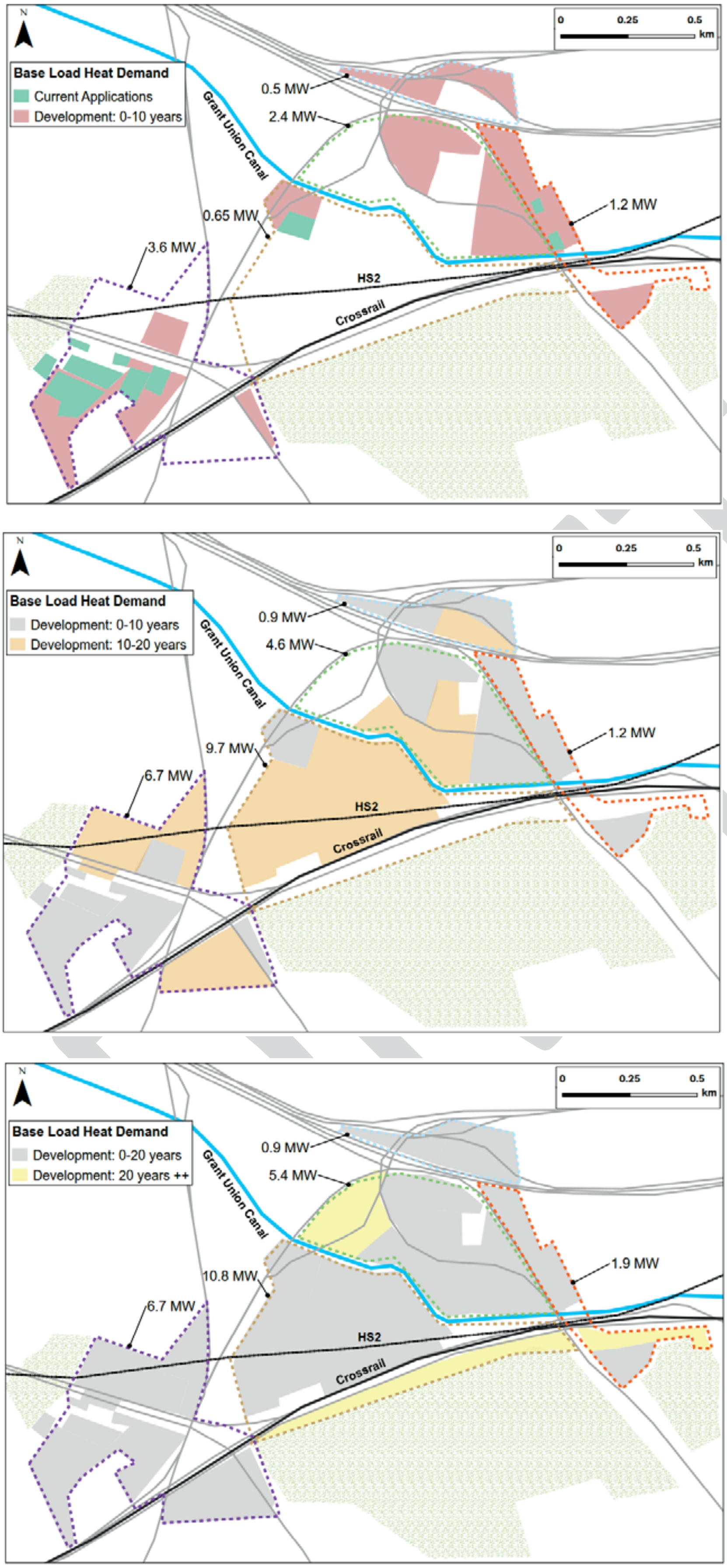

Figure 25. Phased Development and Base Heat Load. [Top: Development in 0-10 Years, incl. Current Applications; Middle: Development in 10-20 Years; Bottom: Development in 20+ Years]

3.4.6 Available Heat Sources

Appendix A sets out a detailed review of local low carbon heat sources that could replace gas CHP as grid electricity emissions decline. Table 4 below provides a summary of the most beneficial heat sources. The summary shows an estimate of the potential heat capacity, the relative capital cost of the heat source and the average CO_2 emissions per unit of heat delivered for different periods in the build out process, taking account of projected decarbonisation of the electricity grid and based on average grid emission factors. This aims to show how the carbon saving potential of different technologies changes dramatically over time.

Low Carbon Heat Source	Baseload Capacity (MW)	Indicative CAPEX (£ per MW capacity)	Carbon intensity of delivered heat to customer via heat network tonnesCO_2/MWh					
			Current Building Regs	2017-20	2021-25	2026-30	2031-35	2036-50
Grand Union Canal (heat pumps)	1 – 3 MW (varies seasonally)	Medium	0.251	0.170	0.113	0.074	0.043	0.021
Aquifer Borehole (heat pumps)	<1.2 MW (per borehole)	High	0.227	0.154	0.102	0.067	0.039	0.019
Sewage network (heat pumps)	200 – 500 kW (per installation)	Medium	0.214	0.145	0.096	0.063	0.037	0.018
Energy from Waste	3 – 10 MW (potentially more)	Low (Most CAPEX for pipe to Powerday)	0.069	0.102	0.100	0.099	0.099	0.098
Total	11 – 22 MW (potentially more)	-	-	-	-	-	-	-
Comparative CHP (building scale)	Any capacity	Medium	0.054	0.251	0.407	0.516	0.601	0.663

Table 4. Summary of Potential Low Carbon Heat Sources

Most heat sources could potentially be accessed early in the development cycle or as development proceeds, with the expectation that the full baseload demands could be met over the first two decades. These would require engagement with a range of stakeholders to develop and take forward and require safeguarding of sites and routes to access them. Some, such as EfW, have potential air quality implications which will need to be considered against the benefits in terms of a potentially cost effective low carbon heat source.

The potential for low-carbon heat sources to meet a significant proportion of the heat demand supports the case for developing a district energy solution, subject to the ability to achieve acceptable revenues for the network operator and heat charges for the consumer. The heat sources identified are unlikely to be the only potential sources of heat, but are those considered to have the greatest promise. Other heat sources might for example include heat recovery from data centres and from the transformers for any new power supply substations, or the generation of heat from food waste streams at Park Royal.

As set out in Appendix A, a number of potential heat sources were explored and ruled out. These included the potential to extract heat from the HS2 tunnel linings, and the possibility of extracting heat from Taylor's Lane Power Station which is situated around 2km north of the development site.

The more promising heat sources are discussed further below:

3.4.6.1 Powerday - Commercial Waste Recycling Centre

Powerday sort and process commercial waste, recovering wood, hard plastics and rubble for resale, and process remaining waste into Refuse Derived Fuels (RDF) and Solid Recovered Fuels (SRF). The RDF and SRF are currently bailed and exported off-site by road to fuel EfW plants in the UK and Europe. Powerday's site is a potentially strategic location for sorting and processing waste, as it has the ability to transport waste and recovered materials by canal, rail and road, although at present the rail and canal links are not being utilised. It is understood that Powerday currently has a significant period remaining of their lease.

It is anticipated that an EfW facility could be developed at Old Oak and be operational within three years to provide between 3 to 5.7MWe of electricity. However, it may be possible to increase the capacity to up to 10 MWe. The available heat offtake will vary depending on the technology type deployed.

If planned development of an EfW goes ahead this would be one of the largest local sources of low carbon heat, and in the early phases of development would be one of the lowest carbon heat sources. Powerday estimate that approximately 50-60% of the RDF/SRF consists of biomass, so the heat supplied from this source would also contribute to meeting London Plan renewable energy objectives.

Heat off-take from an EfW plant will reduce the efficiency and hence revenues for electrical generation, so any EfW licensing or planning approvals will need to safeguard a heat offtake requirement as it will not necessarily increase revenues to sell the heat.

The proposed development of an EfW plant will require planning approval and may be subject to permitting under the Environmental Permitting Regulations 1020 unless the technical process adopted is able to satisfy criteria for exclusion. Permitting would either be the responsibility of the Environment Agency (EA) or the Local Planning Authority, depending on the final plant throughput of waste. There is potential for the Local Planning Authority and / or local residents to object to the proposed development on the grounds of air quality. Even if a plant receives a permit it can still be refused planning permission.

The air quality implications of providing a EfW plant at Old Oak will need to be considered further during the masterplanning stage and in particular, the risk that the emissions from an EfW facility could constrain the ability to deliver future housing development. This could for example be an issue if flue emissions impact on neighbouring tall buildings. Additionally, air quality could be an issue if it prevented delivery of the planned EfW.

The likely price that an EfW operator would need to charge for heat is currently unknown, but clearly would need to be sufficiently low to allow the heat network operator to achieve a sufficient return on any investment in network infrastructure, and to cover their operational costs including the costs of ongoing metering and billing services and future maintenance and plant replacement.

The commercial attractiveness of waste recycling will depend on the ongoing incentive structure for waste management and the prices for reclaimed/recycled materials that can be commanded in the market. The security of an EfW facility as a heat source for the network would be a consideration for any heat network operator and would need to be addressed through appropriate contractual arrangements. By the time that the current 45 year lease has expired on the Powerday site, grid electricity CO_2 emission rates are expected to have fallen to the point where there would be many potential low carbon options to replace the EfW facility as a heat source (including direct electric boilers) but these sources could potentially have different costs for heat production and hence impact on revenues. Future heat network business case modelling will need to account for these risks.

Car Giant is currently planning their energy centre at the north west corner of their site adjacent to the railway lines that form the eastern boundary of the Powerday site. For an EfW facility on the Powerday site to reach this energy centre, pipes could potentially be thrust bored under the railway lines, subject to Network Rail approval.

One of the potential issues in utilising heat from an EfW facility is that the heat source could be delivered in advance of heat loads building up for the sites immediately adjacent to Powerday (Car Giant). This might require intervention to deliver heat network infrastructure early to enable EfW heat to be utilised by development being delivered early in the programme, i.e. Genesis, North Acton or Scrubs Lane.

See Section A.3.3 of Appendix A for further information on Powerday.

3.4.6.2 Grand Union Canal

The BEIS national heat map and initial discussions with the Canal and Rivers Trust (CRT) have confirmed that the canal can potentially provide between 1 - 3MW of heat from the section that passes through Old Oak. The capacity is limited by the slow flow rate in the canal and the need to limit the temperature change within the canal.

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Beyond the capacity limits identified above, no significant constraints have been identified for the extraction of heat from the canal. The CRT are supportive of heat extraction and would be able to support the detailed modelling of abstraction and return water volumes to confirm a more specific heat offtake figure as plans develop.

GlaxoSmithKline currently utilise water from the River Brent to cool their data centre. This retrofit project has been running successfully for a number of years and is providing a significant annual saving in energy costs. The canal-side infrastructure is relatively simple, consisting of a letter box opening in the canal wall allowing water to flow into a 4m deep chamber behind the canal wall from which submersible pumps pump the water to heat exchangers serving the building supply circuits to the chillers. Baffles on the outside of the opening prevent large floating debris entering the chamber and screens filter out smaller debris. Heat supply from the canal could operate in a similar manor with abstracted water serving a heat exchanger to a water circuit serving a heat pump located at the district heating energy centre rather than a chiller. Further detail is provided in Section A.3.1.1 of Appendix A.

Suitable access would need to be provided within the masterplan to locate the necessary canal-side infrastructure and this would ideally be located as close as possible to an energy centre serving development in Old Oak North or Old Oak South. The temperature of the canal will vary significantly over the year, reducing the efficiency of the heat pump in winter and increasing it in summer. The canal could be exploited to serve heat networks or could be exploited to serve individual development plots.

3.4.6.3 Sewer Heat Recovery

Sewer heat recovery is an emerging technology option with limited existing deployment in the UK, but with growing deployment in Europe and North America.

Initial engagement with Thames Water's head of Waste Water Innovation at a meeting on the 7th November suggests Thames Water are interested in exploring the potential for sewer heat recovery and are currently working with Technology provider Suez and London Borough of Haringey to pilot the technology. The Suez technology deploys stainless steel heat exchangers shaped to match the profile of the bottom of the sewer. Sewerage flowing over these heat exchanges transfers heat to water circulating through the heat exchangers, which in turn is circulated to a heat pump where its temperature can be raised to that suitable for low temperature heat networks in buildings.

Sewers need to be at least 1m in diameter to enable man entry access for installation and maintenance. Initial estimates based on the Suez technology suggest that heat outputs could be in the order of 200-500kW for a single installation and that if a single installation were made close to an energy centre in each of the five key clusters of development this would provide around 1-3MW of capacity. Suez is not the only technology provider and alternative approaches are available for extracting heat. The technology could be deployed in the existing sewers or built into new or diverted sewerage networks serving the site. Recoverable heat could be increased should sewer systems be designed such that grey/black water is separated from surface water (since rain events reduce the mean temperature of combined sewers). Some of the existing sewer network consists of combined sewers. As set out in Section 5, the intention will be to reduce surface water flows to the existing combined sewers and keep surface water and fowl water separate for any new sewerage infrastructure.

Thames Water appears keen to pilot the technology. Estimates of heat potential could be refined based on monitoring of sewer temperatures by Thames Water. Further feasibility work would be required to understand the potential commercial arrangements between Thames Water and the heat provider, but this appears a promising heat source with existing successful applications in Europe and North America. AECOM are currently designing a 15MW sewer heat recovery system at a water treatment works in Denver.

There are existing sewers of greater than 1m in diameter on the boundaries of Old Oak South, North Acton and Scrubs Lane. Energy centre siting should consider access to these or planned new sewer infrastructure. OPDC should consider working with Thames Water and wider stakeholders to explore an early pilot of this technology at Old Oak. Sewer heat recovery could be exploited to serve heat networks or could be exploited to serve individual development plots.

Further details of the issues relating to sewer heat recovery are provided in Appendix A Section A.3.4.

3.4.6.4 Open Loop Boreholes

Open loop boreholes drawing water from the chalk aquifer approximately 100m below the site could provide a source of heating and cooling. Water abstraction rates would remain uncertain until boreholes are sunk and are subject to abstraction licenses requiring regular renewal (typically every 12 years). However, there are successful open loop borehole systems serving buildings across London including at the Hammersmith Queen Charlotte's and Chelsea Hospital to the south east of the Site where borehole test records show water extraction rates of 26 litres/second were achieved. AECOM were not able to identify extraction rates for boreholes directly within the Site, but if extraction rates of 20 litres/second were achieved each borehole could serve heat pumps delivering up to 1.2MW of heat.

The EA are likely to require both an extraction and return borehole to maintain water levels within the aquifer. The abstraction and return boreholes require geographic separation to avoid thermal breakthrough. Borehole pairs would also need to be kept geographically separated to avoid thermal interference or derogation of abstraction rates between borehole pairs.

It has been assumed that at least five borehole pairs serving geographically separated energy centres could be accommodated across the development potentially delivering around 6MW of baseload heat in winter or cooling in summer. This would be based on achieving abstraction rates of at least 20 litres/second. As noted above there is no guarantee as to what abstraction rate would be achieved.

Boreholes have the benefit that water temperatures remain relatively stable all year round but the cost of drilling the required boreholes is expected to result in higher capital costs than canal or sewer heat abstraction. Open loop boreholes could be exploited to serve heat networks or could be exploited to serve larger individual development sites.

Section A.3.1.2 of Appendix A provides further detail on the potential issues associated with heat extraction from open loop boreholes.

3.4.6.5 Implication of Low Temperature Heat Sources for Heat Networks

Many of the heat sources identified above would rely on heat pumps to make use of the heat (sewers, canals, boreholes) and this is likely to favour district heating networks designed for low temperature operation, which in turn would require buildings to be designed for low temperature distribution. This would for example require underfloor heating in apartments rather than higher temperature radiators. The Local Plan should seek to promote low temperature networks for those areas where development has yet to commence.

For areas such as North Acton where development proposals are already coming forward and detailed designs will already be commencing, it may be too late to influence building designs. Temperatures might therefore require boosting at a local level if a wider area network is designed for low temperature distribution.

3.4.6.6 Geographic Location of Heat Sources

Notional geographic locations of potential heat sources and their combined capacity are illustrated in Figure 26. In practice the locations of open loop boreholes and sewer heat recovery will be flexible but will relate to the routes of the sewers and their access points. However, Powerday and the canal have fixed locations. One of the factors influencing the locations of energy centres serving heat networks will be to enable them to exploit multiple heat sources from a single location. As an example, an energy centre serving development at Old Oak North would ideally be located to utilise heat from and EfW facility such as Powerday, the canal and the sewer network from a single location.

There are a wider set of factors that will influence energy centre locations including land values, dispersion of flue gases, access for maintenance, ability to provide wider utility connections i.e. medium pressure gas supply, power and water supplies.

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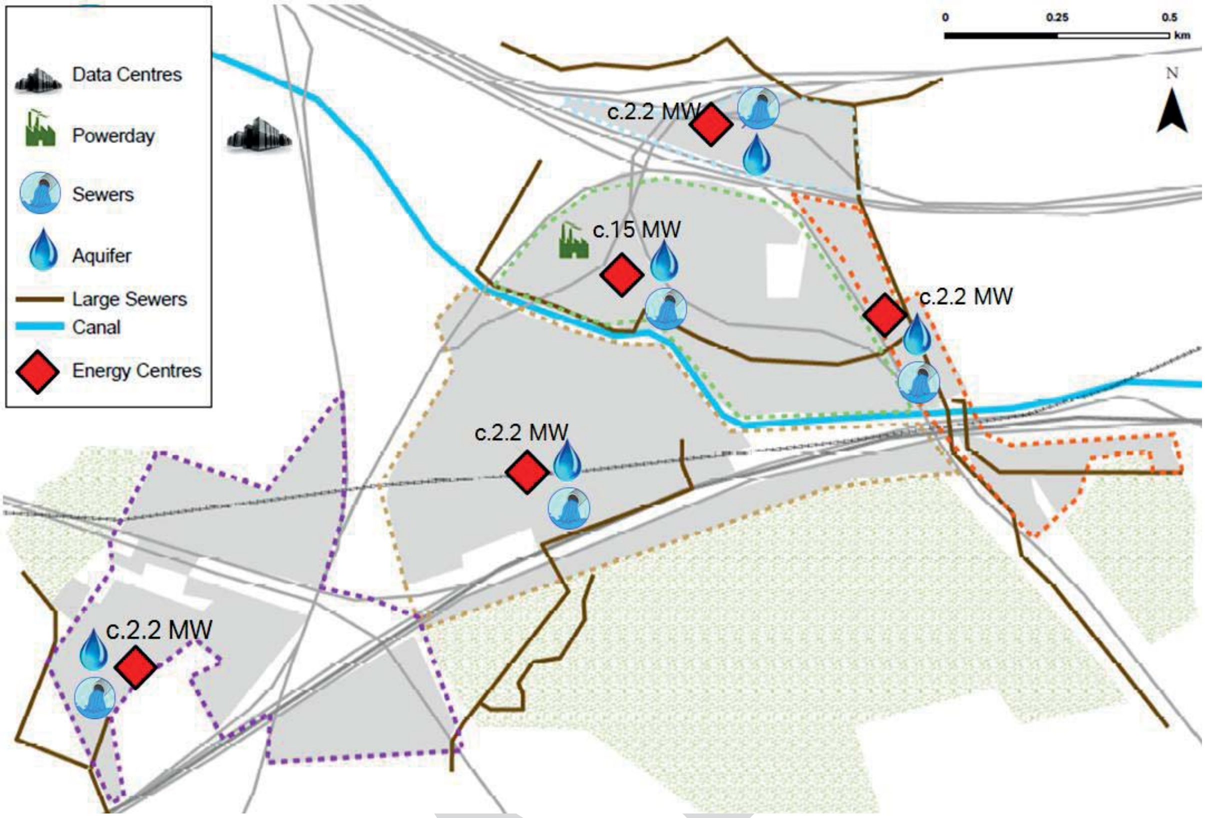

Figure 26. Notional Locations of Heat Sources

A comparison between the early phases of development outlined in Figure 25 and the location of the heat sources outlined above confirms a disconnect between the demand and the potential supply. This problem is particularly acute in the North Acton area, where expected peak loads of c.10 MW and base heat loads of c.3.6 MW after the first 10 years are unlikely to be met by local low carbon alternatives to gas CHP.

The limited capacity of local low carbon heat sources at North Acton (sewer heat pumps or boreholes serving heat pumps), limits the potential for ensuring the strategy at North Acton is low carbon over the medium and long term. For Scrubs Lane and Willesden Junction there is greater potential for the limited low carbon heat sources (sewer heat pumps and aquifer) to meet the required demand.

On the supply side, the emergence of a new EfW site (at Powerday), potentially within three years and with a proposed capacity of between 3 to 5 MW or more of heat, is likely to exceed the projected heat demands for development in Old Oak North immediately adjacent to the plant. It could take around 20 years for the baseload heat demand at Old Oak North (Car Giant) to build up to the point where the full heat supply from an EfW located at the Powerday site could be utilised.

This suggests there may be benefit in interlinking area wide networks to enable low carbon sources to be distributed and utilised more widely while demands build up. Furthermore, the early stages of development are likely to benefit the most from maximising the use of EfW early on, since later development (post 2030) is likely to have a wider range of low carbon sources available for serving heat loads (owing to grid decarbonisation).

3.4.7 Cost and Carbon Savings

To evaluate the potential of district heating to meet key OPDC objectives (namely affordable long term low carbon, resilient, energy supplies), analysis is required to quantify the cost and carbon performance of an area-wide heat network, compared with alternative heat supply options that could be delivered at a block or dwelling level.

Appendix G sets out a comparison of the capital costs, consumer energy costs and carbon savings for alternative combinations of heating technologies and fabric specifications. These compare area wide district heating networks served by different combinations of low carbon heat sources with alternative block based or dwelling based systems. The dwelling carbon emission rates are calculated for different time periods to show how the favourable technology mix will change over time as grid electricity emissions fall.

The assessment work reviewed the emissions for multiple combinations of measures, from which a sub set of the more interesting combinations was selected and capital costs and running costs estimated.

The carbon reductions and costs are compared against those for a typical London Plan policy compliant solution. This solution is expected to be delivered by Developers, at least in the short term (i.e. based on current policy) without any intervention by OPDC.

- Buildings designed to meet Building Regulations Part L Criterion 1 through energy efficient fabric and fixed services alone;
- Development-wide heat networks for each site that comes forward for planning, served by gas-fired CHP housed in a central energy centre;
- Roof-mounted photovoltaics to bring on-site carbon savings to at least 35% below Part L 2013 target emissions (if required, or to the extent possible given space constraints on locations for PV panels); and
- Offsetting of residual carbon emissions off site, directly by the Developer or via payment into an offset fund at the rate established by the local planning authority.

The analysis has focussed on the alternative heating strategies for homes as the expectation is that the servicing strategies for non-residential buildings will be dictated by use. For cooling, it is expected that services will logically utilise high-efficiency vapour compression cooling where required, as this already offers a low carbon solution and will become increasingly low carbon as grid emissions fall. The expectation is that as part of detailed designs, if ground source heating[12] is being considered as a low carbon solution for later phases of development, the design solution is likely to consider the use of the ground array for heat rejection (i.e. cooling) in summer.

3.4.7.1 Typical Servicing Typology

For most technologies, the scale of implementation affects the capital costs. For some technologies, the scale of implementation also changes assumptions about technical performance (e.g. efficiency; the area available to locate equipment, and hence the maximum installable capacity and proportion of demand met etc.).

Four implementation scales were identified as a basis for considering the effects of scale on carbon outcomes and costs:

- **Unit level**: Heating is provided at an individual dwelling (or non-domestic) unit level;
- **Block level**: Heating is centralised at a building level;
- **Development site level**: Heating is centralised at a development parcel level; and
- **Cluster / area-wide level**: Heating is centralised at a cluster-wide, multi-site level.

The 'block' scale of implementation is the one that imposes most constraints on the application and performance of technologies. The size of the roof constrains the potential for roof-mounted PV and solar hot water collectors, and the size of the plot constrains the ground area available for a potential borehole field of a closed loop ground source heat pump system[12].

The most relevant assumed characteristics of a typical block are set out in Table 5.

Storeys	Units per floor	Units	Unit GIA per floor [m^2]	GIA as % of GEA	Roof area [m^2]	Plot area [m^2]
10	12	120	920	90%	1,022	1,200

Table 5. Typical Block Characteristics

It is assumed a typical representative development site consists of 4x10 storey buildings and a single 25 storey building, and will contain approximately 780 units.

3.4.7.2 Carbon Emission Methodology

AECOM analysed 34 'Technology scenarios' and calculated the average carbon emissions of homes in each of five time periods through to full build-out and under three grid electricity decarbonisation scenarios. The grid is projected to decarbonise rapidly through the 2020s and early 2030s and then more slowly to the end of the analysis period. As such, it was important to look at carbon outcomes over short (5-year) periods during the stage of rapid decarbonisation. For the later development period, when decarbonisation has slowed and the projected emissions are more uncertain, a longer time period was used.

The quantum of development projected to come forward in each of the time periods used (based on the 'DRAFT Phasing Trajectory v7.11 Early Scenario for Planning') is set out in Table 6.

Period	Affordable for rent Units [no.]	Private Homes Units [no.]	Total Units [no.]	Total Units [%]	Early Net Office Floor Area (m^2) Combined
2017 - 20	1,112	1,112	2,224	8.2%	14,999
2021 - 25	2,761	2,761	5,521	20.5%	27,869
2026 - 30	2,954	2,954	5,907	21.9%	195,776
2031 - 35	3,032	3,032	6,064	22.5%	321,601
2036 - 50	3,626	3,626	7,251	26.9%	253,779

Table 6. Development Quanta Assumed in each Time Period

Dwelling designs prepared specifically for developments in the Old Oak area were not available, so apartment designs from schemes recently submitted for planning in London, and for which AECOM had existing SAP model layouts and geometry data, were selected as proxies.

Results were modelled for two assumed levels of fabric specification: a fabric specification representative of that designed to substantially reduce space heating demands currently used to meet the London Plan efficiency policies; and an advanced fabric specification. See Appendix G for further details on carbon emissions methodology.

[12] Closed loop ground source heat pump systems circulate a heat exchange fluid through coils buried horizontally or vertically in the ground, the ground is typically at a temperature of around 10 to 12°C. A heat pump is then used to raise the temperature of the circulated fluid to a higher temperature suitable for serving the space or hot water systems in the building. Systems will often be designed to provide heating in winter and cooling in summer, to help keep the ground temperature balanced, particularly where there is a mix of commercial and residential uses.

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3.4.7.3 Capital Cost Methodology

The capital costs of delivering energy and CO_2 reduction targets impact scheme viability and are therefore an important consideration for Developers. Indicative capital costs have been produced which include costs for individual technology components, associated plant and site infrastructure, as well as building systems and/or services within dwellings where these varied across options.

Comparative costs are presented relative to the baseline scenario defined above, which represents a typical London Plan policy compliant solution.

The cost estimates are derived from a bottom up analysis, using a combination of published reference sources and internal AECOM data from previous projects. High level estimates have been developed for system sizes taking into consideration the site context, housing densities and projected heat demand profiles. For certain cost items, such as indicative lengths of primary pipework for district heating network, estimates are based on AECOM experience from schemes with similar housing densities.

For practical comparative purposes the total costs of the installation have been compared. In reality who incurs these costs will depend on the scale of deployment and the procurement and delivery method adopted. As an example a cluster wide district heating scenario is likely to offer potential to pass on some of the delivery cost to a third party ESCO if a sufficient customer base can be guaranteed (ENGIE invested more than £100million in delivering the Olympic Park Heat network on the basis of the likely returns over a 40 year concession period), by comparison a block based electric storage heating system might need to be fully funded by the Developer.

See Appendix G for further cost assumptions.

3.4.7.4 Running Costs for Consumers

A key consideration in arriving at an optimum energy strategy is the impact on running costs for consumers. It is important that the strategy does not lead to unacceptably high costs for consumers relative to other widely available alternatives. This is even more critical given the high proportion of affordable housing to be delivered in the Old Oak area and the Mayor’s aspiration to increase affordable housing provision.

Appendix G sets out the challenges in comparing heating bills for district heating and dwelling based systems. To enable a like for like comparison across technology scenarios, running cost comparisons have been based on the total cost for the consumer of owning, operating, maintaining and replacing the systems over their life.

Running cost comparisons include the fuel/ heat bills, any fixed annual charges (such as the utility standing charges or charges for billing and metering) plus the annualised cost to the consumer of owning, maintaining and replacing the system. This comparison provides a factual basis for comparing costs, but it should be recognised that in reality the consumers’ perception of cost may be different as they will be focussed on the fuel bill they receive. They may not take out a maintenance contract for their heating system or be responsible for maintenance if they are in rented accommodation and therefore perceive this as a cost. However, in most cases they will ultimately be meeting these costs in some way (e.g. through paying for heating system repairs or replacement when a system breaks down or through a service charge or rent that includes maintenance and repair of their heating system).

For more details, please refer to Appendix G.

3.4.7.5 Results of Carbon and Cost Analysis

Table 7 sets out a summary of the results for a number of the technology scenarios. The table compares the average dwelling carbon emission rate per m^2 of net internal area (NIA) for the different technology scenarios for each of the development periods assessed, plus the current capital and running costs that would be expected per m^2 NIA. The technology strategy number (TS) relates to the scenario presented, more detail on the assumptions used for each TS is included in Appendix G.

The table compares a range of technology options:

- At the unit scale these include the provision of electric storage heaters, or the deployment of heat pumps to recover heat from whole house mechanical ventilation systems to serve hot water demands with direct electric top up;
- At the block scale they include closed loop ground source heat pumps served by ground piles providing space heating and hot water to communal heating systems;
- At the development scale they include the default London plan comparator of gas CHP engines with standby and peak load gas boilers; and
- At the cluster wide scale they include a number of scenarios for area wide district heating provision with different assumptions around the heat sources that would be serving the networks.

3.4.7.6 Heat Networks at Development or Cluster/Area-wide Scale

The technology scenarios applicable here are shown in Table 7 and include:

For cluster-wide solutions:

- TS 19: Gas CHP led heat network (70% of heat from gas CHP; 30% from gas boiler)
- TS 22: Powerday and gas CHP led network (40% Powerday; 35% CHP; 25% gas boiler)
- TS 23 Powerday led with some gas CHP and heat pumps (70% Powerday, 15% CHP, 10% heat pumps)
- TS 25: Powerday and heat pump led network (40% Powerday; 30% heat pump; 15% CHP; 15% gas boiler)
- TS28 Powerday heat pump and direct electric boilers (40% Powerday; 30% heat pump; 30% direct electric boiler

For Development solutions:

- TS 1: Gas CHP led high temperature development network (60% from CHP; 40% from gas boiler)

3.4.7.7 Gas CHP Heat Network Options

The results show that at, present (see 2016 column), the London Plan policy gas CHP baseline solution (TS1) is better than all the block or unit scale solutions in terms of CO_2 emissions. However, only 8% of the dwelling units are expected to be built by 2020 and by the period 2021 to 2025, this solution is predicted to result in the highest level of calculated CO_2 emissions. A cluster-wide network across the Old Oak site, which is served by gas CHP (TS 19), would in early phases reduce carbon emissions compared to the baseline development-scale solution, but would in later phases result in even higher emissions, due to the assumed greater proportion of heat from the gas CHP engines (70% compared to 60% for the smaller systems). By the very end of the development period, emissions from gas CHP systems could be up to ten times higher than unit based electrical alternatives. The capital and running costs for both solutions are similar to other cluster-based solutions (described below), and higher than many of the unit and block level solutions. Hence, overall, neither of these gas-CHP driven solutions is particularly attractive in meeting the objectives for the decentralised energy strategy set out in section 3.4.2.5.

It should be recognised that the calculated CO_2 emissions are based on average emission factors as currently required by Part L of Building Regulations and planning policy requirements. These do not reflect the true benefit of CHP in displacing marginal generation plant during periods of peak demand and in reality CHP would still offer benefits to the national energy system beyond the period the SAP calculation method would show. It is also possible that the calculation method could be changed in future, although this is considered unlikely as BEIS recent consultation on changes to SAP continues to promote the use of average emission factors. While gas CHP will offer national system benefits, a Developer seeking to connect to a heat network served predominantly by gas CHP will in future see no benefit in their carbon calculations and they are therefore likely to resist a connection as they will struggle to meet the CO_2 reduction targets required in London Plan policy.

3.4.7.8 Multiple Source Low Carbon Heat Networks

As an alternative, a multi sourced low temperature heat network, that is served predominantly by waste heat from an EfW facility in the early phases of development and can then transition to greater use of electrically driven heat pump solutions could maintain relatively low carbon emissions across the development period, ensuring policy compliance with current London Plan policy requirements for delivery of district heating networks while avoiding this becoming a huge penalty in CO_2 terms as would be the case with a mainly gas CHP driven solution. This is illustrated in Table 7 by TS 23 which offers low carbon emissions in the early years, and by TS28 which offers low carbon emissions in later years. To maintain low carbon emissions the gas CHP and gas boilers that are part of the heat mix in option TS 23 could be replaced by heat pumps or electric boilers at the end of their life, transitioning to the heat mix assumed for TS28. Further business case modelling would be necessary to determine whether the increased costs of heat from electric based systems compared to gas CHP or EfW would enable networks to deliver an economic return on investment. In practice a wide area multi source heat network that retained some use of gas CHP could be expected to enable high revenues to be generated from future electricity market demand balancing mechanisms without a significant carbon penalty in real terms, particularly if the operation of the CHP was electricity led to coincide only with peaks in demand.

It should be recognised that even with this transition, by the 2030's there will be a number of unit or block based electrical systems that could offer lower calculated carbon emissions at reduced capital and reduced total running costs compared to the multi-source low carbon heat network. In this case, for development areas such as Crossrail which are expected to come forward later in the delivery programme there may be carbon and cost benefit in moving away from district heating solutions to unit or block level heat pump or storage heating systems, combined with solar water heating.

The analysis summarised in Table 7 has highlighted the importance of EfW as a heat source in the early years. If EfW cannot be brought forward as a heat source there would be reduced benefit in delivering a heat network. Gas CHP will become a high carbon heat source and most of the other low carbon heat sources identified such as canal, sewer and borehole water extraction could potentially be exploited at a local development scale. The success of a multi-source heat network solution in meeting OPDC objectives is particularly dependant on the permitting and planning approval for heat offtake from a planned EfW facility at Powerday. As set out previously this planning approval will need to consider the air quality implications of the proposed facility and the risk this poses to bringing forward this strategy needs further consideration.

Heat from an EfW facility at Powerday would be reliant on a heat network for its utilisation. If the proposed EfW facility is approved, there would be strategic benefit in utilising the waste heat even if calculations show there are alternatives with lower carbon emissions. If not utilised in a heat network the heat would effectively be wasted and the useful energy lost.

3.4.7.9 Unit/Block Level Options

The technology scenarios applicable here are shown in Table 7 and include:

For Block solutions:

- TS 34: Ground source heat pump led, with advanced fabric spec (60 % of heat from GSHP; 40% electric boiler)
- TS 31: Ground source heat pump led, with London Plan standard fabric spec (60 % of heat from GSHP; 40% electric boiler)

For Unit solutions:

- TS 3: Electric storage/convection heater, with London Plan standard fabric spec
- TS 11: Electric storage/convection heater, with advanced fabric spec
- TS 4: Electric storage/convection heater and solar hot water, with London Plan standard fabric spec

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- TS 12: Electric storage/convection heater and solar hot water, with advanced standard fabric spec
- TS 17: Exhaust air heat pump, with advanced fabric spec
- TS 18: Exhaust air heat pump and solar hot water, with advanced fabric spec

In the early period up to 2020, electric storage heaters (see TS 3, TS 11, TS 4 and TS 12) would have high CO_2 emissions compared with other alternatives, would not be supported by current London Plan policy which promotes district heating (and is unlikely to be supported by emerging London Plan policies), and may need both solar water heating and advanced insulation standards to meet current Building Regulations. However from 2021 onwards, when the majority of the development will be constructed (and the majority of lifetime emissions from pre-2021 constructed buildings will occur), the CO_2 emissions are expected to significantly reduce as the grid decarbonises. They would have relatively low capital costs even when combined with solar water heating and advanced insulation standards, as well as a relatively low overall combined cost for the user, which is largely due to relatively low maintenance and replacement costs helping to offset higher electricity costs.

Block based closed loop ground source heat pumps (TS31) offer a lower carbon solution than storage heaters for all periods. In contrast, they have relatively high capital costs, in particular if combined with advanced insulation standards (TS 34). They have the lowest overall cost to the consumer, partly because the costs of installation are assumed to be borne by the Developer and are not passed onto the consumer in the same way as district heating. The efficiency of the heat pumps means they consume around a third of the electricity compared to equivalent storage heater solutions, although this difference is offset to some extent by the lower electricity tariff assumed for storage heaters.

Unit based exhaust air heat pumps (which utilise the heat in exhaust air from whole house mechanical ventilation systems (MVHR) as a source of heat for operating heat pumps) can be used to generate domestic hot water (see TS 17 and TS 18). Combined with advanced insulation standards, this technology has the lowest carbon emissions from the early 2020 onwards. However, they have relatively high capital costs associated with the combination of individual heat pumps, the MVHR system, and the advanced insulation standards. They also have the highest ongoing costs to consumers, due to the cost of maintaining and replacing these various systems, and due to the assumed use of direct electricity for top up heating. Hence, it is expected that these options are less attractive than the other unit/block based options.

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Technology Scenario				Scenario emissions (Weighted average per unit for time period) $kgCO_2/m^2/year$							Cost uplifts	£/unit
TS no.	Fabric specification	Technology specification	Scale	2016	2017-20	2021-25	2026-30	2031-35	2036-50	Overall average 2017 – 50	Capital cost [/m²]	Annual bill + cost of owning system [/m²/year]
12	Advanced	Direct electric storage heater + solar hot water	Unit based	20.7	14.0	9.3	6.1	3.6	1.7	5.7	£112	£5.87
4	London Plan	Direct electric storage heater + solar hot water	Unit based	30.9	20.9	14.0	9.1	5.3	2.5	8.5	£63	£7.61
11	Advanced	Direct electric storage heater	Unit based	26.9	18.2	12.1	7.9	4.6	2.2	7.4	£95	£5.66
3	London Plan	Direct electric storage heater	Unit based	37.3	25.2	16.8	11.0	6.4	3.1	10.2	£46	£7.47
18	Advanced	Exhaust ventilation air heat recovery heat pump + solar hot water	Unit based	15.4	10.4	6.9	4.5	2.6	1.3	4.2	£186	£14.91
17	Advanced	Exhaust ventilation air heat recovery heat pump	Unit based	15.8	10.7	7.1	4.7	2.7	1.3	4.3	£169	£14.11
34	Advanced	Ground source heat pump (60%) + direct electric boiler (40%)	Block based	18.8	12.7	8.5	5.6	3.2	1.6	5.2	£171	£6.31
31	London Plan	Ground source heat pump (60%) + direct electric boiler (40%)	Block based	25.8	17.4	11.7	7.6	4.5	2.1	7.1	£122	£8.00
1	**London Plan**	**Gas CHP (60%, η elec = 36%) + gas boiler (high temp network)**	**Development based**	**14.4**	**18.5**	**22.1**	**24.7**	**26.7**	**28.1**	**25.0**	**£119**	**£9.34**
25	London Plan	Powerday (40%) + heat pump (30%) + gas CHP (15%) + gas boiler (15%)	Cluster based	12.1	11.8	11.3	10.9	10.7	10.5	10.9	£122	£9.02
22	London Plan	Powerday (40%) + gas CHP (35%, η elec = 39%) + gas boiler (25%)	Cluster based	10.7	13.6	15.6	17.0	18.1	18.9	17.2	£116	£9.02
19	London Plan	Gas CHP (70%, η elec = 39%) + gas boiler (30%)	Cluster based	11.0	17.0	21.9	25.4	28.1	30.0	25.8	£123	£9.02
28	London Plan	Powerday (40%) + heat pump (30%) + direct electric boiler (30%)	Cluster based	20.1	14.7	10.5	7.6	5.3	3.6	7.2	£120	£9.02
23	London Plan	Powerday (70%) + heat pump (10%) + gas CHP (15%) + gas boiler (5%)	Cluster based	9.0	10.1	10.2	10.2	10.2	10.2	10.2	£116	£9.02

Table 7. Comparison of Carbon Emissions and Costs for Alternative Heating Scenarios

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3.4.7.10 Conclusions of Carbon and Cost Analysis

The following summarises the analysis undertaken for carbon and costs performance of the different solution investigated.

1. Heat networks reliant on gas CHP engines as the main heat source are expected to result in the highest calculated carbon emissions. From 2021 onwards, this solution is predicted to result in the highest calculated CO_2 emissions. This makes this solution unattractive for any development post 2021. It also appears unattractive for development pre-2021 as the gas CHP engines will be expected to run for 15-20 years and the calculated cumulative emissions over this period will be higher than most, if not all, other options.

2. A multi-sourced low temperature heat network, where the main heat source is from an EfW facility such as at Powerday, is necessary for any large scale heat network in the Old Oak area. It enables the carbon intensity of a heat network to remain competitive (in terms of emission rates) with unit-and block-scale electric heating options into the 2030s. This would be expected to be integrated with infrastructure scale heat pump options (open loop ground, canal, and sewer source). In later years, direct electric boilers can be included to replace more carbon intensive sources (such as any supporting gas CHP engines or gas boilers). It should however be recognised that not all this benefit may be realised due to the lead in time for the EfW plant itself, which would not be operational until 2021 at the earliest when the heat loads that can utilise it may be limited due to lack of development coming forward prior to this date. This could potentially be overcome if heat were supplied to wider developments such as North Acton, where loads are expected to build up more quickly, but where at present it may be difficult to deliver an area wide heat network due to the multiple land ownerships and need to agree multiple connection agreements. The benefit of a multi sourced low carbon heat network is dependent on the permitting and planning approval for heat offtake from an EfW plant. The risks associated with this require further evaluation.

3. Block and unit scale electricity-based heating systems have the best long term CO_2 outcomes. In particular block-level ground source heat pumps (GSHP) with advanced insulation standards are relatively attractive from 2017 onwards. All other block-level GSHP options and unit-level electric storage heating options are relatively attractive from 2021 onwards when the vast majority of the development will be built out. In general, the electricity-based heating options are competitively priced compared to heat network alternatives, both in terms of capital cost and cost to the consumer. However, such options go against London Plan policy which promotes heat networks. These solutions will also require greater electrical infrastructure.

4. If it is necessary to adopt the current London Plan policy, and the need to maintain the ability to deliver a 35% reduction in carbon, the most favourable strategy at least in the early phases would be to deliver area wide heat networks if these could utilise heat from Powerday initially and then increasingly from heat pumps drawing low grade heat from the canal, sewers and the aquifer, and potentially in the later phases from electric boilers.

5. Based on the findings from this study, a multi sourced low carbon heat network could meet OPDC's strategic objectives for the decentralised energy strategy in terms of policy compliance, long term carbon savings and secure energy supply, assuming that Powerday can be utilised.

6. For later development clusters, such as Old Oak South (Crossrail and HS2) that could potentially be delivered much later in the programme (mostly after 2030), it is possible that London Plan policy will change to reflect the observed change in electricity emission reductions. For development clusters delivered after the 2030's flexibility would ideally be retained to deliver block or unit based solutions in place of heat networks, as these would be expected to offer lower carbon emissions at lower cost to consumers and at around the same overall total capital cost.

7. It should be recognised that there are some limitations in looking at the overall costs of delivery for the alternative options. One of these is that the costs will fall to different parties

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depending on the option chosen and the method of procurement. For example while the overall costs of ground source heat pumps (TS 31) are shown to be only slightly higher than the heat network option (TS 25), in reality it may be possible to get a 3rd party ESCO to partially fund the heat network option, so the capital delivery cost to the Developer may be lower for the district heating option, particularly if it can be delivered at scale.

The analysis presented here indicates that heat networks are likely to be a viable solution to ensure low carbon heat supplies are provided to development at Old Oak. Initial high level analysis has been carried out to consider some of the opportunities and issues the masterplanning team will need to consider in terms of potential energy centre locations and the likely routes for the primary heat network.

3.4.8 Potential Energy Centre Locations and Heat Network Routes

There are significant challenges particular to the Old Oak site that will need to be addressed in order to ensure district heating networks are viable. These include the location of low carbon heat sources relative to heat demand; the availability of plots for siting energy centres; the significant physical barriers present on site (e.g. railways and the Grand Union Canal) as well as significant level changes.

Although there are many challenges to overcome, there are also opportunities presented by the need to significantly enhance the infrastructure around the site, including new roads and bridges. The primary purpose of many of these enhancements will be to provide a more accommodating and coherent townscape. However, they also provide an opportunity for coordinating the design and installation of energy infrastructure, potentially reducing the costs for achieving infrastructure crossings through burden sharing and cooperation.

Appendix C sets out a high level assessment of the network routes that may be required to connect sources of demand and supply and possible locations for energy centres. These will need to be developed further as part of the ongoing masterplanning work, taking account of proposed and competing land uses and the expected timing of delivery. The following summarises the findings in Appendix C.

3.4.8.1 Energy Centre Locations

One of the outcomes of the masterplanning work will be to determine appropriate locations for the energy centres needed to serve district heating networks. A number of land plots have been identified that could potentially host a dedicated energy centre. These include plots which are not currently planned for development, such as the large triangular plot between North Acton and Wormwood Scrubs Park, and the smaller triangular plot immediately to the south of the Powerday site. Additional sites are also potentially available, including on plots currently planned for development or amenity provision. See Figure 27 for potential energy centre locations.

Many of these plots are constrained and are likely to experience difficulties in terms of access arrangements for energy centre construction, and/or challenges associated with routing district heating pipework and utility services to and from the energy centre.

Further constraints include the requirement to locate some potential energy centre technologies adjacent to available heat sources; for example, utilising the Grand Union Canal for water-sourced heat pump energy will require siting an energy centre adjacent or near to the canal. Other examples of locational constraints include the requirement to site energy centre facilities near to the Powerday site in order to take heat from the planned EfW facility (see ‘C’ in Figure 27).

The most viable locations for energy centres are likely to be the northern-most part of the land identified by ‘A’ on Figure 27, and the plot adjacent to Powerday (see ‘D’ in Figure 27 which shows the proposed location for Car Giant’s energy centre).

In addition to the locations shown in Figure 27, energy centres could also be located on individual development plots. These could be used to complement the above options, and be co-located alongside development, potentially at ground or basement level.

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A number of factors should be considered when determining appropriate locations, including the phase in which the plot is expected to be developed; the proximity of the plot to other development sites that could be dependent on heat services; and the proximity of the plot to the low carbon heat source that the energy centre will target for exploiting. Low carbon heat sources that could be utilised in a plot-based energy centre include sewer heat recovery systems, and open-loop heat pump systems extracting heat from the London aquifer.

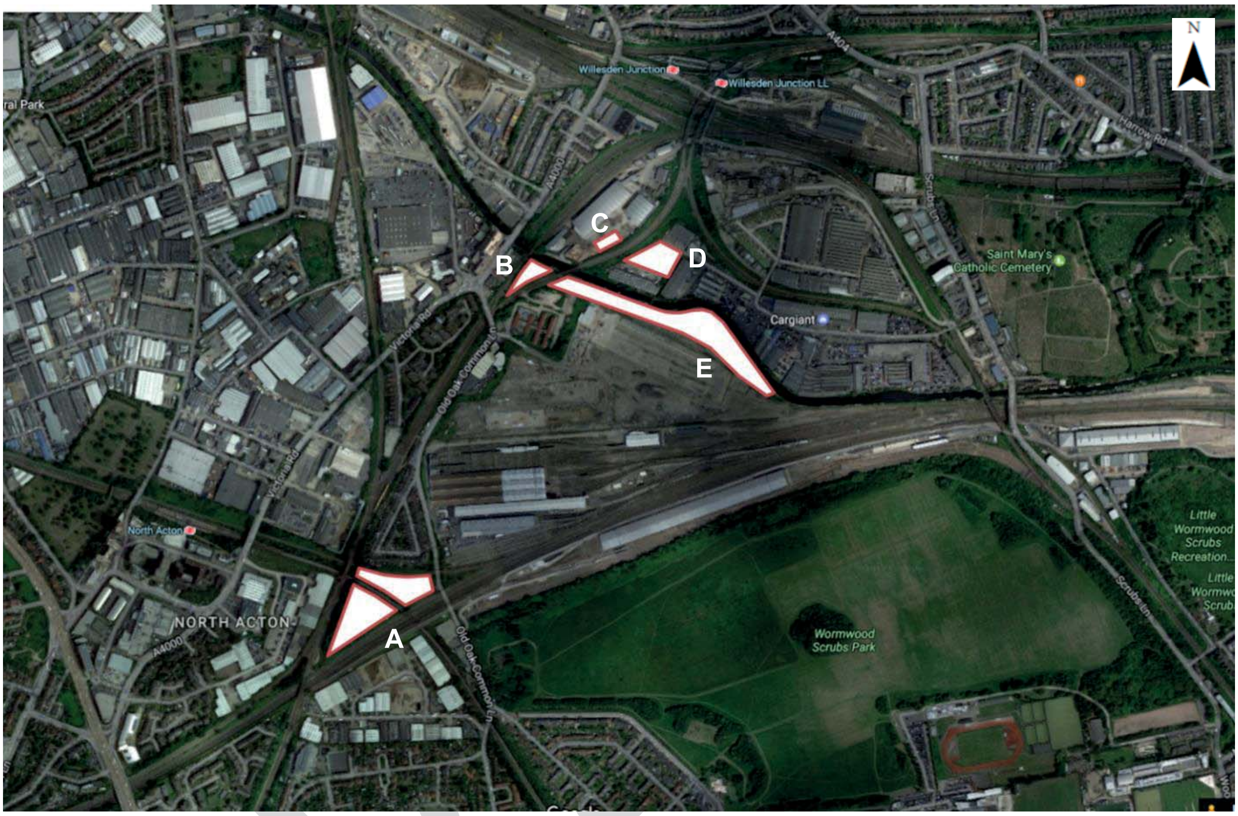

Figure 27. Potential Energy Centre Locations in Old Oak

3.4.8.2 Network Routes

District heating network routes around the Old Oak site are expected to encounter a number of key challenges. These include a number of railway lines (including the planned HS2 line and the Crossrail line currently under construction), the Grand Union Canal, and a lack of available crossing points over these obstacles. The grouping of development into geographical clusters, separated by the numerous railway lines in particular presents significant challenges.

The Willesden Junction and Scrubs Lane clusters are geographically isolated from the other clusters by major railway lines, with access currently limited to an underpass along Hythe Road linking Scrubs Lane to Old Oak North, and a footbridge connecting Willesden Junction to Old Oak North. Further constraints include a weak bridge linking the northern and southern ends of the Scrubs Lane area.

North Acton is separated from the main Old Oak development by key railway lines. Key routes to the rest of the site include Old Oak Common Lane and Victoria Road. The expected upgrades of Victoria Road for HS2 provide an opportunity for possible coordination of heat network delivery and engagement with HS2 is recommended during the masterplanning works in order to explore this opportunity.

Old Oak South and Old Oak North are separated by the Grand Union Canal, which dissects the site. Only one pedestrian footbridge currently connects the two sites; however, significant new road and pedestrian infrastructure is expected to be provided as part of the wider masterplan, which is likely to provide opportunities for co-locating services within the new infrastructure.

Indicative options for energy centre locations and routes for the main district heating transmission network are illustrated in Figure 28. Routes for the primary distribution routes (connecting individual development plots to cluster-based energy centres) should be established during the masterplanning works, and will need to consider the challenges and opportunities identified here.

Secondary pipework (from the boundary of plot development sites to the interface with individual dwellings) and tertiary pipework (within dwellings) will be designed during the detailed design stages of individual plots. Appendix C outlines the standards to which this pipework should be designed.

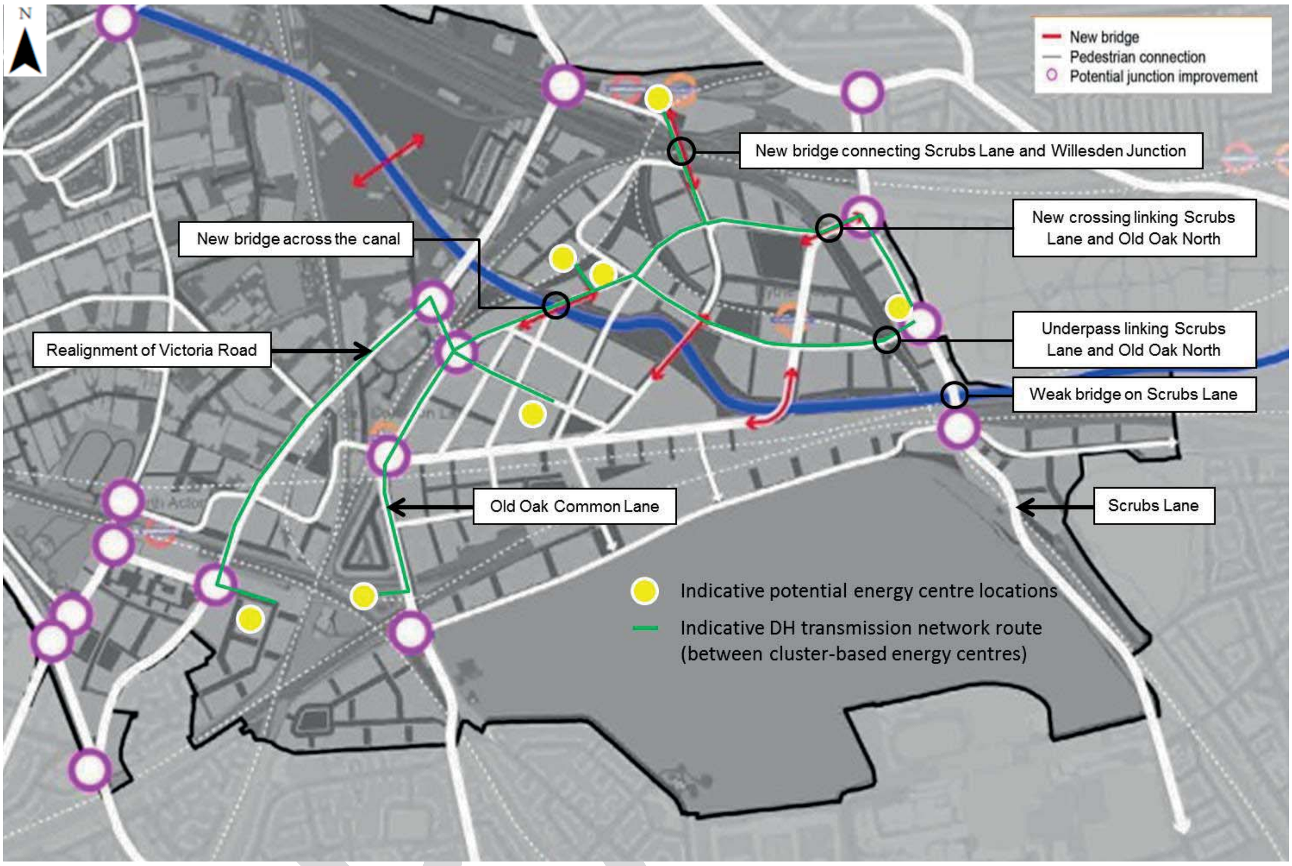

Figure 28. Indicative Route for District Heating Transmission Network and Energy Centre Locations

Note that the routes and energy centre locations shown here are indicative only, and further analysis (of the best routing options and energy centre locations) should be undertaken as part of the masterplanning stage of works.

3.4.9 The Case for Heat Networks at Old Oak

The case for heat networks at Old Oak is dependent on:

- Identifying low carbon heat supplies locally which are sufficient to serve a significant proportion of annual heat demand in the Old Oak development area;
- Identifying a strategy that will result in low carbon heat supplies to development over the short, medium and long term; and
- Identifying appropriate mitigation strategies to overcome the significant physical barriers present on the Old Oak site.

Section 3.4.6 discussed the potential for local low carbon heat sources to provide the expected demand for heat from the development at Old Oak. This was discussed in relation to the potential for these heat sources to replace gas CHP over time. The analysis identified a number of local sources, including a potential EfW facility, the Grand Union Canal, the London Aquifer, and heat recovered from local sewer systems. The latter three sources would all be utilised via heat pumps. Furthermore, analysis indicates that some of the low carbon heat sources identified, (e.g. EfW) could not be fully utilised without the use of heat networks.

Given the anticipated density of development at Old Oak (300-600 dwellings per hectare) with typical block heights of around 10 storeys and many much taller buildings, there will be pressures on the ability to accommodate plant at roof, ground or basement level. District energy schemes offer the ability to remove some of this plant from the buildings and to locate it within energy centres on sites which may be less favourable for development. The high density of development also means the cost of primary network distribution relative to heat demands is reduced.

Section 3.4.7 discussed the different low carbon heat strategies that could be deployed at Old Oak. The analysis investigated the option of generating heat at a district level (cluster-wide), development level, block or building level, or at unit level. Furthermore, different technology options were also investigated, with a view to determine the most carbon-efficient strategy/strategies over the short, medium and long term. The analysis showed that area-wide heat networks are likely to be the most carbon efficient in the short term, and can remain competitive in the medium to longer term, provided that low carbon heat sources derived from electric driven facilities, are incorporated to replace gas CHP.

The analysis has also shown that in later phases heat networks served by gas boilers and gas CHP engines will be one of the highest carbon options and hence if heat networks are delivered, sufficient flexibility and governance is required to ensure that networks transition to lower carbon sources.

The analysis shows that, at least in the early phases, lower cost options such as direct electric heating will have higher emissions than those for heat networks served by gas CHP or by heat from low carbon sources such as EfW and electric heat pumps. EfW is core to the argument for heat networks as it provides very low carbon heat in the period from 2017 to 2025 when emissions for heat pumps have yet to fall to the same level.

Small plot based heat networks served by gas CHP engines offer limited flexibility to upgrade heat sources in future or to tap into geographically dispersed heat sources. If heat networks are to be effective in unlocking the use of local low carbon heat sources they need to be delivered at an area wide scale. This will also provide the flexibility to utilise a range of heat sources, providing greater resilience.

Section 3.4.8 investigated the potential for delivering heat networks. This included identifying potential energy centre locations, and establishing appropriate major network routes, taking account of the many and significant physical barriers around the site. The analysis showed that appropriate solutions to these challenges could potentially be developed, thereby indicating that heat networks that are served by local low carbon heat sources can be a technically viable solution.

Regardless of the relative merits of district heat networks, current policy would require the delivery of district heating networks. There is potential for this policy to change as grid emissions for electricity fall or if the increasing focus on London's air quality results in policies that seek to limit the use of combustion technologies such as gas CHP. However, a large-scale move to electric only heating systems would be expected to be accompanied by the need for significant investment in upgrading London's electricity distribution infrastructure. The costs associated with this may result in a continued push to utilise a range of heat sources, and in particular, heat that would otherwise be wasted such as that associated with waste management.

Should the masterplanning work conclude that the EfW facility is an unacceptable neighbour for a major housing development either on visual or air quality grounds, the strategy for heat networks will need to be reviewed. While the heat pump options could meet part of the base heat load, the expectation is that the cost of providing heat would likely be higher with implications for viability. Unlike EfW, the heat pump sources could all potentially be deployed directly at a block or plot scale without the need for a heat network. If the planned EfW facility cannot go ahead at the currently proposed site, it should be explored whether an alternative site could be identified within Park Royal. Having established the potential for heat networks to deliver the required heating strategy at Old Oak, a number of different delivery model options are explored in the following section.

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3.4.10 Heat Network Delivery Models

Desk based studies have been undertaken to review existing delivery models for district energy schemes and their potential applicability to Old Oak. Interviews were held between AECOM, OPDC and the promoters/operators of the Kings Cross Heat Network, Queen Elizabeth Olympic Park Heat Network, Bunhill Heat Network and the planned Lea Valley Heat Network. A full assessment of the potential delivery models and the lessons learnt from these discussions is set out in Appendix D. A short summary of some of the key findings is set out below.

3.4.10.1 Lessons from Previous Schemes

- All district energy schemes benefit where there is a guaranteed heat demand, a secure source of low carbon heat and unified land holding to provide a strong heat customer base;
- A successful public sector led scheme can enable access to cheap financing, potentially enabling affordable running costs for residents. The Enfield led Lea Valley Heat Network provides a potential model for an OPDC led scheme, but benefits in particular from a potentially secure source of waste heat (Edmonton Eco Park, Enfield are one of the seven partner boroughs on North London Waste Authority), and public sector controlled development agreements for major new development at Meridian Water;
- Strong technical standards need to be promoted to avoid poor design, installation and network performance, in particular in relation to heat losses and flow temperatures. A number of the existing schemes have been affected by poor performance from early phases of delivery and have subsequently needed to increase the focus on technical standards to address this;
- A strong governance model or contractual arrangements are required to maintain ongoing carbon savings, set required standards, price controls, and protection for consumers, as the heat market is unregulated. OPDC will need to use its available powers or any future procurement of infrastructure to influence this;
- Identifying potential private wire customers for power will improve the Internal Rate of Return (IRR) if generation technologies are deployed. HS2 and Crossrail could potentially be customers for power;
- Local plan policies should aim to assist in securing low carbon heat supplies and heat customer demand, by: safeguarding network routes, i.e. requirements to build utilities into crossings etc.; safeguarding access to identified heat sources; protecting potential heat source or energy centre sites through appropriate land designation i.e. designating the Powerday site for industrial use; promoting adoption of best practice technical standards; requiring heat offtake for any planned EfW facilities; requiring planned development to connect into proposed heat networks and to make new provision for heat networks and to enable their extension;and
- There are examples of successful private sector led delivery. Argent has developed a viable fully private sector led and delivered model for their heat network at Kings Cross based on a private sector multi utility procurement model. The scheme has been set up to ensure consumer costs of heating, and heating system maintenance and replacement, are lower than for typical system comparators. Strong focus is provided on consumer protection.

3.4.10.2 Delivery Models

There are many possible models for delivering heat networks in the Old Oak area, subject to them being technically feasible, environmentally beneficial, and financially viable. Establishing the preferred delivery model broadly involves deciding on the ‘delivery vehicle’ and (unless scheme development and delivery is left entirely to the private sector) the ‘contractual structure’ for the scheme.

1. **Delivery vehicle** – Both the nature of the corporate entity that will be established to deliver the scheme, and the relationship between OPDC and this ‘delivery vehicle’ need to be considered.

   Possible delivery vehicles cover a spectrum in terms of ownership from: **wholly public** (internal department or wholly owned municipal companies), through **hybrid**, to **fully private** sector companies (invariably ‘**Special Purpose Vehicles**’ (SPVs), likely to be subsidiaries of specialist energy companies and often afforded exclusive rights to supply heat, e.g. through a concession).

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Examples of a hybrid company include: a **public sector-led SPV** (which could be: a **public + private joint venture**, or a wholly owned, arms-length **municipal limited company**); and a community-owned **mutual limited company** or **cooperative** (although community ownership is initially unlikely to suit the setting up of a large scheme serving new development).

Opting for a publicly owned entity or public & private SPV would imply a direct and strong role for OPDC. Fully private sector delivery implies that OPDC's role would be limited to creating the necessary context (e.g. through planning, incentives, facilitation) for a viable scheme to be delivered by interested property Developers and specialist energy companies.

2. **Contractual structure** – Some of the potential scheme delivery vehicles require a very specific top tier of contracts to be put in place (e.g. memorandum & articles of association for a municipal SPV or JV, master agreement for a concession). A detailed contractual structure then covers the way individual 'development works' and 'operational services' elements of the scheme are to be bundled and procured, what property-related agreements are needed, and any other necessary legal agreements between interested parties. A range of detailed contractual structures may work for a given delivery vehicle and the best fit can broadly be decided independently of, and after, the choice of delivery vehicle.

In practice, only a handful of delivery models are common (to date) or likely to work well for large schemes led by the public sector. These can be broadly characterised as follows:

Model*	Originator	Owner	Vehicle	Finance**	OPDC contracts
Municipal	Public led	Public	Municipal dept. or wholly owned company	PWLB, HNIP funds	Specialist D&B contract; O&M and M&B may be in house or contracted
Municipal SPV / JV	Public led	Public / Joint	JV / SPV (limited company)	PWLB, HNIP funds, debt	Memorandum & articles of association; shareholders agreement; SPV decides contractual structure
Concession	Public led	Private***	SPV	Equity, debt	Master agreement, SLA, connection & heat supply agreements; SPV provides / procures works & services
Private	Private led	Private	SPV	Equity, debt	No contractual links with OPDC (except OPDC as heat customer)

** Delivery model names are solely for ease of reference; ** Sources of external finance not comprehensive; *** Rights of ownership transferred to the concessionaire for the term of the concession; D&B = Design & Build; HNIP = Heat Network Investment Project; O&M = Operation & Maintenance; M&B = Metering & Billing; SPV = Special Purpose Vehicle; SLA = Service Level Agreement; PWLB = Public Works Loan Board*

Table 8. Delivery Model Options

The final extent of OPDC's land ownership, and hence ability to contractually secure heat network connections, is an important consideration in deciding a preferred delivery model. The 'Concession' model, for example, critically depends on the public sector's ability to guarantee connections within a defined concession area. The viability of all (public- or private-led) delivery models for an area-wide heat network provider will depend on a reliable pipeline of connectable heat demands in new development. A firm commitment from OPDC that large areas of land in public ownership will be obliged to connect to strategically planned heat networks in the area will greatly reduce the 'demand risk' for a heat network provider, which would tend to reduce risk premiums, strengthening the provider's business case.

The **possible role of a separate heat distribution network-owning company (PipeCo)** in the area is worth exploring, and might also influence the choice of delivery model and the role that OPDC plays in scheme development. For established parts of the scheme (generation + distribution + connected customers), a PipeCo would own just the heat distribution pipework, accepting relatively low but reliable long-term returns from 'use of system charges', and freeing up capital for the scheme owner to reinvest in expanding the network with new connections and generating capacity. The PipeCo concept is new and might need to be integrated into the delivery model from the outset if it is to be

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successfully applied to a scheme in the Old Oak area. It would rely, as a minimum, on strong strategic and practical support from OPDC/GLA (and potentially on financial backing to establish the PipeCo).

3.4.10.3 Next steps in deciding a delivery model

OPDC's **choice of delivery vehicle** is likely to be driven by:

- Land ownership;
- Strategic objectives; (and consequently);
- Appetite for control and governance of the scheme;
- Decisions on whether to carry or transfer scheme risks;
- Required / acceptable rate of return (hurdle rate);
- Available sources and costs of finance; and
- In-house technical and commercial skills (capacity that exists or can be developed).

These factors essentially point to the next steps that OPDC should take towards deciding on the delivery model through which a heat network scheme or schemes should develop in the Old Oak area:

1. Clarify the extent of OPDC's land ownership and ability to secure heat network connections through development agreements, covenants, or other contractual means.
2. Consider the strategic objectives for a potential heat network serving the Old Oak area, including the importance and relative priorities of carbon savings, Developer cost savings, consumer energy prices / bills, any system / synergistic issues such as interconnections to wider heat networks, and any other relevant issues such as the interests and potential role of neighbouring boroughs.
3. Consider the level of control and governance over the heat network that OPDC is likely to need to achieve the strategic objectives, or that it would prefer for other reasons.
4. Undertake an initial review of scheme risks (including: presence of connectable anchor loads; heat demand evolution; broad design and construction issues; energy prices and other operational issues) and establish whether OPDC would consider carrying or would prefer to transfer each risk.
5. Establish the rate of return that OPDC would set as its own 'hurdle rate' for any financial stake in a scheme delivery vehicle (and if relevant, the rate applicable to a stake in a PipeCo).
6. Confirm the sources of finance available to OPDC (e.g. for scheme development: Heat Networks Delivery Unit, own funds; for delivery: Public Works Loan Board, Heat Networks Investment Project, Green Investment Bank, private debt), corresponding constraints (process, timescales, capital limits, etc.), and the interest rates and any other costs of accessing this finance. As part of this, consider the potential for funds to support scheme delivery to be generated through the Community Infrastructure Levy or through Section 106 as Developer carbon offset payments.
7. Assess OPDC's existing in-house technical and commercial skills relative to the skills capacity needed to establish the delivery vehicle(s) that are of interest.
8. (Crosscutting:) Start to consider OPDC's level of interest in the PipeCo concept, assessing its positive potential against novelty and risk.

Before opting for a preferred delivery model for a heat network scheme serving the area, OPDC would also require initial indicative information on:

- The technical parameters of a feasible scheme (generator types and installed capacities, network length, customer mix and demand levels) given known development proposals and constraints;
- The likely range of rates of return of an indicative scheme for public and private investors.

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3.4.11 Intervention Options for OPDC

There are three broad levels of intervention available to OPDC regarding how to influence and encourage investment in low carbon decentralised energy network infrastructure within the Old Oak development area. These are highlighted in Table 9.

Intervention	North Acton	Scrubs Lane	Willesden Junction	Car Giant	Crossrail & HS2
Leave to the market	Small plot based gas CHP engines			Cluster wide gas CHP networks	
OPDC encourages improved market response	Small plot based gas CHP engines			Cluster wide gas CHP or possibly low carbon sources	Cluster wide possibly with low carbon sources
Public sector-led network delivery	Interconnected local cluster networks served by low carbon sources (subject to proving economic viability)				

Table 9. Likely Outcome for Each Development Area, by Level of Intervention

Broadly speaking OPDC could either leave it to the market to deliver a solution driven by and compliant with the London Plan, or they could strategically intervene and seek to promote wide area heat networks served by a range of low carbon heat sources in each of the main development clusters. Alternatively, OPDC could intervene directly to lead the delivery of a heat network for the area.

3.4.11.1 Leave it to the Market

The default no intervention option would leave the adoption and development of the low carbon decentralised energy network to the market. OPDC could create a supportive local plan policy and masterplan, and enforce this through appropriate planning conditions. However, without further intervention, it is likely that clusters characterised by multiple small land ownerships will not create the area wide energy network that would be desirable and would instead continue to deliver small-scale plot based solutions that utilise small gas CHP engines. This outcome is most likely in areas such as North Acton, Willesden Junction and Scrubs Lane, which are characterised by multiple land ownership plots. For the larger, single-ownership areas like Car Giant, Crossrail and HS2, a more favourable outcome based on cluster-wide networks, would likely be delivered. However, they would currently still be likely to be served by gas CHP engines in the short term. Furthermore, this assumes that the large single land-ownership structure of these areas would be sustained; were these areas to be sub-divided and sold to other market Developers, the further disaggregation of these plots would likely see smaller-scale and plot-based solutions be delivered, and served by small-scale gas CHP engines.

Leaving delivery to the market will involve little or no input or cost for OPDC. Since this option is also the current market norm for Developers, it is also unlikely to hinder development, as Developers are used to this approach and aware of the requirements.

The risks associated with this approach include the likelihood that early-phase development will continue to come forward with sub-optimal and plot-based solutions (as evidenced by the applications made in North Acton in particular). The disaggregated heat demand would mean that low carbon heat sources cannot be maximised, and the flexibility to bring about changes to the mix of heat sources serving development and their carbon content cannot easily be influenced. While gas CHP engines and gas boilers could later be replaced by lower carbon electric boilers, it is unlikely this would happen as they would most likely have higher running costs. The reputational risks to OPDC and the GLA regarding the Mayor’s Zero Carbon commitment will be increased.

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3.4.11.2 Encourage Improved market Uptake

A light-touch intervention could be followed, whereby OPDC seeks to encourage an improved market response through engagement with boroughs, the GLA, land owners and potential ESCO operator to encourage aggregation of plots into cluster-wide networks. This could be further supported by GLA Decentralised Energy Project Delivery unit (DEPDU) funding of feasibility assessments to explore whether landowners could be encouraged to adopt alternative low carbon heat sources. However, the success of this approach would likely be limited to the Car Giant, Crossrail and HS2 sites, due to their large scale and single ownership structure. Smaller sites in North Acton, Scrubs Lane and Willesden Junction would likely continue to come forward with sub-optimal plot-based solutions that are reliant on small gas-fired CHP engines.

Advantages of this approach include the low capital risk to OPDC, with the private sector financing network delivery. For larger sites, it is possible this approach could lead to area wide networks served by local low carbon sources but this would not be guaranteed and OPDC could expect to have limited ongoing governance over the technical solutions and how they would be updated to maintain low carbon emissions over time.

The degree to which the market is interested in investing in heat network delivery will depend on guarantees of connection, which may be difficult to provide in areas with multiple smaller plots. Private sector finance and delivery is likely to be accompanied by the expectation of high internal rates of return on investment, this will limit the degree to which heat sources with less attractive revenue streams can be built into the business model without either higher costs being passed onto consumers, or schemes being perceived as unviable to operate.

3.4.11.3 Public Sector Led Strategic Network Delivery

The option most likely to deliver an integrated and area-wide network that is capable of utilising the available low carbon heat sources in the area and maximise their benefit, is a public sector-led approach to network delivery. This would require the public sector to lead the business case development and delivery of a cluster-wide and interconnected network. Delivery could be undertaken solely by the public sector, or via a public/private sector SPV, subject to business modelling showing the ability to deliver long term economic viability. Such a commitment by the public sector would greatly enhance the potential for delivering the network at the scale and reach required, and would allow small plot developments to share in the benefits of the wider network over time.

The advantages of this option include the ability to plan the network with the long term flexibility to respond to changes in the carbon intensity of the grid and transition from one low carbon heat source to another over time to maintain a low carbon heat source.

If funded by the public sector the lower discount rates could enhance the financial viability of the scheme as a whole enabling heat sources to be utilised that may have higher costs associated with their exploitation or which offer reduced revenue streams compared with gas CHP. The assets created could also potentially provide revenue streams for the public sector, or enable the creation of valuable assets that could later be sold on.

However, fully-led public sector intervention of this kind will require OPDC or other public sector bodies to incur significant capital costs and potentially risk upfront, and ahead of any revenue streams that may result in the future. Robust business modelling would be required to appraise likely rates of return and to appraise alternative approaches to managing risks against a range of possible delivery outcomes. Risks could for example include market conditions leading to delays in development delivery leading to investment in unused/underused assets. If public sector led costs will continue to be incurred during the development stages of the scheme, with further costs associated with governing and operating the scheme.

The delivery models available to OPDC for bringing forward a heat network and their likely effectiveness, will be influenced by the degree to which public sector land ownership is passed onto OPDC.

3.4.12 Assessment of Intervention Options against Objectives

The objectives for the decentralised energy strategy are outlined and discussed in Section 3.4.2 of this report. Table 10 sets out a high level summary of the potential for each intervention option to address the objectives. One star indicates a relatively poor performance against the objectives, while three stars suggests the objective would be met.

Objectives	Leave to Market	Encourage Improved Market Response	Public Sector led Strategic Network Delivery
Timely development	★★★	★★★	★★
Deliverable	★★★	★★★	★★★
Policy compliant	★★	★★	★★★
Affordability to developer	★★	★★	★★★
Affordability to consumer	★★	★★	★★★
Affordable to OPDC	★★★	★★	★
Low carbon energy supply	★	★★	★★★
Energy security and resilience	★★	★★	★★★
Reduced Energy Use	★★	★★★	★★★
Consumer protection	★	★★	★★★

Table 10: Intervention Options and their Response to Objectives

Table 10 is discussed below, first for those objectives that cannot be quantified, and which are therefore discussed qualitatively. For those objectives that can be quantified (i.e. affordability to Developers, Consumers and OPDC, and the provision of low carbon energy supplies), these are discussed in the following sub-sections.

Timely Development

Leaving delivery to the market is expected to mean the market delivers default strategies for individual plots and developments. As such, Developers would be expected to continue to bring forward development that is based on market norms. This would likely mean that development remains unimpeded and timely development is maintained.

Encouraging an improved market response from Developers would likely mean that, although some larger developments will potentially implement some alternative low carbon solutions, market forces and norms will continue to dominate the strategic provision of energy. This will likely have no significant impact on the timely delivery of development.

Public sector led network delivery is unlikely to result in delays to development over the long term. However, there are risks associated with the timely delivery of early phase development, should network delivery complicate or delay the provision of energy supplies in the early development.

Deliverable

The deliverability of solutions is unlikely to be impacted by the level of OPDC intervention.

Policy Compliance

London Plan policy requires the provision of heat networks where viable to do so. Public sector led network delivery would strongly support this policy, and would result in the widest reach and greatest uptake of the network from developments around the site.

Leaving delivery to the market and active encouragement by OPDC for an improved market response would not be expected to deliver full policy compliance with regards the provision of heat networks. However, development can still be policy compliant, should systems be designed such that they can connect to a wider district heating network should it be made available in the future.

Energy Security and Resilience

Energy security and resilience is likely to increase, the more the public sector is involved, due mainly to the increased utilisation of local energy resources. Market led solutions will rely heavily on gas-fed systems in the near to mid-term, with electric led systems coming forward in the long term. However, the range of energy sources that can be utilised in an integrated area-wide network is expected to enhance the security of supply and energy resilience.

Reduced Energy Use

Energy use is unlikely to be significantly affected by the level of intervention undertaken by OPDC. Fabric efficiency will continue to be driven by the increasingly challenging policy targets, and will continue to be an integral part of achieving compliance, although the earlier provision of low carbon alternative to gas CHP, that is likely to result from a public sector led network, may reduce the incentive to further tighten fabric standards that would otherwise be needed to achieve the expected policy targets. Plant efficiency will likely increase for strategies that utilise large energy centres, and the large scale use of heat pumps will ensure the energy consumption in these strategies is minimised. However, a large area-wide district heating strategy will incur energy losses in the transmission and distribution pipework which will likely offset the energy efficiency gains achieved through increased plant efficiency. A public sector led scheme is likely to be accompanied by greater opportunity for Governance around technical standards and the use of smarter control systems in homes and networks, which has the potential to improve efficiency of operation and demand.

Consumer Protection

It is expected that consumer protection will be maximised through strong public sector involvement. Should the public sector deliver a site wide heat network, strong consumer protections can be put in place. Public sector encouragement of market response is likely to provide an improvement on market led delivery, although is likely to provide weaker consumer protection than fully public sector led provision.

Those objectives that can be quantified are discussed below.

3.4.12.1 Carbon Emissions

Figure 29 shows the potential impact of the different intervention options on carbon emissions. The carbon emissions shown are cumulative savings over time in tonnes of CO_2 emissions, resulting from public sector-led network delivery. The analysis accounts for legacy systems and strategies that have been installed in buildings previously developed in earlier phases.

Initial poor carbon performance results from the use of gas boilers in the earliest phases of the public sector led approach, compared to small gas-fired CHP which will likely be used in the alternative scenarios. However, once the public sector led network is developed to the point where legacy and new developments can be connected, carbon savings increase significantly, particularly during the 2020s. Once development progresses into the 2030s, carbon savings will continue to be delivered, albeit at a slower marginal rate.

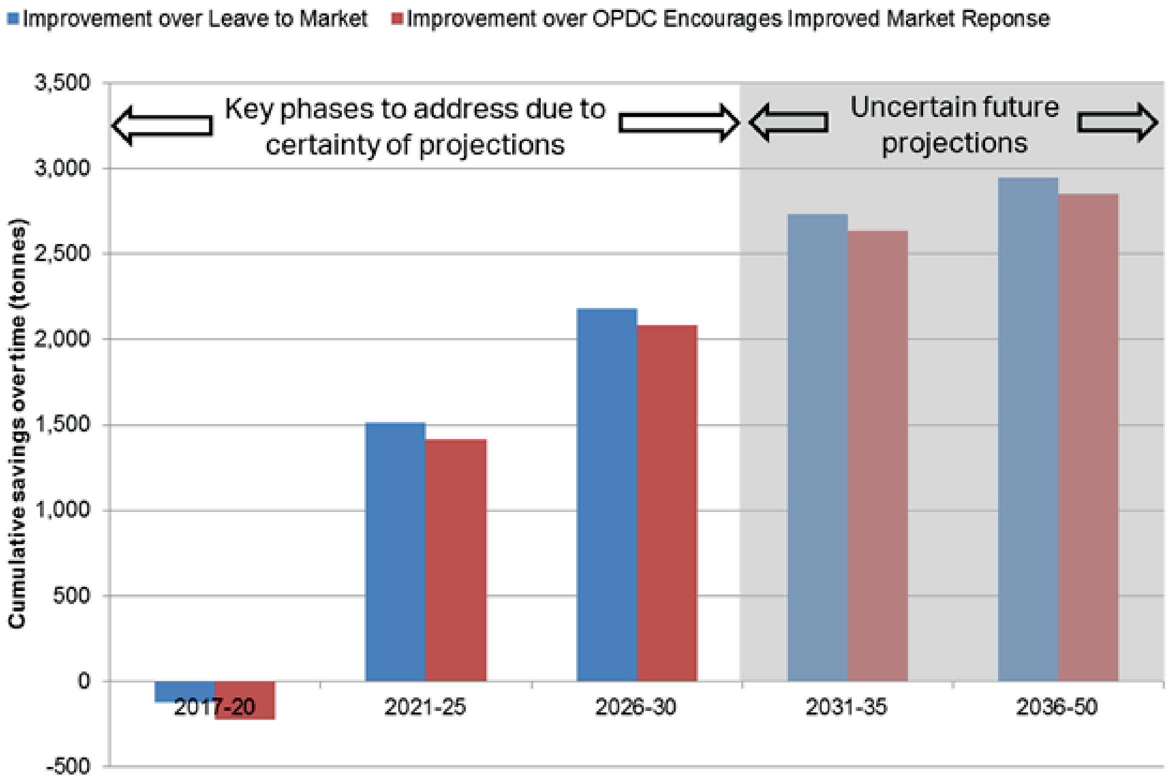

Figure 29. Cumulative Improvement in CO_2 Emissions over time from Public Sector led Network Delivery

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Leave to the Market

For development that is characterised by multiple ownership (e.g. North Acton, Scrubs Lane and Willesden Junction), leaving development to the market is assumed to lead to the widespread deployment of gas-fired CHP in the early phases. It is assumed that the legacy systems within these developments will then adopt gas-fired boiler systems (through to 2050) to replace end-of-life gas CHP. For development coming forward in these areas during the middle phases (from 2021 through to 2030), it is assumed that heat pumps will be the preferred approach for Developers applying for planning consent, since gas CHP led systems will not deliver the carbon emissions savings required by planning policy. It is assumed that these legacy systems are continued through to 2050. For development coming forward in these areas during the final phases of the masterplan (2031 through to 2050), it is assumed that cost pressures and low carbon electricity will allow Developers to adopt direct electric systems.

For Car Giant, it is assumed that a site-wide (Car Giant site) gas-CHP network will be developed from inception with gas boilers as back up. As the carbon benefits of gas-CHP become less favourable, and more development comes online during the 2020s, it is assumed that Car Giant will look to take heat from an EfW facility at Powerday (alongside the legacy gas-CHP system from earlier phases) in order to ensure performance is sufficiently low carbon to secure planning consent for reserved matters applications. As development at Car Giant moves into the 2030s, the gas-CHP is assumed to be replaced at end-of-life by heat pumps. Since all Car Giant development is assumed to be served by a site-wide network, it is assumed that all legacy development at Car Giant will benefit from these changes in technology over time.

For Crossrail and HS2, development does not start to come forward until the late 2020s. It is assumed therefore that electricity will have decarbonised sufficiently by this time to enable heat pump led systems to be the strategy of choice in order to deliver the carbon savings required for planning consent and that Developers would challenge any retained local plan or GLA policy on district heating on the basis of carbon emissions and running cost. End of life replacement for these legacy systems is assumed to be a like-for-like replacement of heat pump technology. However, as development progresses into the 2030s, it is assumed that further decarbonisation of the grid will allow Developers to adopt direct electric systems.

OPDC Encourages Improved Market Response

For North Acton, Scrubs Lane and Willesden Junction, intervention by OPDC to encourage improved market response will likely lead to the same strategic decisions being made by all parties as outlined above in the market led response. This is because of a lack of any alternative to the default scenarios described.

For Car Giant, the story is likely to be similar, albeit with potentially an earlier adoption of EfW heat sourcing. Although leaving it to the market is likely to mean that Car Giant will eventually need to source low carbon heat from somewhere in order to secure the low carbon performance required for planning consent (with EfW and heat pump resources being in plentiful supply in the Car Giant area), OPDC encouragement will likely bring forward the date at which these low carbon resources are exploited.

For Crossrail and HS2, any intervention by OPDC to encourage improved market responses is likely to lead to the same scenario as outlined above for the market led response. This is because the programme of delivery for these sites means that development in these areas is not expected to be subject to the same difficulties in achieving low carbon performance as those developments coming forward earlier in the OPDC trajectory. It is assumed that heat pump technology will be adopted for those plots coming forward in the 2020s, with legacy systems being replaced at end of life with like-for-like systems. For development coming forward in the 2030s, direct electric systems are expected to be proposed.

Public Sector Led Network Delivery

For the public sector led network delivery option, it is assumed that development coming forward up to and including 2020 will be served by gas boilers. This is because it is expected that cluster-wide networks will not be up and running before 2020 due to the time in procuring networks and heat sources such as an EfW facility. The rollout of the network will allow legacy and new development to then be connected, with a mixture of heat pumps and EfW heat being the main source of heat. Gas CHP is assumed to play a supporting role during this time in order to provide revenue streams. When development progresses through into the 2030s, it is assumed that the end of life CHP will be replaced by additional heat pump systems, which will benefit from the decarbonised grid at this time. The proportion of heat demand served by EfW will also decrease as development progresses, as the marginal increase in development will be served less by EfW compared to earlier phases. Legacy gas fired boiler backup is expected to be replaced by electric boiler systems on the network subject to running cost viability.

3.4.12.2 Capital Costs of Delivery

Figure 30 shows the impact of the different intervention options on capital costs. The costs shown are the average costs per dwelling for the different technology options implemented, and represent the total cost of providing energy system infrastructure to the development (i.e. irrespective of who funds it).

The cost of the public sector led option is marginally higher by a few percentage points in the initial years. However, in broad terms (and given the high degree of uncertainty associated with capital cost estimates at this stage) they indicate that a public sector led option would likely not significantly increase capital costs. It therefore follows that the environmental benefits that derive from a public sector led heat network can be delivered at broadly the same gross cost as other, less environmentally beneficial, solutions.

The public sector led option may well be able to offer significant reductions in net cost to Developers once ESCO equity contributions are factored in. The size of the district heating potential under the

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public sector led model makes it inherently more attractive to ESCOs, and thereby it is likely to attract a higher equity share.

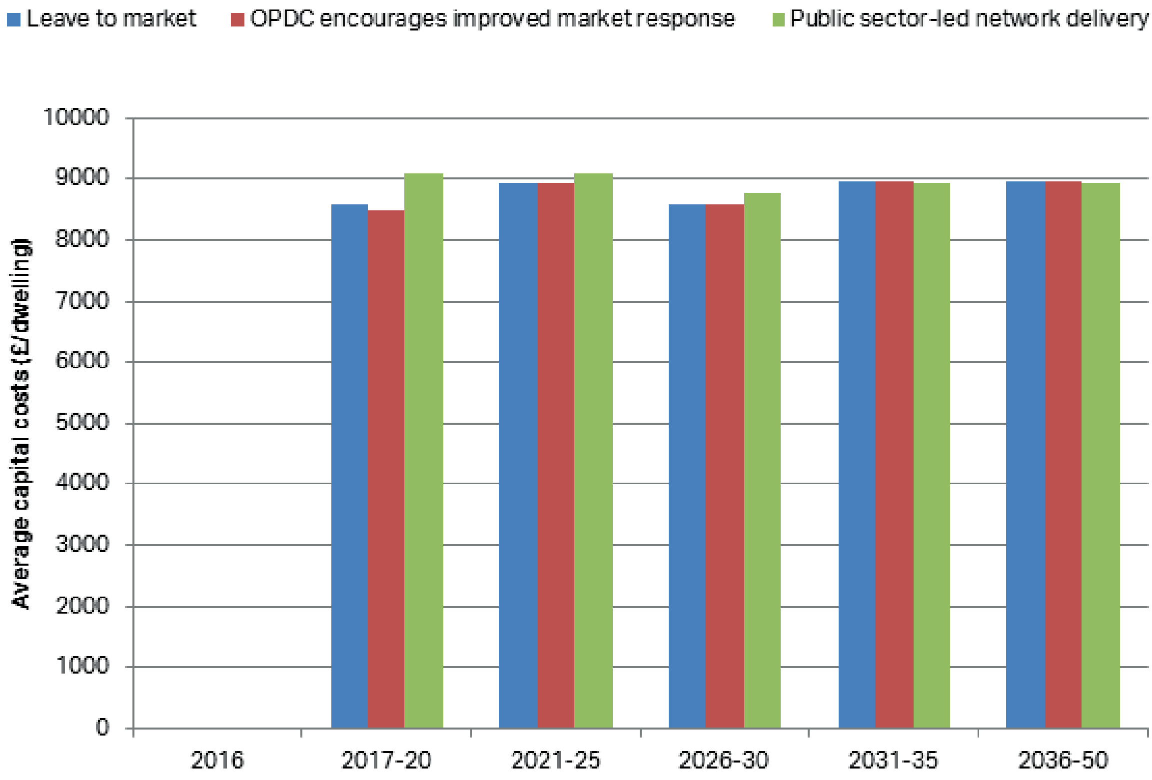

Figure 30. Indicative Capital Costs of Alternative Intervention Options

** Costs exclude professional fees and construction contingencies. Cost estimates have a high degree of uncertainty due to limited design information*

3.4.12.3 Costs to consumer

It is expected that, in line with experiences observed in comparable heat network operations around London and the UK, costs to consumers would be expected to be baselined against those for a gas boiler. Typically, heat network charges to consumers are set at a small discount (potential 5-10%) to gas boiler running costs.

If the heat network is public sector led, then there is the potential for the network operators to prioritise customer costs (subject to financing and other operational costs).

3.4.13 Conclusions and Recommendations

3.4.13.1 Preferred Decentralised Energy Strategy

The preferred decentralised energy strategy for initial phases of Old Oak is to seek to create area wide heat networks served by an energy centre in each of the main clusters of development (North Acton, Old Oak South, Old Oak North, Willesden Junction and Scrubs lane). These networks should ideally be supplied with heat from a combination of local low carbon sources including potentially heat pumps utilising low temperature heat sources such as the canal, sewers and the London aquifer (via open loop boreholes) and a heat offtake from an EfW facility. Gas-fired CHP could also provide heat to the network in the early years of development, providing both carbon emissions savings and generating significant revenue stream that will help to deliver economic viability. Gas boilers will likely also be needed as peaking plant to ensure demand can be met at all times. Note that heat offtake from an EfW plant will be reliant on securing suitable permits and a planning application, and will have some air quality impacts that will need to be considered further.

Depending on the final delivery model, OPDC should consider interlinking these networks. This will provide benefits in terms of extending the ability to utilise available heat sources in other areas of the development, whilst also potentially increasing the economic viability and resilience of the network. It is assumed that the networks will be designed to benefit from a range of heat generation technologies which can be operated to gain economic advantage from changing price signals for electricity generation and use. Preferred delivery models will depend on OPDC's eventual land holding within Old Oak and will be subject to further evaluation of the economic viability and risks associated with utilising the heat sources identified. A key requirement will be to ensure flexibility for heat sources to transition away from gas CHP and gas boilers to alternative low carbon heat sources, as the grid decarbonises.

Analyses of the carbon emissions associated with different forms of heat generation has shown that calculated CO_2 emissions for heat from gas CHP will over time become less desirable when compared to other technologies. While gas CHP could form part of the heat generation mix in the early years, its use in later phases would substantially increase calculated carbon emissions if Part L emission factors remain based on average emission factors. EfW heat could offer the lowest carbon heat source in the early phases with heat pumps offering the lowest carbon heat source from around the early 2020's. Heat pumps are likely to result in higher costs for heat generation compared to EfW, although this will not be confirmed until further details of the planned EfW plant and the commercial arrangements are available. The potential impact on air quality would also need to be considered. In the later phases of development electric boilers could potentially replace gas as peak or standby boiler plant, on the basis of lower carbon emissions, but this would be subject to these being economically viable to operate.

Heat networks are currently required under London Plan policy, and it is assumed this will remain the case in the early phases of development. It is assumed that this strategy would be pursued for development delivered during the Local Plan period up to around 2030. After 2030, it is expected that grid electricity emissions will have fallen to the point where block or dwelling based solutions such as ground source heat pumps, or direct electric heating may start to offer greater benefits than district heating networks in terms of carbon saving. For development clusters delivered after 2030, flexibility will need to be retained to review the strategy prior to delivery to determine whether heat networks continue to offer a sufficient range of benefits in terms of; CO_2 emissions, capital cost, energy cost to consumers and resilient energy supply and whether they remain a requirement of policy. This will depend on how the policy position and fiscal incentives develop in the intervening period.

Heat networks require substantial front loaded investment. Business modelling for heat networks is typically carried out for a 25 year period although concession agreements and contracts may range in length from 20 to 40 years. For those investing in a network they will need to be confident that customers will continue to purchase heat for the assumed operating period. On the basis that planning policy will continue to have a focus on reducing carbon emissions and continue to set targets in this regard, heat networks will need to continue offering carbon savings that can compete with alternative approaches that could be delivered at a dwelling or block level. If they do not, this will potentially become a barrier to reaching heat connection agreements with the Developers of new schemes. Before progressing any public sector led heat network initiatives, detailed business modelling will be required to determine whether the expected customer base and alternative low carbon heat sources that have been identified could offer sufficient revenue streams for viable network operation and maintenance. As identified in Appendix G heat sources such as heat pumps are likely to have reduced revenue generating potential compared to gas CHP leading either to higher costs for consumers or lower internal rates of return.

3.4.13.2 Energy Strategy Risk

In carrying out this study a number of risks have been identified that could impact the delivery of the preferred strategy set out above.

- If a strategic network proposals are not progressed in a timely manner, land owners will deliver sub-optimal gas CHP schemes compliant with current policy, but with limited safeguards for maintaining carbon savings in the future. This is a particular issue for development clusters with many small landowners (as evidenced by North Acton, but also applicable at Scrubs Lane). North Acton will represent one quarter of the heat demand when fully built out.

- The EfW facility is not a guaranteed heat source. The operators will need to obtain necessary permits and a planning approval for the proposed EfW facility. A key consideration for the approval process for an EfW facility will be the mitigation of potential air quality impacts. There is little immediate heat demand local to the proposed EfW plant in the first 10 years of development, implying that to fully utilise EfW, investment may be required upfront to build links to those areas of development with demand (e.g. North Acton).
- The potential air quality implications of EfW pose a risk in terms of a successful planning application. They also present a possible risk in terms of their impact on the ability to deliver future development adjacent to an EfW plant delivered early in the programme.
- The analysis has shown that as the electricity grid decarbonises, there will be a number of electrical heating solutions that will offer lower carbon emissions than any of the heat network options, and which could offer lower capital costs and lower running costs. This presents a risk to any heat network operators in terms of their ability to secure future heat connections from new developments, as well as a risk that the current policy support for heat networks will be diluted in future.
- A number of the low carbon heat sources identified could be expected to offer reduced revenue streams for network operators compared to heat production from the gas CHP engines typically employed in most heat networks delivered in London to date. Further market testing or economic modelling will need to be carried out to determine whether a network can generate an acceptable return for its investors while maintaining acceptable heat prices for consumers.

These risks will require further assessment during the masterplanning phase and as the EfW technology choice becomes known.

3.4.13.3 Next Steps

The following are considered as priorities in terms of next steps in taking the energy strategy forward:

- OPDC and GLA to confirm that the proposed strategy is in alignment with the Mayor’s emerging policy objectives including planned updates to London Plan policy.
- Assess the options for intervening at North Acton to determine whether intervention is still possible to deliver an area wide heat network now or to improve the chances of heat connections being agreed if a heat network can be delivered at a later date. Options might for example include agreeing to remove the need for costly investment in on site CHP capacity in return for stronger commitments to connect to a heat network later.
- Review the air quality implications and likely permitting implications of an EfW facility and seek stakeholder agreement around whether these are outweighed by the benefits EfW heat provision can offer in terms of sustainable waste disposal and low carbon energy supply.
- Develop preferred heat network delivery options alongside masterplan development including continued discussions with the EfW operators, Car Giant and HS2 on their proposed development plans and the ability to develop a heat network solution that utilises the low carbon heat sources identified including EfW.
- Engage with potential energy services companies regarding their interest in supporting the delivery of heat network opportunities in particular for those areas that will be delivered earlier in the programme.
- Consider further discussions with Thames Water and land owners regarding a potential feasibility study to further explore the potential commercial arrangements relating to heat recovery from sewers and the ability to utilise this technology at North Acton or one of the earlier phases of development.
- Develop the parameters for an OPDC led ring fenced carbon offsetting fund including potential project categories that could be supported, the criteria and process that would be applied in recruiting and vetting projects and the approach to managing and monitoring the scheme.

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3.4.14 Considerations for Masterplanning Team

A review of the opportunities, challenges and characteristics of the Old Oak site, and the recommendations described above, has identified a number of priorities for further consideration at the masterplanning phase.

For the initial phases of development, a heat network is recommended, to be served by low carbon heat sources predominantly sourced from EfW, but with significant contributions from other low carbon sources such as the Grand Union Canal, chalk aquifer open loop boreholes, and sewer heat recovery. A key priority for the masterplan will be to identify and safeguard locations for suitable energy centres, and to identify opportunities for routing the network across the physical barriers around the site.

3.4.14.1 Energy Centre Locations

A number of potential land plots have been identified for considering as energy centre locations. These include plots that are not planned for development, e.g. the triangular plot between North Acton and Wormwood Scrubs Park, and the plot immediately south of and opposite to the Powerday site on the south bank of the canal. Other potential locations include plots within development parcels and under landscaped amenity areas to the south of the canal. These land plots should be investigated further alongside plots within the development parcels themselves, with a view to safeguarding suitable plots for energy centres. The key considerations in assessing the merits of potential energy centre locations include:

- Scale of proposed energy centre and the targeted low carbon heat sources to be exploited;
- Proximity of the site to nearby low carbon energy resources;
- Access arrangements to the energy centre for construction, maintenance and operations;
- Viability of routing utilities (e.g. gas, electricity, water) and district heating pipework to and from the site; and
- Potential flue requirements for dispersion of flue gases and the required flue heights relative to neighbouring buildings, and relative to distances to railway lines.

Table 11 sets out indicative energy centre sizes based on plant being located on two floors and based on rules of thumb for energy centres with gas boilers, gas CHP and thermal stores.

	Capacity (MW)	Energy Centre floor area required (m^2)	Energy Centre footprint required (m^2)
Old Oak South	46	2,300	1,150
Old Oak North	23	1,150	575
North Acton	29	1,450	725
Willesden Junction	4	600	300
Scrubs Lane	9	900	450

Table 11. Indicative energy centre sizing

Selected plots for energy centre locations should be safeguarded in the masterplan. Additionally access to the heat sources targeted for exploitation should be safeguarded in the masterplan.

This will include siting an energy centre close to the canal and to Powerday. Siting energy centres relatively close to key access points to main sewer networks and considering the locations for abstraction and return boreholes which will be needed to be located at a significant distance from each other for open loop water abstraction. The separation distance between boreholes should be determined more accurately through ground modelling but could be in excess of 100m.

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3.4.14.2 Network Routing

District heating network routing around the site will be subject to a number of challenges specific to the OPDC area. These include the many railway lines that crisscross the site, including the Crossrail line currently under construction; the HS2 line that is planned to run east-west through the site; London Overground lines; London Underground lines; National Rail lines; and freight lines.

The Grand Union Canal also dissects the site, with currently no substantial link between the two sides in the central region of the development. Furthermore, many of the roads in the area are in a poor condition, with at least one bridge designated as a weak bridge.

Planned new and improved infrastructure crossings and road improvements are likely to provide opportunities for network routing. Key considerations for assessing network routing as part of the masterplanning work include:

- The effect of development phasing on viable network routes and build-out dates;
- The potential for coordinating the design and installation of enabling infrastructure (e.g. bridges and road improvements) with network design and installation;
- The potential for early connection of buildings to the network, in order to initiate and encourage the expansion of the network, thereby providing early revenue streams for the network; and
- Ensuring developments are design to be compatible with and easily connected to the network.

A high level assessment of potential network routes is set out in Appendix C, which will need to be developed further taking account of wider masterplan considerations.

3.4.15 Supportive Local Plan Policy

Local Plan policy should seek to support the preferred strategy outlined in section 3.4.13.1. The key policy areas that the Local Plan will need to cover and address include:

- Ensuring that any new EfW facilities are required to include heat offtakes in their business model and for this to be a condition of planning approvals.
- Promote the use of area wide low temperature heat networks that can work effectively with heat pumps and ensure that new buildings are designed for low temperature heat distribution
- Support the development of and connection to heat networks that are served by alternative local low carbon heat sources and which are not reliant predominantly on gas CHP engines.
- Prevent developments becoming a barrier to further network expansion or to exploiting local heat sources, for example by them removing the ability to access the canal as a heat resource.
- Promote the use of smart building controls and strong technical standards to help manage demands
- Safeguard the delivery of utilities infrastructure crossings, by requiring new bridge crossings, station concourses etc. to be designed to incorporate ducts for heat pipes and taking the opportunity to build in undertrack crossing for any new station infrastructure where network routes are known..

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3.5 Gas

3.5.1 Introduction

3.5.1.1 Stage 1 Overview of Previous Work

The Stage 1 Infrastructure Assessment that was previously prepared by AECOM indicated that it will be necessary to provide a flexible gas supply in order to accommodate potential changes in the Energy Strategy during the lifetime of the development. This initial study also indicated that the existing gas supply network is likely to require reinforcement to accommodate the demand of the full quantum of development.

The Stage 2 Infrastructure Assessment has been undertaken in order to provide greater certainty of the gas supply strategy through further consultation with National Grid (Gas) to identify methods of delivering a flexible gas supply network in a timely and cost effective manner. This study is intended to reduce the risk of constraints in the gas supply network delaying the delivery of new homes and jobs, or restricting the installation of decentralised energy options that require a gas supply.

3.5.1.2 Stage 2 Scope of Work

The overall objective is to provide technical advice to assess the capacity of existing gas supply systems against the future requirements for the Old Oak development area, taking cognisance of alternative development scenarios and phasing.

The following activities have been undertaken as part of this work:

1. Calculations have been prepared to establish the likely variation in gas demand that will occur as the development expands;
2. National Grid (Gas) has been requested to provide an accurate estimate of the supply capacity within the existing gas distribution network and to establish the extent of reinforcement works that are likely to be required; and
3. A high-level distribution network study has been undertaken to identify capacity and future need and to determine the best location for pressure reducing stations.

The conclusion of this study will define the likely size and location of the new gas supply infrastructure, in order to enable planning applications to be determined and permit the detailed masterplan and infrastructure delivery strategy to be developed.

3.5.1.3 Vision and Objectives for the Gas Supply Strategy

A series of strategic objectives have been identified based upon the broad requirements outlined in Section 1.6, to allow the preferred gas supply strategy to be established. Refer to Figure 31 below. These objectives are proposed to enable OPDC to deliver a sustainable development that will incorporate a reliable and resilient gas supply, capable of providing flexibility for alternative energy technologies.

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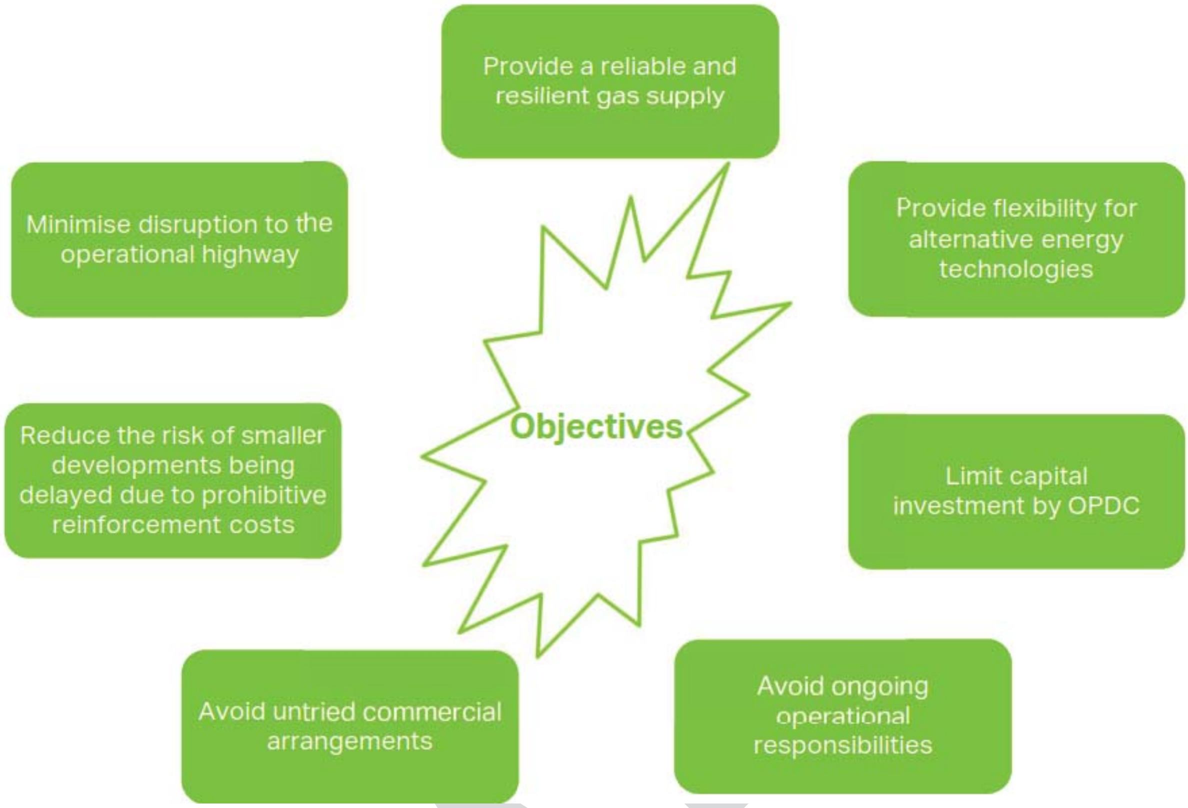

Figure 31. Objectives for the Gas Supply Strategy

3.5.2 Existing Utility Apparatus and Anticipated Demand

3.5.2.1 Gas Industry Framework

All gas in the UK passes through National Grid's national transmission system on its way to consumers. As the sole owner and operator of gas transmission infrastructure in the UK, National Grid (Gas) work with other companies to ensure that gas is available.

In the UK, gas leaves the transmission system and enters the distribution networks at high pressure. It is then transported through a number of reducing pressure tiers, until it is finally delivered to consumers at low pressure. There are eight regional distribution networks, four of which are owned by National Grid, including the distribution network in London that will serve the Old Oak site (Figure 32). National Grid will therefore be responsible for any reinforcement works that are required to ensure that the existing gas supply network has sufficient capacity to supply the proposed development.

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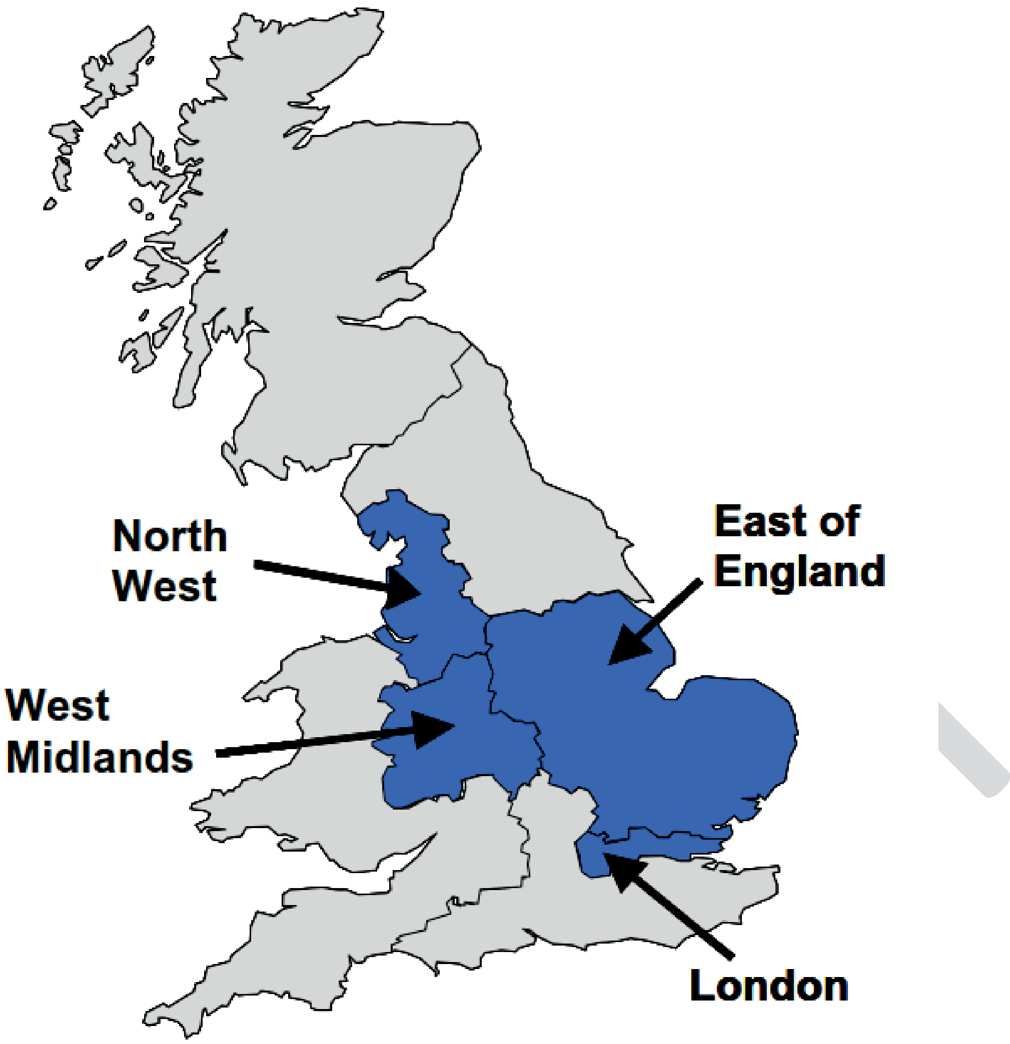

Figure 32. Geographical Layout of National Grid (Gas) Regional Distribution Networks

OFGEM are responsible for regulating the gas industry and they have introduced legislative changes to improve efficiency through the introduction of competition, particularly in network connections and extensions. As a result of these changes, Independent Gas Transports (IGT) may be employed to provide new connections, including final connections to strategic networks. This alternative procurement route can potentially provide opportunities for new assets to be adopted and for adoption payments to be provided from licenced distributors.

3.5.2.2 Existing Gas Supply Networks

National Grid (Gas) Asset Location Plans, which are duplicated in Figure 33, indicate that an existing gas holder is situated to the east of the site. These plans also indicate that medium pressure gas mains extend below the A40, Scrubs Lane and the High Street, which are situated to the southwest, north and southeast of the site respectively.

An existing Pressure Reducing Station (PRS) is situated to the north of the Scrubs Lane / Barlby Road junction, and low pressure mains are also currently located beneath Victoria Road, Old Oak Common Lane and Scrubs Lane.

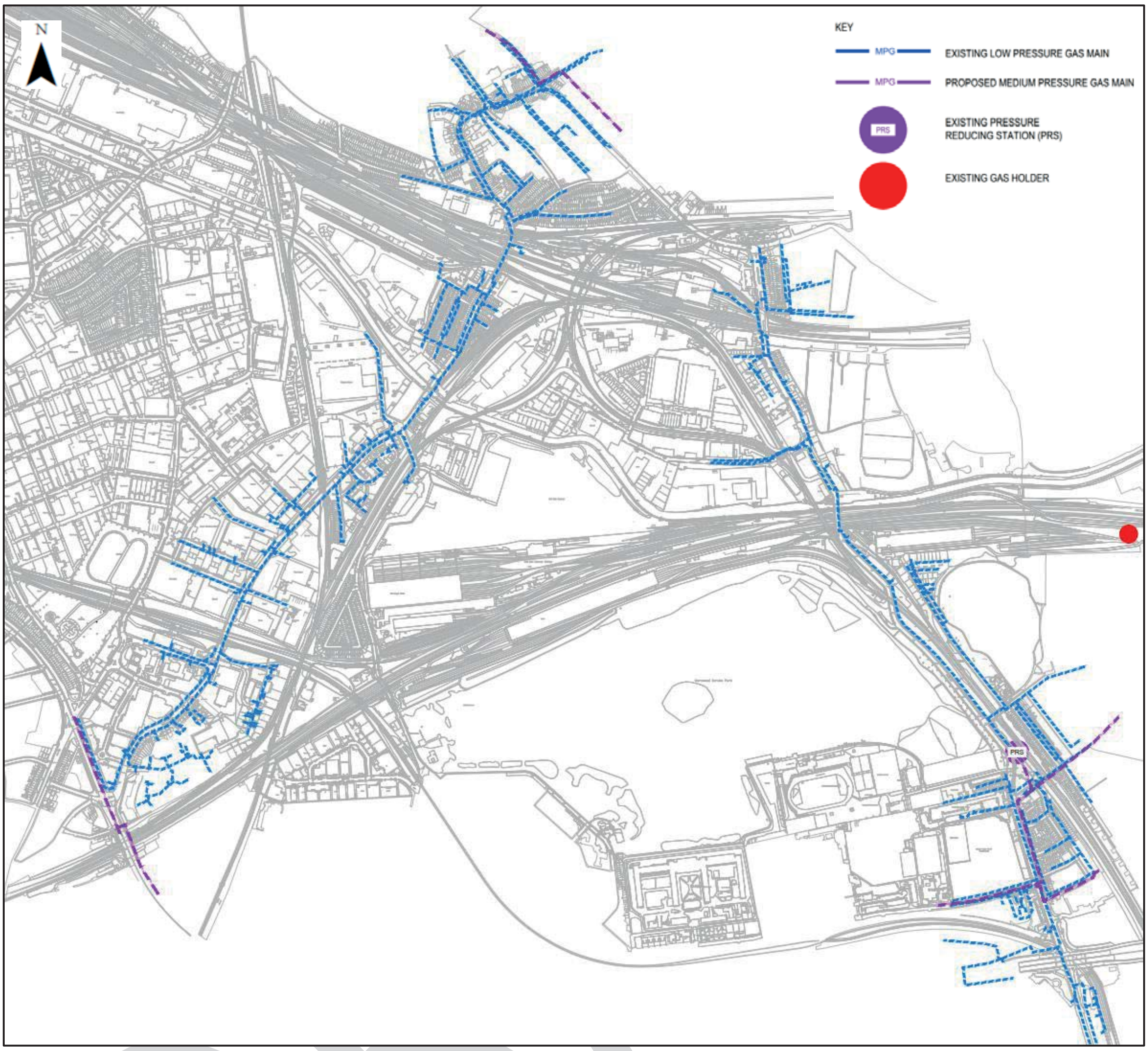

Figure 33. Plan Showing Location of Existing National Grid (Gas) Assets

3.5.2.3 Anticipated Demand

Preliminary calculations have been prepared to estimate the likely variation in demand for gas that will be required to supply the proposed development, and a demand profile is presented in Figure 34. These calculations have been prepared assuming; firstly, that gas will be required to supply CHP (Combined Heat and Power) engines that will generate heat for the entire site; and secondly, that a low pressure gas supply will be provided to commercial units only, as residential units will not be supplied with gas connections for cooking purposes. The demand profile represents a worst gas assessment to ensure that sufficient capacity is provided within the gas supply network as a backup for renewable technologies, as the Energy Strategy will seek to reduce reliance on gas fired CHP where possible.

The gas demand for the CHP plants has been calculated using the heat loads, which have been determined assuming that each dwelling will add 2.4 kW of heat load to the network and that office space heating will be 70 W/m^2, and applying an engine efficiency of 50%. The domestic heat load is based on AECOM experience and extrapolation of a Danish standard, whilst the commercial heat load has been calculated in accordance with BSRIA rules of thumb. This approach represents a robust assessment, as gas demands would be reduced in the event that CHP was not used to generate heat.

The preliminary calculations indicate that the proposed development has potential gas requirement of approximately 130,000 KW.

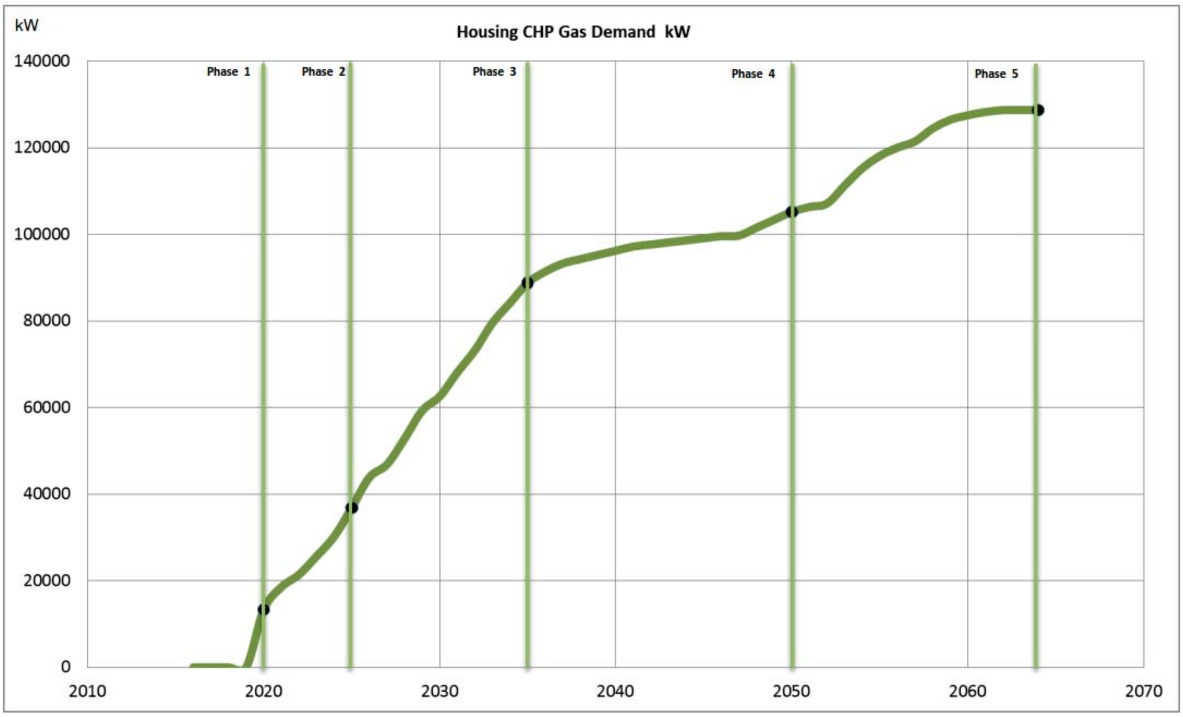

Figure 34. Gas Demand Profile

3.5.3 Constraints

The site is dissected by the Grand Union Canal (Paddington Branch) and by a series of major transport links, including the Great Western Main Line, West Coast Main Line, London Overground and London Underground Lines. Significant highways are also situated in the locality, as the A40 extends close to the southern boundary of the site, whilst Scrubs Lane and Old Oak Common Lane extend along the eastern and western boundary, respectively. These physical constraints divide the development area into a series of discrete sites that must be considered individually when the gas supply strategy is developed.

In addition, the land that is proposed to be redeveloped is owned by multiple public and private parties, as illustrated in Figure 35 below. Each development parcel will become available at a different time and it will therefore be challenging to extend strategic infrastructure across the site.

The location and capacity of key strategic infrastructure assets, such as medium pressure gas mains form key constraints. These assets may be costly and time consuming to relocate or upgrade and sustainable solutions are therefore likely to maximise opportunities for existing assets to be retained.

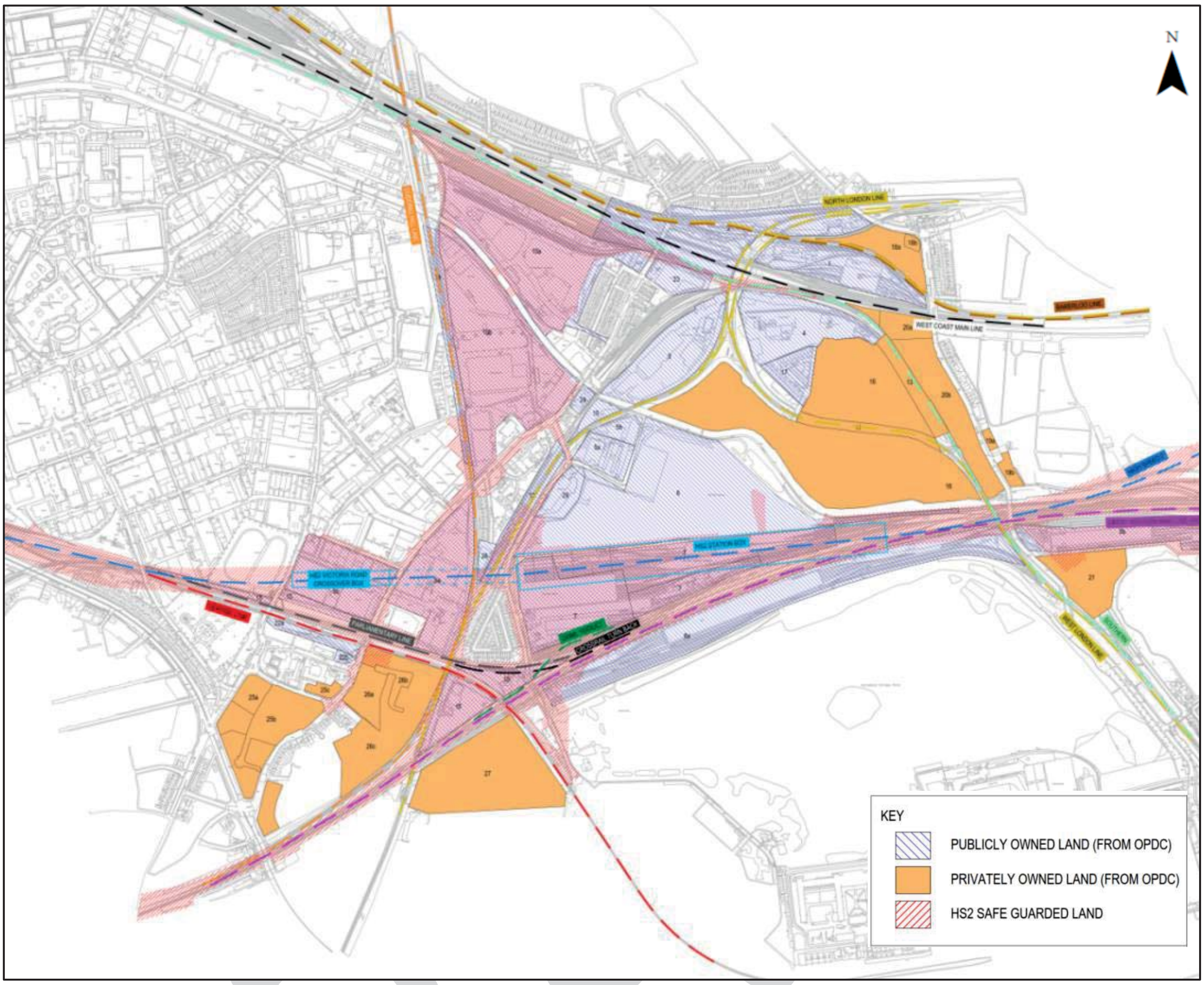

Figure 35. Land Ownership within the Old Oak Opportunity Area

3.5.4 Network Reinforcement and New Supplies

3.5.4.1 Network Reinforcement Requirements

National Grid (Gas) was requested to prepare a Network Impact Assessment; firstly, to obtain an accurate estimate of the supply capacity within the existing gas distribution network; and secondly, to establish the extent of reinforcement works that are likely to be required to supply the proposed development.

National Grid (Gas) has reviewed the demand profile for the proposed development and indicated that an impact assessment will not be required; firstly, as they have no capacity concerns relating to the high pressure gas network that supplies the area; and secondly, as there is unlikely to be a requirement to reinforce either the medium pressure or low pressure networks within the first five years of development.

However, National Grid (Gas) has indicated that it is likely to be necessary to progressively upgrade the existing low pressure mains that extend below Scrubs Lane, Victoria Road and Old Oak Common Lane to form medium pressure gas supplies that are capable of supplying development that will occur after the first five years.

An existing bridge over the railway line that is situated in the southeast corner of the site forms a potential constraint to upgrading the gas main in Scrubs Lane. However, National Grid (Gas) has stated that they anticipate including a new medium pressure gas main within a new HS2 railway bridge that is likely to be constructed in 2019 to overcome this constraint.

3.5.4.2 New Gas Supply Networks

National Grid (Gas) initially indicated that the primary connection point for a future medium pressure supply to the development area is likely to be the 36 inch medium pressure gas main that extends below Scrubs Lane. This connection location introduces a potential requirement for medium pressure mains to be extended across the whole site to serve development within the western part of the site; therefore alternative connections points have been discussed.

National Grid (Gas) has subsequently stated that there is likely to be sufficient spare capacity in the medium pressure gas main that extends below the A40 near North Acton to supply initial phases of development within North Acton, and that additional capacity may be provided by progressively upgrading the existing low pressure mains that extend below Victoria Road and Old Oak Common Lane to form medium pressure gas supplies within the western part of the development. This strategy is ultimately intended to allow the medium pressure mains below Scrubs Lane and the A40 to be connected in order to form a resilient network, as illustrated in Figure 36.

Pressure Reducing Stations will also be required within the site, which are likely to be situated in close proximity to gas fired CHP plants, in the event that they are provided. Low pressure gas networks will be extended from the Pressure Reducing Stations to commercial units only, as gas connections are unlikely to be required to dwellings.

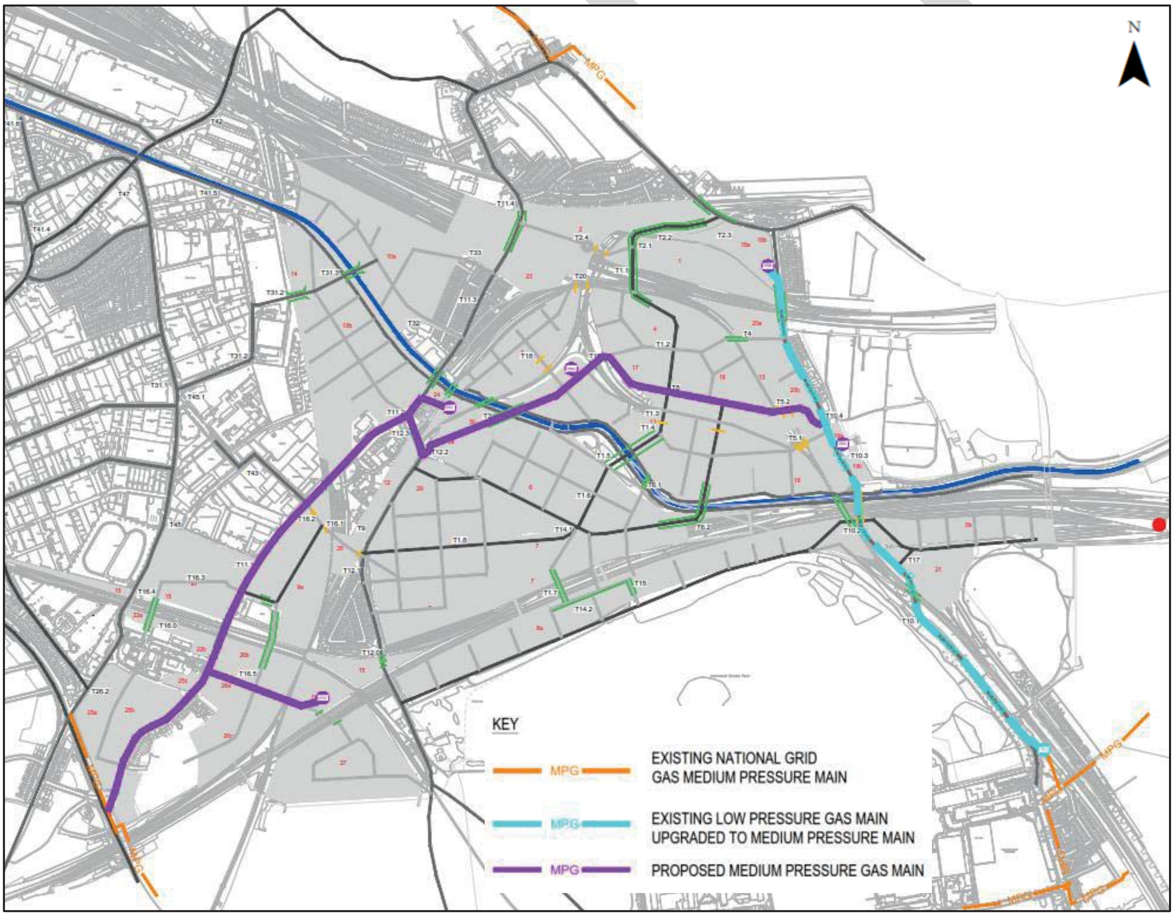

Figure 36. Potential Reinforcement of Medium Pressure Gas Networks

3.5.4.2 Charging Arrangements

National Grid (Gas) is obliged under the Gas Act to apply an economic test where network reinforcement works are required. This test will be undertaken in accordance with the National Grid

(Gas) Connection Charging Statement in order to determine the relative contributions from National Grid (Gas) and the Developer(s), or other third party funding.

3.5.5 Intervention Options for OPDC

OPDC will be required to intervene in order to deliver a sustainable development that will incorporate a reliable and resilient gas supply capable of providing flexibility for alternative energy technologies, in order to satisfy the objectives that are identified in Figure 31.

There are three levels of intervention available to OPDC, which illustrated in Figure 37, and are outlined below.

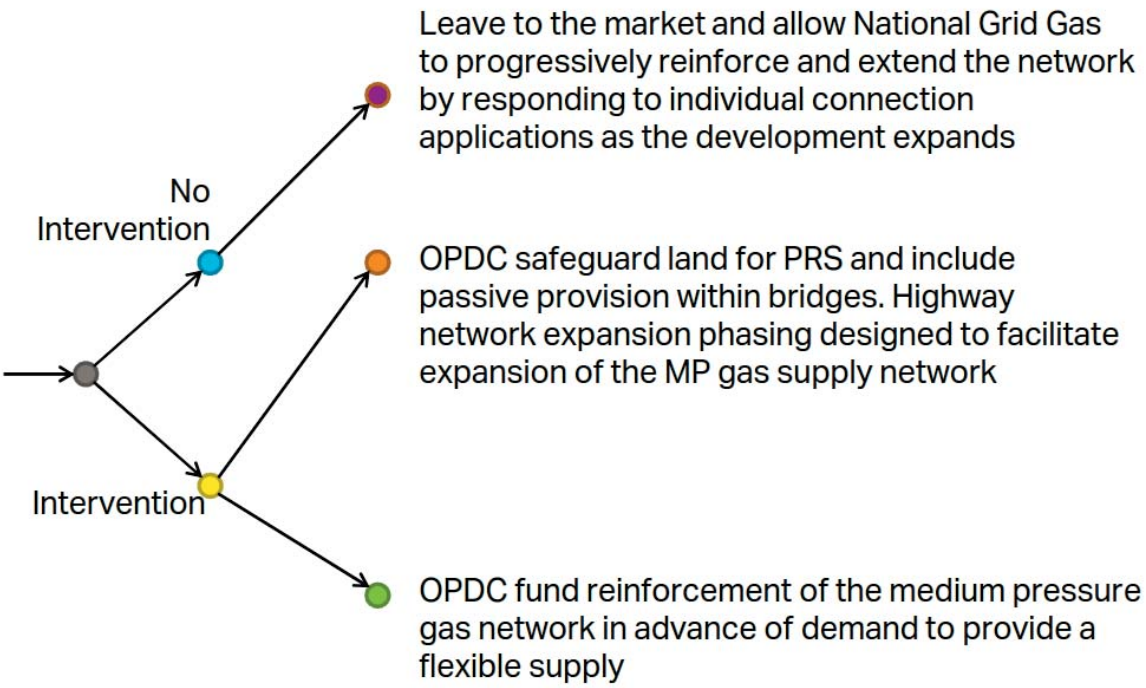

Figure 37. Varying Levels of Intervention to reinforce Gas Network

The following text describes the technical, delivery model and financial aspects of each alternative intervention option in order to enable the relative merits to be assessed.

3.5.5.1 Option G1: Allow National Grid (Gas) to Progressively Expand the Network

Technical Aspects

This option would involve National Grid (Gas) reinforcing and extending the network in response to individual Developer applications only.

Delivery Model Aspects

This option operates within the existing gas supply regulations. However, physical constraints, such as the size of ducts within existing bridges and third party land ownership, may prevent the MP gas network from being expanded in the desired manner, as the site is dissected by a number of transport corridors and land is controlled by multiple parties. This approach may also prevent smaller developments from being delivered until Developers of larger sites fund network reinforcement works.

Financial Aspects

In the event that this option is progressed, then there would be no capital cost and no ongoing financial obligation to OPDC. However, land values may not be maximised due to the lack of a resilient gas supply. In addition, this option could introduce a requirement for the medium pressure gas network to be expanded in an un-coordinated manner, which could generate additional cost and disruption to the existing highway network.

3.5.5.2 Option G2: OPDC safeguard land for medium pressure gas networks and Pressure Reducing Stations

Technical Aspects

This option enables public sector intervention to facilitate network expansion, as OPDC would be required to plan highway works to facilitate expansion of the medium pressure gas network in order to enable corridors to be created for a new medium pressure gas supply to be extended across physical constraints to Energy Centres. OPDC would also be required to safeguard land within the masterplan to accommodate Pressure Reducing Stations and to include passive provision for medium pressure gas mains within bridges.

National Grid (Gas) would be required to progressively upgrade the existing low pressure main that extends along Scrubs Lane to form a medium pressure supply. New medium and low pressure networks that supply gas to the development could be installed by National Grid (Gas) or an Independent Gas Transporter.

Delivery Model Aspects

In the event that this option is selected, then network reinforcements may be procured using existing regulations. However, there is still a risk of extended disruption to the highway if the gas supply network is progressively upgraded. There is also a risk that smaller developments may be delayed until Developers of larger sites fund network reinforcement works.

This approach is less flexible than Option G3, and there is therefore a residual risk that constraints in the gas supply network could delay the delivery of new homes, jobs and Energy Centres if the development trajectory changes.

Financial Aspects:

Financial contributions from OPDC would be minimised if this option was selected. However, the commercial implications of the alternative phasing of highway works will require review. Land values may be enhanced although Developers will still be required to fund reinforcement works.

3.5.5.3 Option G2: OPDC safeguard land for medium pressure gas networks and Pressure Reducing Stations

Technical Aspects

This option enables public sector intervention to maximise development delivery and viability, as it would involve OPDC obtaining funding or Developer contributions to enable the network to be reinforced ahead of need. In the event that this option was selected then OPDC would be required to request National Grid (Gas) to reinforce the existing low pressure network that extends along Scrubs Lane to form a medium pressure supply in a single operation. New medium and low pressure networks that supply gas to the development could be installed by National Grid (Gas) or an Independent Gas Transporter.

OPDC would also be required to plan highway works to facilitate expansion of the medium pressure gas network in order to enable corridors to be created for a new medium pressure gas supply to be extended across physical constraints to Energy Centres. In addition, OPDC would be required to safeguard land within the masterplan to accommodate Pressure Reducing Stations and to include passive provision for medium pressure gas mains within bridges.

Delivery Model Aspects

This option would enable a resilient gas supply to be provided to accommodate potential changes in development trajectory. It would also allow network reinforcement works to be delivered in a co-ordinated manner to minimise disruption to the highway and to reduce overall cost.

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However, OPDC would be required to obtain funding or Developer contributions to allow the network capacity to be increased in advance of demand. In addition, there is a risk that the full capacity of the reinforced network may not be required in the event that the energy strategy or development trajectory change in the future.

Financial Aspects

The provision of a flexible and resilient gas supply could enable land values to be maximised. However, OPDC would be required to provide additional financial contributions to allow the network capacity to be increased in advance of demand in order to provide a flexible supply.

There is also a risk that capital investment may not be fully funded by Developer contributions until a significant portion of the site is developed.

3.5.6 Evaluation of Alternative Options

A Multi Criteria Analysis has been undertaken in order to establish which of the proposed options satisfies the objectives illustrated in Figure 31 most effectively. The results of this analysis are presented in Table 12 below.

The Multi Criteria Analysis indicates that the preferred intervention option is likely to involve OPDC safeguarding land to enable Medium Pressure Gas Mains to be extended through the development to Pressure Reducing Stations, as this option would satisfy key objectives, such as providing flexibility for alternative energy technologies and reducing the risk of smaller developments being delayed, whilst minimising capital investment to OPDC and avoiding untried commercial arrangements.

This analysis also indicates that benefits would be obtained in the event that OPDC funded the expansion of a medium pressure gas network ahead of need. However, this option may not be preferable; firstly, as it introduces a requirement for significant capital investment by OPDC; secondly, as it introduces a requirement for untried commercial arrangements; and finally, as there is a risk that the full capacity of the infrastructure that is installed may not be fully utilised in the event that the Energy Strategy reduces reliance on gas fired Combined Heat and Power in the future.

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Objectives	NGG reinforce network	Safeguard land for PRS and gas mains	OPDC fund reinforcement work
Provide a reliable and resilient gas supply	★★★	★★★	★★★
Provide flexibility for alternative energy technologies	★★★	★★★	★★★
Limit capital investment by OPDC	★★★	★★	★
Avoid ongoing operational responsibilities	★★★	★★★	★★★
Avoid untried commercial arrangements	★★★	★★★	★★
Reduce the risk of smaller developments being delayed	★	★★	★★★
Minimise disruption to the operational highway	★	★★	★★★

Table 12. Evaluation of Alternative Intervention Options

3.5.7 Conclusion and Recommendations

National Grid (Gas) has advised that the existing gas infrastructure in the vicinity of Old Oak will need to be progressively reinforced to provide sufficient capacity. This study has outlined a range of cost effective and sustainable intervention options that are required to deliver a flexible and resilient gas supply in a timely manner.

These options have been evaluated and the preferred gas supply strategy involves OPDC intervening to facilitate network expansion by:-

- Planning new highway works to facilitate expansion of the medium pressure gas network in order to enable corridors to be created for a new medium pressure gas supply to be extended across physical constraints to Energy Centres;
- Safeguarding land within the masterplan to accommodate Pressure Reducing Stations;
- Including passive provision for medium pressure gas mains within bridges;
- Establishing regular dialogue with National Grid (Gas) in order to allow proposed reinforcement works to be co-ordinated with other plant relocation works that are proposed for HS2 in order to ensure the optimal solution for all parties.

3.5.8 Fixes and Priorities for Masterplanning Team

National Grid (Gas) will be required to reinforce the existing network by progressively upgrading the existing low pressure mains that extend below Scrubs Lane, Victoria Road and Old Oak Common Lane to form medium pressure gas supplies, before extending new medium pressure gas connections to Energy Centres.

The masterplan will form the key mechanism for including spatial provision to enable new medium pressure gas mains to be extended through the development in a cost effective and coherent manner in order to rationalise the existing infrastructure provision.

Conceptual design drawings have been developed to illustrate the location of the existing and proposed medium pressure gas mains in order to inform the masterplan, which are included in Appendix I. These drawings indicate that the masterplan should be futureproofed by including spatial or passive provision for the following features, which are required to enable the existing medium pressure gas network to be extended to Pressure Reducing Stations situated adjacent to Energy Centres:-

- Sufficient space should be provided within new highways to accommodate medium pressure gas mains that will extend from Scrubs Lane, Victoria Road and Old Oak Common Lane to the new Energy Centres;
- Ducts should be incorporated within new bridges and structures to allow the proposed medium pressure gas network to be extended through the development in order to overcome existing physical constraints, such as the Grand Union Canal and road and rail corridors;
- Land should be safeguarded close to Energy Centres to facilitate the installation of Pressure Reducing Stations.

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4. Potable Water

4.1 Overview

4.1.1 Stage 1 Overview of Previous Work

The Stage 1 Infrastructure Assessment and the Integrated Water Management Strategy (IWMS) that were previously prepared by AECOM confirmed that the existing potable water supply network is likely to require reinforcement to accommodate the demand of the full quantum of development. These initial studies also identified opportunities for using alternative sources of water to supply non-potable uses, as the Grand Union Canal extends through the site and there is therefore an opportunity for water to be abstracted and treated to form a non-potable water supply.

The Stage 2 Infrastructure Assessment has been undertaken in order to enable options for supplying potable and non-potable water to the development to be rationalised through consultation with Thames Water and the Canal and River Trust. This work is necessary to inform the preparation of the Local Plan, enable determination of planning applications and to inform the preparation of the detailed masterplan.

4.1.2 Stage 2 Scope of Work

The overall objective of the Stage 2 Infrastructure Assessment is to firstly, assess the potable water supply capacity; and secondly, to rationalise options for satisfying the objectives of the IWMS by confirming sustainable/cost effective methods of supplying potable and non-potable water to the Old Oak Development.

In order to establish the preferred water supply strategy, the following activities have been undertaken:

(i) Calculations have been produced to estimate the variation in potable and non-potable demand from the proposed development, as the development expands.

(ii) Thames Water undertook a Strategic Impact Assessment of the water supply network to establish whether the existing water resources and strategic supply network have sufficient capacity to accommodate the demand of the proposed development and they have established triggers for reinforcement works.

(iii) Alternative water supply options have been evaluated considering commercial and environmental factors in order to establish the preferred solution.

The conclusions of this study will define policy for the Local Plan, and it will verify the likely size and location of potable water supply and treatment infrastructure in order to enable planning applications to be determined and permit the detailed masterplan and infrastructure deliver strategy to be developed.

4.2 Vision and Objectives for the Water Supply Strategy

A series of strategic objectives have been identified to allow the preferred water supply strategy to be evaluated, which are illustrated in Figure 38 below.

These objectives are proposed to enable OPDC to deliver a sustainable development that will comply with the requirements of the Integrated Water Management Strategy, by providing a resilient water supply that reduces demand for a centralised water supply.

Figure 38. Objectives for the Water Supply Strategy

4.3 Existing Utility Apparatus and Anticipated Demand

4.3.1 Existing Potable Water Supply Networks

Thames Water is responsible for the provision and maintenance of the potable water supply distribution networks that extend through the Site. Thames Water Asset Location Plans, which are duplicated in Figure 39, indicate that the Site extends across two adjoining water supply zones to the east and west. The eastern area is served by 16 and 21 inch cast iron water mains that extend below Scrubs Lane from Barrow Hill, whilst the western area is served by two 30 inch water mains that extend below Old Oak Common Lane from Shoot Up Hill.

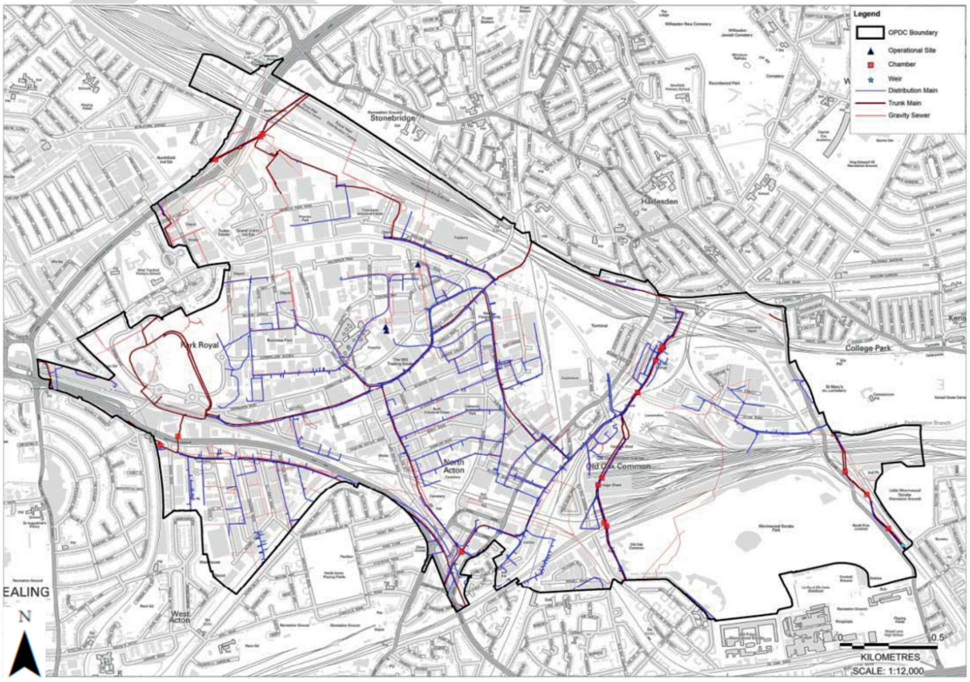

Figure 39. Thames Water Asset Location Plans

4.3.2 Anticipated Demand

Preliminary calculations have been prepared to estimate the likely variation in the volume of potable and non-potable water that will be required to supply the Proposed Development, and a demand profile is presented in Figure 40. These calculations have been prepared using the following information that is contained within the Thames Water Developer Studies Hydraulic Modelling Guidelines January 2016:

- Water demand for new residential dwellings = 250 litres per day per dwelling;
- Water demand for new offices premises = 750 litres per 100 m^2;

The calculations also assume that 35% of water used within residential dwellings is used for toilet flushing and that this figure increases to 43% for office buildings.

4.3.2.1 Old Oak water demand

The preliminary calculations indicate that the Proposed Development has potential to generate a requirement for approximately:

- 11,700 m^3/day of water, which comprises;
  - 7,200m^3/day potable water
  - 4,500m^3/day non-potable water

The initial calculations also demonstrate that approximately 60% of water demand is from residential tenures and 40% is from commercial tenures.

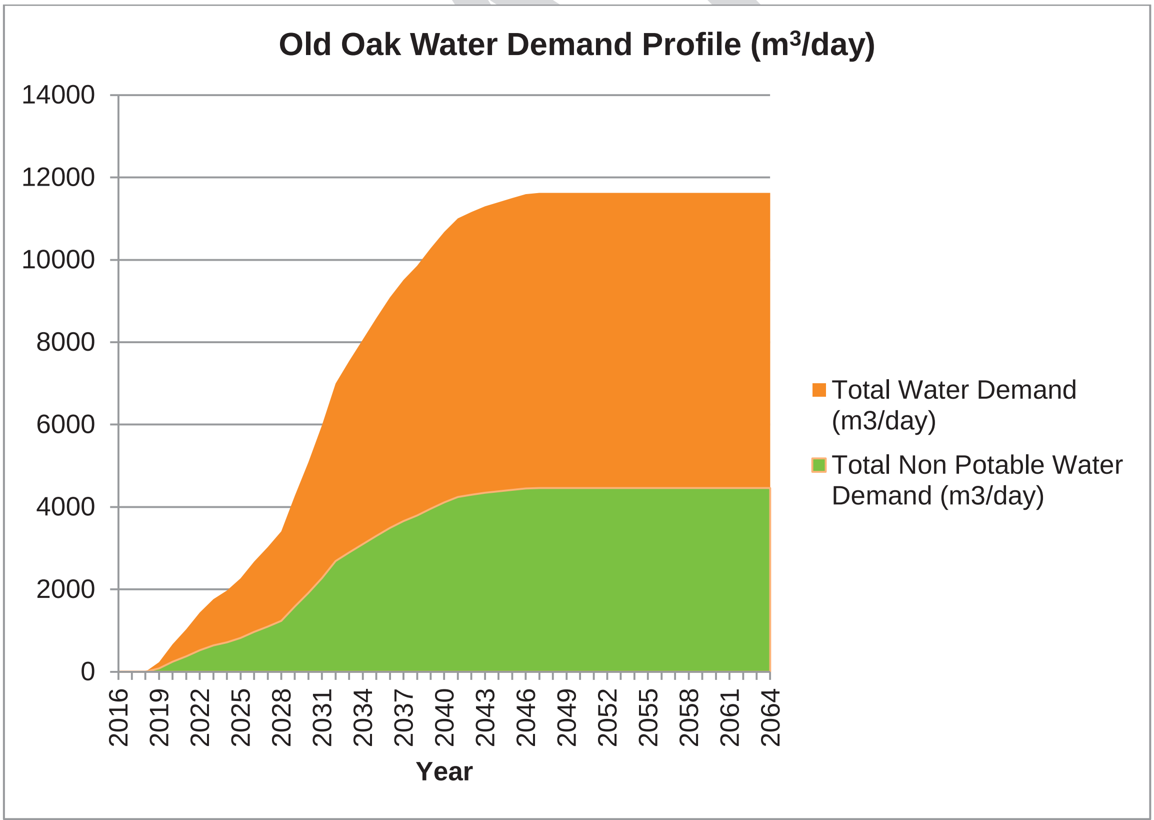

Figure 40. Potable and Non-Potable Water Demand Profile (excluding HS2)

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4.4 Regulations and Existing Planning Policy

4.4.1 Regulatory Environment

Thames Water currently implements strategic improvements to the water supply infrastructure on a five year basis, to comply with the Asset Management Plan schedule agreed with OFWAT. The current Asset Management Plan (AMP6), which extends from 2015 to 2020, does not include any allowance for improvement works to supply the Old Oak development. Improvements to the existing infrastructure that is required before 2020 will need to be funded by Developers, OPDC, or from the existing budgets.

Thames Water is seeking to identify growth that will occur after 2020, during AMP7, and consultations with Thames Water have been undertaken to allow them to plan for growth in the Old Oak area, so that they may apply to OFWAT for funding to enable strategic water mains to be installed. However, this approach could result in a phased upgrade of the infrastructure supplying Old Oak, which will increase disruption along the route of the water mains.

4.4.2 Water Supply Challenges

Consultations with Thames Water have indicated that there are short term challenges relating to network capacity, and long term challenges associated with water resource capacity that require resolution in order to generate a sustainable development at Old Oak. These challenges are outlined below.

4.4.2.1 Short term Challenge

Thames Water has indicated that the existing water supply network will not provide sufficient capacity to accommodate the anticipated demand from the proposed development, due to the significant increase in development density. In order to respond to the short term challenge, Thames Water has undertaken a Strategic Potable Water Impact Assessment, which is included with Appendix J.

The Impact Assessment concludes that it will be necessary to provide a new cross connection between 21” CI and 16” CI mains in Barrow Hill Zone in order to adjust the boundary between the Barrow Hill and Shoot Up Hill water supply zones, as illustrated in Figure 41 below. This work will enable a new supply to be provided to the site from the Shoot Up Hill water supply zone, via the 30” CI main in Old Oak Common Lane, with a proposed 400mm main extending through the site to the 16” main in Scrubs Lane.

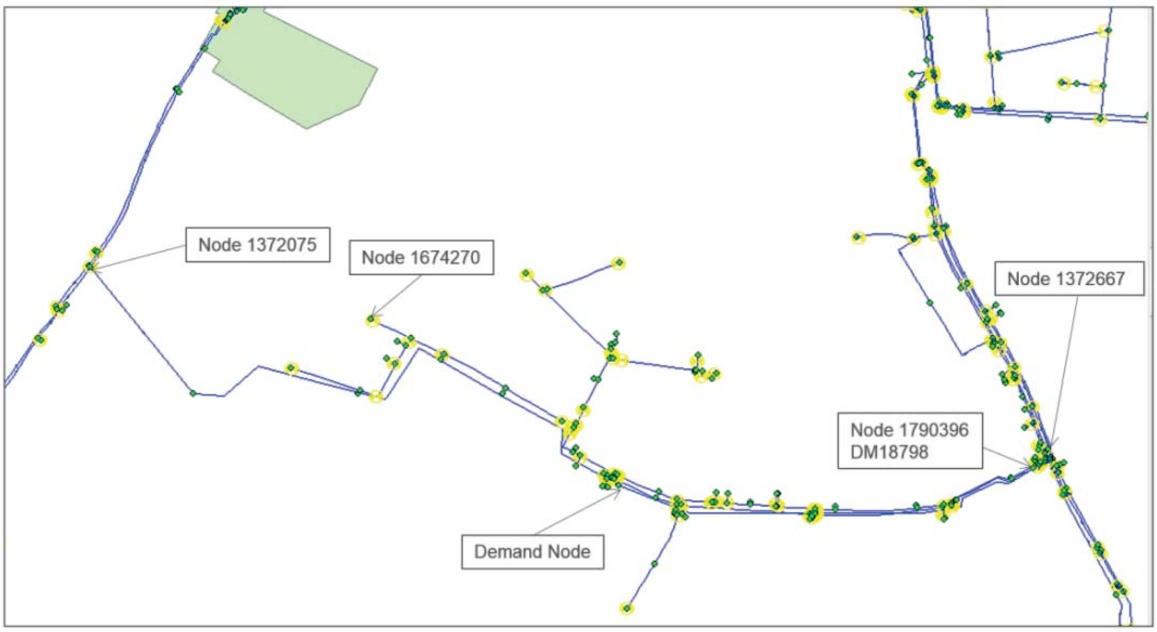

Figure 41. Extract from Thames Water Impact Assessment

4.4.2.2 Long term Challenge

Thames Water has indicated that the water demand within Greater London is forecast to exceed the available water supply, as the demand is predicted to grow due to increasing population, and the rainfall yield is predicted to reduce due to climate change, as illustrated in Figure 42 below.

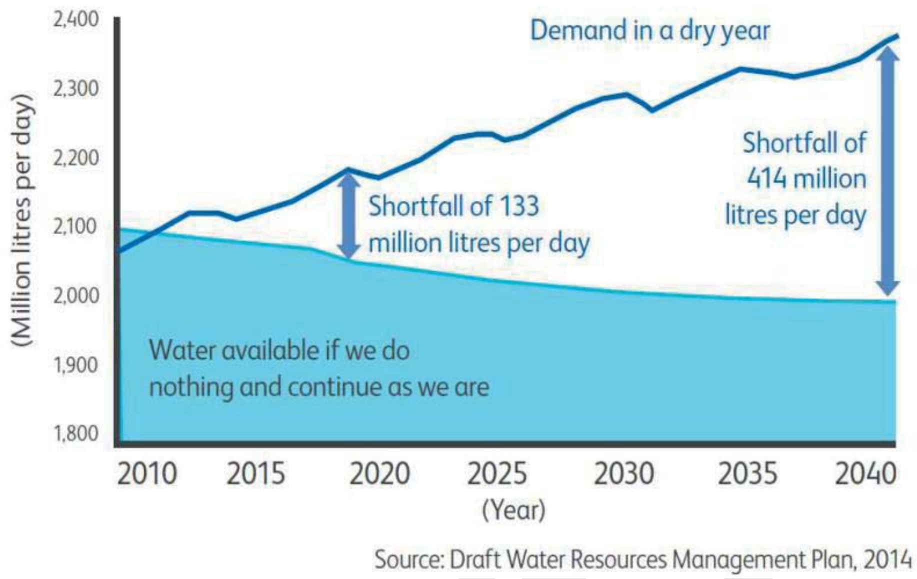

Figure 42. Thames Water Forecast Gap between Supply and Demand in London

Thames Water is implementing multiple measures to reduce the water supply deficit, which include leakage reduction, installation of additional meters and water recycling, as illustrated in Figure 43. The information presented within this figure also indicates that water reuse forms the most significant component of the deficit reduction, and that Thames Water is planning to implement this measure within the lifetime of the Old Oak development. In the event that the measures listed within Figure 43 do not adequately reduce the deficit, then Thames Water may be required to use the desalination plant at Beckton to supply potable water, as it is capable of providing 150 million litres per day. The use of desalination is a last resort, as it is an energy and carbon intensive process, and policy has been included within the London Plan to encourage the use of demand reduction and water recycling measures within new developments in order to reduce the likelihood of desalination being required.

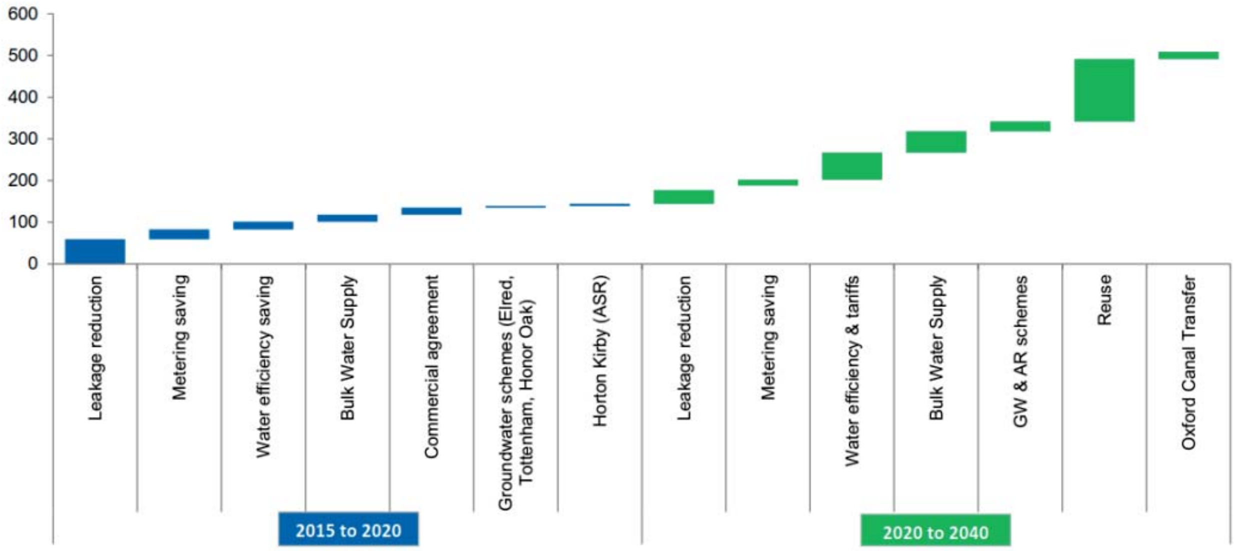

Figure 43. Thames Water Intervention Methods to Reduce Water Supply Deficit

For Old Oak, the long term challenge may be partly addressed by using the Local Plan policy to reinforce the London Plan by promoting the use of water recycling in order to comply with the requirements of the Integrated Water Management Strategy, and thereby reduce the likelihood of the Beckton Desalination Plant being required to supply water to London.

4.4.3 Political Context: London Plan

The London Plan Policy contains the following relevant requirements, which are provided to address the short term and long term water supply challenges:-

- *"Policy 5.15 Water use and supplies - The Mayor will work in partnership with appropriate agencies within London and adjoining regional and local planning authorities to protect and conserve water supplies and resources in order to secure London's needs in a sustainable manner by:*

  a minimising use of mains water
  b reaching cost-effective minimum leakage levels
  c in conjunction with demand side measures, promoting the provision of additional sustainable water resources in a timely and efficient manner, reducing the water supply deficit and achieving security of supply in London
  d minimising the amount of energy consumed in water supply
  e promoting the use of rainwater harvesting and using dual potable and grey water recycling systems, where they are energy and cost-effective
  f maintaining and upgrading water supply infrastructure
  g ensuring the water supplied will not give rise to likely significant adverse effects to the environment particularly designated sites of European importance for nature conservation.

  Development should minimise the use of mains water by:

  a incorporating water saving measures and equipment
  b designing residential development so that mains water consumption would meet a target of 105 litres or less per head per day

  New development for sustainable water supply infrastructure, which has been selected within water companies' Water Resource Management Plans, will be supported."

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4.4.4 Current Market Response to London Plan Water Supply Policy

A review of planning applications for emerging sites within the Old Oak Opportunity Area indicates that Developers typically are currently providing water efficient appliances, but that they are not proposing to use water recycling measures, potentially to minimise capital and operational cost.

In the absence of strong Local Plan policy, there is a risk that Developers will continue to submit premature planning applications, which will not include provision for water recycling measures. This approach would introduce a risk that opportunities for minimising potable water demand will be missed and increase the impact that the development will have upon water resources.

4.4.5 Integrated Water Management Strategy

The Integrated Water Management Strategy (IWMS) for the Old Oak Opportunity Area seeks to reinforce the requirements of the London Plan by establishing a framework that will define how water and wastewater should be managed in a sustainable manner within the Old Oak Opportunity Area. The IWMS identifies the following key criteria, which relate to water supply:-

- *"To reduce as far as possible the demand for centralised water supply by re-using water resources and wastewater resource on site;*
- *To deliver this objective in the most sustainable way, bearing in mind the need to ensure the overall viability of the site."*

4.5 Constraints

The site is dissected by the Grand Union Canal (Paddington Branch) and by a series of major transport links, including the Great Western Main Line, West Coast Main Line, London Overground and London Underground Lines. Significant highways are also situated in the locality, as the A40 extends close to the southern boundary of the site, whilst Scrubs Lane and Old Oak Common Lane extend along the eastern and western boundary, respectively. These physical constraints divide the site into a series of discrete sites that must be considered individually when the water supply strategy is developed.

In addition, the land that is proposed to be redeveloped is owned by multiple public and private parties, as illustrated in Figure 44 below. Each development parcel will become available at a different time and it will therefore be challenging to extend strategic infrastructure across the site.

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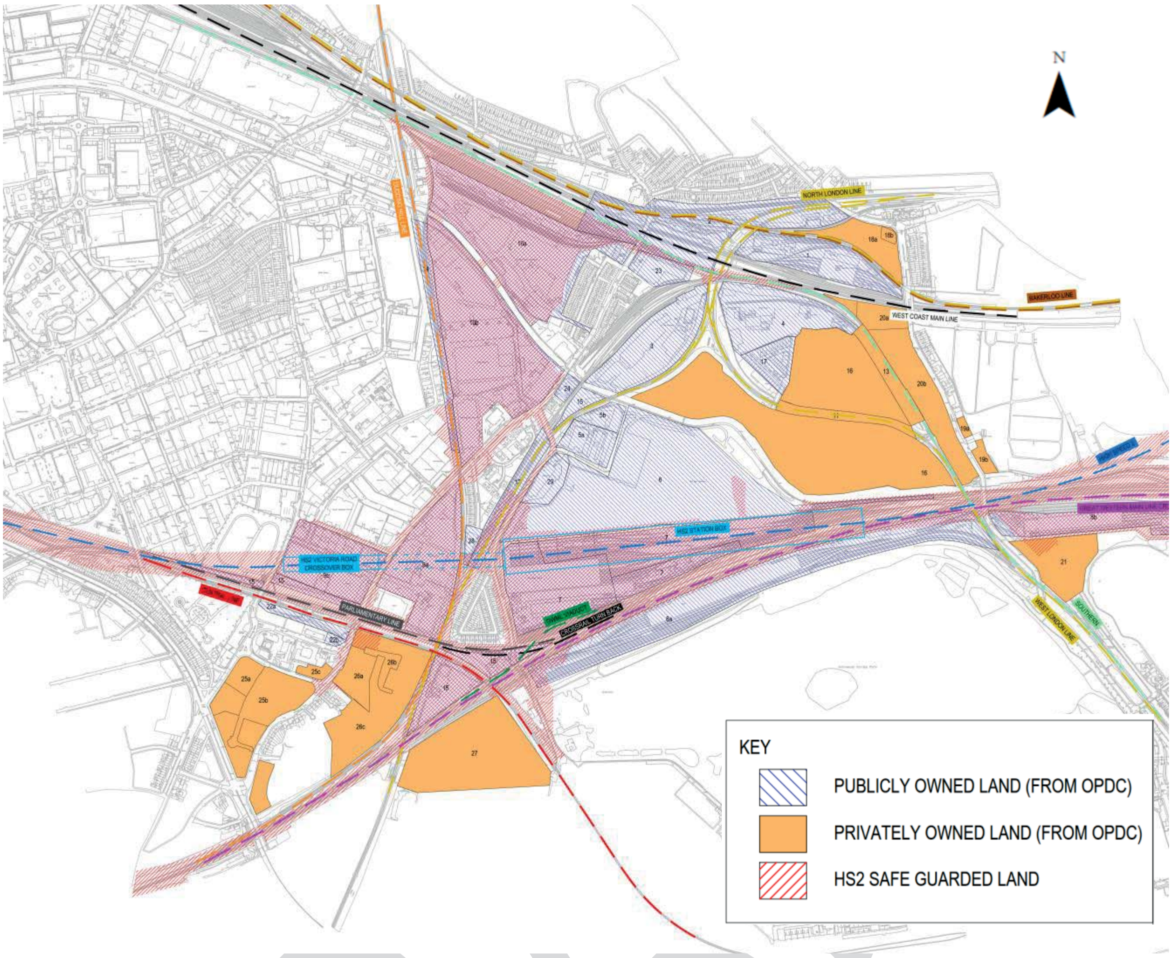

Figure 44. Land Ownership within the Old Oak Opportunity Area

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The location and capacity of key strategic infrastructure assets, such as potable water trunk mains form key constraints. These assets may be costly and time consuming to relocate or upgrade and sustainable solutions are therefore likely to maximise opportunities for existing assets to be retained.

4.6 Opportunities

4.6.1 Grand Union Canal

The Paddington Arm of the Grand Union Canal extends through the Old Oak site and a considerable volume of water is stored within a 43km long pound (Figure 45). A unique opportunity for recycling water within the Old Oak site has been identified, which involves abstracting water from the Grand Union Canal and treating it to allow it to be reused as a non-potable water supply.

In order to verify the feasibility of this option, the Canal and River Trust (CRT) would need to undertake an abstraction assessment to quantify the volume of water that may be abstracted from the Grand Union Canal. Unfortunately, this assessment was not possible at the point of this Phase 2 study. However, CRT has indicated that under the current arrangements, a consumptive abstraction of up to 4.5 Ml/d, which is required to accommodate the non-potable demand of the whole development, is not feasible. CRT has indicated that there are potentially options available to increase the supply of water into the Hydrological Unit, although this requires more detailed investigation, and this option has currently been discounted.

Figure 45. Grand Union Canal

Alternative water recycling options have therefore been identified, which include rainwater harvesting and greywater recycling and the suitability of these options has been evaluated within the following sections of the report.

4.6.2 Rainwater Harvesting

4.6.2.1 Introduction and Principle

Rainwater run-off from the roof areas can be collected and stored for non-potable uses within the building. Examples of non-potable uses would be irrigation, toilet and urinal flushing. Potable water must be provided for any use where the water is likely to be ingested.

The rainwater, after treatment, would need to be stored and distributed separately from the potable supply in clearly identified tanks and pipework systems.

The potential volume of water available depends on the catchment area, from the roof areas which discharge rainwater run-off to the storm water drainage system. The permeability of the surfaces and the precipitation for the location would be taken into account.

Rainwater falling onto roofs should be collected and transferred down the buildings and run via an independent drainage system to rainwater harvesting tanks.

Rainwater falling onto hardstanding areas shall be allowed to flow directly to the underground drainage system as it is more likely to be contaminated and would need further treatment before it can be used.

4.6.2.2 Annual Pattern of effective Rain Collection

Rainfall is not consistent over the year. Examination of monthly averages presented in Figure 46 indicates that the average for February, March, April and July is significantly lower than for the remainder of the year.

The monthly average may also not fall consistently during these 4 months, with all of the monthly precipitation falling during 1 week. This also applies to a lesser extent to the other 8 months, although is not as critical since the average rainfall for these months is much higher. This could mean that for 16 weeks of the year water may need to be supplied from potable sources.

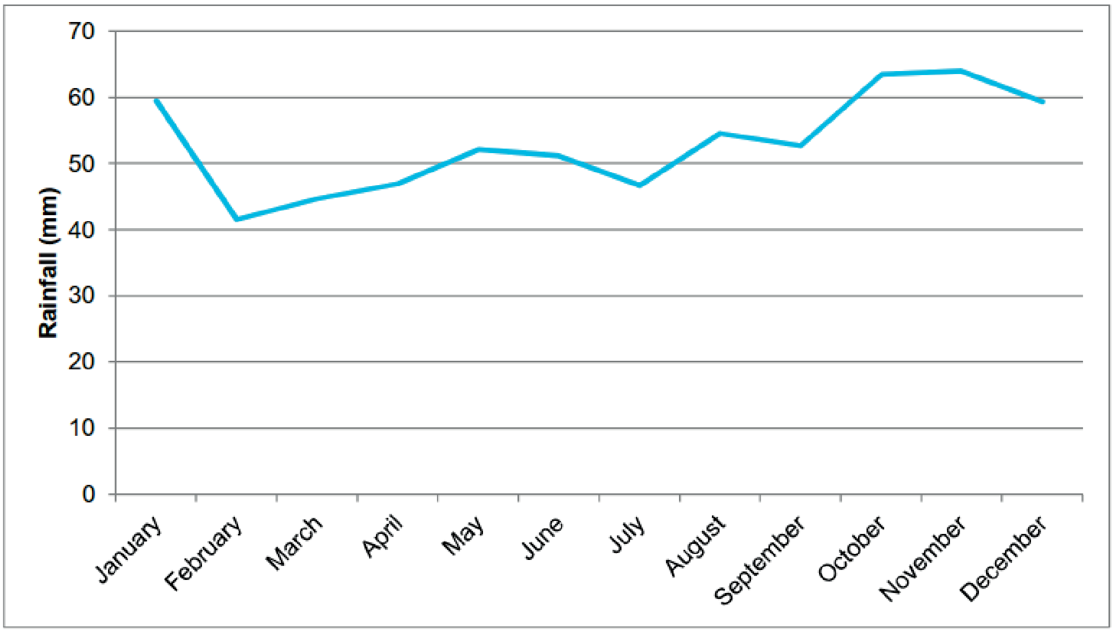

Figure 46. London Average Monthly Rainfall, as Recorded between 1960 and 2015

4.6.2.3 Conveyance to Storage and Use

The roof rainwater outlets and rainwater pipework will convey water under gravity to the below ground drainage system which runs via a drainage network with inspection chambers to below ground clean rainwater collection tanks. There will be several tanks around the site as shown on the previous plan conveniently located to reduce the length and therefore depth of drain runs and associated cost. Storm water drains would be fitted with in-line self-cleaning filter units prior to the tank connection, which would divide the flow into clean water that would flow into the tank. The water with entrained debris would be permitted to discharge to the storm water main sewer, SuDS or watercourse. A tank overflow and backflow prevention valve would discharge to the same point.

The clean rainwater retained in the storage tanks would be pumped to relevant appliances within the building, which would supply water via a separate reclaimed water pipework system to serve toilets and urinals. The pumps would be a submersible type, fitted with a flexible suction line complete with a float to maintain the suction head just below the waterline and a high output suction filter. During periods when there is no precipitation for more than 5 days, water would automatically be provided to the non-potable storage tanks within the building from Thames Water potable water supply.

Proprietary rainwater harvesting systems are manufactured by Aquality. Figure 47 contains an extract from the Aquality brochure to illustrate the typical layout of a rainwater harvesting system that may be used for a large commercial application.

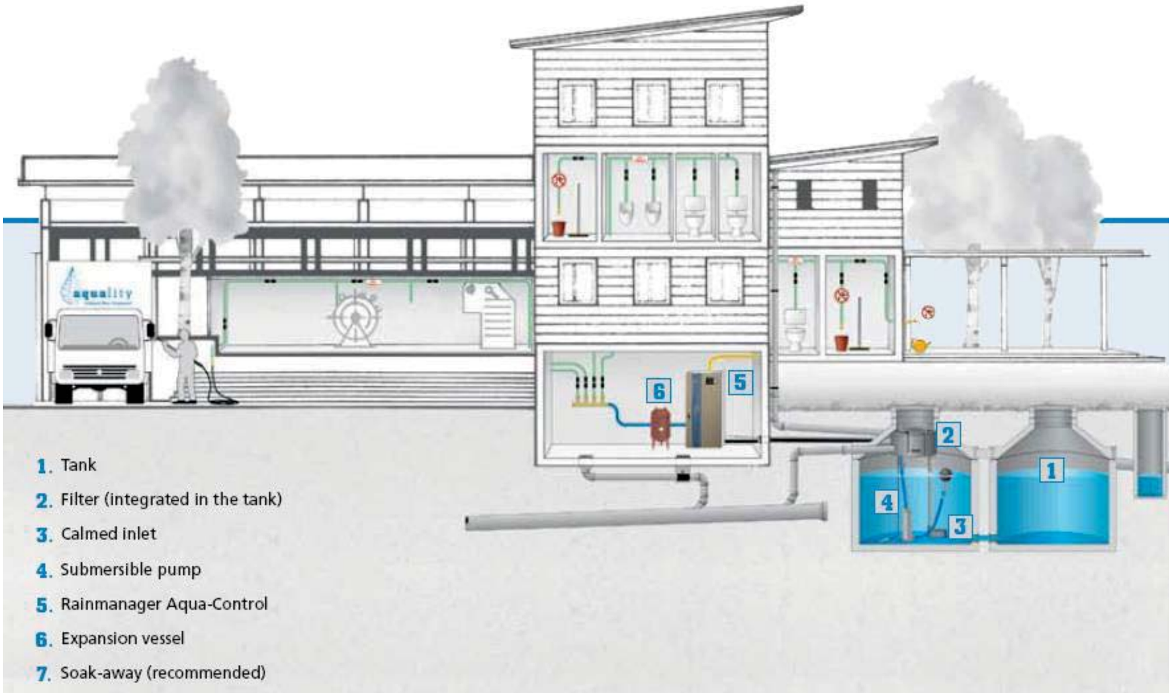

Figure 47. Typical Rainwater Harvesting System for a Large Commercial Application

(Source: Aquality)

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4.6.2.4 Suitability within the Old Oak Opportunity Area

The demand for non-potable water within the Old Oak will significantly exceed the rainwater yield due to development density. The use of rainwater harvesting systems in isolation from other water recycling systems is therefore unlikely to effectively reduce potable water use. However, rainwater harvesting systems may be used in combination with other systems, such as greywater recycling, in order to maximise yield the yield of non-potable water and minimises installation and maintenance costs.

4.6.3 Greywater Recycling

4.6.3.1 Introduction and principle

Greywater is defined by the Chartered Institution of Building Services Engineers (CIBSE) as water that was originally supplied as potable water, but has already been used for some other application such as bathing or hand basins. Greywater recycling systems enable this water to be collected, stored and treated to permit it to be reused for non-potable supply requirements, such as irrigation and toilet flushing, rather than being discharged directly to the receiving sewer.

4.6.3.2 Suitability within the Old Oak Opportunity Area

Greywater recycling systems are not considered to be desirable for residential tenures, as they require frequent maintenance by experienced operatives and there is a risk that the water supply could become contaminated in the event that potable and non-potable networks are cross connected.

However, Greywater recycling systems could be effectively deployed within commercial tenures of the development, as building occupants would generally employ specialists to maintain equipment installed within the building. Greywater recycling systems have potential to reduce potable demand by up to 43% in commercial properties, as illustrated in Figure 48.

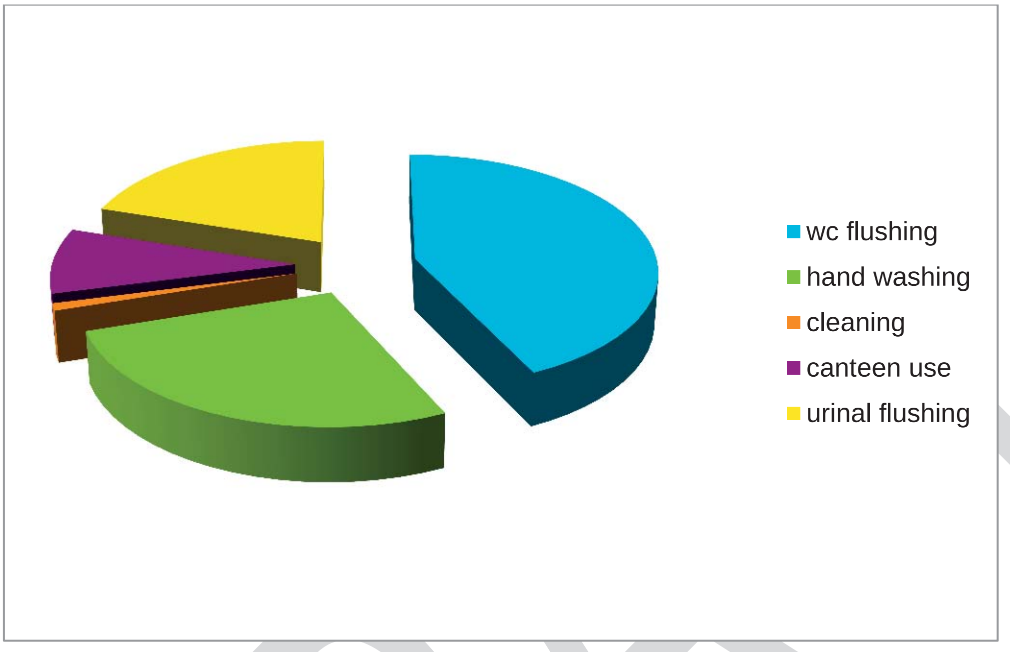

Figure 48. Water Demand in a Typical Office

(Source: Shouler, M., Griggs, J and Water Construction British Research Establishment Information Paper, November 1988)

4.6.3.3 Collection

Greywater may be collected from wash hand basins and showers and discharged by gravity through separate 'Greywater' stacks to below ground drainage. A network of drainage pipework and inspection chambers would convey the Greywater to a below ground Greywater collection tank. There may be several tanks located conveniently around the development to reduce the length and depth of drainage runs and associated cost. Greywater deteriorates quickly if left untreated for more than 24 hours and therefore the tank size and system would be designed to limit storage of Greywater. The tank would be provided with an overflow to the foul drain fitted with a valve to prevent backflow of foul water into the system. 'Black' water, comprising wastewater containing faecal matter and urine, would discharge separately to foul drainage.

Water used to wash cooking utensils will contain some fats, grease and oils which, if allowed to accumulate will cause fouling, offensive odours and potential blockages, leading ultimately to malfunction of the reclaimed water system. Generally, this type of water source (from kitchens) is to be avoided as a source of Greywater.

Similarly waste from laboratories, laundries, spas and swimming pools may contain chemicals that require special consideration prior to discharge to the foul drainage system as well as organic particulate matter and possibly pathogenic micro-organisms and should not be considered for recovery as part of a Greywater system.

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4.6.3.4 Conveyance to Storage and Use

Greywater would then be pumped from the collection tank(s) through filtration and treatment plant to non-potable storage tanks within the building, which would supply water via a separate, clearly identified, reclaimed water pipework system to serve WC's and urinals. The potential volume of water available will depend on the pattern of use of sanitary appliances but is generally considered to be a more predictable source than rainwater.

The extent to which Greywater will be recycled to individual buildings will be established by undertaking detailed viability studies at the detailed design stage, at which targets will be set according to the occupancy level and building type/use.

Greywater recovery systems would need to include a backup water supply connection from Thames Water to ensure that the system can cope during periods of reduced greywater discharge, high-use or maintenance.

Figure 49 shows the typical layout of a greywater recycling system that may be used for large commercial applications.

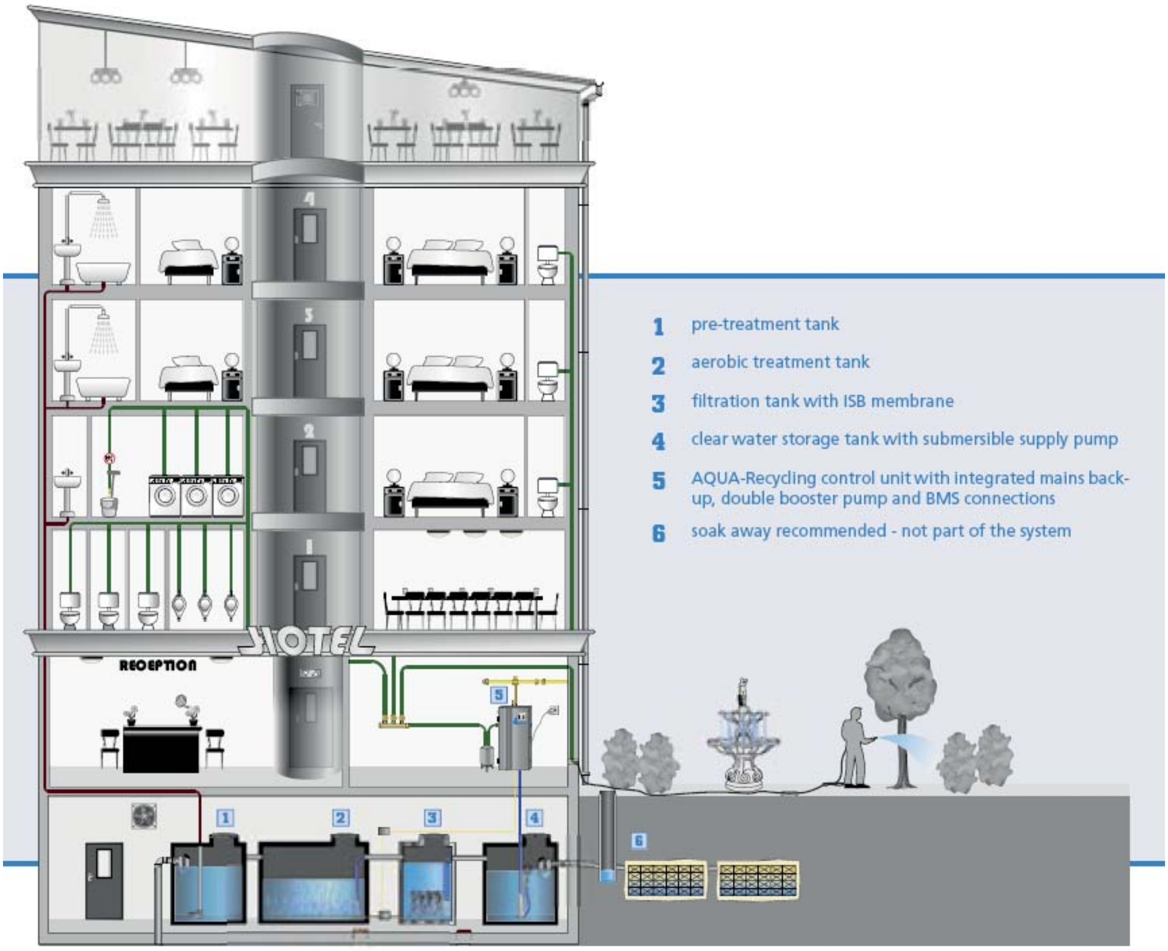

Figure 49. Typical Greywater Recycling System for a Commercial Application

(Source: Aquality)

4.7 Intervention Options for OPDC

OPDC will be required to intervene in order to deliver a sustainable development that will comply with the requirements of the Integrated Water Management Strategy, by providing a resilient water supply that reduces demand for a centralised water supply in order to satisfy the objectives defined in Figure 38.

Interventions may be considered in the short term in order to overcome constraints in the capacity of the existing potable water infrastructure, whilst long term interventions may be considered in order to reduce the impact that the development will have upon water resources.

4.7.1 Short Term Interventions

In the short term, two levels of intervention are available to OPDC to overcome constraints in the capacity of the existing water supply network, which are illustrated in Figure 50 below:-

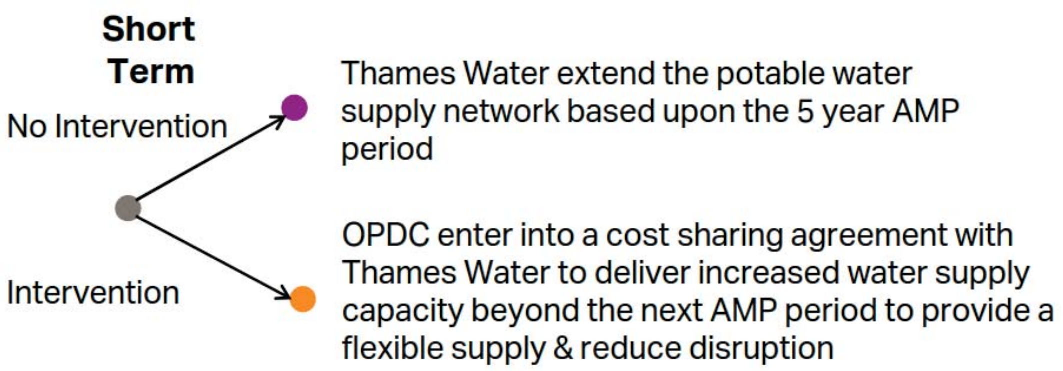

Figure 50. Varying Levels of Intervention to reinforce Water Supply Network

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The following text describes the benefits and risks associated with each option in order to enable the relative merits to be assessed.

4.7.1.1 Option ST1 – Thames Water Proactively Extend the Potable Water Supply Network

Thames Water gradually extends the existing potable water supply network by applying to OFWAT to obtain funding during each five year AMP period. Demand reduction fittings and individual meters provided within dwellings and commercial buildings to minimise water demand.

This option addresses short term challenge with minimal cost to OPDC and it represents the current market norm for Developers that comply with the requirements of the London Plan. In addition, OPDC intervention would be minimised.

However, there is a risk that this option may not enable network improvements to be implemented in a coordinated manner and disruption could be caused to the highway network. In addition, there is also a risk that this solution may not provide a flexible, resilient water supply that would accommodate potential future changes in the development trajectory, as the network capacity would be gradually expanded each five years and sufficient capacity may not be available to supply additional volumes of potable water generated be accelerated development expansion.

4.7.1.2 Option ST2 – OPDC enter into a Cost Sharing Agreement with Thames Water to Deliver Increased Water Supply Capacity Ahead of Need

OPDC would be required to obtain funding or Developer contributions to enter into a cost sharing agreement with Thames Water to allow network improvements to be delivered ahead of the five year AMP period. This option would enable public sector intervention to maximise development delivery and viability.

This option would enable network improvements to be delivered in a co-ordinated manner to minimise disruption to the highway and to reduce overall cost. In addition, resilience would be provided within the network to accommodate potential changes in development trajectory and land values would be maximised through the early provision of a resilient water supply. However, there is a risk that capital investment may not be fully funded by Developer contributions until a significant portion of site is developed.

4.7.2 Long Term Interventions

In the long term, two levels of intervention are available to OPDC to reduce the impact that the development will have upon water resources, which are illustrated in Figure 51 below:-

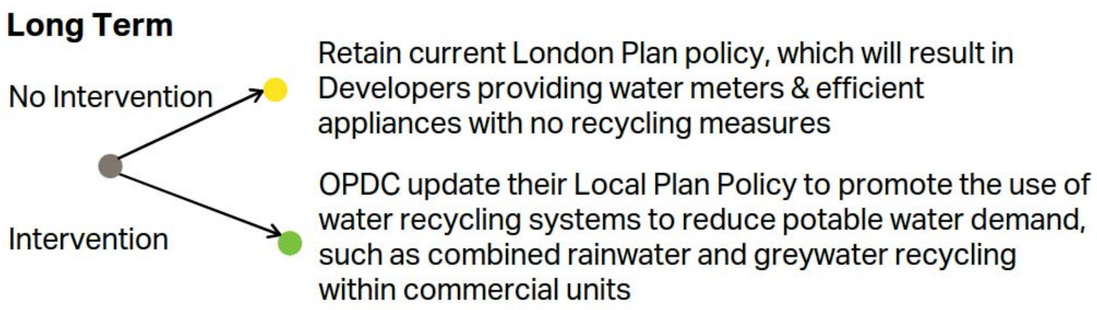

Figure 51. Varying Levels of Intervention to reduce Potable Water Demand

The following text describes the benefits and risks associated with each option in order to enable the relative merits to be assessed.

4.7.2.1 Option LT1 – Retain Current London Plan Policy

In the event that London Plan policy in retained and it is not strengthened using Local Plan Policy, then Developers are likely to provide water meters & efficient appliances with no recycling measures.

Water efficient appliances would enable the demand for all water to be reduced, through use of demand reduction fittings, such as spray taps, low-flow showers, low and dual-flush toilets and passive infra-red detectors to inhibit automatic flushing urinals. These fittings could reduce water usage in the following manner, based on the BISRIA "Typical Dwellings" figures:-

- Showers with the use of a flow regulation could save approximately 32 litres/head/day and still maintain the required level of comfort;
- Dual flush toilets could save approximately 28 litres/head/day;
- Spray taps could save 2 litres/head/day.

Central water meters could also be installed on all individual dwellings and commercial properties as part of planning requirements together with check meters within commercial properties so that the occupants can determine the extent of their water use. Evidence suggests this would encourage them to consider how they use the water and will lead to a reduction in water use as occupants become conscious of their water use.

This option would provide benefits, as land values would not be reduced through the introduction of a requirement for water recycling, energy would be minimised and there would be no risk of contamination of water supply due to cross connection of potable and non-potable water mains.

However, there is a risk that the development will fail to address long term water supply challenge, as opportunities for reducing potable water demand will not be maximised. This option also generates a significant reputational risk to OPDC and the GLA through lack of compliance with the IWMS.

4.7.2.2 Option LT2 – OPDC Update their Local Plan Policy to Promote the use of Water Recycling Systems

This option would introduce a requirement for OPDC to update their Local Plan policy to place an obligation on Developers to provide demand reduction and water recycling measures to reduce potable water demand. Policy requirements could also potentially include an obligation for Developers of commercial tenures to be required to provide combined rainwater and greywater recycling systems

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and water efficient appliances, and for Developers of residential tenures to be required to provide water efficient appliances and individual water meters.

In addition, this option would enable the potable water demand to be reduced with minimal investment from OPDC, as plot scale systems would enable water to be locally reused without a strategic non-potable water network. This approach would comply with the requirements of the IWMS in order to address the long term supply deficit and contribute to an exemplar development.

However, there is a risk that the commercial land value could be reduced due to additional construction and maintenance cost of greywater & rainwater harvesting systems, and it would cause the energy demand could be increased due to the requirement for pumping. There is also a risk of contamination of the water supply due to cross connection of potable and non-potable water mains, although risk may be mitigated by only applying water recycling measures to commercial tenures.

In the event that this option is selected, then the full extent of reinforcement works to the potable supply are still likely to be required to may still be required to provide backup in the event that the water recycling measures are being maintained.

4.8 Evaluation of Alternative Intervention Options

A Multi Criteria Analysis has been undertaken in order to establish which of the alternative short term and long term intervention options satisfies the objectives illustrated in Figure 38 most effectively.

4.8.1 Evaluation of Short Term Intervention Options

The Multi Criteria Analysis that is presented in Table 13 below indicates that the preferred short term intervention option is likely to involve OPDC entering into a cost sharing agreement with Thames Water to deliver increased capacity ahead of need, providing that Developer funding is obtained, as this approach would enable the timely delivery of the development, generate increase land values, and it would minimise disruption to the transport network.

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Objectives	Thames Water reinforce network	OPDC enter into cost sharing agreement
Reduce demand for a centralised water supply	★	★
Reliable resilient water supply	★★★	★★★
Avoid ongoing operational responsibilities	★★★	★★★
Limit capital investment by OPDC	★★★	★
Affordable to the developer	★★	★★★
Affordable to the consumer	★★	★★
Enable timely development delivery	★★	★★★
Policy compliant	★	★
Avoid barriers to development	★★	★★★
Deliver objectives in a sustainable manner	★★	★★

Table 13. Evaluation of Alternative Short Term Intervention Options

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4.8.2 Evaluation of Long Term Intervention Options

The Multi Criteria Analysis that is presented in Table 14 below indicates that the preferred long term intervention option is likely to involve OPDC updating their policy; firstly, to promote the use of water efficient appliances and visible metering systems within residential tenures; and secondly, to promote the use of combined rainwater and greywater recycling systems within commercial dwellings.

This intervention option has been selected, as it reduces the demand for a centralised water supply, whilst avoiding additional capital expenditure and ongoing maintenance responsibilities for OPDC. The selection of on plot water recycling features is also intended to avoid barriers to development, and to enable the development to be expanded in a timely manner, as the water recycling features may be integrated within each development parcel as it is released.

Objectives	Retain London Plan Policy	Promote use of water recycling systems
Reduce demand for a centralised water supply	★	★★★
Reliable resilient water supply	★★★	★★★
Avoid ongoing operational responsibilities	★★★	★
Limit capital investment by OPDC	★★★	★★★
Affordable to the developer	★★	★
Affordable to the consumer	★★	★★★
Enable timely development delivery	★★	★★
Policy compliant	★	★★★
Avoid barriers to development	★★	★★
Deliver objectives in a sustainable manner	★	★★★

Table 14. Evaluation of Alternative Long Term Intervention Options

4.9 Conclusion and Recommendations

This study has outlined a range of cost effective and sustainable intervention options that are required to overcome short term constraints in the capacity of the existing potable water supply network, and to minimise the long term impact that the proposed development will have upon water resources.

The preferred water supply strategy involves OPDC obtaining funding or Developer contributions to allow them to enter into a cost sharing agreement with Thames Water to deliver a resilient and flexible potable water supply network ahead of need.

The preferred strategy also involves OPDC providing policy within the Local Plan; firstly, to place an obligation of Developers of commercial tenures to provide combined rainwater and greywater recycling systems to minimise potable demand; and secondly, to place an obligation on Developers of both residential and commercial tenures to provide water efficient appliances and individual meters.

This strategy is intended to minimise the demand for a centralised water supply, by encouraging changes in behaviour within residential dwellings, and by using recycled water for non-potable purposes within commercial units where behaviours are more difficult to influence. This long term intervention measure will reduce the impact that the development will have upon water resources in order to comply with the requirements of the IWMS.

4.9.1 Supportive Local Plan Policy

Local Plan Policy will need to be developed and adopted in order to support the initiatives and objectives established by this study. Draft policy requirements are outlined below:-

"Policy EU3: Water

Development proposals will be supported where they:

a) *collaborate with OPDC and its development partners to deliver an integrated strategy for supplying potable and non-potable water;*

b) *appropriately contribute to and/or deliver the required water infrastructure identified within OPDC's Infrastructure Delivery Plan (IDP);*

c) *maximise the efficient use of potable water by:*
   i. *delivering on-site water re-use technologies, including rainwater harvesting and/or greywater recycling, where these are shown to be viable.*
   ii. *designing residential development to exceed the Mayor's per capita water use target of 105 litres a day where viable;*
   iii. *designing all non-residential development to reduce the baseline water consumption by 25%;*
   iv. *incorporating appropriate technologies and systems that will help occupiers to monitor, manage and reduce water usage, such as smart metering and sub-metering where appropriate,*
   v. *implementing appropriate resident training and monitoring; and*
   vi. *On major development, submitting a strategy setting out how the targets in the policy will be secured and achieved and providing evidence that water efficient fixtures and fittings have been used on smaller developments."*

4.9.2 Fixes and Priorities for Masterplanning Team

The masterplan will form the key mechanism for including spatial provision to enable new potable water mains to be extended through the development in a cost effective and coherent manner and thereby rationalise the existing infrastructure provision.

Conceptual design drawings have been developed to illustrate the location of the strategic potable and non-potable water infrastructure in order to inform the masterplan, which are included in Appendix K. These drawings indicate that the masterplan should be futureproofed by including spatial or passive provision for the following features, which are required to enable the existing potable water network to be reinforced and extended:-

- Sufficient space should be provided within new highways to accommodate the new 400mm trunk main that will extend between the 30 inch cast iron main in Old Oak Common Lane and the 16 inch main in Scrubs Lane;
- Ducts should be incorporated within new bridges to allow the proposed potable water network to be extended through the development in order to overcome existing physical constraints, such as the Grand Union Canal and road and rail corridors;
- Commercial units should be designed to provide sufficient space to incorporate combined rainwater and greywater recycling systems.

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5. Foul & Surface Water Drainage

5.1 Introduction

5.1.1 Stage 1 Overview of Previous Work

The Stage 1 Infrastructure Assessment and the Integrated Water Management Strategy (IWMS) that were previously prepared by AECOM indicate that there is no additional capacity within the existing combined sewers to accommodate the additional foul flows that will be generated by the development. In order to create capacity within the combined sewer to accommodate the additional foul flow generated by the increased development density, it is likely to be necessary to provide Sustainable Drainage Systems (SuDS) within the development, to enable the peak surface water discharge rate from rainfall events with a return period of up to 1 in 100 years to be reduced. These systems will occupy space within development parcels or areas of public open space and preliminary calculations were previously prepared to estimate the volume of storage that will be required within the site to allow adequate space provision to be included within the masterplan.

Consultations undertaken with the Canal and River Trust during the production of the Stage 1 Infrastructure Assessment also highlighted an opportunity for uncontaminated surface water runoff from development parcels that are elevated above the canal to be redirected away from the combined sewer to the canal, in order to reduce the volume of water that is treated at Beckton Sewage Treatment Works.

The Stage 2 Infrastructure Assessment has been prepared to enable options for managing surface water and disposing foul water to be rationalised through further consultation with Thames Water and the Canal and River Trust.

5.1.2 Stage 2 Scope of Work

The overall objective of the Stage 2 Infrastructure Assessment is to provide technical advice; firstly, to assess the foul and surface water sewer capacity; and secondly, to rationalise options for satisfying the objectives of the Integrated Water Management Strategy by confirming sustainable and cost effective methods of managing surface water and disposing foul water generated by the Old Oak Development.

The following activities have been undertaken as part of this work:

- Design information has been prepared to inform drainage capacity assessments, including conceptual foul and surface water drainage drawings that define the location and peak discharge rates of new foul and surface water connections to the combined sewer, and illustrate the extent of sub catchments that are proposed to discharge surface water to the Grand Union Canal.
- Thames Water has been consulted to verify the size of SuDS that will be required to reduce the peak surface water discharge to the combined sewers sufficiently to create capacity for the additional foul flows.
- The Canal and River Trust has been commissioned to prepare a Discharge Assessment that will verify the feasibility of discharging water to the canal.
- Alternative foul disposal and surface water management options have been evaluated considering commercial and environmental factors in order to establish the preferred solution.

The conclusion of this study will define policy that may be included in the Local Plan, and it will verify the likely size and location of strategic foul sewers and strategic SuDS required within each development parcel in order to enable planning applications to be determined. This information will also permit the detailed masterplan and infrastructure delivery strategy to be developed.

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5.1.3 Vision and Objectives for the Foul and Surface Water Drainage Strategy

A series of strategic objectives have been developed based upon the broad requirements described in Section 1.6 to allow the preferred foul and surface water strategy to be evaluated.

These objectives are illustrated in Figure 52 below and are proposed to enable OPDC to deliver a sustainable development that will comply with the recommendations of the Integrated Water Management Strategy, by minimising the volume of surface water that will be discharged to the combined sewer and ensuring that the combined foul and surface water discharge will not be increased.

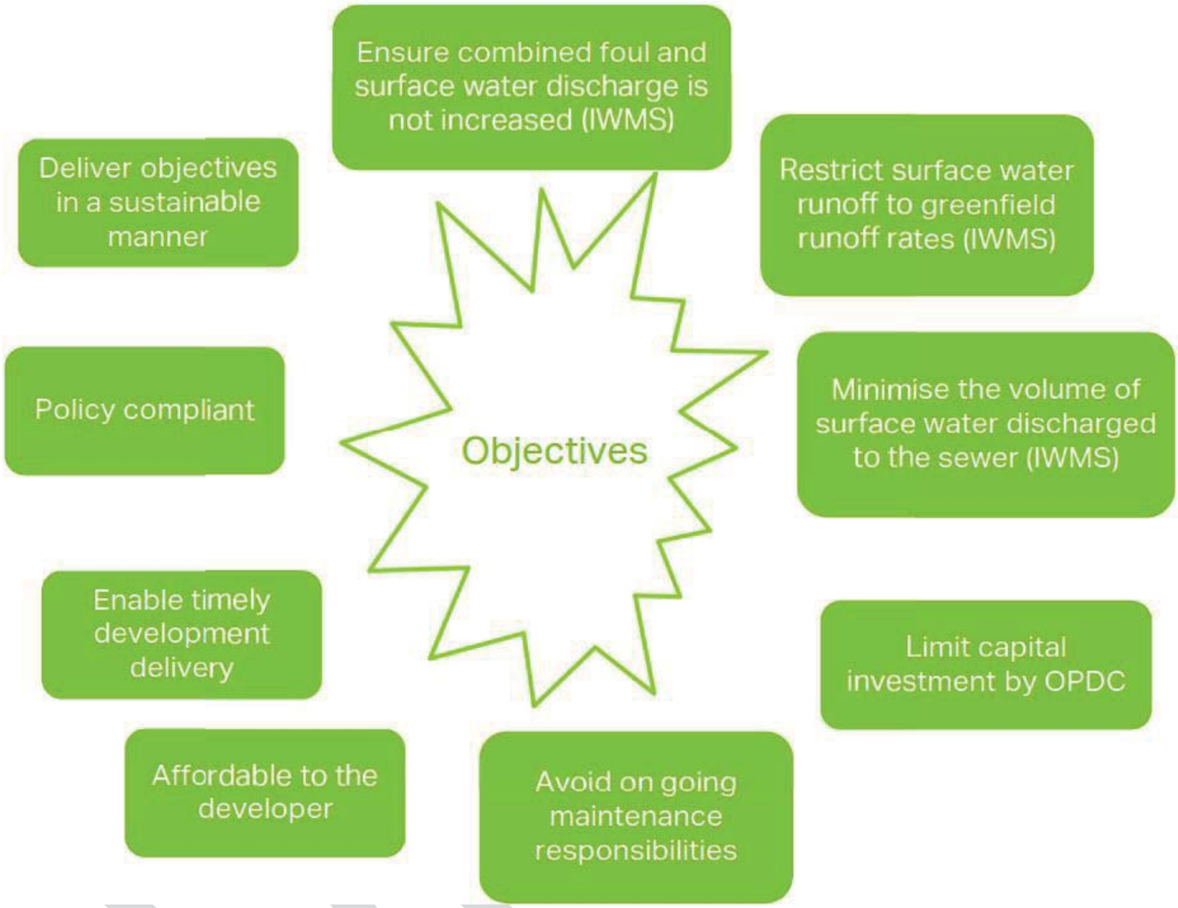

Figure 52. Objectives for the Foul and Surface Water Drainage Strategy

5.2 Existing Sewers and the Impact of Climate Change

5.2.1 Vision and Objectives for the Foul and Surface Water Drainage Strategy

Thames Water is responsible for the foul and surface water networks that extend through the Old Oak area and for the associated Wastewater Treatment Works at Beckton.

Thames Water Asset Location Plans highlight the presence of the following five strategic combined sewers that extend through the Old Oak area, as illustrated in Figure 53:

- The Stamford Brook Sewer (Mainline East Branch) flows in a south-westerly direction from the centre of the Site, across Wormwood Scrubs Park and along Old Oak Common Lane;
- The Stamford Brook Sewer Diversion flows in a southerly direction along the A4000, which is situated in the northwest corner of the Site, before turning east and flowing across the Site adjacent to the Grand Union Canal and ultimately discharging to the Wood Lane Sewer;

- The Middle Level Sewer No 2 Brent Valley Section flows in an easterly direction below Tubbs Road and the A404, which are situated directly to the north of the Site;
- The Wood Lane Sewer flows in a south easterly direction below Scrubs Lane, which extends along the eastern site boundary; and
- The Middle Level Sewer No 1. Main Line flows in an easterly directions to the south of the Great Western Railway Line.

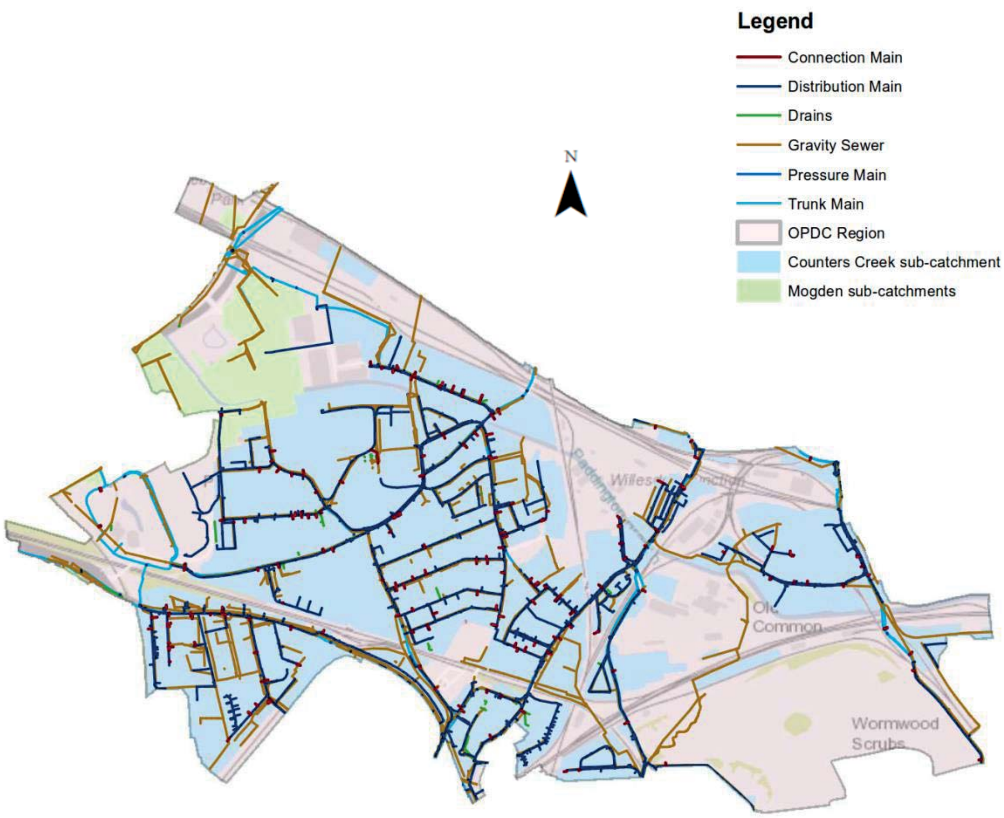

Figure 53. Existing Combined Sewers

5.2.2 The Impact of Development and Climate Change

Thames Water combined sewers generally provide sufficient hydraulic capacity to accommodate foul flows generated by the existing development in addition to surface water runoff generated during rainfall events with a return period of up to 1 in 30 years. However, the hydraulic capacity of the existing sewer will be eroded by climate change, as the Environment Agency publication entitled “Flood Risk Assessments – Climate Change Allowances”, which was published in February 2016, indicates that rainfall intensity has potential to increase by up to 40% by 2070.

To exacerbate matters further, the proposed development within the Old Oak Opportunity Area is relatively dense and it will cause the peak foul discharge to be increased significantly by approximately 1,300 l/s, based on the rates defined within Sewers for Adoption 7th Edition. The combined impact of climate change and the proposed development has potential to increase the risk of sewer flooding within existing urban areas, as illustrated in Figure 54, unless mitigation measures are identified. The Stage 2 Infrastructure Assessment identifies a series of intervention options and mitigation measures that may be implemented in order to ensure the flood risk is not increased within the Old Oak Opportunity Area.

Figure 54. Sewer Flooding within London

5.3 Regulatory Environment and Existing Planning Policy

5.3.1 Flood and Water Management Act (2010)

The Flood and Water Management Act (FWMA) was introduced in England and Wales on 8 April 2010. It was intended to implement Sir Michael Pitt's recommendations following the widespread flooding of 2007, when more than 55,000 homes and businesses were flooded largely caused by surface water run off overloading drainage systems. The Act was also a response to the need to develop better resilience to climate change.

The Act requires better management of flood risk and it creates safeguards against rises in surface water drainage charges and protects water supplies for consumers. It also gives a new responsibility to the Environment Agency for developing a National Flood and Coastal Risk Management Strategy, and gives a new responsibility to Local Authorities, as Lead Local Flood Authorities, to co-ordinate flood risk management in their area.

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5.3.2 Lead Local Flood Authorities

Lead Local Flood Authorities (LLFAs) are County Councils and Unitary Authorities. Under the FWMA, LLFAs are required to:

- prepare and maintain a strategy for local flood risk management in their areas, coordinating views and activity with other local bodies and communities through public consultation and scrutiny, and delivery planning.
- maintain a register of assets – these are physical features that have a significant effect on flooding in their area
- investigate significant local flooding incidents and publish the results of such investigations
- establish approval bodies for design, building and operation of SuDS
- issue consents for altering, removing or replacing certain structures or features on ordinary watercourses
- play a lead role in emergency planning and recovery after a flood event.

LLFAs and the Environment Agency are required to work closely together, to ensure that the plans they are making both locally and nationally link up. An essential part of managing local flood risk will be taking account of new development in any plans or strategies.

If a flood occurs, all Local Authorities are ‘category one responders' under the Civil Contingencies Act. This means they must have plans in place to respond to emergencies, and control or reduce the impact of an emergency. LLFAs also have a new duty to determine which risk management authorities have relevant powers to investigate flood incidents to help understand how they happened, and whether those authorities have or intend to exercise their powers.

By working in partnership with communities, LLFAs can raise awareness of flood and coastal erosion risks. Local flood action groups (and other organisations that represent those living and working in areas at risk of flooding) will be useful and trusted channels for sharing up-to-date information, guidance and support direct with the community.

LLFAs should encourage local communities to participate in local flood risk management. Depending on local circumstances, this could include developing and sharing good practice in risk management, training community volunteers so that they can raise awareness of flood risk in their community, and helping the community to prepare flood action plans. LLFAs must also consult local communities about its local flood risk management strategy.

5.3.3 Thames Water

Thames Water is responsible for operating and maintaining public foul and surface water sewers in the Old Oak Area. Thames Water play a major role in managing flood risk, as they manage the risk of flooding to water supply and sewerage facilities, and the risk to Others from a failure of their infrastructure.

The main roles of sewerage companies in managing flood risks are to:

- make sure their systems have the appropriate level of resilience to flooding, and maintain essential services during emergencies;
- maintain and manage their water supply and sewerage systems to manage the impact and reduce the risk of flooding and pollution to the environment;
- provide advice to LLFAs on how water and sewerage company assets impact on local flood risk;
- work with Developers, landowners and LLFAs to understand and manage risks – for example, by working to manage the amount of rainfall that enters sewerage systems; and
- work with the Environment Agency, LLFAs and district councils to coordinate the management of water supply and sewerage systems with other flood risk management work. They also need to have regard to FCERM plans in their own plans and work.

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Where there is frequent and severe sewer flooding (classified as sites included on the DG5 Register), sewerage undertakers are required to address this through their capital investment plans, which are regulated by Ofwat.

5.3.4 Amendments to Policy on Sustainable Drainage Systems (SuDS)

Following a consultation by Defra on the delivery of SuDS in 2014, the Department for Communities and Local Government (DCLG) issued a Written Statement outlining the Government's response regarding the future of SuDS in light of the delayed implementation of Schedule 3 of the Flood and Water Management Act (FWMA). Schedule 3 of the FWMA was to establish a new SuDS Approval Body (SAB) that would sit outside the existing planning system and would both approve designs for SuDS within applications, but also adopt and maintain SuDS systems assuming the minimum design standards were met.

The Written Statement was followed by a further consultation exercise carried out in December 2014 by DCLG on the proposal to not introduce SABs, but instead to make Lead Local Flood Authorities (LLFAs) statutory consultees for planning applications with regards to surface water management, and the Government published its formal response in March 2015. The NPPG has subsequently been amended to reflect the new approach to implementation of SuDS in development, giving more weight to the provision and maintenance of SuDS, alongside other material considerations, during the determination of a planning application.

As of 6th April 2015 Local Planning Authorities (LPAs), are now expected to ensure that local planning policies and decisions on planning applications relating to major development include SuDS for the management of run-off, unless demonstrated to be inappropriate. The LLFA has also been made a statutory consultee in the planning process.

5.3.5 London Plan

The London Plan contains the following relevant requirements:-

- *"Policy 5.13 Sustainable drainage:- Development should utilise sustainable urban drainage systems (SuDS) unless there are practical reasons for not doing so, and should aim to achieve greenfield run-off rates and ensure that surface water run-off is managed as close to its source as possible in line with the following drainage hierarchy:*

  1. *store rainwater for later use*
  2. *use infiltration techniques, such as porous surfaces in non-clay areas*
  3. *attenuate rainwater in ponds or open water features for gradual release*
  4. *attenuate rainwater by storing in tanks or sealed water features for gradual release*
  5. *discharge rainwater direct to a watercourse*
  6. *discharge rainwater to a surface water sewer/drain*
  7. *discharge rainwater to the combined sewer.*

  Drainage should be designed and implemented in ways that deliver other policy objectives of this Plan, including water use efficiency and quality, biodiversity, amenity and recreation. Within LDFs boroughs should, in line with the Flood and Water Management Act 2010, utilise Surface Water Management Plans to identify areas where there are particular surface water management issues and develop actions and policy approaches aimed at reducing these risks.

- *Policy 5.14 Water quality and wastewater infrastructure:- The Mayor will work in partnership with the boroughs, appropriate agencies within London and adjoining local planning authorities to:*

  a. *ensure that London has adequate and appropriate wastewater infrastructure to meet the requirements placed upon it by population growth and climate change*

  b. *protect and improve water quality having regard to the Thames River Basin Management Plan*

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Development proposals must ensure that adequate wastewater infrastructure capacity is available in tandem with development. Proposals that would benefit water quality, the delivery of the policies in this Plan and of the Thames River Basin Management Plan should be supported while those with adverse impacts should be refused.

Development proposals to upgrade London's sewage (including sludge) treatment capacity should be supported provided they utilise best available techniques and energy capture.

The development of the Thames Tideway Sewer Tunnels to address London's combined sewer overflows should be supported in principle. Within LDFs boroughs should identify wastewater infrastructure requirements and relevant boroughs should in principle support the Thames Tideway Sewer Tunnels."

4.3.6 Integrated Water Management Strategy

The Integrated Water Management Strategy (IWMS) for the Old Oak Opportunity Area identifies the following key criteria, which relate to foul and surface water drainage:-

- *"To ensure that the rate of wastewater and surface water discharge to the sewer is no greater than it is from the site usage of the Opportunity Area in the present day;*
- *To minimise the volume of water discharged to the sewer;*
- *To manage surface water runoff to a position that would match runoff from the site if it were undeveloped (greenfield); and*
- *To deliver these objectives in the most sustainable way bearing in mind the need to ensure the overall viability of the site."*

5.3.7 Current Market Response to London Plan Drainage Policy

A review of planning applications for emerging sites within the Old Oak Opportunity Area indicates that Developers are not generally proposing to provide SuDS with sufficient capacity to restrict the peak discharge from rainfall events with a return period of up to 1 in 100 years plus 40% climate change to greenfield runoff rates.

In the absence of strong Local Plan policy, there is a risk that Developers will continue to submit premature planning applications, which will not include sufficient attenuation storage to mitigate the impact of increased foul flows and increasing rainfall intensities due to climate change. This approach would cause the residual capacity within the combined sewers to be eroded and would increase the risk of sewer flooding, unless additional attenuation storage is provided within subsequent phases of the development.

5.4 Constraints

The Old Oak site is heavily constrained by the presence of transport corridors, varying topography, existing surface water flooding and large existing combined sewers. The Foul and Surface Water Drainage Strategy has been developed to minimise the impact that the development will have upon these constraints in order to increase viability, as described below.

5.4.1 Transport Corridors

The site is dissected by the Grand Union Canal (Paddington Branch) and by a series of major transport links, including the Great Western Main Line, West Coast Main Line, London Overground and London Underground Lines. Significant highways are also situated in the locality, as the A40 extends close to the southern boundary of the site, whilst Scrubs Lane and Old Oak Common Lane extend along the eastern and western boundary, respectively. These physical constraints divide the

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site into a series of discrete sub-catchments that have been considered individually whilst the foul and surface water drainage strategy has been developed.

5.4.2 Topography

A review of topographical information provided within the LiDAR Digital Terrain Model that is illustrated in Figure 55 indicates that the land within the Old Oak site generally falls from north to south. The natural topography has been artificially modified by infrastructure development, such as the excavation of the siding for the Great Western Main Line and the creation of the Grand Union Canal. However, the area of land that is situated on the northern side of the Grand Union Canal generally falls towards the canal, whilst the area of land to the south falls towards Wormwood Scrubs.

These topographical constraints heavily influence the foul and surface water drainage strategy, as they will be difficult to overcome, particularly when defining catchment areas and suitable outfalls for proposed surface water drainage networks and SuDS, as the use of pumped systems is considered to be undesirable.

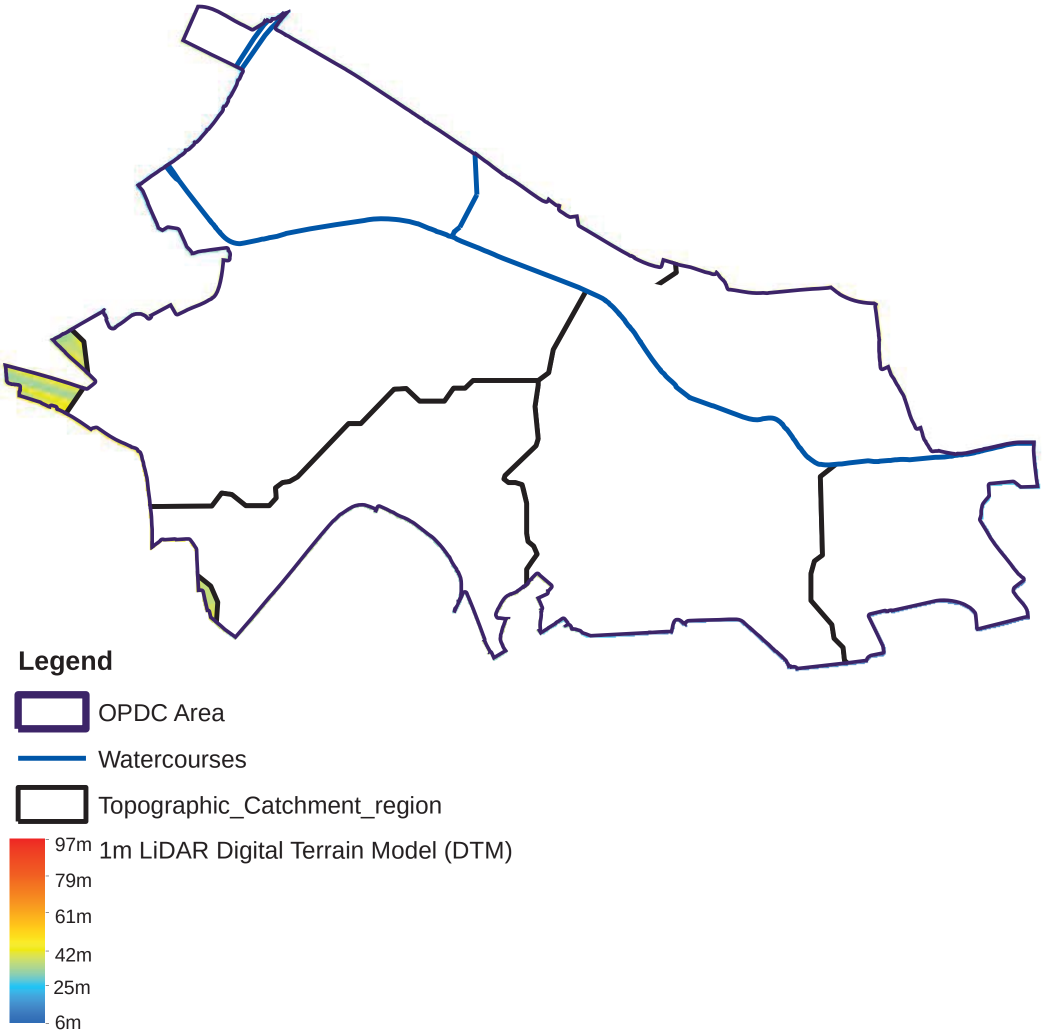

Figure 55. Surface topography and natural hydrological catchments across the Opportunity Areas

5.4.3 Existing Surface Water Flooding

The Environment Agency Flood Risk from Surface Water mapping, which is duplicated in Figure 56 below, highlights the potential for significant volumes of surface water to accumulate within the Old

Oak site. In order to mitigate the existing risk of surface water flooding, it will be necessary to provide SuDS and carefully design external levels within the site to enable surface water generated during exceedance to flow overland through the site without affecting proposed or existing buildings.

Figure 56. Environment Agency Flood Risk from Surface Water Map

5.4.4 Existing Combined Sewers

The location and capacity of key strategic infrastructure assets, such as combined sewers form key constraints. These assets may be costly and time consuming to relocate or upgrade and sustainable solutions are therefore likely to maximise opportunities for existing assets to be retained when the masterplan is developed.

5.5 Opportunities

5.5.1 Grand Union Canal

The Canal and River Trust has indicated that there is an opportunity for uncontaminated surface water runoff from development parcels that are elevated above the canal to be redirected away from the combined sewer to the canal, in order to reduce the volume of water that is treated at Beckton Sewage Treatment Works. This approach is also likely to enable the volume of SuDS that are provided within development plots to be reduced, as the permissible greenfield discharge rate may be applied to the smaller sub-catchment of the site that discharges to combined sewers, rather than the whole site.

The Canal and River Trust has undertaken an assessment to verify the feasibility of discharging surface water to the canal, which is contained in Appendix L. This assessment concludes that it is likely to be possible to discharge surface water from the Old Oak development site into the Paddington Arm of the Grand Union Canal, due to the considerable attenuation that may be provided by the 43km canal pound. In addition, various engineering works have been identified as potential methods of mitigating the flood risk from the additional discharge, ranging from the crenulation of weir crests to the installation of tilting weir gates, which are shown in Figure 57.

Figure 57. Crenulated and Tilting Weir Structures

5.5.2 Sustainable Drainage Systems that deliver Multiple Benefits

SuDS will be required to ensure that the peak rate of discharge generated during rainfall events with a return period of up to 1 in 100 years plus 40% climate change is restricted to greenfield runoff rates. However, there is an opportunity to carefully select a series of SuDS to form a cascading system of Source Control and Site Control features that will combine to deliver wider benefits, by forming a management train that will improve water quality, and enhance the existing landscape and ecological habitats, as outlined below:-

- Source Control features may be provided within individual development plots to manage surface water runoff as close as possible to where it falls as rain. Source control measures include features such as rainwater harvesting, green roofs, permeable block paving and storage crates and tanks.
- Site Control features generally receive an attenuated discharge from Source Control features, or highways, and they are provided to manage surface water runoff within the wider development. Site control features include rain gardens or detention basins, which could be installed within areas of Public Open Space that will be distributed throughout the site.

The following SUDS techniques are listed the "SUDS Manual" (CIRIA document C753) and they have been specifically identified as being suitable for use within the Old Oak development.

5.5.3 Green Roofs & Podium Deck Storage

Source control features such as living, or green roofs and brown roofs utilise the roof space as an attenuation feature, which intercepts runoff at source and discharges water at a manageable rate. These features can also encourage biodiversity through the careful selection of plant species. The provision of these forms of roof within the development can also reduce the volume of surface water runoff that is discharged to the drainage network, through evapotranspiration.

In the event that podium decks are incorporated within the development to form an addition living space that is constructed over car parks, then these areas may be used to accommodate attenuation storage, through the introduction of permavoid systems situated below permeable paving or landscaped areas, as illustrated in Figure 58 below.

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Green roofs and podium deck storage systems enable surface water to be attenuated at a high level within the development and provide an opportunity to reduce the size of other underground structures, if the green roofs are employed extensively.

Figure 58. Permeable Paving and Landscaping over a Permavoid System on a Podium Deck

5.5.4 Permeable/porous surfaces

It is anticipated that the proposed development will incorporate permeable paving, as this is an ideal solution where large hard paved landscapes are proposed, particularly given that it removes the requirement for unsightly gullies (Figure 59). In addition, roof drainage can discharge through porous sub-bases within areas such as parking bays, thus slowing the rate of water leaving a wider catchment area.

Both permeable and porous surfaces include a granular sub-base, which can provide a stage of treatment of surface water through filtration and microbial action (biodegradation). The depth of the granular sub-base can be increased to suit storage requirements and could be supplemented with thin cellular storage or drainage blankets, which would be wrapped in an impermeable membrane.

Any areas of gravel or permeable paving that are provided within the Old Oak site would need to be lined to prevent the ingress of contaminants, or elevated groundwater.

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Figure 59. Permeable Paving within Car Parking Bays

5.5.5 Underground Attenuation Features

Underground storage features can be formed using oversized pipes or cellular tanks.

Pipe storage utilises oversized pipes and on line flow control devices such as orifice plates or hydro-brakes to store surface water and attenuate flows to acceptable discharge rates. Storage pipes are placed immediately upstream of flow control devices where below ground drainage is to be employed.

Cellular pre-formed storage features can be placed off-line to intercept surface water before it enters the main drainage network. These cells can be placed under hard standing areas such as car parks and drives, or alternatively in courtyards, as illustrated in Figure 60. It is proposed that these features are installed with a gravel filtration layer, or beneath vegetation where appropriate, to remove contaminants from the water.

Figure 60. Underground Cellular Storage Tank

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5.5.6 Rain Gardens / Detention Basins

The Old Oak development will be relatively dense; however, it will also incorporate some areas of public open space that could be designed intelligently to incorporate attenuation storage in the form of rain gardens or detention basins (Figure 61). These features fill in times of heavy rainfall and assist in regulating water from a large catchment before water is gradually released back into the receiving sewers, or canal, at managed rates.

Where rain gardens or detention basins are located close to the source of the surface water runoff, they can be relatively small. This approach would be beneficial for the Old Oak development, particularly given that a series of small features can be easier to maintain and would offer more resilience to blockage than a large feature.

Where rain gardens or detention basins are provided for site control, they can require large areas of land and can therefore only be located where there is sufficient space. However, these areas can be landscaped to provide amenity space local residents, and contribute to urban cooling.

Rain gardens and detention basins also provide the facility for contaminant removal through sedimentation and biodegradation.

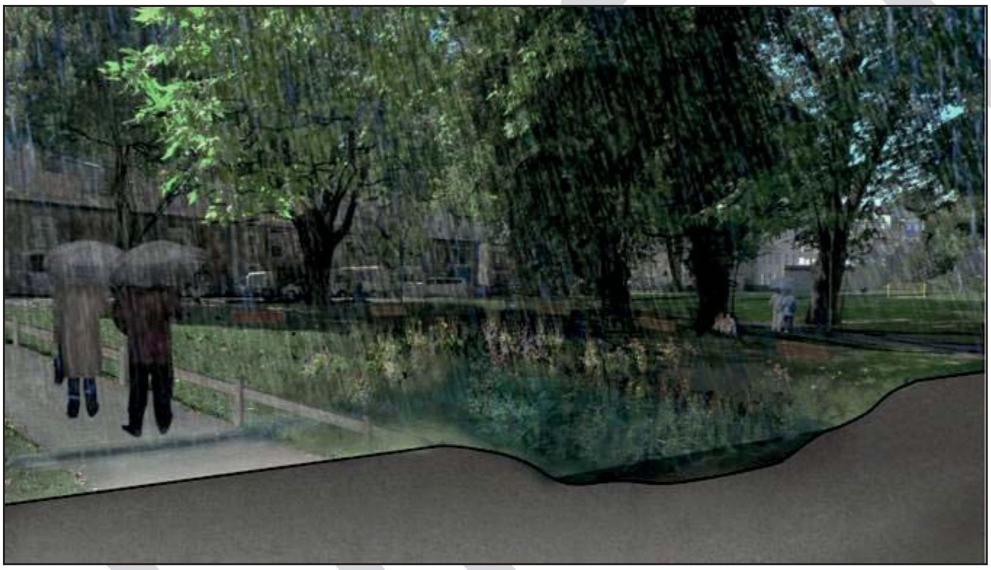

Figure 61. Detention Basin / Rain Garden within area of Multifunctional Public Open Space

5.5.7 Application of Features

A combination of features will be required within development plots, including permeable paving with gravelled/granular sub-bases and filtered cellular storage are proposed for the development. The remainder of any required attenuation storage and contaminant removal may be provided in the form of site control features, such as rain gardens or detention basins within green spaces. Complex control devices will be installed downstream of each feature to limit flows to greenfield runoff rates.

Typical details of proposed SuDS features are illustrated on the drawings contained in Appendix M. While the features shown on these plans and discussed in this drainage strategy are not exhaustive, each plot within the proposed development should be designed to incorporate at least one of the suggested features at source to ensure no flooding will occur within the plot boundary for a 1 in 100 year plus climate change event. The form of attenuation that is selected will need to provide at least one level of treatment to surface water runoff from any section of road within the plot boundary prior to the discharge to the drainage network.

5.6 Intervention Options for OPDC

OPDC will be required to intervene in order to deliver a sustainable development that will comply with the requirements of the Integrated Water Management Strategy, by minimising the volume of surface water that will be discharged to the combined sewer and ensuring that the combined foul and surface water discharge will not be increased.

There are three levels of intervention available to OPDC, which are illustrated in Figure 62 below:-

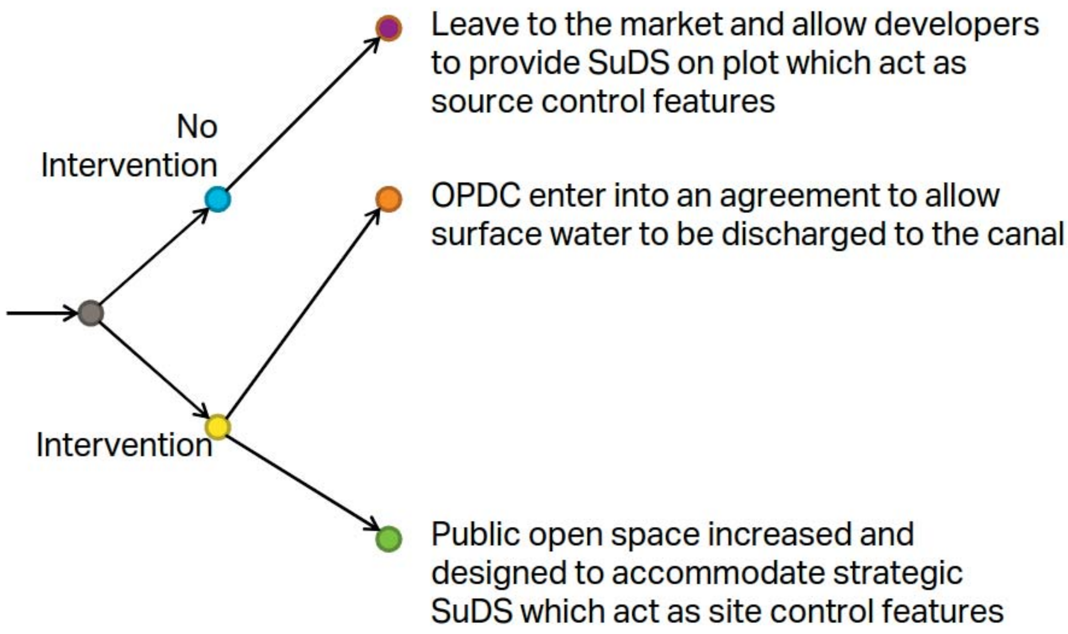

Figure 62. Varying Levels of Intervention to Manage Surface Water

The following text describes the technical, delivery model and financial aspects of each alternative intervention option in order to enable the relative merits to be assessed.

5.6.1 Option D1:- SuDS Provided on Plot to act as Source Control Features

This option involves providing SuDS on plot only, in the form of source control features, such as green roofs, blue roofs, rainwater gardens, porous paving and cellular storage tanks. These features would be required to provide sufficient capacity to restrict the peak surface water discharge from rainfall events with a return period of 1 in 100 years + 40% climate change to greenfield runoff rates.

5.6.1.1 Technical Aspects

Surface water will be attenuated at source; therefore the size of surface water sewers that are provided to convey flows from development plots to the combined sewer or canal will be minimised.

The size and cost of SuDS that are proposed on plot may be minimised by carefully designing the levels of less vulnerable areas of the site to accommodate excess surface water generated during rainfall events with a return period of greater than 1 in 30 years above ground, providing that Site specific Flood Risk Assessments are prepared to demonstrate that property will not flood during rainfall events with a return period of up to 1 in 100 years plus 40% climate change.

Rainwater harvesting devices may also be provided to enable surface water to be intercepted, treated and reused for toilet flushing, as described within the emerging options paper for Water Supply.

5.6.1.2 Delivery Model Aspects

The Local Plan would be required to include policy that aligns with the London Plan in order to reinforce the requirement for SuDS to be provided on plot to fully restrict the peak discharge to greenfield runoff rates.

Developers would be required to design the development to provide capacity for a significant volume of water to be stored on plot. This option introduces a technical challenge given the density of the development, although this requirement is consistent with the London Plan.

SuDS that are installed on plot will generally be retained in private ownership and Developers will therefore be required to employ management companies to maintain these systems in order to ensure that they function effectively over the lifetime of the development.

5.6.1.3 Financial Aspects

OPDC financial commitment will be minimised, as Developers will be required to deliver SuDS on plot.

Well-designed multifunctional greenspace that accommodates surface water alongside other functions can add value to the development. However, SuDS features are generally more expensive to construct and maintain than traditional drainage systems and there is therefore a risk that land values may be reduced by the requirement for Developers to install and maintain large volumes of attenuation storage on plot.

The size and cost of surface water sewers that are provided to convey flows from development plots to the combined sewer or canal will be minimised.

5.6.2 Option D2:- SuDS provided within areas of public open space to act as Site Control Features

This option introduces a requirement for areas of public open space to be extended to accommodate SuDS features in the form of site control features, such as rainwater gardens or detention basins to provide a secondary level of attenuation and water quality improvement.

5.6.2.1 Technical Aspects

Surface water will not be fully attenuated at source; therefore the size of surface water sewers that are provided to convey flows from development plots to the combined sewer, or canal, will be increased when compared to Option D1.

Site levels will need to be carefully designed to enable overland flood flows generated during extreme rainfall events to be directed away from properties, as adoptable sewers may only accommodate rainfall generated during events with a return period of 1 in 30 years.

The size and cost of SuDS features that are proposed within areas of public open space may be minimised by carefully designing the levels of less vulnerable areas of the site to accommodate excess surface water generated during rainfall events with a return period of greater than 1 in 30 years above ground, providing that flood maps are provided to demonstrate that property or strategic highways will not flood during rainfall events with a return period of up to 1 in 100 years plus 40% climate change.

5.6.2.2 Delivery Model Aspects

The masterplan would need to be designed to include extended areas of public open space that may accommodate strategic SuDS features in the event that this option is selected; therefore the net developable area will be reduced and development density may increase.

OPDC are likely to be responsible for installing and maintaining SuDS within areas of public open space; therefore OPDC would have an ongoing maintenance liability if this option is selected.

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5.6.2.3 Financial Aspects

Developers will be required to provide a smaller volume of attenuation storage on plot; therefore land values may be maximised. However, OPDC are likely to be required to obtain funding to install and maintain SuDS within areas of public open space.

The cost of surface water sewers that are provided to convey flows from development plots to the combined sewer, or canal, will not be minimised when compared to Option D1.

5.6.3 Option 3:- Discharge surface water to the Grand Union Canal

This option involves discharging surface water from development parcels situated within the catchment of the Grand Union Canal directly to the canal, in preference to the existing Thames Water combined sewer.

5.6.3.1 Technical Aspects

This approach would potentially reduce the volume of attenuation storage required to be provided within development parcels that discharge surface water directly to the Grand Union Canal, in the event that the Canal and River Trust confirm that surface water may be discharged at rates exceeding the existing greenfield runoff rate.

This option would also minimise the volume of water that Thames Water will be required to treat at Beckton Sewage Treatment Works. There is also potential for the volume of attenuation storage that is provided within plots that discharge surface water to the combined sewers to be reduced, as the permissible greenfield runoff rate may be applied to a smaller sub-catchment rather than the whole site.

5.6.3.2 Delivery Model Aspects

OPDC would be required to obtain an agreement from the Canal and River Trust for surface water to be discharged to the Grand Union Canal. OPDC would also be required to enter into an agreement for the installation and maintenance of the proposed outfalls, as the Canal and River Trust are unlikely to enter into multiple agreements with separate Developers.

The masterplan may potentially be designed to accommodate SuDS with a smaller capacity. The London Plan indicates that this approach is more preferable than discharging surface water to combined sewers and it would ensure compliance with the London Plan drainage hierarchy.

5.6.3.3 Financial Aspects

Land values could potentially be increased, as Developers will be required to install smaller volumes of attenuation storage on plot. However, OPDC would be required to obtain funding or Developer contributions to construct and maintain outfalls to the Grand Union Canal, as the Canal and River Trust are unlikely to enter into multiple agreements with separate Developers.

5.7 Evaluation of Alternative Options

A Multi Criteria Analysis has been undertaken in order to establish which of the proposed options satisfies the objectives most effectively. The results of this analysis are presented in Table 15 below.

The Multi Criteria Analysis indicates that the preferred intervention option is likely to involve OPDC entering into an agreement with the Canal and River Trust to enable Developers to discharge surface water to the Grand Union Canal as it would satisfy key objectives, such as complying with policy, minimising the volume of water discharged to the sewer, increasing affordability to the Developer, and ensuring that these objectives are delivered in a sustainable manner.

The Multi Criteria Analysis also indicates that benefits would also be obtained by designing the masterplan to accommodate multifunctional SuDS, as costs and ongoing maintenance responsibilities for Developers would be reduced. However, these costs and ongoing liabilities would be transferred to

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OPDC and funding sources would therefore need to be identified in order to allow this intervention option to be delivered effectively.

Objectives	On plot attenuation	Discharge surface water to the canal	Increase POS to accommodate SuDS
Ensure overall discharge rate to sewer is not increased	★★★	★★★	★★★
Minimise volume of water discharged to sewer	★	★★★	★★
Restrict surface water runoff to greenfield runoff rates	★★	★★★	★★★
Limit capital investment by OPDC	★★★	★	★
Avoid ongoing maintenance responsibilities	★★★	★★	★
Affordable to the developer	★	★★	★★★
Enable timely development delivery	★★★	★★★	★★
Policy compliant	★	★★★	★★
Deliver objectives in a sustainable manner	★	★★★	★★

Table 15. Evaluation of Alternative Intervention Options

5.8 Conclusion and Recommendations

This study has outlined a range of cost effective and sustainable intervention options that are required to comply with key objectives listed in Figure 52, which include minimising the peak rate and volume of surface water discharged the existing combined sewer network, in order to reduce the risk of sewer flooding and create capacity for additional foul flows generated by the development.

Consultations with OPDC have indicated that the preferred drainage strategy involves including policy within the Local Plan; firstly, to place an obligation on Developers of parcels that discharge to the existing combined sewer network to provide SuDS on plot to restrict the peak discharge from rainfall events with a return period of up to 1 in 100 years plus 40% climate change to greenfield runoff rates; and secondly, to encourage Developers of parcels situated within the catchment of the Grand Union Canal to discharge surface water to the canal and to make financial contributions to cover the construction and maintenance cost of outfalls to the Grand Union Canal.

Physical constraints within the Old Oak site limit the ability to provide a single, fully integrated surface water drainage network that incorporates source control features on plot, and site control features positioned strategically within the development, as it will not be practical to extend sewers across proposed bridges. However, opportunities for integrating a cascading system of features within the development should be maximised; firstly, by providing source control features on plot, potentially in the form of intensive green roofs, porous paving and geocelluar storage tanks; and secondly, by designing areas of public open space to form site control features that will accommodate excess surface water generated during extreme rainfall events, particularly when these areas are situated in close proximity to the receiving combined sewer network or Grand Union Canal.

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5.8.1 Supportive Local Plan Policy

Local Plan Policy will need to be developed and adopted in order to support the initiatives and objectives established by this study in order to ensure that Developers implement the preferred Drainage Strategy. Draft policy requirements are outlined below:-

"Policy EU3: Water

Development proposals will be supported where they:

- *d) collaborate with OPDC and its development partners to deliver an integrated strategy for managing foul and surface water;*
- *e) appropriately contribute to and/or deliver the required water infrastructure identified within OPDC's Infrastructure Delivery Plan (IDP);*
- *f) minimise the impact that the development will have upon on the hydraulic performance of the existing combined sewer network and reduce the risk of surface water flooding, by:*
  - *i. actively following the London Plan drainage hierarchy and deliver other objectives of London Plan policy, including water use efficiency and quality, biodiversity, amenity and recreation, where practical.*
  - *ii. providing Sustainable Drainage Systems (SuDS) on site with sufficient attenuation storage capacity to allow the peak rate of surface water generated during rainfall events with a return period of up to 1 in 100 years plus 40% climate change to be restricted to greenfield runoff rates, where surface water is discharged to the combined sewer, or to achieve the permissible discharge rate agreed by the Canal and River Trust where surface water is discharged to the Grand Union Canal.*
  - *iii. where on-site measures alone would not achieve this rate deliver and/or contribute to off-site strategic SuDS and/or proposed outfalls to the Grand Union Canal;*
  - *iv. according with any relevant requirements of local authority Surface Water Management Plans and requiring major developments to submit Site Specific Flood Risk Assessments (FRA) as part of the application process;*
  - *v. alleviating localised surface water drainage problems where these have been identified within the Integrated Water Management Strategy (IWMS), surface water management plans or the Site specific FRA; and*
  - *vi. submitting a Drainage Strategy as part of major development proposals, demonstrating how development will enable capacity to be released within the existing combined sewer network to accommodate additional foul flows, without compromising the ability of other Developers to meet future development needs;"*

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5.8.2 Fixes and Priorities for the Masterplanning Team

The masterplan will form the key mechanism for including spatial provision within the development to enable SuDS to be incorporated.

Conceptual design drawings are provided within Appendix M to define the surface water management requirements for each of the development parcels within the Old Oak site, including the parcel area, permissible runoff rate and minimum volume of attenuation storage. These drawings also provide details of suitable forms of SuDS, including green roofs, podium deck storage, porous paving and cellular storage to demonstrate that it will be practical to integrate the required volume of storage within each development parcel.

The design drawings also define the location of areas of public open space that is likely to be provided within each development parcel to allow the Masterplanning Team to consider the practicality of incorporating site control features within these areas.

The drawings that are provided within Appendix M indicate that the masterplan should be futureproofed by including spatial provision for the following drainage features:-

- SuDS should be provided within plots, and areas of public open space, that discharge surface water to the existing combined sewers in order to enable the peak discharge from rainfall events with a return period of up to 1 in 100 years plus 40% climate change to be restricted to greenfield runoff rates;
- Outfalls should be provided to enable surface water from sites within the catchment of the Grand Union Canal to be discharged directly to the canal in preference to the existing combined sewers. SuDS should also be provided within plots that discharge surface water to the Grand Union Canal to enable the peak discharge from rainfall events with a return period of up to 1 in 100 years plus 40% climate change to be restricted to rates agreed with the Canal and River Trust; and
- In the event that it is not practical to provide SuDS with sufficient volume to accommodate rainfall generated during events with a return period of 1 in 100 years plus 40% climate change, then external levels within car parks and landscaped areas should be carefully designed to enable excess flows generated during rainfall events with a return period of greater than 1 in 30 years to be stored above ground without affecting property.
- The requirement for large diameter combined sewers to be diverted should be minimised by designing the masterplan to incorporate new sections of highway along the route of existing sewers.

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OPDC
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PARK ROYAL
DEVELOPMENT
CORPORATION

Utilities Study

Appendices A to F

2017

MAYOR OF LONDON

Appendix A Potential Heat Sources at Old Oak

A.1 Executive Summary

This technical note was prepared in December 2016 as an interim deliverable to inform the development of the strategy set out in the main body of the Stage 2 report. It summarises the low carbon heat sources that could potentially supply district or communal heat networks serving planned development at Old Oak.

Development in the Old Oak & Park Royal opportunity area could deliver approximately 26,970 new homes and over 800,000 m^2 of new non-domestic floor area. Development is expected to be multi-phased and capitalise on the significant transport infrastructure improvements planned for the area. Development of this scale will result in a significant demand for energy, in particular heat energy to service space heating and domestic hot water loads. Although improvements in building fabric standards continue to reduce the demand for energy in new buildings, it is expected that the development will exhibit high demand for heating, led primarily by hot water demand. An initial calculation of heat demand for the scheme at full build out indicates a peak heat load of c.100 MWth. A thermal profile of this scale and type, including appropriate levels of thermal storage, would likely mean a base heating load of 20 – 30 MWth.

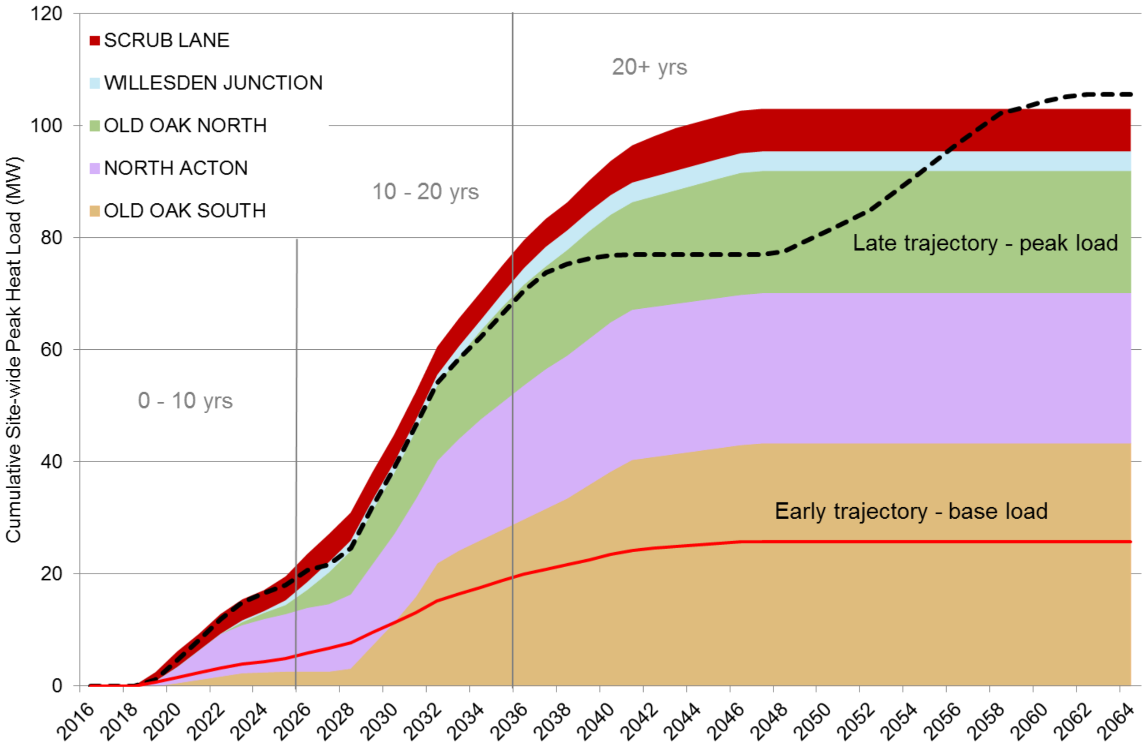

Figure A.1.1. Projected Peak Heat Demand

(Source: 'Phasing Trajectory v7.11_Early Scenario for Planning')

This compares with a recent report by Atkins[1] which estimates that the annual thermal energy requirement for residential buildings to be between approximately 64,000 – 127,000 MWh/year, and 11,000 – 81,000 MWh/year for the office and retail buildings, giving a total of between 75,000 – 208,000 MWh/year for the scheme as a whole. Appropriate sizing of thermal storage would indicate a baseload of approximately 15 – 35 MWth. A further report by Arup[2] indicates that the total heating energy use in the Old Oak and park Royal development is expected to be 180,000 MWh/year, which, should appropriate thermal storage be used, provide a base load of approximately 30 MWth.

[1] OPDC Environmental Target-Setting and Delivery Study, Atkins, September 2016
[2] OPDC & LWARB Circular Economy Scoping Study for Old Oak and Park Royal, Arup, December 2016

The density of development being planned for the area could potentially limit the viability of providing low carbon heating services via block (individual apartment building) or dwelling based solutions, due to space constraints or the visual and noise impacts of large numbers of individual heating units. It is likely therefore that a rationalised approach for the Old Oak area would include provision of centralised generation of low carbon heat and distribution to individual units via an area-wide heat network. This is also the strategy that would be required by London Plan policy. However, the long term case for an area-wide heat network, in terms of ensuring it remains a strategy that enables developments to continue to reduce their CO_2 emissions, is dependent on it being able to continue being served by low carbon heat sources.

The current outcome of London Plan policy is that in many cases small (50-300kW) gas-fired Combined Heat and Power (CHP) engines are installed to serve communal heating systems in individual developments. Gas-fired CHP has traditionally been an effective low-carbon heat supply option. This is due to local gas CHP electricity generation displacing higher carbon electricity that would otherwise come from the grid. However, as the grid decarbonises (as a result of increased penetration of renewable energy technologies, new nuclear generation, and the decommissioning of ageing coal-fired power plants), the carbon emissions benefits associated with CHP will reduce dramatically. While CHP currently provides net carbon savings compared to gas-boiler heating, it is expected that CHP will stop offering net carbon emissions reductions by the early 2030's (based on bespoke marginal emissions factors for CHP deployment). However, the calculated savings in national Part L calculation methods could start to show no saving much earlier due to the use of average rather than marginal grid electricity emission factors for these calculations. Some projections and methodologies show that CHP will no longer offer carbon savings by 2021-2022[3].

Alternative dwelling or block based strategies for ensuring the low-carbon supply of heat include renewable energy sources such as solar thermal or PV systems, air source heat pumps and ground source heat pumps. However, the density of the planned development (expected to be around 300-600 dwelling per hectare) may constrain the potential of some of these options for very tall buildings. For example, the capacity of solar thermal systems and solar photovoltaics could be constrained by the proportion of unshaded roof and façade area in relation to the overall development floor area. Similarly, the large-scale deployment of air source and ground source heat pumps could be limited by the available footprint and roof area in relation to building height and density. It is therefore expected there will be merit in utilising district energy networks, where these can be served by local low carbon heat sources of sufficient capacity. If necessary, local low carbon heat sources could be supplemented with gas CHP to provide a multi-source strategy for resilient heat generation.

A.1.1 Available Heat Sources to Serve District and Communal Systems

A number of large potential local heat sources have been explored. These are shown geographically in Figure A.1.2, and include:

- Water sources (including the London Aquifer and the Grand Union Canal);
- Taylor's Lane Power Station (possibility of recovering heat from an existing power station);
- Powerday (potential waste to energy plant);
- Heat recovery from the sewage network;
- Heat recovery from transport tunnels (including from ventilation shafts, tunnel linings and water drainage from HS2 tunnels); and
- Heat recovery from data centres.

Table A.1.1 provides a high level summary of the findings for each heat source, based on stakeholder discussions, and a conventional gas CHP comparator, including:

- An initial estimate of the available heat capacity that could be delivered to a heat network;
- The relative carbon intensity of the heat source (kg CO_2 per kWh of heat delivered, excluding network losses) based on current SAP 2012 emission factors and for proposed SAP 2016 emission factors;

[3] An Operational Lifetime Assessment of the Carbon Performance of Gas Fired CHP and District Heating, CIBSE Technical Symposium, ARUP, April 2016

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- A relative rating of the likely capital and operational costs; and
- Anticipated delivery constraints.

A red, amber, green assessment has been applied to show their relative merits against these issues.

Heat sources shown red for deliverability are considered unlikely to make a contribution to meeting Old Oak's heat demands. All other sources explored are considered to have potential to serve heat networks at Old Oak and are considered further below.

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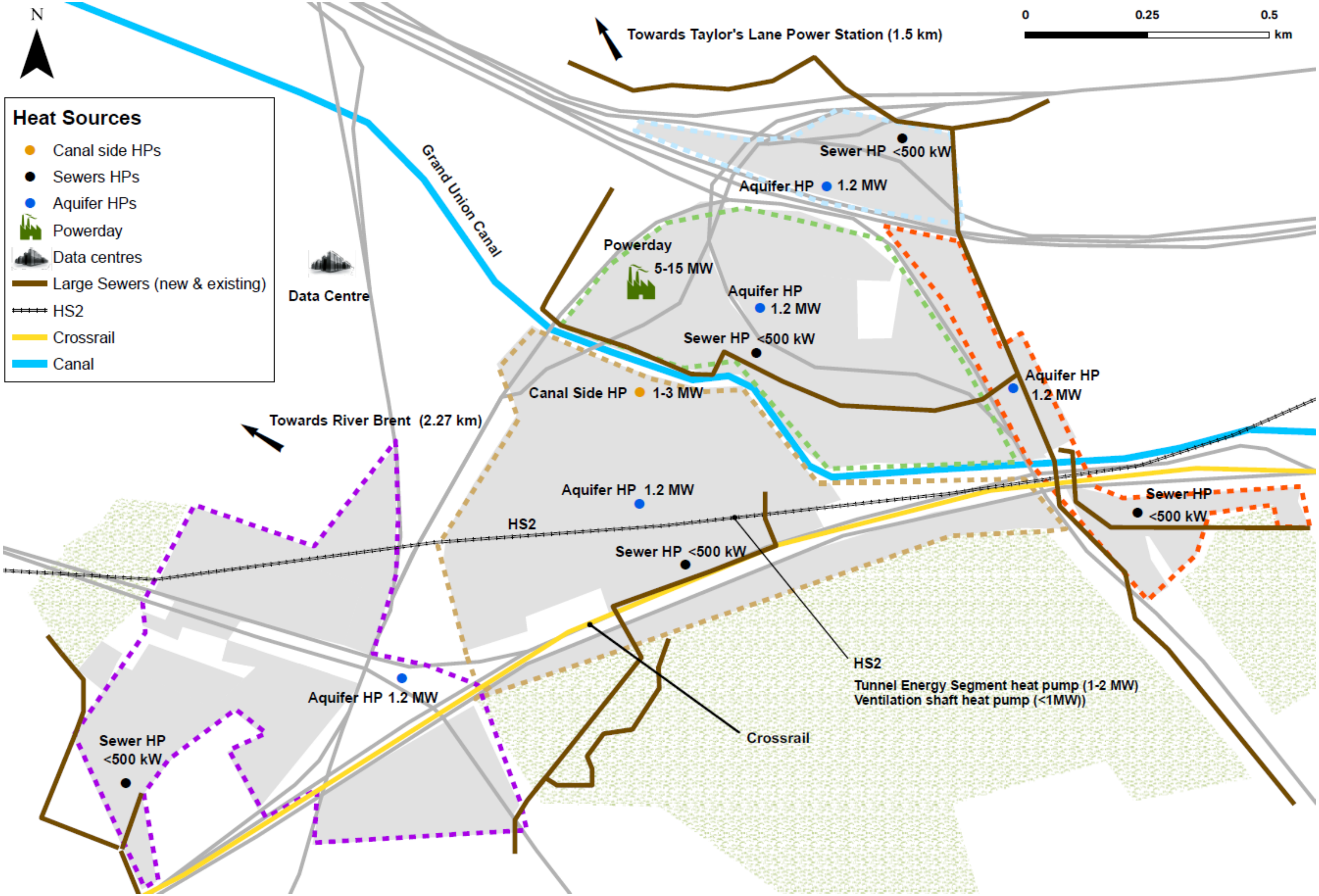

Figure A.1.2. Potential Heat Sources

Heat source	Delivered Heat MWth	Carbon intensity of heat generated (kgCO2/kWh)		Relative Capital Cost	Relative Opex	Deliverability
		SAP 2012	Proposed SAP 2016			
Grand Union Canal heat pump	1 – 3 MW	0.251	0.192	Medium	Medium	Heat or cooling extraction from the canal appears a deliverable option that would be supported by the Canals & Rivers Trust (CRT). Water abstraction infrastructure will be needed adjacent to the canal and necessary licenses obtained and renewed
London aquifer heat pump	<1 (per borehole)	0.227	0.174	High	Medium	Extraction of water from the aquifer will require sinking boreholes to a depth of c.100m. Extraction rates will be uncertain until boreholes are sunk, but this is a potentially deliverable source of heating and cooling that has been exploited elsewhere in London. Necessary licenses would need to be obtained and renewed.
Taylor's Lane Power Station heat recovery	-	0.083	0.063	High	Low	This option is not deliverable. E.ON have confirmed this plant is only licensed to operate as a peaking plant 100 hrs p.a. E.ON have no immediate plans to provide alternative plant.
Energy from Waste	5 – 10 MW (potentially more)	0.069	0.103	Low	Low	This option is reliant on third party provision of an energy from waste facility and a successful planning consent and permitting. Thrust boring under railway lines to distribute heat and identifying an entity to purchase and supply heat would be required. While this creates some uncertainty it appears possible that this option could be delivered.
Sewage network heat pump	200 – 500 kW (per installation)	0.214	0.164	Medium	Medium	This is a relatively novel technology for the UK but has been delivered successfully by Suez and others in Europe. Thames water is positive about a potential pilot, but this will depend on commercially attractive terms. 6 number of 200 m length heat recovery installations could be provided.
Ventilation shaft heat pump	<1	0.242	0.186	Medium	High	The Bunhill heat network has shown that tunnel heat recovery is possible to deliver, however, the main HS2 tunnel vent shafts are outside the Old Oak area and station vent shafts would more logically supply loads within HS2 rather than a wider network.
Tunnel Energy Segment heat pump	1 – 2 MW	0.241	0.185	High	Medium	This option would be reliant on HS2 for its delivery, discussion with HS2 confirm there is no plan to install this technology.
Tunnel drainage heat pump	Negligible	0.265	0.203	High	High	This option would be reliant on HS2 for delivery, water is expected to flow to tunnel vent shafts outside the Old Oak area and hence considered undeliverable
Data centres heat recovery	TBC	0.200 (summer) 0.265 (winter)	0.154 (summer) 0.203 (winter)	Medium	Medium	The deliverability of this option is unknown and would require further discussion with the operator. Heat pipework would need to cross land outside the development delivery parcels. However it is in relatively close proximity to a planned HS2 logistics tunnel.
Gas-fired CHP comparison	Any capacity	0.054	0.216	Low	Low	Delivery within control of OPDC or private developers will require medium pressure gas supply but this is required for resilience for all other options. Will need to comply with London Plan air quality standards.

Table A.1.1. Summary Table of Potential Heat Sources at Old Oak

A.1.1.1 Thermal Capacity of Available Heat Sources

Overall, there are a number of potential heat sources that could be used and should be investigated further. It can be seen from Table A.1.2 that if all could be delivered they could meet most of the expected baseline heat demand of 20 – 30 MW. The potential heat output from the data centre will depend on a detailed investigation of the technical challenges of implementation and the interest of the operator in enabling heat recovery.

The potential availability of significant low-carbon heat sources supports the case for developing a district energy solution as part of the masterplanning work.

Heat Source	Viable heat source (MW)
Grand Union Canal serving heat pumps	1 – 3 MW varies seasonally
London aquifer serving heat pumps	5 no. 1.2 MW open loop boreholes = 6 MW
Sewage network serving heat pumps	5 no. 200m installations = 1 – 3 MW
Energy from Waste	3 – 10 MW (potentially more)
Total	**11 – 22 MW**

Table A.1.2. Summary of Recommended Heat Sources

A.1.1.2 Carbon Content of Heat

Of the heat sources explored, waste heat from an EfW facility would offer the lowest carbon heat source in the short to medium term, and potentially the lowest cost, although this would be subject to negotiations with the EfW operator. Low temperature heat sources serving heat pumps are more carbon intensive than EfW, but would quickly become less carbon intensive than gas CHP and the carbon content of the heat they provide will continue to fall as grid electricity emission factors fall, meaning they would be future proofed for long term carbon savings. The higher the temperature of the heat source the higher the efficiency of the heat pump and the lower the carbon emissions per unit of heat delivered. The chalk aquifer and sewers are expected to have higher temperatures than canals in winter and hence slightly improved carbon emission factors.

The carbon content figures shown in Table A.1.1 assume that technologies will be serving heat networks with current typical operating temperatures of 80°C flow and 60°C return. However, industry best practice encourages lower circuit temperatures and larger temperature differences between supply and return (delta T of 30°C recommended). The carbon content for all heat pump technologies will reduce if serving low temperature district heating networks of 70°C flow, 40°C return. As the majority of low carbon heat sources identified rely on heat pumps for their exploitation there is a strong argument for exploring the use of low temperature district heating networks at Old Oak.

A.1.1.3 Costs and Deliverability

Heat offtake from an EfW facility could have relatively low costs both in capital and running costs terms, relative to other heat sources, as the heat generation capital and maintenance costs would potentially be met by the EfW provider. A tariff would however need to be paid for the heat. Most of the heat pump sources will require investment in related infrastructure, for example: construction of boreholes to reach the aquifer, construction of a leat and associated water filtration to extract water from the canal, or implementation of heat exchangers and modification of the sewer - all of these are likely to have higher capital costs than conventional gas CHP solutions.

It is assumed in all cases that the heat supply plant would be located in an energy centre building which would require medium pressure gas supplies as gas boilers are expected to be required for backup or peak demands in all cases.

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A.1.2 Findings and Recommendations

A.1.2.1 Geographic Distribution of Heat Sources

Phasing of infrastructure investment against phasing of planned development, means it is likely that a number of energy centres will be required serving the different areas within Old Oak. These can seek to exploit the available local heat sources and be delivered to suite the specific phasing of development.

Having reviewed the available heat sources there are some notable geographic and phasing considerations. Old Oak North and the Car Giant Site are well served by heat sources, having potential access to heat from EfW, the canal, sewers and from the chalk aquifer.

Old Oak South could access heat from the canal or boreholes and, assuming a primary heat network extension across the canal, could utilise heat from an EfW facility, although the heat demand for Old Oak North could potentially absorb a large proportion of the available heat from EfW.

The only alternative low carbon heat sources identified locally to development in North Acton would be open loop boreholes and possibly sewer heat extraction. Any work to develop a network in these areas should seek to test the viability of utilising these sources, to avoid locking the development into a gas-CHP only solution.

While each development area should seek to exploit the sources available locally, there will be potential merit in terms of resilience in seeking to link up local networks over time. Creating a district wide network would also enable sharing of available low carbon sources over a wider area.

A.1.2.2 Heat Source Summary of Findings

A.1.2.2.1 Energy from Waste

The most attractive of the low carbon heat sources is considered to be an EfW facility proposed by Powerday and located in Old Oak North. Powerday plans to install a medium-size EfW plant on their site (potentially offering up to 5 MWth of heating capacity). There would be potential for this capacity to be increased to 10MWth based on current waste throughputs, or up to c.50% of the total anticipated base load).

The carbon intensity of the available heat is expected to be very low and to remain low into the future. Additionally, the temperature offtake of any EfW heat export is expected to be high enough to serve a heat network without the need to use heat pumps to raise temperatures to those useful for a heat network. Powerday has significant time remaining on their lease, meaning they could remain a reasonably long-term energy supplier subject to a supportive planning framework, successful permitting applications, and appropriate contractual arrangements. In addition, the proximity of the proposed EfW facility to the development around Old Oak, means the costs of connecting low carbon heating infrastructure to nearby buildings is likely to be low.

With some of the earliest development coming forward now (e.g. Genesis and North Acton), low carbon heating from an EfW facility could form part of the masterplan energy strategy from the outset. Although subject to programme constraints, the upgrade and realignment of Victoria Road (linking the Old Oak site to North Acton) that is planned as part of the HS2 works offers a potential opportunity for installing DH pipework along this route as part of the works. Powerday has confirmed their interest in serving part (or more) of the new development. Initial calculations suggest that EfW could meet most of the baseline heat demands of the Car Giant site.

The potential air quality impacts and odours resulting from the proposed EfW facility will need to be considered further during the masterplan phase. However, OPDC should seek to protect Powerday as a potential heat source by ensuring any future planning approval for an EfW facility is conditional on there being a heat offtake and on the use of an advanced thermal technology rather than incineration. OPDC could also help protect the long term use of the site for waste treatment operations through a suitable land designation within the local plan.

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A.1.2.2.2 Sewer Heat Recovery

There are potentially large heat resources available in the local sewer network. This technology would use heat exchangers laid on the floor of sewers to extract heat from the sewerage flow, with heat pumps operating to increase the low-grade temperature. Although this would act only as an indirect heat source, requiring heat pumps to increase the temperature of a secondary loop to those required by an area-wide heat network, the warm source temperature (of the sewerage) would provide a significant source of low grade heat. It is anticipated that up to 3 MW would be available, should installations of heat recovery systems of the type used in France by Suez be deployed. (It is noted that other sewer heat recovery technologies are under development and trialled, which could potentially mean more heat could be recovered.) However, in order to maximise the potential of this resource, a number of local heat substations/energy centres would need to be installed around the Old Oak site. This is because the technology currently limits the length of heat exchangers arranged in series to approximately 200 m (in order to avoid hydraulic and pumping problems). Each 200 m length of heat exchangers is expected to produce 200 – 500 kW of heat. The heat capacity estimates provided in this note assume that 5 installations would be created close to energy centres delivered to serve each main phase of development. There is potential for greater implementation possibly directly serving individual development blocks. The commercial and contractual arrangements for exploiting such sources have yet to be tested in the UK. Thames Water is supportive of the principle of working with OPDC to pilot this technology at Old Oak.

A.1.2.2.3 Open Loop Boreholes

Another potential large heat resource is the London Aquifer. The aquifer is a large reservoir trapped in porous rock (e.g. chalk) deep underground, at a depth of c.100m. An open loop system could be installed in boreholes that allow water from the aquifer to be brought to the surface. This water (typically at c.14°C) would be used as a source medium for water-sourced heat pumps to elevate temperatures in a secondary circuit up to temperatures suitable for an area-wide heat network. In order to maintain aquifer water levels, the extracted water would need to be reinjected back into the reservoir after heat exchange has been undertaken. Similarly, in order to maintain aquifer temperatures, the temperature change of reinjected water, relative to the extracted water, would need to limited to c.10°C. Similarly, there would likely be limitations to the total amount of heat that could be extracted throughout the year. If abstraction rates of c.20 l/s per borehole were obtained, it is expected that up to c.1.2 MW of heat could be provided to a heat network via a heat pump. However, in order to avoid thermal short-circuiting of the aquifer reservoir, borehole pairs would need to be spaced significant distances from each other. This limits the potential use of the aquifer as a heat source, and would require borehole pairs to be spaced out across the Old Oak site. It is assumed that at least 5 borehole pairs could be accommodated and delivered close to energy centres or major load centres. In combination these could potentially deliver up to 6MW of heat based on water extraction rates obtained for other nearby boreholes. However, the water abstraction rate cannot be guaranteed until the borehole has been sunk, and this could significantly impact on estimated heat extraction should abstraction rates prove low.

A.1.2.2.4 Grand Union Canal

The Grand Union Canal can also be used as a significant low-grade heat source. Discussions with the Canals & Rivers Trust (CRT), and research into government sources[6], indicate that between 1 – 3 MW of heat can be extracted from the canal as a source medium for a water source heat pump. In the same way that the London Aquifer is used as a heat source, water would be extracted from the canal in order to extract heat from it, via a water source heat pump, before being pumped back into the canal at a lower temperature. Limitations on the temperature changes that CRT would allow in the canal will limit the amount of heat that could be extracted from the canal throughout the year. The use of this source will require an energy centre site to be safeguarded close to the canal as well as work to the canal wall to create a leat to house the water off-take equipment.

A.1.2.2.5 Heat Recovery from Data Centres

Heat recovery from nearby data centres (in particular the large Powergate facility to the immediate west of the Old Oak site), could be used as another low grade heat source. The high electrical loadings of data centres mean they often experience significant cooling loads, and therefore require significant heat rejection equipment. This low grade heat could be recovered for use as a source medium for heat pumping to serve an area-wide heat network. Although the greatest opportunity for heat recovery is during summer (when the opportunities for free cooling in the data centre are limited, and the ambient conditions could allow recovery

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of heat to occur at higher temperatures and therefore higher heating efficiencies), this is also when the demand for heat at Old Oak will be at its lowest. This non-coincidence between load and opportunity may be balanced however, if heat can be extracted efficiently during summer months and stored in seasonal storage facilities for use during winter months. A potential tie-up between heat recovery at the data centre/s and a ground source system such as the London Aquifer could provide an opportunity to maximise the use of these two technologies. This could involve excess heat being recovered from the data centre during the warm summer months, and stored underground in the aquifer for reuse during subsequent winter months. This could potentially increase the efficiency and scale of the aquifer's use as a heat resource during winter, while also maximising the efficiency of heat recovery from the data centre in the summer. However, such an approach would be subject to further detailed discussion with the Environment Agency (EA), on successful ground source water abstraction and rejection rates and close management of water and environmental temperatures. It is further noted that the potential heat recoverable from the data centre will depend on a detailed investigation of the technical challenges of implementation and the interest of the operator in enabling heat recovery.

As noted above many of these heat sources are low temperature sources that act as a source medium for heat pumps to elevate temperatures up to the operating temperature of a local heat network. In order to maximise the efficiency of the heat pumps, it would therefore be beneficial to reduce the operating temperatures of the heat network (typical operating temperatures of heat networks in the UK are c.80/60°C; reducing these to c.70/40°C would increase network and heat generation efficiencies). This would likely require significant intervention from OPDC and require standards to be set for the mechanical design for development coming forward, in order to ensure compatibility between the buildings and a low temperature network.

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A.2 Introduction

A.2.1 Context

The scale of the development projected to occur in the Old Oak area of West London is expected to have significant demands for energy, and in particular demand for heat for space heating and hot water. This Technical Note provides a high level assessment of the projected heat demand and discusses the strategies that could be deployed to service this demand. Potential strategies include:

- Traditional dwelling-based solutions (e.g. gas boiler systems);
- Block or plot based solutions (e.g. communal boiler systems); or
- Area-wide solutions (e.g. District Heat (DH) networks).

Traditional dwelling-based solutions in the UK utilise individual gas-fired boilers in each dwelling, providing space heating and domestic hot water. Because of the historically high carbon content of grid electricity, this strategy has offered a lower carbon strategy than grid electricity-driven heating systems (e.g. wall-mounted electric radiators or storage heaters). However, as the carbon content of grid electricity is being reduced rapidly, the advantage of individual gas-fired boilers over electrically-driven systems is being reduced.

In response to the priority of reducing carbon emissions, other lower carbon heating technologies have been deployed in recent years. The historically high carbon content of grid electricity, relative to natural gas, has meant gas fired Combined Heat and Power (CHP) provides a lower-carbon solution to gas boilers (because the electricity generated displaces high carbon electricity that would otherwise have to be supplied from the grid). CHP is best deployed at large scale (due to the increases in electrical generation efficiency and plant utilisation that comes with scale), so they have often been deployed for block/plot based solutions or in area-wide DH networks.

However, the reducing carbon content of grid electricity is now leading to the carbon saving benefits of gas CHP being eroded. A typical CHP-led district heating system is expected to generate heat with the same carbon intensity as that from a typical individual gas boiler when the carbon intensity of grid electricity falls to 0.341 $kgCO_2/kWh$[4]. For context, the current Building Regulations assume a carbon intensity for grid electricity of 0.519 $kgCO_2/kWh$. Although grid electricity carbon intensity fluctuates, depending on the load on the grid and the mix of generation technologies being deployed at any one time (e.g. wind, coal-fired power stations, nuclear), the value assumed for current Building Regulations is considered to be significantly higher than the current average year-round intensity. The Department for Business Energy and Industrial Strategy (BEIS) has recently launched a consultation on proposed changes to SAP (the Building Regulations compliance methodology for dwellings) including a proposal that the average grid CO_2 emissions factor is reduced from 0.519 currently to 0.398 $kgCO_2/kWh$.

Projections by a number of bodies suggest that the carbon intensity of grid electricity will continue to reduce significantly in the future. See Figure A.2.1 for projections through to the early 2040s. For more details and discussion of this analysis, please see *Technical Note – Carbon Emission Factor*, which is appended to the main report as Appendix F.

Analysis by Arup[3] (and quoted in Atkins' report[1]) indicates that the decarbonisation is expected to result in CHP ceasing to be a carbon saving technology by the early 2020's. This is in line with our own findings of the savings that would be reported in planning calculations, but it is important to recognise these calculations are based on grid-average carbon intensity for electricity. Government guidance[5] for appraisal of publicly funded projects is that when assessing the carbon savings arising from gas-fired CHP bespoke marginal carbon emission factor projections should be used for the electricity generated by CHP, not electric grid-average carbon intensity projections. This is to account for the anticipated interaction with the grid-based generators, whereby gas-CHP is expected to displace generation from gas-fired Combined Cycle Gas Turbine (CCGT) facilities rather than a weighted average of all generators (as implied by using grid-average figures). Using bespoke carbon intensity projections in the calculation of carbon emissions relating to gas-fired CHP is expected to delay the point at which gas-fired CHP becomes ineffective in reducing carbon

[4] Assuming gas boiler efficiency of 90%; CHP electrical efficiency of 38%; CHP thermal efficiency of 40%; district heating distribution losses of 10%; and gas carbon intensity of 0.216 $kgCO_2/kWh$ (current Building Regulations).
[5] Bespoke Gas CHP Policy: Summary of Analysis Results & Conclusions, Department of Energy & Climate Change, December 2014

emissions until approximately 2032. It could be later depending on the mix of marginal plant that is required to meet changes in electrical demand as the grid decarbonises.

The SAP emission factors for future compliance periods are based on a projection made by BRE in the recent SAP 2016 consultation. This sets a projection for emission factors applying to three year periods. .

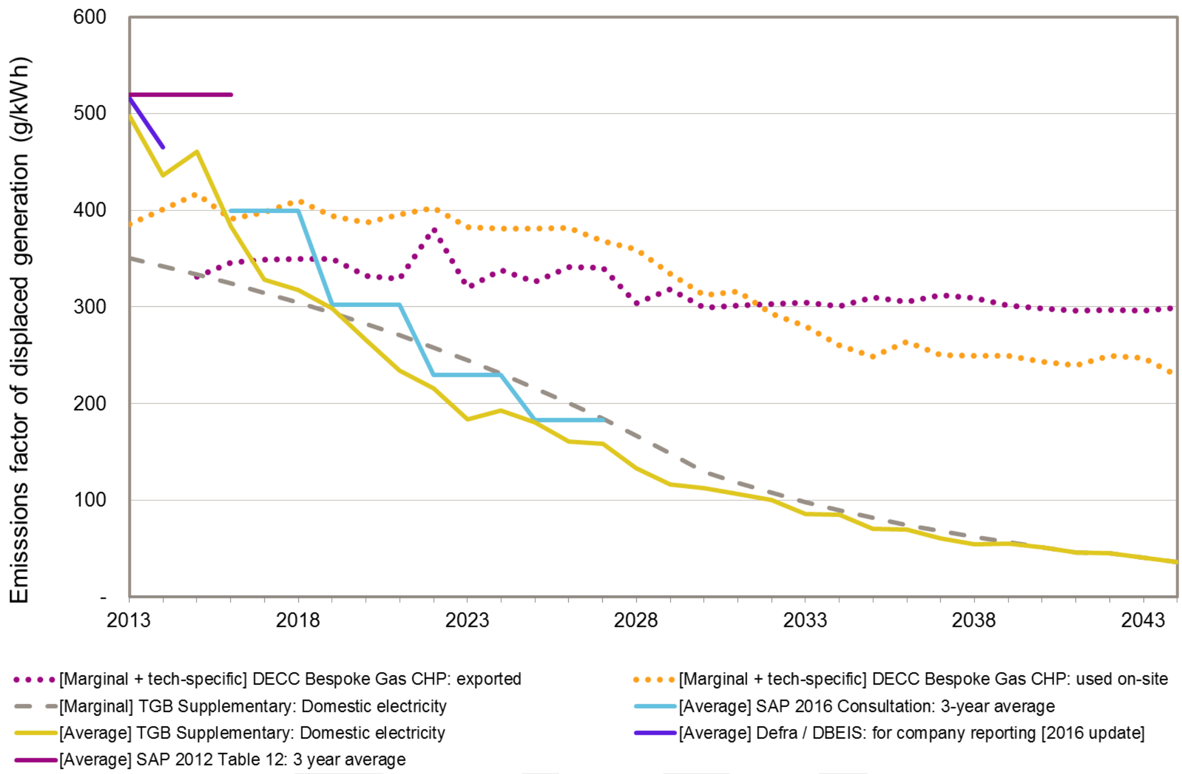

Figure A.2.1. Projected Carbon Intensity of Grid Electricity

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Decarbonisation of the electricity grid will lead to significant changes in the carbon intensity of available technologies that could be deployed to provide heating services to the development at Old Oak. Heat from electrically-driven systems (e.g. heat pumps) is expected to naturally decarbonise over time in line with grid decarbonisation, while heat from gas CHP will become more carbon intensive over time. Conventional gas boiler heating systems are expected to stay roughly stable (ignoring any potential decarbonisation of the mains gas supply due to increased injection of renewable gas supplies).

For these reasons, alternative heating strategies and heat sources need to be investigated in order to ensure the development at Old Oak future-proofs the low carbon supply of heating services as grid emission factors change. Part of this analysis needs to consider whether upfront investment in district energy solutions is expected to increase or reduce flexibility for maintaining cost effective provision of low carbon heat.

A.2.2 Projected Heat Demand

The demand for heat for anticipated development at Old Oak is expected to be significant. At full build out (using the development trajectory “v.7.11_Early Scenario for Planning”), the development will host 26,967 new dwelling units and approximately 814,000 m^2 of new commercial office accommodation. Although not defined in the development trajectory received by AECOM, the scheme is also expected to host additional facilities, including retail, leisure and community facilities, in addition to healthcare centres.

In order to accurately determine the impact of low carbon strategies and heat sources, detailed modelling of the heat loads encountered in each building type and their profiles will be required. However, to provide context for assessing the likely heat demands and the relative contribution that different heat sources could make to these, a high-level assessment of the expected heat loads has been made here.

The received development trajectory has been used to establish an approximate heat load build up over time. Please see Figure A.2.2. (Note that the load estimates account only for dwellings and commercial office space. It is expected that the total heat load, including all additional usage types, could be significantly larger than that shown in Figure A.2.2.)

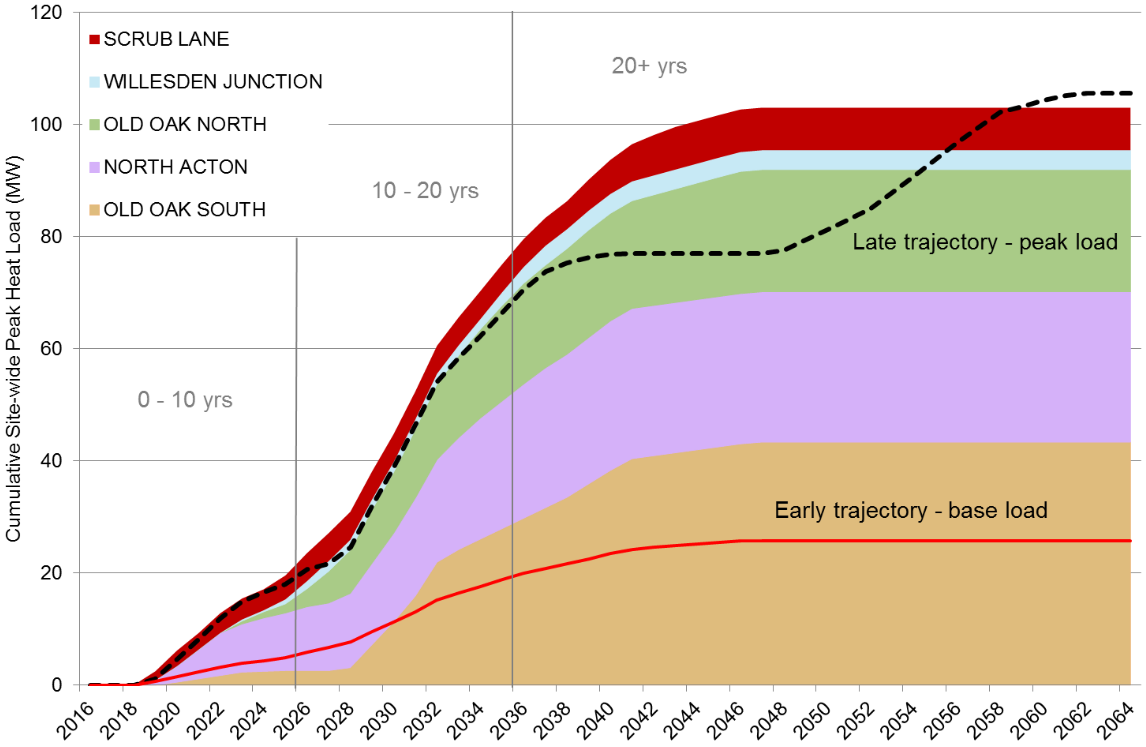

Figure A.2.2. Projected Peak Heat Demand

(Source: 'Phasing Trajectory v7.11_Early Scenario for Planning')

The load estimates have been calculated using the following high level assumptions for expected peak load conditions, and also accounts for simple diversity (the effect of not all customers requiring peak load services simultaneously).

- Dwellings: 40 kW peak provision for domestic hot water (DHW) heating

6% diversity for domestic hot water coincident loads

Space heating assumed not to be coincident with domestic hot water loads

Load requirement for space heating of c.35W/m^2 and 80% coincident diversity

- Offices: Space heating peak load of 70 W/m^2

70% coincident diversity

DHW heating load not considered

It is estimated that the Old Oak scheme will have a peak heat demand of 90 – 100 MW at the point of use (excl. non-office and non-residential accommodation), and an expected base load of 20-30 MW. Losses in distribution networks are expected to increase the demand for heat from thermal generators to above c.100 MW as shown in Figure A.2.2. Note that this demand assessment represents a worst case and makes no allowance for improved insulation standards over time. This is broadly in line with the analysis presented by Atkins[1].

The following outlines the available heating strategies.

A.2.3 Heating strategies

A.2.3.1 Demand Reduction

A number of strategies are available to ensure the development is provided with low carbon heating services. On the demand side, design specifications can impact significantly the demand for and consumption of heat. For dwellings, design and construction standards that meet Passivhaus standards (which require high levels of insulation and air tightness in excess of those required by Building Regulations) can reduce the demand for space heating significantly. While a typical high density development would expect annual space heating demand to be between 30 – 40 kWh/m^2, Passivhaus standards require a maximum of 15 kWh/m^2 (effectively more than halving the allowable demand for space heating). Passivhaus also requires the overall heating system energy input to be no greater than 10 kWh/m^2 (which effectively requires the use of systems such as heat recovery units to reduce the demand on the heating services). Passivhaus does not require limitations on the demand for domestic hot water.

Although building all Old Oak dwellings to Passivhaus standards would significantly reduce the demand for heat, requiring all new build dwellings to be built to the necessary standards would have significant cost impacts. There is, however, likely to be a case for improving efficiency standards to some degree.

On the supply side, conventional options for localised dwelling or block/plot based systems include Air Source Heat Pumps (ASHP), Ground Source Heat Pumps (GSHP), Solar Hot Water (SHW) systems, and solar Photovoltaic (PV) systems. A high level assessment of the likely applicability of these systems to the expected high density development of Old Oak is set out below.

A.2.3.2 Air Source Heat Pumps

ASHPs will inherently benefit from the future decarbonisation of grid electricity, with the carbon intensity of the heat provided reducing naturally as the electrical input to the system (mostly for operating the compressor) becomes less carbon intensive.

However, although ASHPs could be used on a per-dwelling basis, this would require fan-based evaporator units to be located on the façade of each dwelling. This is unlikely to be aesthetically acceptable, and is not expected to be an attractive solution for such a high-density scheme.

The use of ASHPs on a block/plot-based system is potentially viable, although there will be planning, architectural, and general arrangement challenges regarding where to locate the large evaporator units that would be required.

Owing to the size of the array that would be needed to provide significant quantities of heat, ASHPs are also not well suited to use on area-wide DH networks, where land will be at a premium, as energy centres would need to be much larger to accommodate the required evaporators.

A.2.3.3 Ground Source Heat Pumps

In much the same way as for ASHPs, GSHPs will also benefit from the future decarbonisation of grid electricity. However, the potential deployment of GSHPs could be constrained by the available land area, relative to the floor area of and number of homes being planned. For the taller buildings this may limit the proportion of the heat load that can be served, requiring back up from other systems potentially including gas or electric boilers.

GSHPs could contribute to a block/plot based system or DH network.

A.2.3.4 Solar Hot Water

Although SHW would also benefit from the decarbonisation of grid electricity, the Coefficient of Performance (CoP) of the system is so high that it is already a near-zero carbon heat source. While heat pumps operate compressors to generate heat, SHW systems are passive and require only a simple pump to circulate water around the panel and storage vessel.

In the UK well designed systems can typically meet around 50% of annual domestic hot water use although the actual utilisation will depend on occupant behaviour and the timing of hot water use.

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Roof mounted SHW systems could be deployed on a per dwelling basis, although they would need to be located close to each dwelling in order to reduce the pipe lengths from the solar collectors to the thermal storage tank. This would likely limit their use to apartments near the top of buildings, or provide only a small proportion of the heat demand if linked to a communal system.

Façade mounted evacuated tube solar collectors (see Figure A.2.3 for an example of façade-mounted solar thermal collectors in Sweden) could also be viable for unshaded south facing or south-west or south-east facing façades, but would require careful integration from an aesthetic and architectural perspective. SHW systems are best suited to low density development. While they could be deployed at Old Oak to meet the hot water needs of the upper floors of blocks or to apartments adjacent to unshaded south facing façades, their contribution to meeting overall heat demands may be constrained by the available area of unshaded roof and wall areas relative to the overall scale of development. Serving more than the upper floors from roof mounted panels can become inefficient and costly due to pipe lengths between the heat generation and supply point, and the significant riser spaces required to accommodate these pipes. While solar water heating should be encouraged, an additional system for meeting the majority of hot water demands will be required..

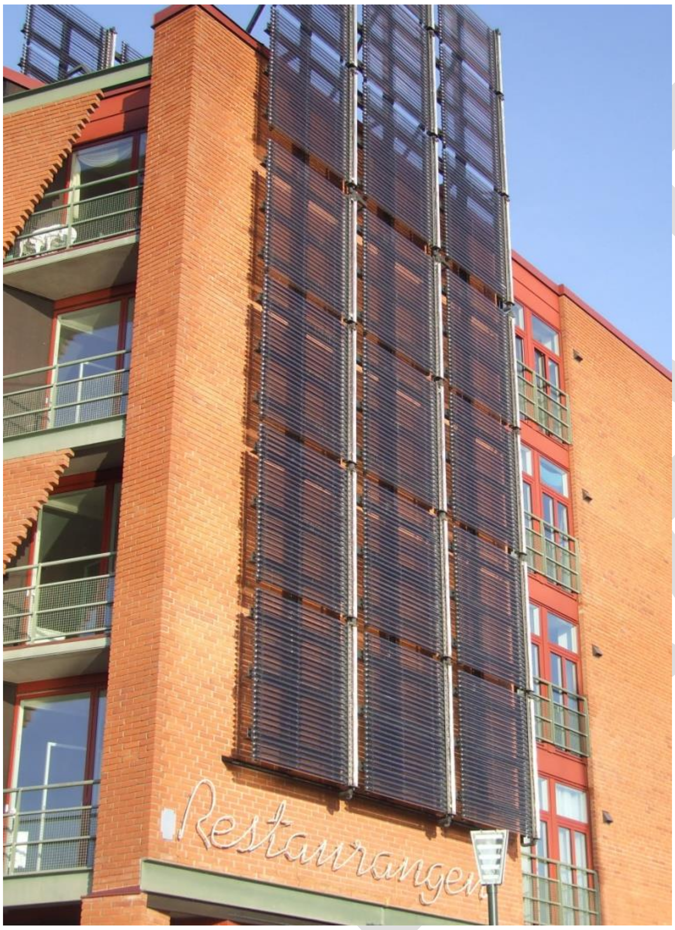

Figure A.2.3. Evacuated Tube Solar Thermal Collectors on Unshaded Facade (Western Harbour, Malmo, Sweden)

Some schemes have used ground-based solar collectors to provide hot water to communal heating systems or district heat systems. Work by Atkins to develop Environmental and Sustainability standards for OPDC has demonstrated that Old Oak is likely to have a relatively low proportion of open space. It is therefore unlikely that space would be available for ground based solar water heating panels directly feeding into district heating networks.

While the application of solar water heating is likely to be limited, ideally delivery models for Old Oak should seek to identify a model that would not preclude the use of low carbon renewable heat sources to provide at least part of the load.

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A.2.3.5 Solar Photovoltaic

Although solar PV is a zero carbon technology, the carbon benefits of solar PV will reduce over time, as the grid decarbonises. This is because the electricity generated by PV will be displacing electricity that becomes increasingly less carbon intensive. However, while the contribution that a given capacity of PV will make to meeting London Plan CO_2 reduction targets will reduce, it will remain a beneficial technology in terms of supplying local low carbon electricity.

While solar PV is not typically deployed directly for providing heating services, some system providers have utilised PV for hot water heating to exploit loopholes in the way Feed in Tariffs are administered. For smaller installations, payments for exported electricity are not metered and are based on typical assumed export rates based on the capacity of the system installed. These payments can effectively be supplemented by dumping the generated electricity into hot water heating via an immersion heater rather than exporting it as the tariff payment assumes. This effectively results in an additional income by reducing payments for DHW heating. As the grid decarbonises in the longer term, and there is a greater shift to electric-based heating, power generated from electricity could increasingly support heating. Currently it is typically fed into landlord supplies to maximise its use on site and to displace costly grid supplied electricity, but it could in future supply heat pumps and other electrically based heat sources. Development in cost effective battery storage could also increase the proportion of PV generated electricity that could be utilised on site rather than being exported.

Like solar water heating the contribution that PV can make to demands at Old Oak is expected to be limited by the available unshaded roof or façade area in relation to the overall development density. This will limit the contribution to either electrical or heating demands that building-integrated or roof-mounted PV could make. However, work by Atkins has estimated that around 20 MW_{peak} of PV might be integrated into buildings at Old Oak.

Expected cost reductions for PV manufacture and developments in thin film technologies (which have better generating properties in diffuse light) may increase the potential application of PV, with a greater ability to apply PV cost effectively to vertical facades or as an integrated film on the surface of glazing systems. These however would be subject to aesthetic and architectural considerations.

Overall, the expected physical constraints on dwelling-based and block/plot-based low carbon heating solutions are likely to favour area-wide DH solutions that can remove roof top and other plant from the buildinfs, provided they can be supplied by low carbon heat sources at a sufficiently low cost to be affordable to residents. In order to safeguard and future-proof the development for low-carbon heat solutions, alternative heat sources therefore need to be identified that could replace or operate alongside gas CHP as the carbon benefits of gas CHP decline.

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A.3 Potential Local Heat Sources For Communal or District Heating Schemes

The potential heat sources investigated in this Technical Note are:

- Water sources, including the:
  - London Aquifer;
  - Grand Union Canal and River Brent;
- Taylor's Lane Power Station;
- Powerday renewable fuels;
- Heat recovery from the sewage network;
- Heat recovery from transport tunnels, including:
  - Ventilation shafts;
  - Tunnel linings;
  - Water drainage from London Underground or other transport tunnels; and
- Heat recovery from data centres.

Where applicable, these heat sources are shown in Figure A.3.1.

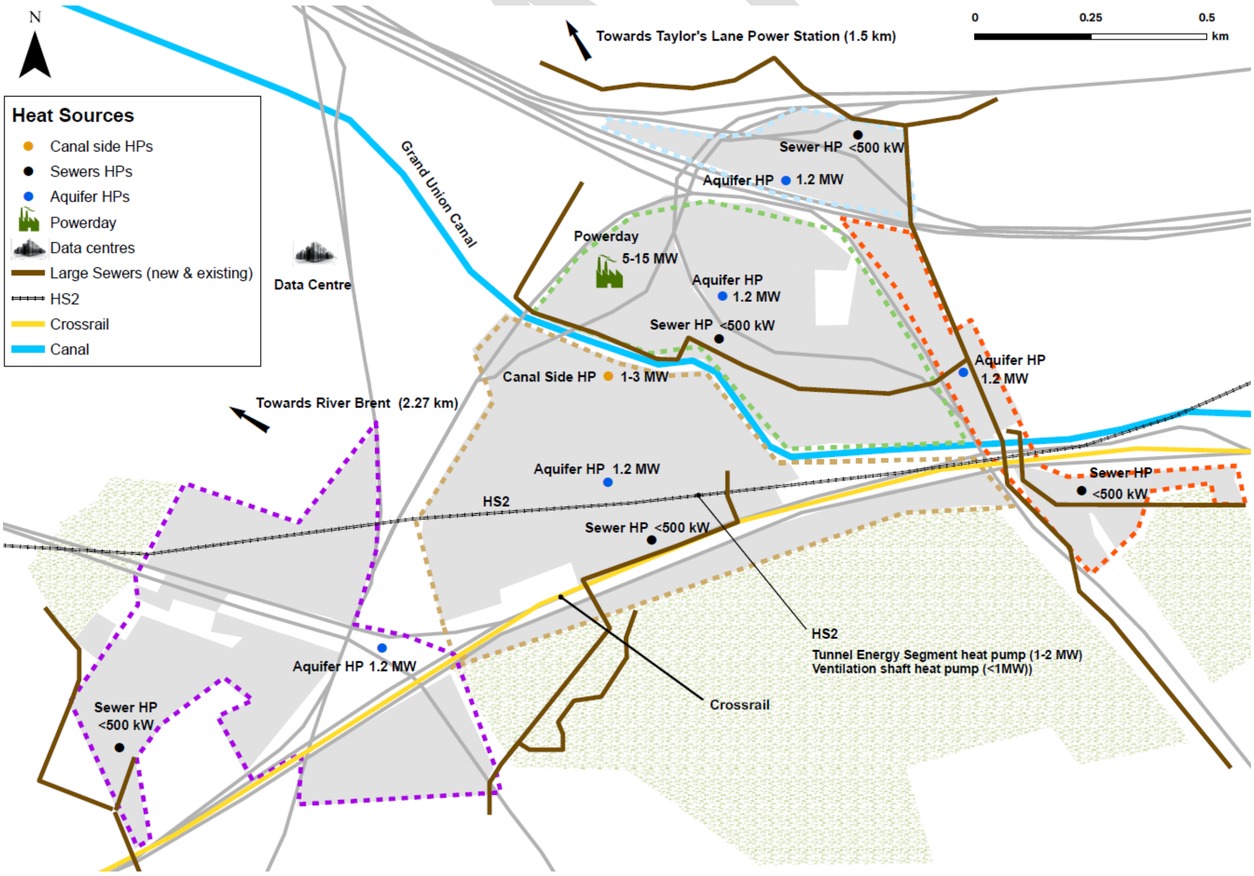

Figure A.3.1. Potential Heat Sources

The following sections discuss each technology in detail. The summary section at the end of this Note outlines the likely capacity of each of these potential heat sources, and the viability of their use, including the expected carbon content of the supplied heat and a qualitative high level assessment of their likely relative costs.

A.3.1 Water Sources

Heat pumps are electrically driven systems which raise the temperature from that of a heat source to a desired temperature which can be used to provide heating. They are typically used to service space heating systems, but can also be used to supply domestic hot water. The efficiency of heat pump systems are inversely proportional to the temperature 'uplift' achieved (i.e. the greater the uplift from the source temperature to the supply temperature, the less efficient the system).

Water source heat pumps (WSHP) utilise a large body of water as the heat source. The size and ability of the body of water to replenish any extracted heat via WSHP systems determines the thermal capacity (both the peak MW extraction, and the annual MWh extraction limits) which the WSHP can operate at.

The key water source options in the area include both surface water and sub-surface water.

A.3.1.1 Surface Water Abstraction for Heat Pumps

On the surface, the River Brent runs to the west of Park Royal industrial estate, while the Grand Union Canal runs through the northern half of the Old Oak site. Heat extraction from these resources would be undertaken using open-loop heat exchangers. This technology would extract water from the canal/river, in a process called abstraction. The water would then be pumped to a nearby heat exchanger, which would transfer heat from the water into a closed-loop circuit. The water would then be pumped back into the canal/river. The closed-loop circuit is then used as a heat source for the evaporator side of a heat pump serving the primary circuit of a DH network.

In addition to planning consent, the use of these resources as a source of heat would be conditional upon obtaining both an abstraction licence (for taking water from the canal/river) and an environmental permit (to enable discharge back into the canal/river). Abstraction licences and environmental permits can be obtained from the Environment Agency (EA). The EA develops Catchment Area Management plans typically on a 12 year cycle and licenses are therefore time limited and will need to be renewed. Possible reasons for non-renewal may include the licensee having a poor record of maintaining required water quality or temperature limits, of if the catchment area is being over exploited. The risk from the latter should to some extent be managed by the EA not offering licenses where they would be expected to have a detrimental impact on the water catchment.

There are a number of examples of using surface water resources such as rivers and canals as heat sources in the UK. While many of these examples utilise large rivers (e.g. the Thames), the most relevant example for Old Oak is the use of the Grand Union Canal to provide cooling for GlaxoSmithKline (GSK) at their headquarters building in Brentford. This scheme abstracts 2,400 m^3 of water per day in order to provide cooling to the company's data centre. Unwanted heat is discharged safely to the canal. GlaxoSmithKline estimates that up to 1,400 MWh of energy is saved each year, displacing approximately 276 tonnes of CO_2 and generating cost savings of around £180,000 per year. Please see the Attachment I at the end of this note for further details.

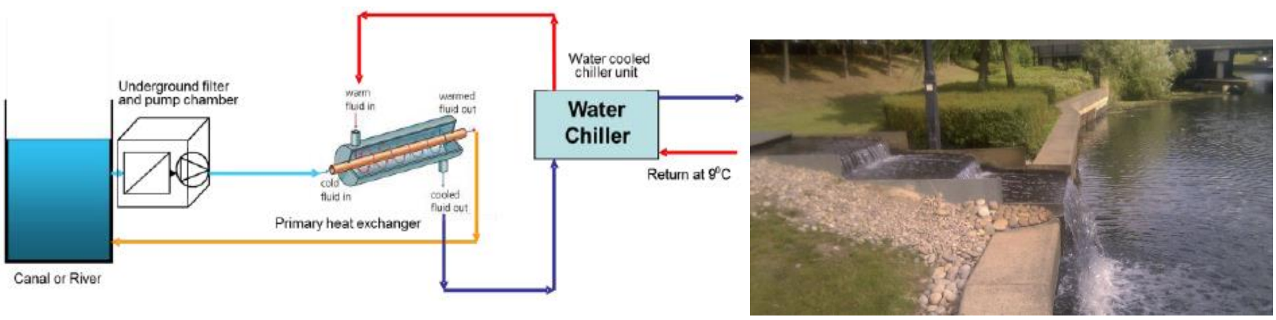

Figure A.3.2. Schematic Diagram of GSK System (left) and Return Water Discharge to Canal (right)

(Source: GSK)

The Department for Business, Energy and Industrial Strategy (BEIS), which provides a high-level assessment of available water heat sources via the National Heat Map[6], indicates that the River Brent can provide approximately 650 kW of heat capacity, while the Grand Union Canal in the area can provide 1.6 MW of heat capacity. Discussion with the CRT has confirmed that the canal in this area could provide between 1 – 3 MW of heat (but the exact figure would need to be determined by hydraulic modelling). It is likely that there will however be limitations on the total amount of heat that can be extracted over a given time period (either on a seasonal or annual basis). The potential for increasing the amount of extractable heat from the canal, by using it as a source of cooling in summer months is possible, although this would need to be confirmed through additional investigations and detailed modelling.

Given the proximity of the canal to major heat loads in the proposed development, compared to the River Brent (which runs to the west of the Park Royal industrial estate), the Grand Union Canal is considered the more viable heat source. Correspondence with the CRT has confirmed that the use of the Grand Union Canal in particular as a source of heat would be welcomed. In general the EA has greater concerns about warming London's water bodies rather than cooling them, although they can be used for cooling provided temperature limits are observed.

An open-loop system for extracting heat from the river or canal would require specialist equipment, including an abstraction facility for taking water from the canal known as a leat; a chamber for pumping, screening and filtration; pipework to take the filtered canal water to a plant room; and a heat exchanger to transfer heat to a second closed-loop circuit. It may be possible and desirable to locate the filtration chamber and/or heat exchanger in a plant room adjacent to the canal, in order to limit the pumping of canal water large distances to the heat exchanger. Further pipework would then be required from this initial heat exchanger to pump the closed-loop circuit to another plant room, where a heat pump would elevate temperatures in a third circuit to that required for the primary DH network. CRT has indicated that it may be possible to route pipework along or beneath the towpath beside the canal. Heat loss is likely to be limited by the relatively small temperature difference between the canal water and ground temperature, although reducing the distance between heat source and demand will reduce pumping energy requirements.

Surface water sources could be used to provide both heating in winter months, and cooling in summer months. However, careful design considerations would be needed to ensure the extraction and/or rejection of heat from these water sources does not breach limits on the amount of energy that can be sourced from them, and does not degrade their potential to offer a long-term and sustainable source of energy.

A.3.1.2 Borehole Water Abstraction for Heat Pumps

Sub-surface bodies of water that could potentially be used as a heat source include the London Aquifer. The bedrock geology in the London area, and in particular the area around Old Oak, is dominated by the London Clay Formation. Beneath this clay layer are further layers of rock, which include permeable formations known as the Chalk Basal Sands that comprise White Chalk, Thanet Sand and Lambeth Group Upnor Formation. These strata contain what is known as the London lower aquifer, a permanent body of water. Boreholes in the Old Oak area indicate that the depth to the top of the Chalk is between 80 – 95 metres below ground level (mbgl).

The Chalk is a low storage, high transmissivity aquifer, with flow and storage occurring in both fractures and in the rock matrix. Most flow occurs in the fractures, with storage in the matrix released to the fractures when groundwater levels fall. For open-loop ground source heat extraction, boreholes would usually be used to abstract and recharge from the Chalk. Transmissivity in the Chalk varies according to the fractured nature of the stratum; a more fractured zone often leads to greater transmissivity, and therefore the potential for greater extraction rates. The extraction rate cannot be guaranteed and will not be known with certainty until the borehole is sunk and pumping tests carried out, to obtain site-specific transmissivity values for the Chalk. Typically it can range from 15m^3/day to zones where hundreds of m^3/day are possible; Fry 2009[7] confirms that, of the sites that are active or undergoing investigations, the most common system design is a pair of wells where a non-consumptive abstraction of 10 – 20 l/s (864 – 1,728 m^3/day) is operated for combined heating and cooling. The EA confirms that in 2016 groundwater levels in Old Oak had risen in the preceding 5 – 6 years[8].

[6] http://tools.decc.gov.uk/nationalheatmap/
[7] Lessons from London: Regulation of open-loop ground source heat pumps in central London, V.A. Fry, May 2009
[8] Management of the London Basin Chalk Aquifer, Status Report 2016, Environment Agency

The London Aquifer could be used for heat extraction using the same broad principles as those used for canal/river heat sources, abstraction from the canal being replaced by pumped abstraction from a borehole sunk into the chalk. While there are examples of abstraction-only boreholes serving development in London (e.g. Portcullis House, Westminster and Sadlers Wells Theatre), it is likely that if multiple boreholes were being proposed the EA would require the abstracted water to be returned to the aquifer via a return borehole to maintain ground water levels; this is known as a doublet system. The rate and volume of water that can be utilised will be limited to the lowest value of the abstraction rate and the volume at which the water can be recharged back into the aquifer from the return borehole. When discharging heated or cooled water to the aquifer, the water is considered a pollutant and the groundwater temperature would require assessment to ensure that the heat is within guideline values. The EA recommend a maximum change in temperature of 10°C between abstraction and discharge. Risk assessment is required to demonstrate that there are no adverse environmental impacts associated with the discharge of heated waters.

In order to ensure thermal stability in the aquifer, the EA's preference is for a balance between heat reinjection to (in building cooling mode) and heat abstraction from (in building heating mode) groundwater doublet schemes. These doublet schemes however require boreholes to be sufficiently spaced in order to avoid thermal breakthrough (or 'thermal short circuiting') within the aquifer. Thermal short-circuiting occurs in instances where the cooler water discharge back into the aquifer (in heating mode) reduces the temperature of the warmer water within the aquifer. This thermal short-circuiting would result in lower efficiencies of the overall heating system. When providing new boreholes, the applicant will be required to demonstrate that they have not derogated the water extraction rate for existing boreholes in the area before a formal abstraction license is granted. Although a general rule for aquifers in the London area is that borehole doublet pairs should be spaced approximately 500m from each other, it is recommended that site-specific investigations, ground modelling and risk assessments are undertaken, as it is strongly influenced by the hydraulic gradient and the local fracturing and fracture connectivity within the Chalk layer. For reference, schemes in Central London are typically spaced between 250-500 m from adjacent systems[7].

In addition to the licences and permits required for using canals and rivers in this way, the use of the London aquifer would require a groundwater investigation consent to be obtained from the EA. Abstraction and discharge licenses would also be time dependent and subject to renewal.

The London Aquifer could be used to provide both heating in winter months, and cooling in summer months, or potentially simultaneous heating and cooling. However, careful design would be needed to ensure the extraction and/or rejection of heat from these water sources does not breach limits on the temperature and abstraction rates and volumes which EA will require to be monitored and which will limit the energy available.

The use of the London aquifer as a source of heat to serve the proposed development at Old Oak is considered technically challenging. A number of boreholes would need to be drilled, to a depth of c.100m in order to enable the abstraction of aquifer water and the discharge of water back into the aquifer. Submersible pumps are typically used to raise the water and these require clearance above the well head to enable pumps to be lifted for maintenance or replacement. Further equipment would be required, including a heat exchanger to transfer heat to a second closed-loop circuit, which may then need to be pumped to another plant room, where a heat pump would elevate temperatures on a third circuit (the primary DH circuit).

It is estimated that, with ideal spacing arrangements, approximately 12 pairs of doublet boreholes could be accommodated within the Old Oak area. However, given the potential constraints over the siting of boreholes and their proximity to energy centres, it is assumed that, for the purposes of this study, a maximum of 5 are likely to be able to be accommodated next to energy centres. It may be possible to accommodate additional boreholes in order to directly serve individual development plots; this should be assessed on an individual basis. Although testing would need to be done to ascertain the achievable flow rates from the initial borehole, 20 litre/sec for the achievable extraction rate (based on typical systems in the London area) would indicate that each doublet pair could provide approximately up to 1.2 MW of heating/cooling (accounting for the efficiency of the system). With a total of 5 doublets, aquifer heating could provide up to 6 MW of heating (25,000 MWh p.a.) to a heat network. It must be noted that the extraction rate will be highly dependent on the local properties of the chalk and extraction rates will not be known until the borehole is sunk.

An example of the use of the London Aquifer for this purpose includes the installation at St George Wharf development in Vauxhall. The residential building is currently the tallest building in the Vauxhall/Nine Elms area, and uses the London aquifer as the lead source of heating the building in the winter and cooling in the summer[9]. Other schemes in London include Portcuillis House, and the Royal Festival Hall[10].

A.3.2 Taylor's Lane Power Station

Taylor's Lane is a gas-fired power generating facility located approximately 2km to the north of the OPDC site boundary in Willesden. The site was commissioned in 1979, and is now operated by E-ON. The plant was originally designed for 132 MW electrical capacity; however, correspondence with E-ON confirms that the plant has since been downrated to 99 MW electrical power generation.

E-ON has also confirmed that the plant is only licensed to operate for a maximum of 100 hours per year and that the engines used are relatively old and have relatively poor characteristics in terms of their air quality impacts. E-ON has no immediate plans to upgrade the site and do not see the Taylor's Lane site providing an opportunity for heat or power provision for Old Oak. Had a heat source been available a major hurdle would have been routing this via the many infrastructure barriers between Taylors Lane and Old Oak.

This heat source has therefore been ruled out.

A.3.3 Powerday

Powerday operates the largest Materials Recycling Facilities (MRFs) in Southern England. Its main facility in London is located at Old Oak, approximately 300m south of Willesden Junction Tube and Overground station, and immediately to the north of the Grand Union Canal. The facility opened in 2006, leasing the land from Network Rail. It is understood that a significant length of time still remains on the current lease.

The facility at Old Oak is licenced to process approximately 1.6 million tonnes of construction and demolition waste, municipal waste, and commercial and industrial waste a year from across London and beyond[11]. Were the facility to process the maximum allowable under this licence, it would be able to process c.10% of all of London's waste generated every year (c.15 million tonnes[12]). The current site however, has the capacity to process approximately 50% of the licenced maximum (up to 800,000 tonnes p.a.).

The site operates 24 hours a day, 7 days a week, separating materials of value that can be resold to recycling facilities (e.g. wood products, hard plastics, metals and cardboard). Residual materials (which include soft plastics, small wood chips and unrecoverable paper and cardboard) are processed into Refuse Derived Fuels (RDF) or Solid Recovered Fuel (SRF) products. These products are currently transported off site by road for use in EfW plants throughout the UK and Europe. Powerday estimates that approximately 31% of the waste that arrives on site is eventually processed into RFDs or SRFs. The RDF and SRF typically have a biomass content of between 50-60% and are therefore considered relatively low carbon fuels. The specific energy content (MJ/kg) can be varied to suite the requirements of the end user. Powerday has indicated that it plans to further expand their customer markets.

Almost all of the material arriving and leaving the site is transported by road. However, road access to the site and the surrounding industrial area is problematic, with only two main access roads connecting the site to the main arterial roads (A40 and Harrow Road). Access to the Harrow Road is further restricted by a bridge on Scrubs Lane, over railway lines serving the Bakerloo Line, which is subject to an 18 tonne weight limit. A canal wharf has been built on site. However, it is understood this is not currently used for transporting material on and off site in a significant way. The site is also served by a railhead, which can be used for moving material on and off site. The licence for processing the maximum of 1.6 million tonnes requires a third to be delivered each by rail, road and water (i.e. the canal) and hence the mass that could be delivered by road would be limited to 533,000 tonnes.

[9] http://stgeorgewharfapartments.net/the-tower
[10] Open-loop ground source heat pumps and the groundwater systems: A literature review of current applications, regulations and problems, C. Abesser, British Geological Survey (Natural Environment Research Council), 2010
[11] http://www.powerday.co.uk/facilities/old-oak-sidings-materials-recycling-facility/100/
[12] London Plan 2015 (see para 5.68 of Policy 5.16 for 2012 figure)

Figure A.3.3. Powerday Commercial Waste Sorting and Recycling Centre.

(Note the fog mist in the image is water vapour used to supress dust.)

The Powerday site currently only processes incoming waste into RDFs and SRF, which is subsequently exported off site. Powerday does not currently operate an EfW plant on the site or nearby. In order for the site to be a viable and consistent source of heat for a DH network, an EfW plant would need to be operational. With the current Powerday facility providing significant quantities of RDFs and SRFs, the potential for the low carbon and renewable generation of heat and power is significant.

Powerday confirmed that they intend to install EfW equipment on site, with a number of capacity options under consideration (3 MWe, 5 MWe or 5.7 MWe). This would be subject to a successful planning application and the acquisition of necessary permits and licences. Planning applications for EfW sites often experience strong public opposition. GLA waste policy would not support direct incineration technologies, and approval is likely to be dependent on utilising advanced thermal processes to improve efficiency and limit emissions. Potential impacts on air quality and consideration of flue heights and topple distances to surrounding rail lines are some of the issues that would need to be considered if proposals come forward.

Powerday confirmed that their expectation would be for a grid connection to be installed in order to support the export of power generated directly to the electricity grid. However, not all the electricity generated will be exported, as the parasitic power of the Powerday site (i.e. the power requirements to support the site's operations) is approximately 2.2 MWe. Any excess power generated by a future EfW plant is expected to be exported to the grid but should a local electrical consumer be identified, whose demands are large enough to make the direct sale of electricity to them commercially viable, it is expected that Powerday would welcome a Private Purchase Agreement (PPA) with the 3rd party consumer. Network Rail or Transport for London (TfL) could potentially have substantial power demands. This could potentially be done via a Licence Lite mechanism.

Although the 'grades' of heat (i.e. temperature) from different technology options (generation via a steam turbine or reciprocating engine) would vary, it is expected that both technologies could support a well-designed and best practice heat network. For reference, steam turbine technology generates high-grade (i.e. high temperature) heat, in the form of steam, which can be used to generate hot water for a heat network. The heat recoverable from reciprocating engines however, is both high-grade (heat recovered from the high-temperature (c.450°C) flue/exhaust gases) and low-grade (c.90°C heat recovered from the 'engine jacket' used for cooling the engine). However, since a well-designed and best practice network should operate flow conditions below these temperatures, both technology choices are expected to be able to provide heat to any potential future heat network.

A 5.7 MWe EfW plant could require approximately 50,000 tonnes of RDF/SRF p.a. to operate. AECOM estimates that, based on the expected calorific value of the fuels (~13 MJ/kg[13]) and expected operating hours of c.8,000 p.a., the electrical efficiency of the EfW plant would be c.24%.

13 http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.showFile&rep=file&fil=ENERGY_WASTE_CERTH_2012_pres.pdf

The 50,000 tonnes of RDF/SRF p.a. fuel input (required to operate a 5.7 MWe EfW plant) would represent approximately 20% of the site's current total c.250,000 tonnes p.a. of RDF/SRF production capacity (produced from a current sorting capacity of 800,000 tonnes p.a. of received waste). At present, Powerday produce around 100,000 tonnes p.a. of RDF/SRF a year, which exceeds the minimum required to power the largest EfW plant that is currently being considered.

Figure A.3.4. Proposed Location for Powerday EfW Facility, with Railway Lines and Car Giant Site beyond

Were the Powerday site to operate at its full current operating capacity of 800,000 tonnes p.a. of waste received, the facility could produce approximately 250,000 tonnes of RDF/SRF p.a.

Heat pipework would need to be carefully routed to enable any export of heat generated on the Powerday site. Given the site location between the canal and a number of railway lines, options for routing the pipework off the site could include thrust boring beneath these infrastructure barriers. The current proposed location for the EfW plant is to the south east of their main warehouse and to the north west of the railway lines. There is potential to thrust bore under the railway to reach the large Car Giant site to the east of the site. The feasibility of this and acceptability to Network Rail would require further assessment.

Overall, the potential for Powerday to provide heat is considered significant. An EfW plant onsite could be a significant source of low-carbon heat for early phases of development, should Powerday be able to submit a successful planning application. A successful use of this heat source will rely on heat customers with a sufficient demand being identified, an operator being able to invest in the infrastructure required to connect supply with demand, and commercial terms and timing risks being acceptable to all parties. The capacity of the heat available could depend on the EfW technology adopted.

Local planning policy could be used to create a supportive environment for this technology by protecting the site for future waste use and by requiring that any EfW facilities are required to provide heat off-take to achieve planning approval.

Further investigations will need to address the potential air quality concerns associated with any new EfW facility.

A.3.4 Sewage Network

Sewage infrastructure carries warm material from which heat could potentially be recovered for use in a DH network. Systems such as this are gaining interest in both the UK and internationally.

Suez (of France) has experience of 15 case study installations of sewer heat recovery in France, and is seeking opportunities in the UK. In the UK, Thames Water and Suez are working on a pilot project in the London Borough of Haringey to trial heat recovery from sewers to supplement the heat provided by two existing gas-fired boilers serving a communal heating system for two tower blocks on an existing estate. As this project is currently under development, and would be the first of its kind in the UK, it will be a test bed for trialling the technology, and the potential commercial and contractual arrangements.

The technology consists of curved metal heat exchangers approximately 1m in length, which are designed to fit the profile of the sewer (see Figure A.3.5).

The units are designed to be small enough to be taken down through existing access chambers and then connected together in series along the bottom of the sewer to form a single length of heat exchanger. The maximum length that can currently be installed is 200m (maximum length is limited by pumping and hydraulic considerations). The panels are designed to have a thin profile so as not to obstruct the flow in the sewer, but are strong enough to ensure they allow maintenance engineers to walk over the top of them. Installation requires the sewer flow to be diverted for the few days the panels take to install. Water flows through the heat exchanger panels to provide heat to a heat network via heat pumps, which lift the temperature up to the desired flow temperature of the network. Works will be required to create a connection between the heat exchangers in the sewer and the network at the surface.

Figure A.3.5. Sewer Heat Recovery Plates Prior to Installation (left), and In Situ (right)

(Source: SUEZ, UK)

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The largest Suez scheme in France, at the Sainte-Geneviève in Nanterre, was opened in October 2011. It operates 2 no. 400 kW heat pumps over a length of 200 m of heat recovery units, serving 800 homes, a school and retail units. The flow in the sewer is typically in a temperature range of 15-21°C. Approximately 1,337 MWh of heat is recovered from waste water each year. [14]

Suez's installations typically achieve heat outputs of 2 – 5 kW/m^2 of heat exchanger (or c.1 – 2 kW/m of installation), with annual heat output of c.6 – 20 MWh/m p.a. (delivered to network). In the current absence of details on flow temperatures and flow rates for the sewers that cross Old Oak, these case study figures are used for analysis for the Old Oak area.

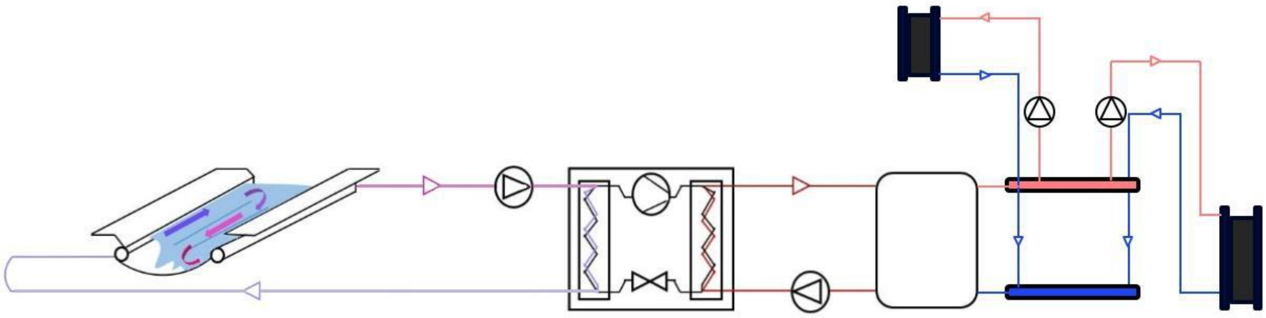

Figure A.3.6: Typical Sewer Heat Recovery Schematic of Suez System

[14] Recovery of sewer heat: 2 case studies on a district heating and a swimming pool application, Suez, October 2016

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Another example of heat recovery from sewers is in Vancouver, Canada, where the facility at Southeast False Creek Neighbourhood Energy Utility serves 395,000 m^2 of residential, commercial and institutional accommodation (including 4,389 residential units) via a 4.7 km DH network[15]. The facility, which combines a sewage pumping station and heat recovery units, began operations in 2010 after a C$30m investment. It supplies approximately 70% of the annual energy demand of its customers, with the remaining 30% being provided by top-up gas-fired boiler units. In 2015, the facility generated 30,172 MWh, and reduced CO_2 emissions by 2,436 tonnes (or 60% of the emissions associated with space heating and hot water provision in the buildings it serves). Further examples of heat recovery from sewers in North America include installations at Whistler, British Columbia and one currently being designed for the city of Denver, Colorado. Lessons learnt from these systems include the benefits that arise from using separate sewers for waste streams and surface run-off flows. Separating these systems allows heat recovery from the warm waste sewer at higher and more stable temperatures (i.e. not impacted by rain events), which increases operational efficiencies.

Thames Water believes that sewer heat recovery could offer significant potential at Old Oak, in addition to Thames Water's wider network. Thames Water[16] has indicated that they would potentially be interested in piloting the technology at Old Oak.

Opportunities at Old Oak could include the installation of heat recovery in existing sewers, or in the new sewer networks that would likely need to be installed to enable development at Old Oak. These could serve individual buildings, or a wider DH network.

There are a number of potential constraints that need to be considered however. These include physical constraints such as the sewer being large enough for installers to work within and install the panels, and access points large enough to get panels down and into place. The minimum diameter that is considered possible for people to work within a sewer is 900mm. Given the restrictions on the maximum length of heat exchangers that can be installed in series, should sewer heat recovery be extensively used it would require a number of heat substation plots. These could be co-located in individual development plots, or on available plots of land that are not planned for development. However, they would need to be located adjacent to the mains sewers that would be used for heat recovery. For the purposes of this study, it is estimated that a maximum of c.6 no. sewers could host 200 m length heat recovery systems in suitable locations for the heat to be usefully accessed.

The capacity of the heat that can be extracted is dependent both on the volume flow of the sewerage, but also the velocity at which it passes over the heat exchanger. As the temperature of the sewer material will fluctuate with rain events, it is likely that Thames Water would restrict the maximum temperature drop in the flow to no more than 5°C (detailed parameters would need to be developed for a specific project), in order to prevent the temperature in the sewer dropping to a point where it impacts the necessary microbial process at the treatment works further downstream. Thames Water has in previous discussions with AECOM indicated they would need to avoid the inflow temperature at the water treatment works dropping below 10°C.

Initial calculations indicate that between 1 – 3 MW of heat could be delivered to a local heat network from 6 number of heat recovery systems installed on the Old Oak estate[17]. Annual heat recovery could be between 8,000 – 12,000 MWh p.a.[18]

Were the potential for heat recovery from sewers to be taken forward, further technical analysis would need to be conducted to ascertain the capacity of the system, including consideration of the sewer dimensions, flow rates, routes and current access points for existing sewers that cross the Old Oak site, and the potential temperature of the flow in the sewer under typical conditions. AECOM has asked Thames Water to provide data they have on temperatures and flows in the local network; however, it appears unlikely Thames Water currently collect this data but they have indicated it would be relatively easy for them to install a simple monitoring device.

Contractual agreements between OPDC and Thames Water would likely need to cover the cost of heat (which could be informed by the pilot scheme, currently being undertaken in Haringey), that would take

[15] http://vancouver.ca/home-property-development/southeast-false-creek-neighbourhood-energy-utility.aspx
[16] Nick Mills, head of Waste Water Innovation at meeting on 7th November
[17] Based on 6 number of 200 m length sewer heat recovery installations, recovering between 1.1 – 2.8 kW/m heat from sewer. This is raised to network operating temperatures via a heat pump (CoP 2.9). Assumed deltaT of sewerage of 5°C.
[18] Based on 6 number of 200 m length sewer heat recovery installations, recovering between 7 – 10 MWh/m of heat from sewer. This is raised to network operating temperatures via a heat pump (CoP 2.9). Assumed deltaT of sewerage of 5°C.

account of installation costs, operational cost implications, and the costs for reaching contractual agreements. Agreements would need to address future access arrangements for maintenance, protections around restrictions to flow, any limitations on the capacity of heat that can be extracted, the impact on sewerage flow temperature, the responsibility for maintenance or repair costs for the sewer, and compensation agreements.

Subject to the considerations identified above and being able to develop an acceptable commercial position for Thames Water and the heat provider/customer, there appears to be no obvious technical barriers that would prevent this technology being deployed in sewers of a suitable dimension. The fact that schemes have been delivered successfully in other countries suggests that it may be possible to agree acceptable commercial arrangements and this technology is considered to be worth pursuing further.

A.3.5 Transport Tunnels

With subterranean railway tunnels experiencing elevated temperatures throughout the year (due to the heat generated by platform activities and the acceleration and breaking of trains), there is the potential to recover significant amounts of heat. Heat recovery from subterranean transport infrastructure can be achieved through the deployment of a number of technologies (including air-source, ground-source and water-source heat pumps). These include the recovery of heat from warm tunnel ventilation air, from the tunnel wall lining materials, or from pumped drainage water.

The recovery of heat from subterranean tunnels or transport infrastructure is potentially an option for enabling low-carbon heat infrastructure on the OPDC site. This is particularly so given the significant railway infrastructure that will be installed in or nearby to the Old Oak area.

A.3.5.1 Ventilation Heat Recovery

The recovery of heat from warm ventilation air can be achieved by placing heat recovery units (modified air source heat pumps) in the warm air currents rising through ventilation shafts. The first system of this kind will be installed to serve the Bunhill Heat and Power scheme in the London Borough of Islington. Correspondence with the Decentralised Energy Project Officer at Islington Council has confirmed that the system operates in a ventilation shaft which discharges approximately 70 m^3/s of air from the tunnels serving the Northern Line. As the Northern Line is a deep-set line on the London Underground network, the temperature of the discharged air varies between 14-30°C, depending on the time of day and the season. Whilst these temperatures are too low to serve a DH network directly (the Bunhill scheme operates heat pumps to provide water at 80°C), the temperatures are significantly higher than ambient. This results in significant efficiency gains for the heat pump compared to conventional heat pumps operating in ambient air[19].

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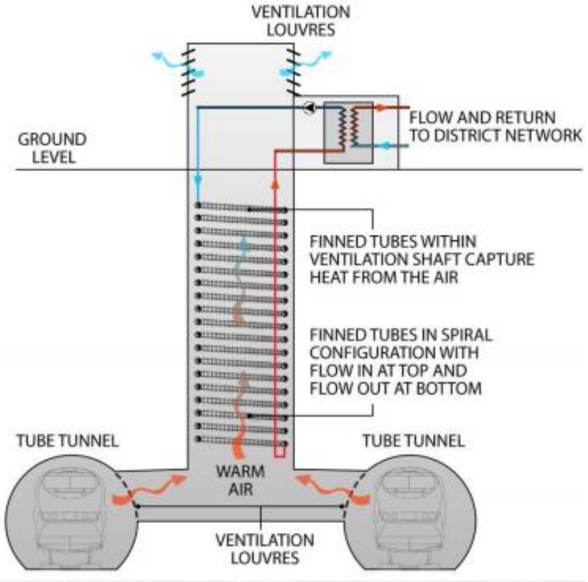

[19] Net gain in efficiency would vary, and be dependent on the elevation in temperature from ambient conditions and the temperature at which the heat pump provide heat to the heat network

Figure A.3.7. Heat recovery from metro tunnels

(c/o Secondary Heat: London's Zero Carbon Energy Resource, GLA[20])

The conditions within the Bunhill ventilation shaft enable significant quantities of low-grade heat to be recovered; the Project Officer has indicated that a 1 MWth heat pump will be installed (at the time of writing, the system is under construction, with the ventilation shaft currently being rebuilt by London Underground). However, the heat pumps and heat exchangers require specific design characteristics to enable their effective operation. This is due to the high particulate content of the ventilation air, which is expected to result in challenging and potentially corrosive operating environments. Other technical challenges include the high pressure loadings (due to tube train movements) on the fans used to ensure air flow rates are maintained. Correspondence with the Project Officer for the Bunhill scheme has indicated that there are potentially other technologies (such as those outlined below) that may be less challenging from a technical/maintenance perspective. The Decentralised Energy Project Officer has indicated that the system is expected to meet a large proportion of the load for the full network for most of the year, and all the load in summer.

The new transport infrastructure planned for the Old Oak area will require ventilation facilities to enable effective and safe operation. However, the Crossrail route will be a surface line when it reaches the Old Oak area[21]. Although there are likely to be some subsurface activities for any potential future Old Oak Crossrail station, the potential for significant ventilation needs for subsurface Crossrail activities will be minimal.

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[20] http://www.bre.co.uk/filelibrary/events/BRE%20Events/Developing%20heat%20networks/Peter_north.pdf
[21] http://www.networkrail.co.uk/improvements/crossrail/

The proposed High Speed 2 (HS2) line is expected to operate in bored tunnels throughout its route in the Old Oak area[22]. These tunnels will require ventilation shafts to operate along the route to enable effective air dispersion within the tunnels as the trains operate. According to a recent paper on journey times and frequencies[23], HS2 will operate up to 18 trains per hour, with each train carrying up to 1,100 passengers. (For reference, typical Northern Line trains at the Bunhill ventilation heat recovery facility can carry up to 665 passengers[24].) It is therefore expected that the recoverable heat from any potential future HS2 tunnel ventilation shaft could be roughly comparable to the heat recovery expected at the Bunhill facility (peak output of 1 MWth, with total annual heat provided to a local heat network approximately 3,000 – 4,000 MWh p.a.).

However, discussions with HS2 Ltd have confirmed that the main tunnel ventilation shafts are expected to be located outside the Old Oak area. The exceptions to this include the ventilation shafts serving the new HS2 station. It is expected that, were HS2 to be supportive of heat recovery from warm ventilation air, it would be best utilised to serve the operations of the HS2 station itself, rather than a larger area-wide network subject to further assessment of station demands.

It has been concluded that tunnel ventilation heat recovery is unlikely to provide a major heat source for heat networks at Old Oak, however, the opportunity for heat recovery from the HS2 Station ventilation shaft should be considered by those bringing forward the station design and this could be addressed through future planning discussions with HS2.

A.3.5.2 Tunnel Lining Heat Recovery

Heat recovery from tunnel wall linings was considered for a demonstration tunnel between Tottenham Court Road and Fisher Street shaft on the Crossrail line. The technology, known as Tunnel Energy Segments (TES), was designed to use embedded pipework within the tunnel lining concrete segments, through which water would be pumped in a closed loop heat pump system. This is effectively a ground source system, utilising a source medium which is warmer than normal ground conditions at the same depth.

Nicholson et al[25] estimated that, for a 500m stretch of tunnel, TES could provide approximately 1,200 MWh of heat annually. Heat extraction could peak at approximately 30 W/m^2 of tunnel surface area (approximately 600 W/m tunnel length), with an average heat extraction of 13 W/m^2 (250 W/m). The same source also estimates that the manufacture and installation of the TES system would cost between £400 and £530 per metre run of tunnel. It is understood that this technology was not proposed for inclusion in the Crossrail construction.

It is understood that the use of TES technology was also considered in a submission to the London Underground Board for inclusion in the Northern Line Extension (NLE), currently under construction. While the concepts and principles were considered to be well formed, hurdles such as the approval of materials and the Operation and Maintenance (O&M) impacts of the scheme (whole life impact and those related to warranty) were considered significant. As a result, it is understood that the use of this technology was not proposed for the NLE.

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[22] http://interactive-map.hs2.org.uk/
[23] Journey Times and Frequencies, HS2: Engine for growth, July 2013 (http://assets.hs2.org.uk/sites/default/files/consulation_library/pdf/P2C37_Journey%20times%20and%20frequencies%20LOW.pdf)
[24] https://tfl.gov.uk/corporate/about-tfl/what-we-do/london-underground/rolling-stock
[25] The Design of Thermal Tunnel Energy Segments for Crossrail, UK, Nicholson et al, Institute of Civil Engineers, Engineering Sustainability Volume 167 Issue E53

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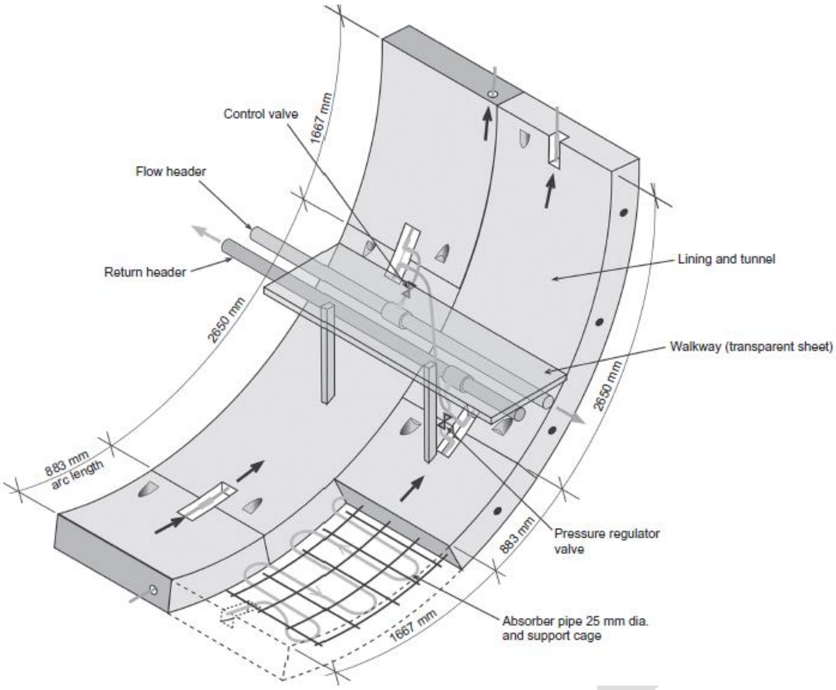

Figure A.3.8. Schematic Diagram of TES Design

(Source: Institute of Civil Engineers[26])

Efficiency gains on the heat pumps used to supply a heat network which sources heat from TES technology are achieved through the relatively high temperatures of the heat source (relative to ground temperatures in areas not affected by tunnel heat build-up). While the technology represents a significant source of heat, its recovery through this technology is considered technically and logistically challenging, given the need to install the TES system during the construction of the tunnels, the pressure testing required for each segment as it is installed, and the potential access problems associated with maintenance.

The Old Oak site is surrounded by many key railway lines, some of which also dissect the site. Although many of these lines are surface lines in this area (including Crossrail), the proposed High Speed 2 (HS2) line is expected to be tunnelled in the Old Oak area. As a conservative estimate, approximately 2.5 km of HS2 tunnels crossing the central Old Oak site (between Scrubs Lane and Old Oak Lane, including both east and west tunnels) could be fitted with the TES technology that was examined for Crossrail and considered for the NLE. Calculations indicate that the potential recoverable heat from the tunnels in the immediate area around Old Oak could amount to approximately 5,000 MWh p.a., with a peak output of between 1 – 2 MW. Given that additional lengths of tunnels could be fitted with TES technology, extending outwards from the core Old Oak area bounded by Scrubs Lane and Old Oak Lane, there may be potential for larger quantities of heat to be recovered. However, the baseline figures used for this analysis assumed the same heat output predicted for Crossrail would also apply to the HS2 tunnels. This may not be achievable, given the likely less frequent services of HS2 compared to Crossrail.

Further potential challenges in relation to this technology being deployed successfully at Old Oak include the required dependence on successful cooperation with HS2 in the design, construction and operation of TESs in the tunnels. Discussions with HS2 Ltd have confirmed that TES technology was considered for use on HS2 but will not be taken forward.

It has been concluded that TES will not provide a source of heat for heat networks at Old Oak.

A.3.5.3 Tunnel Drainage Heat Recovery

Tunnel drainage water could also potentially be used as a source of heat. This drainage water collects in tunnels as it leaches out of the surrounding earth. In order to stop flooding of the track, pipes are laid below the ground alongside and beneath tracks to redirect surface water away from the railway and back into the

[26] The design of thermal tunnel energy segments for Crossrail, UK, Nicholson et al, Institute of Civil Engineers, Volume 167, Issue ES3

water table. This constant maintenance ensures the safe operation of the railway, while also ensuring the rails and the sleepers that support the rails are kept in good working order. (Transport for London (TfL) estimates that this maintenance extends the life of the track from 20 years to between 45-60 years.[27])

This option would effectively utilise water source heat pumps to extract low grade heat from drainage water. Efficiency gains on the heat pump are achieved through the same principles as those described above; the temperature of the water relative to other sources of heat at the surface means increases the efficiency of the heat pump.

Discussions with HS2 indicate that tunnel drainage will be designed to direct tunnel water to sumps at the bottom of the tunnel vent shafts which are outside the Old Oak area where it will be pumped out. The tunnel gradient falls away in both directions from the station which is elevated to assist with breaking and acceleration of stopping trains; the vent shafts are located at a low point on the line. As the extraction points are outside the Old Oak area, it is unlikely tunnel drainage water would provide a viable source of heat. While initial discussions with HS2 did not determine the likely volume of water, the expectation is that volumes would be relatively small and unlikely to offer a major heat source.

It has been concluded that tunnel water extraction is unlikely to provide a significant heat source for Old Oak.

A.3.6 Heat Recovery from Data Centres

Data centres are used extensively to host data servers. The Powergate data centre is an example of a data centre in the Park Royal estate, located approximately 600 m west of the Powerday site (see Figure A.3.9), it is a large data centre that provides approximately 15,000 m^2 of data centre space and 29 MW of customer data capacity.

Figure A.3.9. Location of Powergate Datacentre (in red), with Powerday (in blue) for Reference

Owing to their very high data rack power densities (up to 20 kW per rack, or 2 kW/m^2), data centres typically have very high year-round cooling requirements. While some of this cooling can be undertaken using free cooling during the winter months, for most of the year, active mechanical cooling is required. Publicly available data suggests the facility is fitted with a maximum of 36 MW of cooling capacity (plus redundancy), provided via chilled water systems. Chilled water systems circulate water in flow/return pipework to provide cooling (flow temperatures are typically c.6°C, return c.12°C), with the temperature difference serving the cooling load. Chillers and heat rejection units (cooling towers) are used to reduce the temperature of the return chilled water back down to supply temperatures.

[27] https://tfl.gov.uk/campaign/tube-improvements/behind-the-scenes/track-renewal?intcmp=21272

This is a significant source of low-grade heat, with an expected peak heat rejection of c.40 MW, which could potentially be recovered. An illustration of how this could be done is shown in Figure A.3.10. There are however, a number of key constraints on the amount and temperature of the heat that could be recovered.

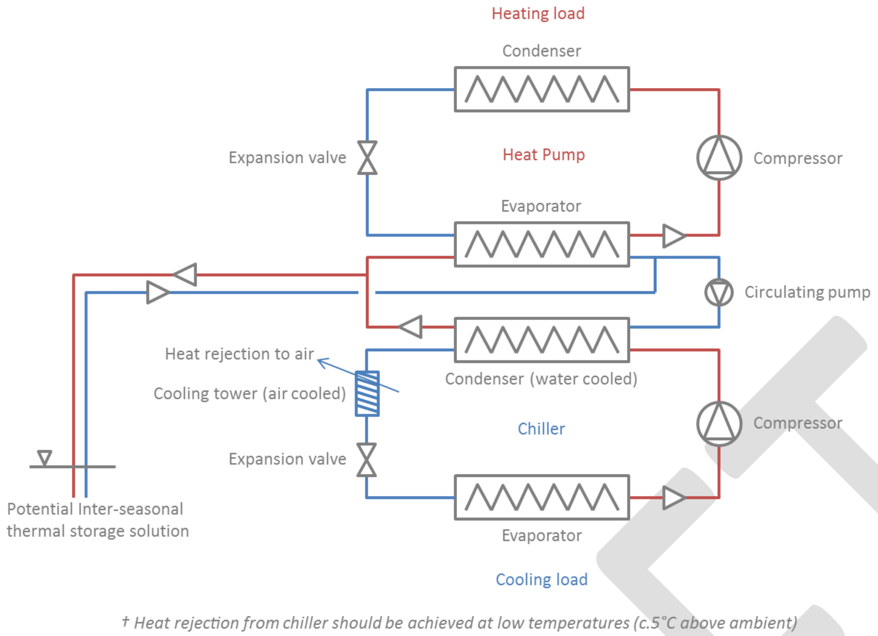

Figure A.3.10. Schematic of Potential Heat Recovery from Data Centre Cooling Equipment

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It is understood that the facility makes use of free cooling at certain times of the year, thereby significantly reducing the potential for recovering heat during winter and shoulder seasons for use in an area-wide heat network. The 40 MW heat rejection through mechanical chiller work that is seen in peak summer conditions, is therefore significantly reduced in non-peak seasons, perhaps to c.10 MW.

Additionally, the sensitivity of operating temperatures on the efficiency at which the data centre's chiller plant operates significantly limits the temperature at which heat can be recovered from the cooling system. In order not to negatively impact the efficiency of the data centre's cooling plant, the temperature on to the heat pump evaporator (which serves to cool the condenser on the chiller unit) should not be more than c.5°C above ambient[28]. This means that, during summer, when ambient temperatures are high (c.25 – 30°C), heat could potentially be recovered at c.30 – 35°C. However, during winter, when ambient temperatures are low (c.5°C), heat recovery could only be undertaken at c.10°C.

These low-temperatures of heat rejection from the cooling plant will therefore not be able to serve as a direct heat source for use in an area-wide district heating system. However, it could act as an indirect heat source, whereby heat pumps use the rejected heat as a source to supply heat at the temperature used in the supply route of the local heat network. However, since the heat source is likely to be only c.5°C higher than ambient, the benefit, compared to ambient-air sourced heat pumps, could be limited.

Although the temperatures at which heat is recovered could be increased (thereby increasing the efficiency of the heat pump operation), the resulting reduction of the chiller unit operation would likely mean that a compensatory regime, that facilitates additional payments from the heat network to the data centre, would need to be put in place. This additional payment would need to offset the reduced efficiencies, and therefore increased energy consumption, at the data centre. A further point to note is that the net effect, of increasing the temperature at which heat is recovered, on the carbon efficiency of energy use (in both the data centre cooling system and the heat recovered for use in a heat network) would remain the same (i.e. the decreased carbon intensity of the heat output from a heat pump sourced by rejected heat at the data centre, would be counterbalanced by the increased carbon intensity of the cooling output from the data centre chillers).

[28] c.5°C allows for the increased specific heat capacity of water, compared to air, and therefore the effectiveness of water to act as a cooling medium, compared to air. This is important, since the absence of heat exchange through water onto a heat pump circuit would mean that heat rejection from the data centre's chillers would need to occur via an air-cooled cooling tower.

These constraints and considerations mean that the optimum use of data centres as a heat source is during summer periods, when the mechanical cooling load at the data centre is highest, and when ambient conditions mean that heat can be recovered at a temperature that would allow efficient operation of a heating-load oriented heat pump. However, an area-wide heat network at Old Oak will experience low heat loads during summer, due to the absence of a space heating demand (DHW loads will likely be the main load during summer months). This non-coincident alignment of load and maximum opportunity means the effective use of data centre heat recovery is limited, unless it is coupled with inter-seasonal thermal storage.

Potential inter-seasonal thermal storage solutions could potentially include injection of heat into the London Aquifer, or other sub-surface ground-based storage systems during warm summer months, for extraction later in the year during colder winter months when the demand for heat is high.

A further barrier to use of heat from an existing data centre will be the priority of the data centre operator to maintain maximum operational resilience. Ensuring resilience of data storage will far outweigh any consideration of energy cost or carbon emissions and hence there is no guarantee that an operator would be willing to explore the retrofitting of technology that may be perceived to add risk to their operation. Further detailed discussions would be required with any data centre operator to explore their attitude to this risk, these have not been held to date.

Furthermore, the data centre is located some distance from the Old Oak site, which would involve significant costs to run primary pipework to the data centre and obtain the necessary consents for doing so. It is noted that the proposed HS2 logistics tunnel, that is being considered to carry excavated material (EM) from the tunnel boring activities to the rail head for disposal, would pass relatively close to the data centre. In future, this tunnel could potentially provide a route for heat network pipes subject to no other use being identified by HS2. There would be challenges making connections from the tunnel to energy centres or points of load at the surface and the likely ongoing maintenance requirements for the tunnel would need to be considered. It is also not guaranteed that the appointed tunnel contractor would pursue the construction of a logistics tunnel as their preferred method of disposing of EM.

It has been concluded that while heat could potentially be recovered from the data centre, there are some significant challenges to the deliverability of this option, but it should not be ruled out at this stage.

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A.4 Summary

A.4.1 Heat source capacity

The approximate capacity of each of the heat sources is indicated in Table A.4.1, for both peak capacity output (MW) and total annual energy output (MWh p.a.).

Heat source	Heat delivered to network (MWth)	Heat delivered to network (MWh p.a.)	Comment
Grand Union Canal heat pump	1 – 3	5,000 – 13,000	Hydraulic modelling will be needed to confirm outputs once specific demand profiles and proposed operating temperatures are known.
London aquifer heat pump	<1.2 (per borehole)	<25,000 (5 no. boreholes)	Ground hydraulic modelling will be required to determine minimum distances between boreholes. Outputs will be unknown until boreholes have been sunk and pumping tests carried out. Balanced heat extraction & injection likely to be favoured by the EA.
Taylor's Lane Power Station heat recovery	-	-	Communications with E-ON have confirmed that E-ON do not consider the use of current facilities as a viable source of waste heat.
Energy from Waste	3 – 10 (potentially more)	24,000 – 80,000	Capacity based on planned EfW facility.
Sewage network heat pump	200 – 500 kW (per installation)	8,000 – 12,000 (6 no. installations)	Based on 6 no. 200 m length heat recovery installations in existing sewers with diameter >900 mm (considered accessible).
Ventilation shaft heat pump	<1	3,000 – 4,000	Based on 1 no. ventilation shaft
Tunnel Energy Segment heat pump	1 – 2	>5,000	Based on estimated 13 W/m^2 heat extraction for 6.2 m diameter tunnel between Scrubs Lane and Old Oak Lane. [29]
Tunnel drainage heat pump	Negligible	Negligible	Outputs expected to be small and likely drainage points outside Old Oak area.
Data centre heat recovery	TBC	TBC	Capacity will vary seasonally and would be subject to more detailed technical assessment and detailed design considerations.
Gas-fired CHP comparison	Any capacity	Any capacity	Would ideally be sized to meet the base load, and to operate c.6,000 hours p.a. CHP could operate as a part of a multi-energy source Energy Centre.

Table A.4.1. Approximate Heat Capacity of Heat Source

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A.4.2 Heat Source Carbon Content

Table A.4.2 provides an indication of the expected carbon intensity of the heat generated from the various sources discussed in this Technical Note. The SAP 2012 figures are based on the current fuel type emission factors that support calculations in Part L of Building Regulations and which would be used by developers submitting applications today. The second column (SAP 2016) uses the emission factors that BEIS have recently proposed as part of a consultation on updated emission factors for a proposed revised SAP 2016. These include the assumption that average emission factors for grid electricity drop from 0.519 $kgCO_2/kWh$ to 0.398 $kgCO_2/kWh$. The SAP 2016 figures are intended to indicate the substantial impact that even these

[29] The design of thermal tunnel energy segments for Crossrail, UK, Nicholson et al, Institute of Civil Engineers, Engineering Sustainability, Volume 167,Issue ES3, June 2014

early changes to electricity grid emission factors would have on relative emissions of heat pump based technologies compared with gas CHP.

The carbon intensities associated with the use of heat pumps are dependent on both the temperature of the source medium (e.g. water temperature) and the supply temperature to the network. The figures for heat pumps assume a low temperature heat network would be deployed with a supply temperature of 70°C. A good practice heat network serving Old Oak should ideally be designed to operate at a low temperature as this will improve system efficiency. The figures for conventional CHP comparator assumed an 80°C supply temperature.

It should be noted that the emissions factors shown are for the generator with allowance for the losses in the distribution network. They do not however take account of the combination of technologies that would likely be needed to run a network from a practical perspective. For example a gas CHP engine cannot meet 100% of the heat load for technical and economic reasons, and typically if gas CHP is the main heat source serving a network, gas boilers will be providing 20 to 40% of the heat on an annual basis depending on how well the system is designed and operated.

It is likely that a best practice network would have primary network losses (losses from the generator to the heat substation serving an individual development plot) of between 5 to 10% (higher in the early years while loads build up) and secondary network losses (the losses from the individual plot heat substation to point of use in the dwelling) of 10-15%. Total losses of 20 – 25% would not be unreasonable; losses for recently delivered networks in London have been shown in some cases to be far higher. The figures shown include an allowance for the electrical power for pumping based on the SAP assumption that pumping energy is 1% of the heat energy delivered.

The relative carbon performance of each thermal generator technology option is shown here in Table A.4.2. For more details and analysis of carbon trajectories please see Appendix F of the main report, Appendix G provides analysis of the carbon emissions for different technical scenarios.

Carbon Intensity of Heat (kgCO_2/kWh)	**Carbon content based on SAP 2012**	**Proposed SAP 2016 emission factors**	**Energy driver[30]**	**Comment**
Grand Union Canal heat pump	0.251	0.192	Electricity	Average water temperature assumed to be 5.5°C[31] .
London aquifer heat pump	0.227	0.174	Electricity	Chalk aquifer average temperature of 14°C assumed[8].
Taylor's Lane Power Station heat recovery	0.083	0.063	Waste heat from power station	Table 12 SAP: Waste heat from power station. Communications with E-ON have confirmed that E-ON do not consider the use of current facilities as a viable source of waste heat.
Energy from Waste	0.069	0.103	Refuse Derived Fuel	Table 12 SAP: Heat from boilers – waste combustion.
Sewage network heat pump	0.214	0.164	Electricity	Average sewage temperature of 18°C assumed[14].
Ventilation shaft heat pump	0.242	0.186	Electricity	Assumed average ventilation air temperature of 22°C, based on maximum and minimum temperatures experienced at Bunhill Energy Centre in Islington (14 - 30°C).
Tunnel Energy Segment heat pump	0.241	0.185	Electricity	Assumes 17.5°C average temperature, based on expected 13W/m^2 heat extraction[29].

[30] Table 12, Standard Assessment Procedure (SAP) for Energy Rating of Dwellings, 2012 edition, version 9.92 (October 2013)
[31] National Heat Map (http://tools.decc.gov.uk/nationalheatmap/)

Carbon Intensity of Heat (kgCO_2/kWh)	Carbon content based on SAP 2012	Proposed SAP 2016 emission factors	Energy driver[30]	Comment
Tunnel drainage heat pump	0.265	0.203	Electricity	Average drainage temperature of 10°C assumed.
Data centre heat recovery	0.200 (summer) 0.265 (winter)	0.154 (summer) 0.203 (winter)	Electricity	Assumes heat recovered at temperatures no greater than ambient plus 5°C. Therefore significant seasonal variation.
Gas-fired CHP comparison	0.054	0.216	Gas	As with all cases above this is for the engine only and ignores network heat losses and pumping energy. It illustrates the dramatic impact that proposed changes to electricity emission factors will have on the carbon savings from gas CHP.

Table A.4.2. Carbon Content of Heat Source Delivered to Customer via Heat Network

Note that, for those technologies that use electricity as the main driver will benefit in the longer term, due to the expected reduction in grid electricity carbon intensity.

A.4.3 Heat Source Cost Context

For a detailed discussion of cost analysis, please see Appendix G of the main report. A high level comparative assessment of the cost context is provided here for information. Please see Table A.4.3. The assessment is made on a 'per kWh of heat' basis.

Note that this analysis is qualitative in nature. A detailed assessment of all costs, income stream and available grants and tax reliefs will need to be undertaken at a later date. It is assumed that all energy centres would require a gas supply for backup gas boilers so would be common to all cases. Assumed all would require an energy centre and distribution network to serve the building demands so this is ignored for this qualitative comparison.

	CAPEX	OPEX	Capex Comments	Opex Comments
Grand Union Canal heat pump	Medium	Medium	Canal water extraction infrastructure and associated land costs, pipe networks to access canal. EIA and licensing application costs, potential CRT costs.	Maintenance and cleaning of river water filters, general maintenance of heat pumps, river water quality, fish and temperature monitoring associated with license approval.
London aquifer heat pump	High	Medium	Twin 100m+ borehole costs, submersible pumps, plant room costs, license application costs.	General maintenance of submersible pumps and heat pumps, water quality and temperature monitoring associated with license approval.
Taylor's Lane Power Station heat recovery	High	Low	Significant cost of connection route.	Cost of heat purchase from power station.
Energy from Waste	Low	Low	Technology costs low if planned in as part of Powerday delivery. Relatively short primary pipe route to Energy Centre in Old Oak North, possibly significant cost for negotiations with network rail for undertrack crossing.	Relatively limited maintenance cost as maintenance of heat generation plant falls to EfW operator.

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	CAPEX	OPEX	Capex Comments	Opex Comments
Sewage network heat pump	Medium	Medium	Costs for heat exchanger installation in sewer, creating connection to surface, pipe runs from sewer to energy centre or plant room.	Potential maintenance payments to Thames Water for heat exchangers. Maintenance for heat pumps.
Ventilation shaft heat pump	Medium	High	Substantial costs for planning and implementation of heat recovery technology in tunnel shaft. Associated costs for heat pumps and pipe runs to tunnel vent.	Substantial maintenance for cleaning of heat exchanges to remove particulate build up. Likely rigorous safety testing related to train operator safety regime. Maintenance for heat pumps.
Tunnel Energy Segment heat pump	High	Medium	Substantial cost for technology development testing and additional cost of tunnel delivery. Cost for tunnel to surface connection, associated pipe runs to energy centres.	Potential for substantial maintenance cost if systems leak or fail but limited maintenance cost in tunnels if implemented successfully. Assumed on-going costs for maintenance and inspection but possibly borne or shared by tunnel operator as serves to extract heat. Maintenance for heat pumps.
Tunnel drainage heat pump	High	High	Assume water pumped to surface by HS2 anyway. Additional cost for pipework to energy centre and cost of heat pumps.	Maintenance and inspection costs for pumps possible borne/shared by train operators. Heat pump maintenance.
Data centre heat recovery	Medium	Medium	Significant cost for pipe run (c.600m) to nearest development/energy centre. Design and retrofit of heat offtake and potential back-up systems. Contractual agreements and negotiations with data centre.	Rigorous operational maintenance and testing at data centre to maintain resilience. Potential additional costs to compensate any loss of performance of the data centre's chiller plant.
Gas-fired CHP comparison	Medium	Low	Gas engine cost.	Gas engine maintenance contract.

Table A.4.3. Cost Context of Heat Source

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Attachment I

Please see overleaf for Case Study information on GlaxoSmithKline canal-based cooling installation.

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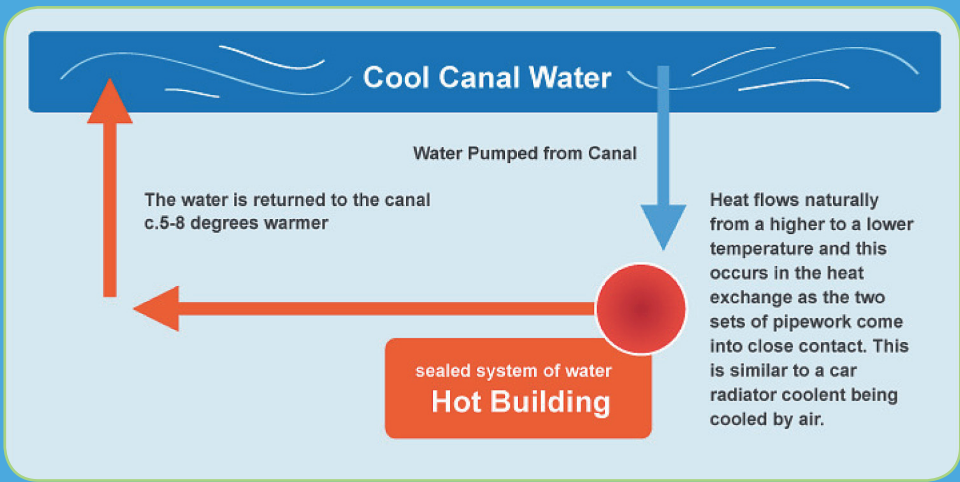
linden environmental

Linden Environmental is a consultancy working to help organisations dramatically reduce their energy bills by using canal and river water to cool buildings. We are part of the Linden Organisation, a group of companies that has been trading for over twenty years.

Linden Environmental offers systems that use river and canal water to cool large buildings, dramatically reducing air conditioning costs and providing better working conditions for staff. This is a tried and tested technology that has been working in some locations for almost thirty years, with organisations such as University of Huddersfield and GlaxoSmithKline in their global headquarters building in London.

How does it work?

It is heat exchange technology, similar to that used in everyone's fridge or radiator in a car. To put it simply, we take water from a waterway, bring it to a heat exchanger and draw out the heat from the building into the canal or river water.



The two fluids do not come into contact but exchange heat across a fine barrier. The coolant is then pumped around the building helping to keep the temperature at a pre-determined level and the water is returned to the waterway downstream of where it was extracted, slightly warmer than it was drawn in. The system is sealed so unlike other air-conditioners there is no need to treat the water, it never mixes with any other fluid used in the building thereby eliminating the risks of legionella.

Linden Environmental works with a range of partners to deliver our services to clients, including being the exclusive reseller of British Waterways' water for cooling schemes. We also work with organisations such the Environmental Association for Universities and Colleges to raise awareness of water cooling for buildings as an option to reduce costs and carbon.

British Waterways eauc

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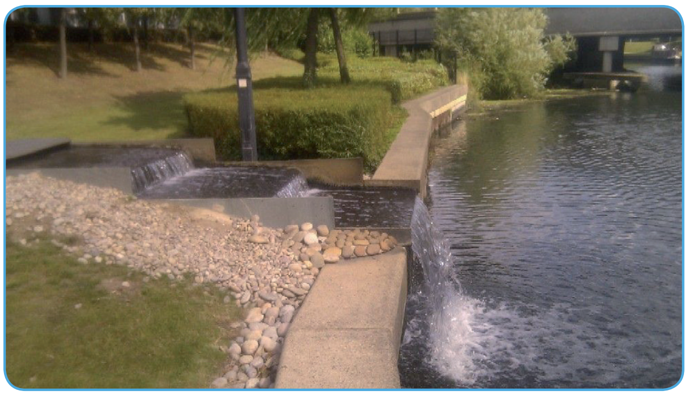
linden environmental

Case Study

GlaxoSmithKline

GlaxoSmithKline had an increased demand for cooling capacity in the global data centre, located at GSK House. Meeting this 1 MgW cooling need had a high cost in electricity consumption and carbon. GSK, Johnson controls and British Waterways devised a project to reduce energy consumption by utilising canal water. The Environment Agency (EA) set strict parameters so as not to affect the wildlife or the biodiversity surrounding the canal and the project managers worked hard to ensure that the heat dissipation is considerably less than the limits set by the EA, and aim to improve the water quality of the canal. The non-consumptive system reduced their electricity bill by over 50% and saved 276 tonnes of carbon each year. The scheme won the British Institute of Facilities Management 2010 Sustainability and Environmental Impact Award.

At its simplest it is a system that dissipates unwanted heat generated in the data centre by discharging it safely to a local waterway, in this case, the Grand Union Canal. Through two heat exchangers, waste heat from the data centre is transferred through 1km of newly installed piping to the chiller located in a newly constructed plant room in the basement. It is here the waste heat is passed out to be discharged over a waterfall which dissipates some of the heat before flowing back into the canal.



GSK significantly reduced the amount of power/ electricity it used compared to traditional air cooling. Initial figures estimated the amount of power used each year would be 1,794,816KW but after the first year of actual operation the amount was reduced further to 1,212,898KW per annum versus traditional air cooling which would consume 2,589,281KW. By using water rather than air cooling for the data centre saves 1,376,383 KWh p.a. and it estimated that a further 500,000 KWh p.a. can be saved with the spare capacity within the system. This amounts to a total carbon saving of 276 tonnes each year. The financial savings from the scheme were originally £131k a year but with some other improvements have increased to almost £200k a year.

Far from damaging the canal environment the heat exchanger system has made an improvement to the locality. The canal does suffer with one regular difficulty, on hot summer days when the flow of water is minimal, the oxygen levels in the canal reduce which severely stresses all of its fish and in very severe conditions they die. By returning the water from the heat exchanger via the cascade and waterfall, additional air is introduced in to the canal water and, locally to the cooling system, the levels of oxygen are improved. The elegantly designed cascade and waterfall and the comprehensive information board on the west bank of the canal has also raised interest in the canal.

Appendix B Summary of Energy Strategies for Existing Planning Applications in the OPDC Area

B.1 Executive Summary

This short briefing note was prepared in November 2016. It provides a high level summary of the energy strategies being proposed by the developers of sites in the OPDC area at the time the review was undertaken. AECOM reviewed the OPDC planning portal for submitted applications and downloaded the Energy Statement for all sites where they were available. AECOM reviewed the summary section of each statement to obtain a high level overview of current plans.

The aim of this exercise was to help inform which landowners AECOM and OPDC should be seeking to engage with regarding their energy strategies and in particular to identify which sites were currently proposing gas CHP fuelled communal heating networks.

Section B.2 provides a map showing the approximate location of the sites reviewed and a table providing a high level summary of the energy strategy proposed for each of the developments and whether or not they are proposing an on-site communal heating system served by CHP and whether they make reference to a connection to a wider network.

We were not able to locate energy statements for Gypsy Corner, the Power House or Hilltop Works. The latter two proposed developments are very small which may explain why no separate energy statement was available.

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B.2 Summary of Sites Reviewed

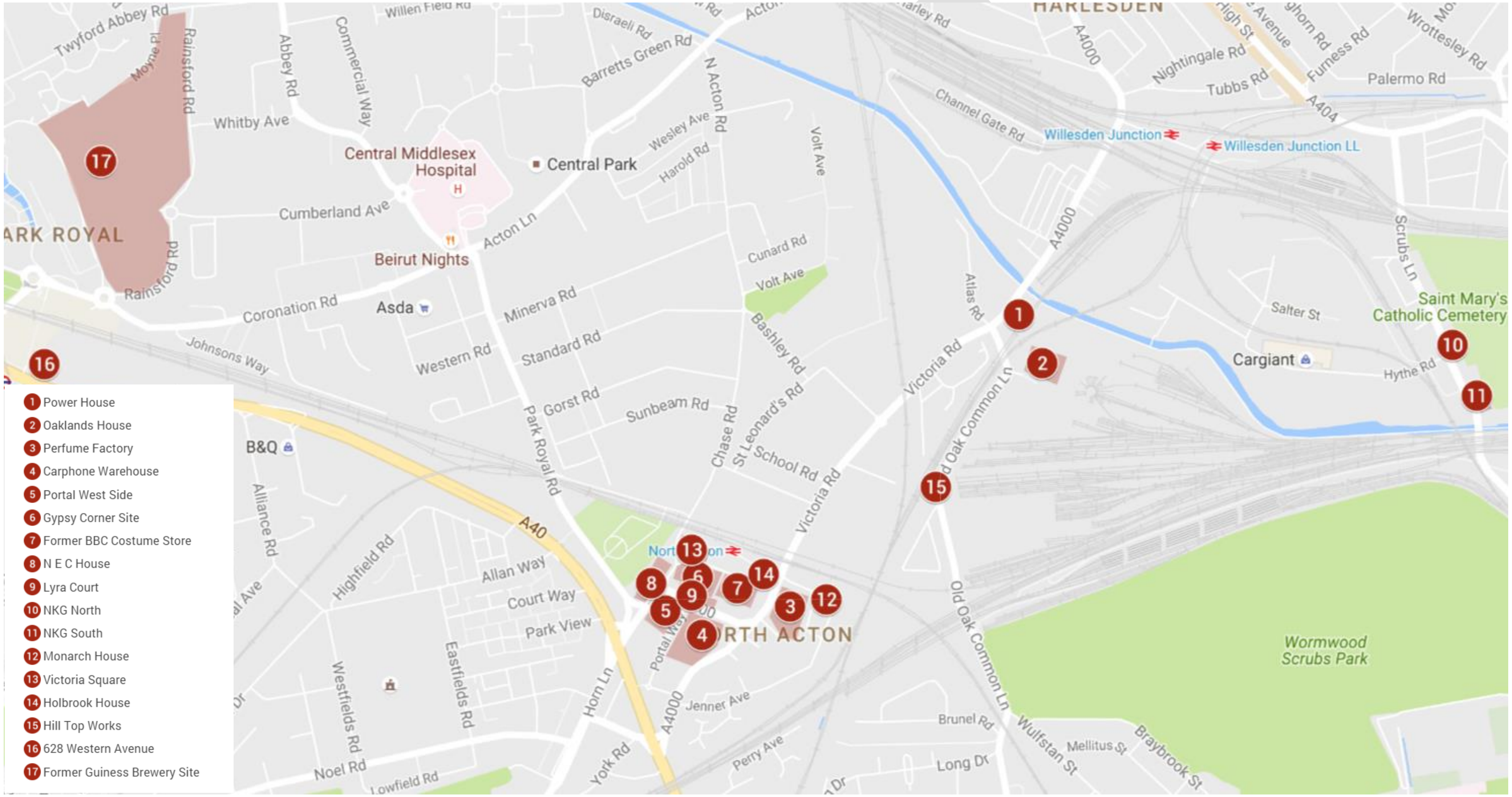

Figure B.2.1. Approximate Location of Sites Reviewed

Reference	Development	No. of Residential units	Floor area of commercial elements	CHP Provision	Connection to DH network	Renewable technologies in place
1	Power House	21 self-contained flats		unknown	unknown	unknown
2	Oaklands House	605 residential units	3,500 m^2	Gas-fire CHP engine (398 kWth) to serve residential elements	Future proofed design to allow for connection to a wider district heating scheme as part of the overall Old Oak Decentralised Energy Strategy	-
3	The Perfume Factory	534 residential units	• 6,147 m^2 Class B1/live work • 2,175 m^2 Class B1; • 1,381 m^2 Class A1/Class A3 • 548 m^2 Class A1/Class A3 • 564 m^2 Class D1 nursery	Either gas-fire CHP (207 kWth) on-site or connection to One Portal Way's Energy Centre	Discussion for connection to One Portal Way's Energy Centre for creation of a district system	300 m^2 of Photovoltaic panels
4	Carphone warehouse / One Portal Way	764 residential flats	5,134 m2 (A1, A2, A3, A4, A5 Use Classes, D1, D2 use classes and A1-A5, B1a, D1, D2, C3 Use Class).	Gas-fire CHP engine (400-600kWe)	Possibility of expanding the energy centre to serve adjacent developments. Future proofed design to allow for connection to a site-wide network.	Biomass boilers to supply 25% of the heat demand 300 m^2 of Photovoltaic panels
5	6 Portal Way/ Portal West	578 residential flats	3079.2 m2 (use class A1 and/or A2 and/or A3 and/or A4 and/or B1 and/or D1 and/or D2)	Gas-fire CHP engine (200 kWth) to serve residential elements	Connection to nearby sites has been investigated. Future proofed design to allow for connection to a site-wide network.	ASHPs for commercial units
6	Gypsy Corner Site (Ebbett, Trentham and Poulton Courts)	Building 1 : 61 residential units Building 2 : 120 residential units	Building 1 : • 125 m^2 A1, A2, A3, A4 & A5 use classes • 576 m^2 B1a use class Building 2 : • 343 m^2 A1, A2, A3, A4 & A5 use classes • 805 m^2 B1a use class	unknown	unknown	unknown

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Reference	Development	No. of Residential units	Floor area of commercial elements	CHP Provision	Connection to DH network	Renewable technologies in place
7	Former BBC Costume Store	• 718 bedrooms of student accommodation • 4 studios for academic staff	286 m^2 (A1/A2/A3/A5 Use Classes)	If biomass plant installation is not approved, a combination of CHP/ground source heat pumps will be considered.	-	Biomass plant (200-250 kW) serving DHW/space heating.
8	N E C House	• 592 study rooms • 66 students studios • one rector studio	• 1,675 m^2 (Use Class B1) • 930 m^2 (use classes A1/A2/A3) • 130 m^2 (use class D1)	Gas-fire CHP engine (203 kWth) to serve student accommodation tower	-	2 no. roof mounted arrays of 50 m^2 of Photovoltaics.
9	Lyra Court/Portal Way	184 student units	382 m^2 (Use Class A1, A2,A3,A5,B1,D1)	Gas-fire CHP engine (25 kWe) to serve circa 40% of the DHW demand.	-	-
10	North Kensington Gate North	48 residential units	165 m^2 (Use class A1/A2/A3)	No (communal boilers are proposed)	Future proofed design to allow for connection to OOPOA District Heat Network	Photovoltaic panels (32 no. of 9.9 KWp)
11	North Kensington Gate South	170 residential units	600 m^2 ((Use class A1/A2/A3/B1a)	Gas-fire CHP engine (110 kWth) to provide space heating and DHW to all residential elements and DHW to non-residential elements	Future proofed design to allow for Connection to OOPOA District Heat Network	Photovoltaic panels (24 no. of 7.7 KWp)
12	Monarch House	-	133 bed hotel	CHP system to preheat the domestic hot water service	-	ASHP to provide the heating and cooling requirements of the bedrooms, café and back of house area
13	Victoria Square	151 residential units	673 m^2 (Use Class A1, A2,A3,A5,B1,D1)	Gas-fire CHP engine (61 kWth)	-	-

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Reference	Development	No. of Residential units	Floor area of commercial elements	CHP Provision	Connection to DH network	Renewable technologies in place
14	Holbrook House	424 bed spaces	Ground floor ancillary student accommodation and a commercial unit for flexible Use Classes A1, A2, A3, A5, B1 or D1 uses.	CHP (201kWe,) providing DHW and up to 40% of the space heating requirements of the student residences.	Future proofed design to allow for connection to a site-wide network, should such a connection be legally, technically and economically feasible.	20kW ASHP to provide approximately 10% of the space heating requirements and 100% of the cooling requirements A 35kWp solar photovoltaic (PV) array
15	Hill Top Works	nine self-contained flats	-	unknown	unknown	unknown
16	628 Western Avenue/Park Plaza	-	158 bedroom hotel (6850 square metres) 1870 square metres comprising of an indicative office (B1 use class) and associated landscaping, public realm improvements, car and cycle parking,	2no. CHPs (15kWe) to provide space heating and DHW.	Future proofed design to allow for connection to a site-wide network	183 m^2 of Photovoltaic panels
17	Former Guinness Brewery Site		49,797m2 of B1(c), B2 and B8 floor space, café and gatehouse			• Solar thermal panels • 760 m^2 of Photovoltaic panels

Table B.2.1. Summary of Sites Reviewed

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Appendix C Heat Networks & Energy Centres

C.1 Executive Summary

This technical note summarises the issues and considerations around the development and siting of district heating networks and supporting energy centre facilities that could potentially serve the planned development at Old Oak. It is intended to help inform future masterplanning work.

Development in the Old Oak area is expected to provide approximately 26,000 new homes alongside significant non-residential facilities to support the effective development of a new district in West London. The expected high density of development is anticipated to be favourable to the successful deployment of a district heating network in the area. However, there are significant challenges, particular to the Old Oak site, that will need to be addressed in order to ensure district heating is viable at Old Oak. These include the location of low carbon heat sources relative to heat demand; the availability of plots for siting energy centres; and the significant physical barriers present on site (e.g. railways and the Grand Union canal).

Although there are many challenges to overcome, there are also opportunities presented by the need to significantly enhance other infrastructure around the site, including roads and bridges. The primary purpose of many of these enhancements will be to provide a more accommodating and coherent townscape. However, they do provide an opportunity for coordinating the design and installation of energy infrastructure, potentially reducing costs through burden sharing and cooperation.

C.1.1 Low Carbon Heat Opportunities

A number of low carbon heat sources have been identified in the Old Oak area. These include:

- The potential to connect to an EfW facility;
- Heat extraction from the London Aquifer;
- Heat recovery from the sewer system; and
- Heat extraction from the Grand Union canal.

The geographic location of these heat sources will impact significantly the design of any proposed energy systems.

C.1.2 Energy Centres

A number of land plots have been identified that could host a dedicated energy centre. These include plots which are not currently planned for development, such as the large triangular plot between North Acton and Wormwood Scrubs Park, and the smaller triangular plot immediately to the south of the Powerday site. Additional sites are also potentially available, including on plots currently planned for development or amenity provision. See Figure C.1.1 for potential energy centre locations.

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Figure C.1.1 Potential Energy Centre Locations in Old Oak

The triangular plot between North Acton and Wormwood Scrubs Park (see plot A in Figure C.1.1) is not expected to be developed on, and has therefore been identified as a key potential opportunity for siting a significant energy centre. The available area is significant (consisting of c.20,000 m^2 of land) and is split over two plots by a key surface railway line (the Underground Central line). A large key substation currently occupies part of the smaller site, although it is anticipated that the plot could also accommodate an energy centre of a significant size (up to c.2,000 m^2 for a double height energy centre).

The larger of the two plots in the area between North Acton and Wormwood Scrubs Park currently hosts a disused building that could be replaced with an energy centre of significant size (potentially up to 3-5,000 m^2 or a double height arrangement). However, both this site and the adjacent smaller plot are characterised by challenges regarding access. Both sites are surrounded by railway lines that represent significant barriers and obstacles for access, both for the construction of any energy centre, and for future operation and maintenance procedures. Old Oak Common Lane however does provide some access to the eastern edge of the smaller plot, although any use of this route for accessing a potential energy centre in this plot will need to accommodate the needs of the substation that currently occupies part of this plot.

The railway lines also represent obstacles for providing utility access routes and for routing District Heating (DH) pipework into and out of these plots. However, pipework/utilities could be routed out of the sites alongside the Central Line (and beneath the railway lines running along the western and southern edges of the plot) towards the North Acton developments to the west and south of this plot. For the smaller plot, potential routes to/from the smaller plot could be achieved via the adjacent Old Oak Common Lane. Alternatively, thrust boring techniques could be used to direct services/utilities/pipework underneath railway lines; however consent from Network Rail would be needed to do this.

Other potential plots for locating an energy centre are also identified, including a small triangular plot adjacent to the canal and immediately to the south of the Powerday site (see plot B in Figure C.1.1). Due to the irregular shape of this plot, it is unlikely to be able to accommodate an energy centre with a footprint larger than 800 m^2. This plot will also represent challenges in terms of access, particularly for construction and operation/maintenance, as the plot is bounded by surface railway lines on two sides, and the canal on the other. There are however potential routes in and out of the plot for utilities and DH pipework, along the canal towpath leading east from the site adjacent to the canal.

Other potential energy centre plots include the proposed EfW facility at Powerday (see C in Figure C.1.1), the energy centre proposed by Car Giant (see D in Figure C.1.1), and the proposed landscaped amenity space on the south bank of the canal (see E in Figure C.1.1).

Additionally, there is the potential to locate energy centres in plots identified for development. These could be used to complement the above options, and be co-located alongside development, potentially at ground or basement level. However, a number of factors should be considered when determining appropriate locations, including the phase in which the plot is expected to be developed; the proximity of the plot to other development sites that could be dependent on heat services; and the proximity of the plot to the low carbon heat source that the energy centre will target for exploiting. Low carbon heat sources that could be utilised in a plot-based energy centre include sewer heat recovery systems, and open-loop heat pump systems extracting heat from the London Aquifer.

C.1.3 Network Challenges and Opportunities

DH network routes around the Old Oak site are expected to encounter a number of key challenges. These include a number of railway lines (including the planned HS2 line and the Crossrail line currently under construction), the Grand Union canal, and a lack of available crossing points over these obstacles. The grouping of development into geographical clusters, separated by the numerous railway lines in particular does represent significant challenges (see Figure C.1.2).

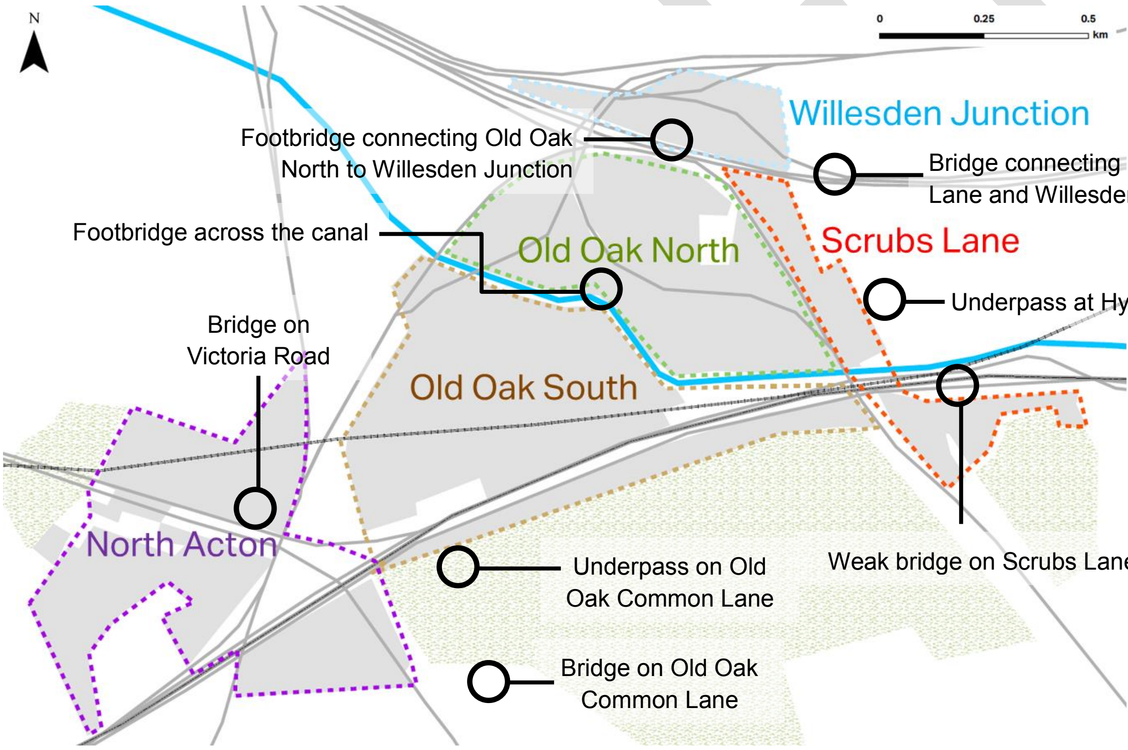

Figure C.1.2 Clustering of Development at Old Oak

The Willesden Junction cluster is geographically isolated from the rest of the site by major railway lines running east-west. With only a footbridge currently linking Willesden Junction to the development plots in Old Oak North, a new road bridge is expected to be provided (see Figure C.1.3). This new link will likely provide a key route for utility and potentially DH network routes; coordination at the Masterplanning stage of works will be required to safeguard the potential to use this link for DH routing of pipework to the Willesden Junction cluster.

The Scrubs Lane cluster is also isolated from neighbouring clusters. Although there is a bridge connecting the Scrubs Lane cluster to Willesden Junction in the north, this bridge is likely to carry key existing utility routes. Furthermore, the southern-most part of the Scrubs Lane cluster is currently only connected to the rest of the cluster by a bridge which spans the canal and the railway lines which will in future be used for Crossrail services. This bridge is weak however, and is subject to loading restrictions. Connections to the Old Oak North development are currently provided via a single underpass road beneath the railway line at Hythe Road. See Figure C.1.2. However, many of these crossings are expected to undergo improvements as part of the wider works to enable development in the Old Oak area (see Figure C.1.3). Coordination at the Masterplanning level will be required in order to establish and safeguard the potential for utilising these roads and bridges as conduits for routing DH pipework.

North Acton is in the south-western most part of the Old Oak site, and is separated from the main Old Oak development by key railway lines. Key routes to North Acton include Old Oak Common Lane and Victoria Road. These roads provide crossings over the various railway lines in the area, via both bridges and underpasses (see Figure C.1.2). However, many of these routes and crossings are expected to undergo significant upgrades as part of the enabling works for the wider Old Oak development, including a significant realignment of Victoria Road due to HS2 requirements (see Figure C.1.3). Engagement during the Masterplanning works will be needed in order to establish the potential of these roads for routing DH networks.

Old Oak North and Old Oak South are separated by the Grand Union canal, which dissects the site. Although only one pedestrian footbridge currently connects the two sites (see Figure C.1.2), significant new road and pedestrian infrastructure is expected to be provided as part of the Masterplan (see Figure C.1.3). Within Old Oak North, the existing railway line running through the site towards the southeast is expected to be raised to provide an elevated section of the line. This will open up the potential of laying DH network pipework along the new road network planned for the area.

In Old Oak South, development will mostly occur on podiums, raised above the new railway infrastructure planned for the area (Crossrail sidings and HS2); design of the podium system will need to accommodate heat network pipework requirements assuming development of these plots occurs prior to substantial decarbonisation of the electricity grid, and DH services are required for these developments. The expected improvements to Old Oak Common Lane are also likely to provide opportunities for network routing to the southern-most areas of Old Oak South which are separated from the rest of the site by Crossrail and HS2 infrastructure. An alternative route to the southern-most parts of Old Oak South could also be reached via new footbridges that may be provided in the Masterplan (see Figure C.1.3); coordination at the Masterplanning phase of works will be needed in order to safeguard these routes and establish the potential incorporating DH pipework.

Figure C.1.3 shows the expected new infrastructure provision for the Old Oak area, including new road bridges, pedestrian bridges, new road networks and potential junction improvements.

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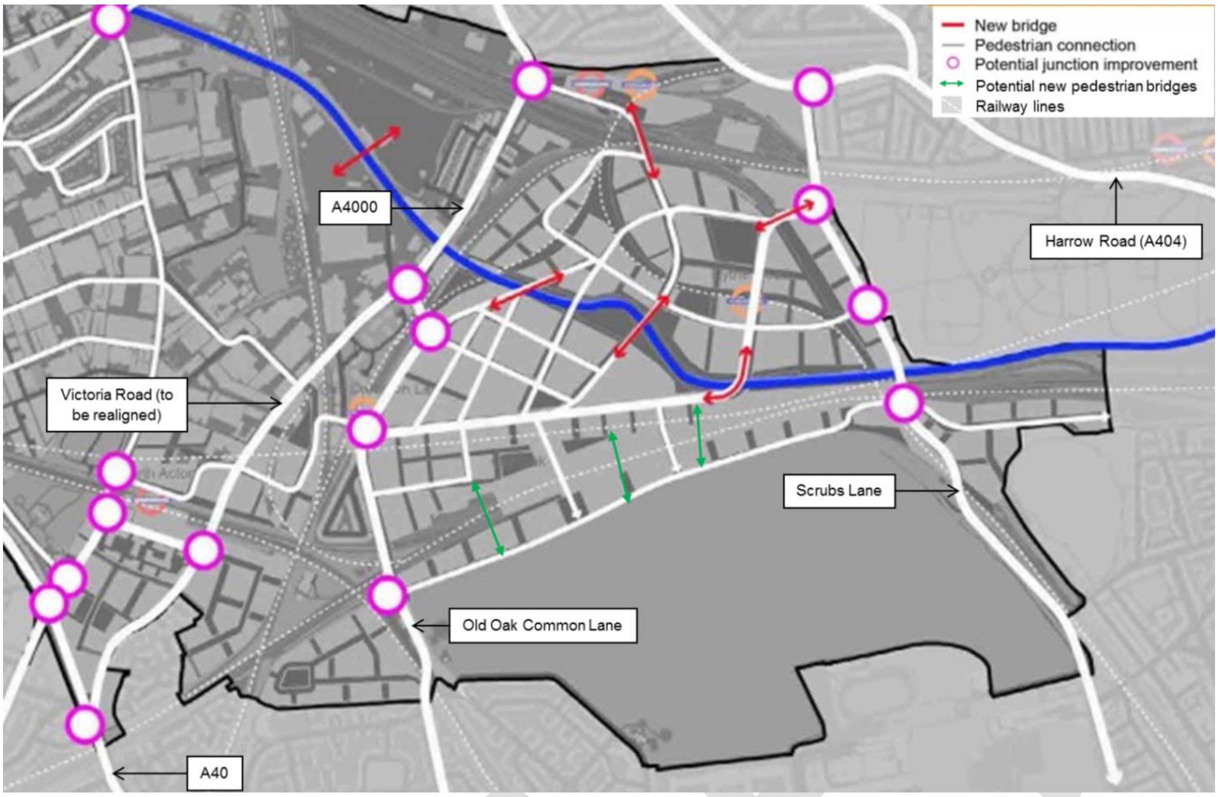

Figure C.1.3 Expected new infrastructure provision

C.1.4 Indicative routes

Indicative options for energy centre locations and routes for the main DH transmission network are illustrated in Figure C.1.4. Routes for the primary distribution routes (connecting individual development plots to cluster-based energy centres) should be established during the Masterplanning works, and will need to consider the challenges and opportunities identified in this Technical Note.

Secondary pipework (from the boundary of plot development sites to the interface with individual dwellings) and tertiary pipework (within dwellings) should be designed to the standards set out in Section C.5 of this Technical Note during the detailed design stages of individual plots.

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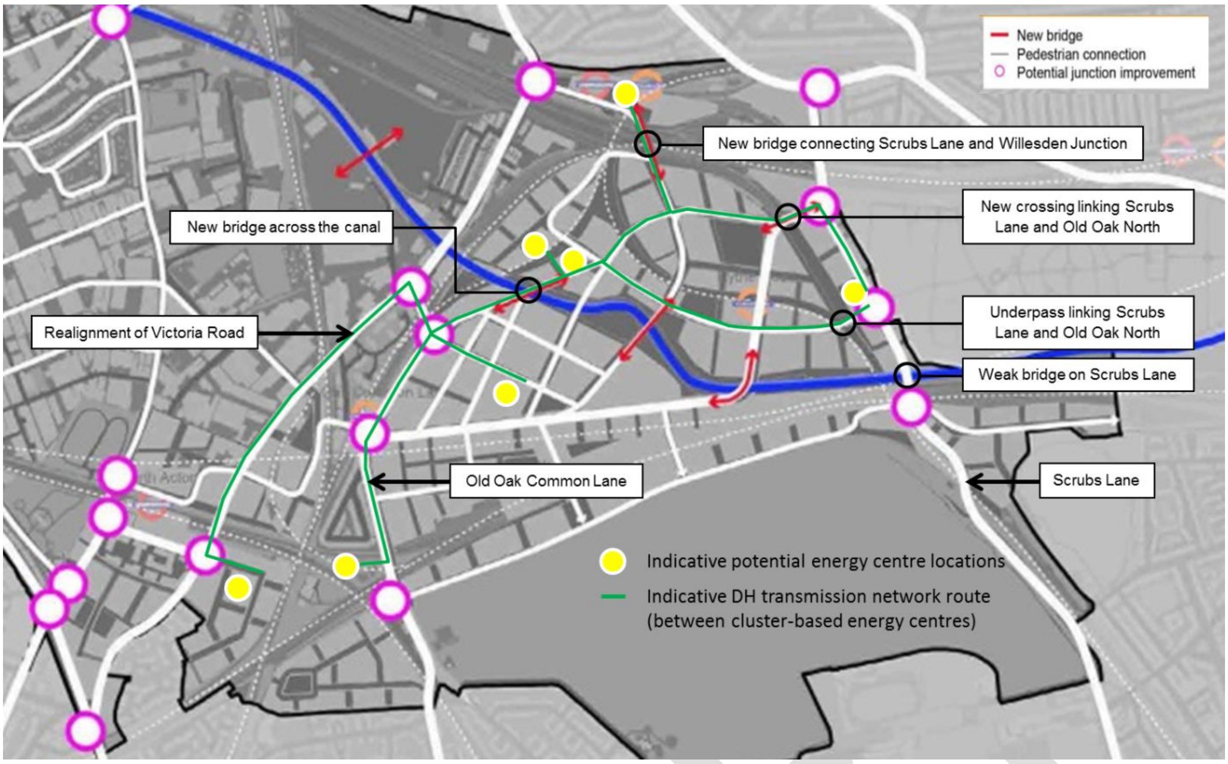

Figure C.1.4 Indicative route for DH transmission network and energy centre locations

Note that the routes and energy centre locations shown here are indicative only, and further analysis (of the best routing options and energy centre locations) should be undertaken as part of the masterplanning stage of works.

Determining appropriate network routes will need to consider the viability of linking North Acton to the wider network; the two main options for this include via Victoria road or via Old Oak Common Lane. Both of these roads are expected to undergo improvement works as part of the wider works to enable development in the area (in the case of Victoria Road, realignment of this route is expected as part of HS2 works).

New bridge and road crossings are also expected as part of the improvement works to enable development in the area. While the primary purpose of these new crossings are expected to be to ensure a more coherent and accommodating townscape, they are likely to provide a secondary purpose to enable utility and services routes to cross the site. It is recommended that the design of the Masterplanning works is coordinated with discussions regarding DH pipework, in order to safeguard potential route options.

Key crossings and routes that should be considered for incorporating DH pipework are outlined in the following sub-section.

C.1.5 Key considerations for Masterplan

Key considerations for the Masterplanning works that relate to determining appropriate locations for energy centres, and for the routing of DH pipework (transmission and primary distribution pipework), include the following:

- Identifying key crossing points across the canal;
- Identifying key road crossings across railway lines to reach the Scrubs Lane and Willesden Junction clusters;
- Safeguarding these key crossings to ensure that their design can accommodate DH network pipework;
- Identifying when key crossing points would need to be delivered in order to enable expansion of the network to key demand clusters;

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- Identifying energy centre locations and safeguarding access to them for construction, maintenance and network route access; and
- Identifying opportunities for coordination with the installation of other utility infrastructure, and either construction of new civil infrastructure or the upgrading of existing civil infrastructure.

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C.2 Introduction

C.2.1 Context

The development projected to occur at Old Oak will require significant new energy infrastructure, including services for both space heating and for domestic hot water generation.

The viability of low carbon heat sources has been investigated by AECOM with findings presented in a separate Technical Note[1]. The heat sources found potentially viable include the utilisation of water sources such as the London Aquifer and the Grand Union Canal; in addition to a potential EfW facility; and local sewage networks.

If these low carbon heat sources can be viably utilised as sustainable sources of heat in addition to conventional heat sources such as gas Combined Heat and Power (CHP), a network system to distribute the heat to different development parcels and customer buildings will likely be required to maximise the benefits associated with their use.

District Heating (DH) networks are simply a means of distributing heat that is generated in one location (typically an energy centre, containing heat generators such as boiler units), and delivering it to a customer in another location. This is done on a 'district' level, covering large areas of development. While conventional utilities provide electricity and gas infrastructure to the customer's door, DH services provide thermal energy (heat) for use by the customer. Although an interface between the DH service and the customer is required (typically through the use of Heat Interface Units (HIUs) at the plot or building boundary), the use of DH facilities does however negate the need for gas-fired combustion plant in customer buildings. Additionally, mains gas infrastructure may also not need to be provided to each building, unless required for catering or other uses.

DH networks typically distribute water in a dual circuit of insulated pipework. A typical network circulates warm water in "flow" pipework at a temperature greater than the parallel "return" pipework. Extraction of heat from the network by customer systems results in the return pipework being at a lower temperature than the supply pipework. The extracted heat is replenished through the use of heat generators in the energy centre.

DH networks can operate at a variety of temperature settings. Commonly used temperature regimes operate flow temperatures of c.70-90°C, with return temperatures of c.40-60°C (providing a temperature difference between flow and a return, or dT of c.30°C). However, older networks typically operate at higher temperatures and pressures (Medium Temperature Hot Water) and a smaller dT (20) but with very little commonality of design.

There is a concerted move however to ensure new networks operate with lower temperatures and/or with as large a dT as possible, since this both improves the efficiency of heat generation and reduces significantly the flow rate of circuited water required (and therefore the power required to pump the water around the circuit). There is no common standard for DH design in the UK. Industry guidance is available[2], which identifies best practice but it is not a requirement nor suitable if the heat customer systems are inappropriately designed.

Pipe sizes can also be significantly reduced for networks with high dTs, thereby significantly reducing the installation costs for the pipework. There is also a move to reduce overall circuit temperatures, as this can also improve the efficiency of heat generation, while also reducing the heat losses experienced in the distribution pipework (by reducing the temperature gradient between the pipework and the surrounding medium, e.g. earth).

Heat networks typically consist of:

- Transmission network – transmission network connecting different energy centres in each geographic cluster (transmission networks are not always employed in DH systems in the UK, although they are commonly used in Scandinavian countries for large, interlinked networks);

[1] Technical Note 1: Heat Sources, AECOM, 2016
[2] CIBSE CP1: Heat Networks: Code of Practice for the UK: Raising standards for heat supply, CIBSE /ADE, July 2015

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- Primary network – main distribution pipework from an energy centre(s) to the boundary of a development parcel or plot;
- Secondary network – pipework from the boundary of a development parcel to the building and in the case of residential buildings to the heat interface unit (HIU) of the dwelling units (including ‘risers’ and ‘laterals’ within the building); and
- Tertiary network – pipework within dwellings, from the HIU to the point of service (e.g. hot water taps or central heating radiators).

The heat networks under consideration in this Technical Note are the transmission network and the primary distribution route. The secondary and tertiary networks are the subject of building- or plot-level design. However, guidance on appropriate design principles for secondary and tertiary networks is provided. Please see Section C.5 for more details.

Further considerations for this Note include the potential locations for energy centre(s), as these will have direct impacts on the network and route. Energy centres would likely host any HIUs required for incoming low carbon heat supplies, conventional heat generation plant such as gas CHP engines, heat pumps, and standby or peak load gas boilers. Additional plant that would likely need to be located within an energy centre include water treatment plant and pressure stations for the network; thermal storage units for maximising the utilisation of low-carbon heat sources; pumping equipment; and any electrical switchgear needed. Energy centres housing gas boilers or gas CHP also normally require a medium pressure gas supply. All combustion plant including CHP engines and gas boilers will need to be designed to meet air pollution emission limits set out in the Mayor’s Supplementary Planning Guidance on Sustainable Design and construction and this may also require flue treatment units (e.g. Selective Catalytic Reduction (SCR) units).

Energy centres also typically require large plots of land; if designed with flexibility for multiple future energy sources this may impact on space requirements. Suitable locations for energy centres in the Old Oak area are discussed in this Technical Note.

C.2.2 Key Considerations

Should DH be considered a viable and preferable site-wide energy strategy for the development at Old Oak, key considerations for the early phases of development will be to ensure that:

- Developments are designed to be compatible with, and easily connected to, a local DH network;
- The potential for first-phase connection to local heat sources is explored, in order to initiate and encourage the phased expansion of the network;
- Potential routes for DH networks are safeguarded on and around the plots being developed;
- The utilisation of available heat sources in the area is not compromised (e.g. locations for, and access to and from, local heat sources and distribution facilities are safeguarded); and
- Consideration is given to undertaking construction of enabling nearby infrastructure, during construction of the first plots, in order to make future connections of customer plots to the network easier. The potential for coordinating the installation of this infrastructure alongside other utilities should also be investigated to establish potential cost savings.

C.3 Energy Centres

Energy centres are dedicated facilities for generating energy for use in a DH system. Energy centres typically consist of:

- Heat generating plant (e.g. Combined Heat and Power (CHP), gas boilers);
- Thermal storage vessels (used to shift the demand for and generation of heat, in order to more fully utilise low-carbon or economically valuable heat resources);
- Pumps (to pressurise the circulating water in the distribution network);
- Pressure vessels (to control and equalise the pressure in the distribution network);
- Water treatment equipment (to maintain the water quality in the distribution pipework);
- Flue emissions control equipment, if applicable (e.g. SCR for NOx emissions controls);
- Ancillary equipment (including ventilation equipment for ensuring the energy centre building and plant is adequately ventilated; electrical switchgears; heat rejection units for rejecting waste heat; pipework; valves; insulation; and noise attenuation); and
- Building Management System (BMS) and control platform.

Appropriate locations for energy centres are discussed below.

C.3.1 Energy Centre Locations

There are a small number of plots around the masterplan site that have not been identified for development. These include the triangular site in North Acton immediately to the northwest of Wormwood Scrubs Park, and the smaller triangular site in Old Oak South immediately opposite the Powerday site on the south bank of the Grand Union canal. Additional opportunities adjacent to the canal could be utilised for accessing the canal for water source heating and/or cooling. These are labelled in Figure C.1.1 alongside the planned energy centre on the Car Giant site, and the energy from waste facility planned at Powerday. These opportunities are discussed in turn as follows.

C.3.1.1 Plot near North Acton

The total land area is approximately 22,000 m^2. However, the site is bounded by railway lines, with the Central Line also running through the centre of the site, dissecting the site into a larger parcel approximately 12,000 m^2 in land area, and a smaller parcel of approximately 8,000 m^2. See Figure C.3.1.

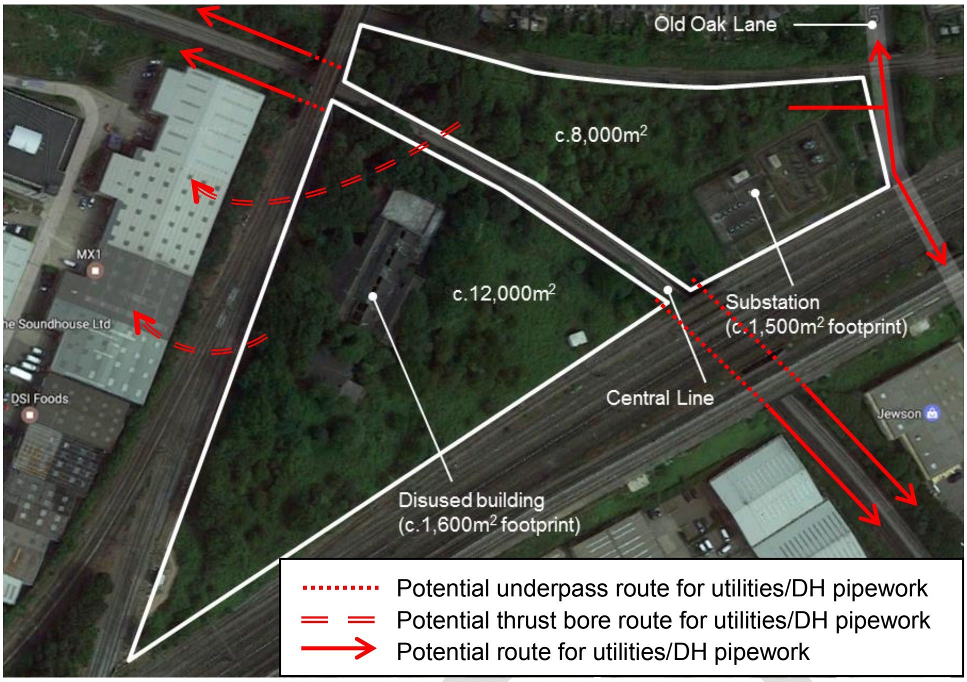

Figure C.3.1 Plot adjacent to North Acton

The larger of the two plots currently hosts a disused building which has a footprint of approximately 1,600m^2, indicating that an energy centre of around 3-5,000 m^2 floor area could be accommodated. Routing out of the site for pipework or utility services is potentially possible under the railway lines, via a thrust bore operation, or alongside the Central Line running west to the North Acton development area (and beneath the railway line running along the western edge of the triangular plot). However, access for construction, operation and maintenance is likely to be a key challenge for this site, with the land bounded on all sides by railway lines, which may render this site unusable.

The smaller of the two plots currently hosts a large substation with a footprint of c.1,500 m^2. Given the criticality of a substation like this, it is likely that any additional development on this plot would need to accommodate the substation and any access required for it. However, it is expected that the plot could still host an energy centre with a footprint c.1,000 m^2 (providing total floor area of up to 2,000 m^2 if a double height energy centre is developed). Access could potentially be achieved via Old Oak Common Lane, although a steep gradient between the road and the plot would need to be overcome. Routing could also utilise Old Oak Common Lane towards the later-phase developments in North Acton to the south of this plot. Routing of utilities or district heating pipework could be directed to the main North Acton development site potentially under the railway line using thrust boring. Any routing of pipework under or adjacent to railway or Underground lines is likely to require extensive engagement with Network Rail and or Transport for London (TfL) for necessary approval of works.

3.1.2 Plots adjacent to the Canal

There is an available plot of land adjacent to the canal and opposite the Powerday site on the north-western edge of the Old Oak South site. See Figure C.3.2. The total land area is approximately 3,400 m^2; however the unusual shape of the plot is likely to limit significantly the footprint that could be used for an energy centre. It is estimated that an energy centre of c.800 m^2 footprint could be accommodated; should double height construction be used, a larger facility could potentially be accommodated. It is expected that this plot would be large enough to accommodate the necessary plant and equipment required for a canal-sourced heat pump system. Alternatively, it could also be used as a location for boreholes to enable an aquifer sourced heat pump system.

However, this triangular site is very challenging in terms of access, with the site bounded on two sides by railway lines, and the canal on the third side. Access for construction, operation and maintenance may need to be provided via the canal. However, routing of utilities or district heating pipework could potentially be

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provided along or beneath the canal towpath towards the main Old Oak South site, and across new footbridges towards the Old Oak North site.

A further opportunity to consider in relation to this site is that it sits above the planned route for HS2's planned logistics tunnel that would take excavated material from the HS2 tunnelling works for disposal via the rail network. If constructed, the tunnel might in future provide an opportunity for routing utility infrastructure.

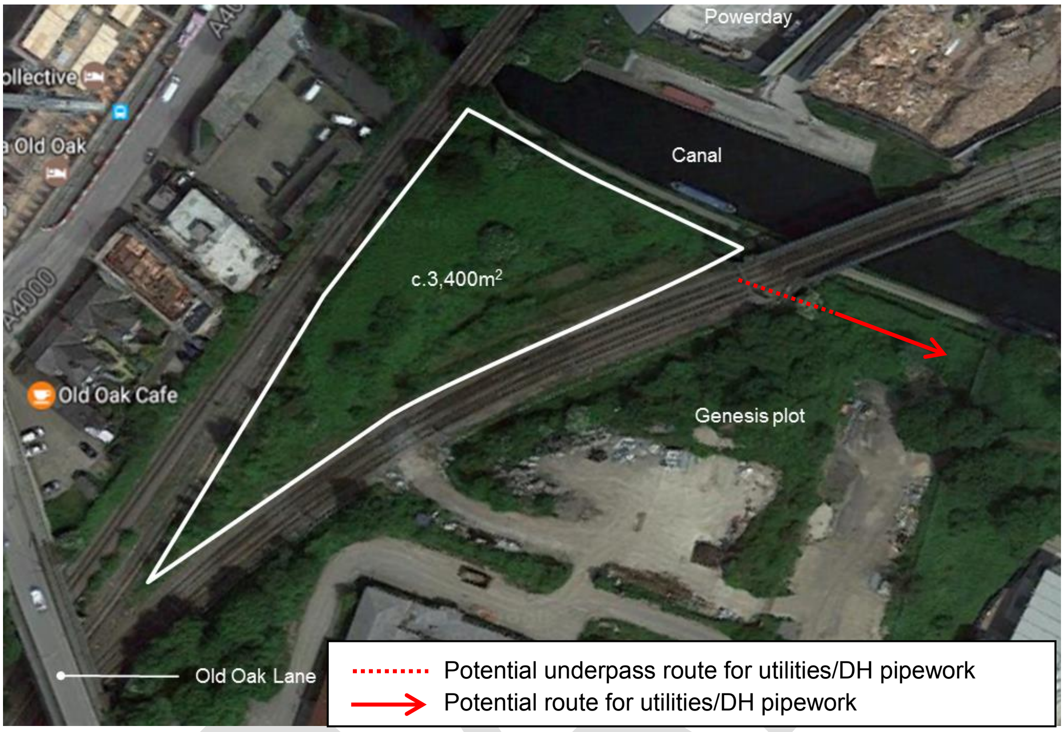

Figure C.3.2 Plot adjacent to Genesis & Canal

There is additional land available adjacent to the canal in Old Oak South. See Figure C.3.3. This land is anticipated to be landscaped, in order to maximise the opportunities for creating an attractive townscape for the area.

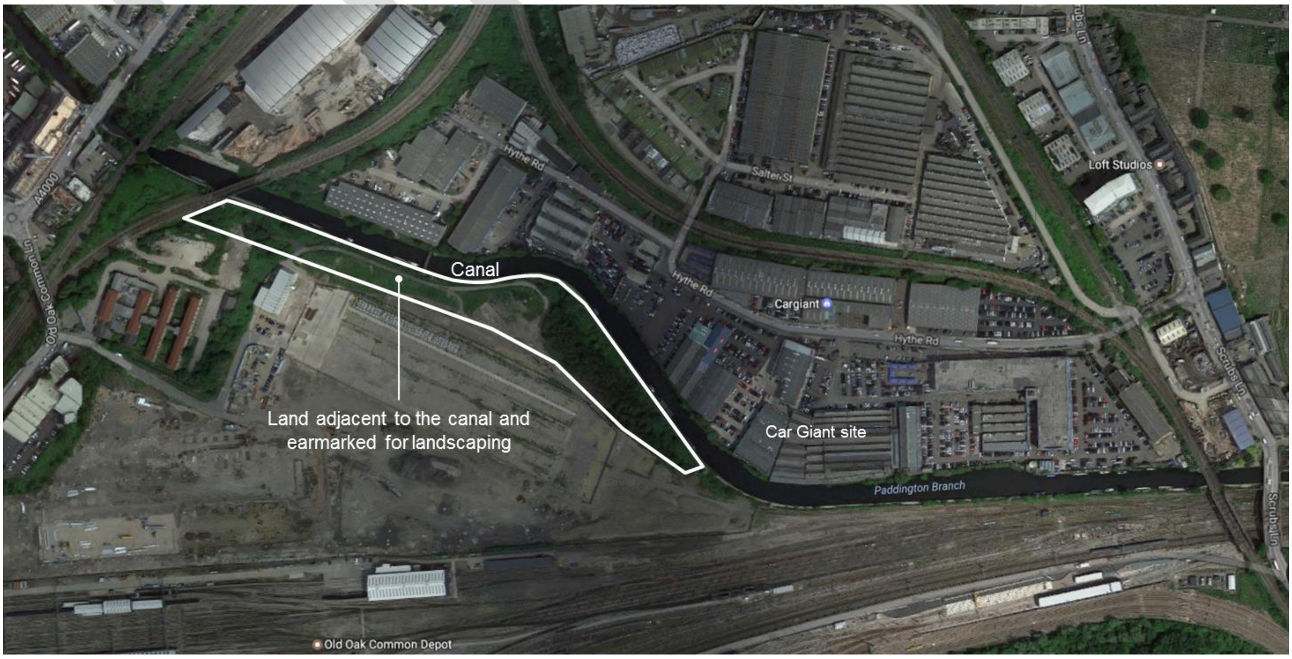

Figure C.3.3 Land adjacent to the canal scheduled to be landscaped

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Although this land will unlikely be suitable for locating a traditional energy centre (owing to its prime canal-side location), it may be possible to house a canal-based water source heat pump system. An example of creating a system that could complement an attractive canal-side amenity space has been demonstrated at the GlaxoSmithKline facility in Brentford that utilises the River Brent for cooling purposes. See Figure C.3.4. A similar system, designed to be sympathetic to the expected landscaping of this area could potentially be a solution for exploiting a canal-based water-sourced heat pump system at Old Oak.

Figure C.3.4 GlaxoSmithKline Water-Sourced Heat Pump System at the River Brent

3.1.3 Powerday

Powerday operates a large commercial waste management business in a large plot in the northwest of the Old Oak North site. The facility processes and sorts waste into constituent categories for resale, including metals, wood products and hard plastics. The majority of the residual materials (including soft plastics, small wood chips and unrecoverable paper and cardboard) are processed into Refuse Derived Fuels (RDFs) for sale to EfW plants across the UK and Europe.

Powerday is developing proposals for an EfW plant (expected size 3 – 5.7 MWe) on their site at Old Oak, to be fuelled entirely by the RDFs produced onsite. The EfW plant could offer the potential to export significant amounts of heat to neighbouring development sites in the Old Oak area. Powerday has indicated that it intends to locate the EfW facility on their own site. For more information, please see Appendix A of the main report.

Enabling connection of the EfW facility to the wider Old Oak site will be challenging, since the site is surrounded on all sides by railway lines or the canal. The site is currently accessed via a small access road leading under railway lines to the northeast of the site. See Figure C.3.5.

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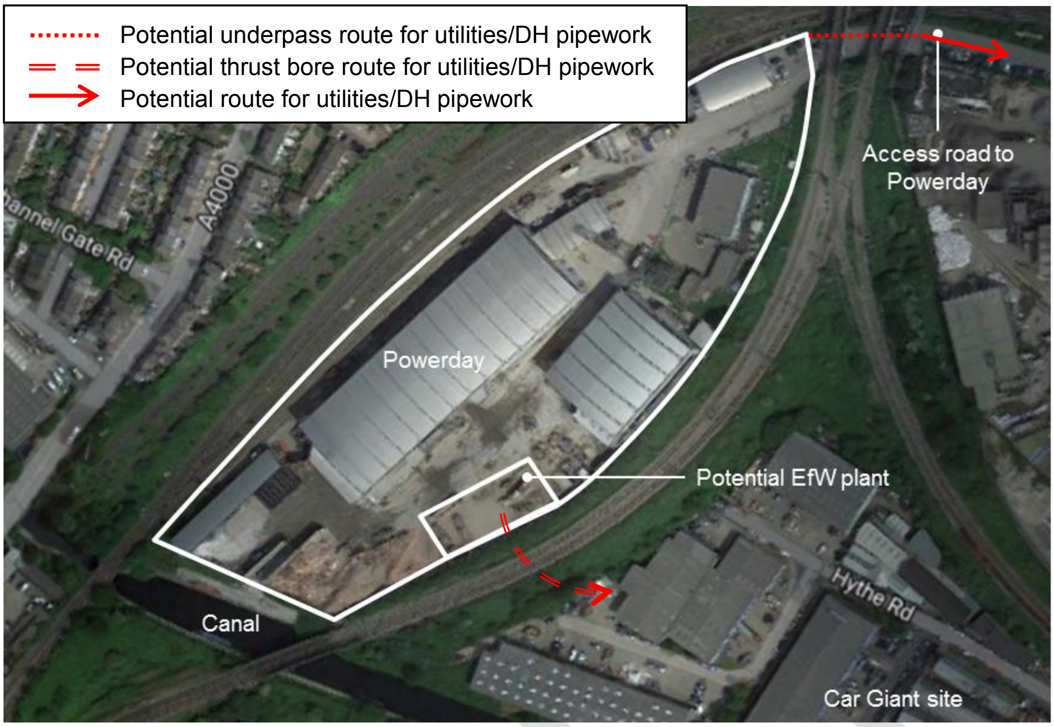

Figure C.3.5 Powerday

A potential option for reaching the Car Giant site would be thrust boring beneath the railway to the east of the Powerday site. This option could feed heat generated by an EfW facility into an energy centre located on the western edge of the Car Giant site. Initial discussions with Car Giant suggest this would be their favoured location for an energy centre. The feasibility of thrust boring beneath the railway would need to be explored further with Network Rail.

If the facility is to serve other developments around the Old Oak area, the potential for routing pipework through the Powerday site and along (beneath) the access road to Powerday should be investigated, as this could be a more economical solution compared to thrust boring beneath the railway line. However, the impact of such works on the operation of Powerday, both during construction and operationally should be considered. There may also be existing utilities present beneath the access road, which could restrict the viability of this route. Further investigation of these potential limitations should be undertaken during the masterplanning works.

3.1.4 Development Site Energy Centres

Development plots could potentially be used to complement the above options for accommodating energy centres. These could be located in any of the anticipated development plots, although a number of factors should be considered when determining appropriate locations. These include the phase in which the plot is expected to be developed; the proximity of the plot to other development sites that could be dependent on any heat services provided by the energy centre; and the proximity of the plot to the low carbon heat sources targeted for exploiting. Low carbon heat sources that could be utilised in a plot-based energy centre include sewer heat recovery systems, and open-loop heat pump systems extracting heat from the London Aquifer. Energy centres incorporated into the development could also be sited to enable heat extract from the canal, for example an energy centre at the West of Car Giant's site could be located close to the canal and with the boundary of Powerday's site.

Existing and expected new large sewers (>1m diameter minimum required for maintenance access) in the area are expected to offer the potential for 200 – 500 kWth of heat output per installation, generating c. 1-2,000 MWh of annual heat output (per installation). Suez Plc has confirmed that the installations they operate in France are subject to a number of design limitations. These include a maximum length of continuous heat exchangers of 200 m (due to hydraulic limitations), and a maximum distance between the heat exchanger and a heat pump of 300 m[3].

The London Aquifer offers a potential source for delivering heat to a local or area-wide network. The use of aquifer-sourced heating will need to consider the space requirements of borehole equipment, heat pumps and heat interface units within the basement of a development plot. Space will need to be retained above the boreholes for the equipment needed to lift the submersible pumps for maintenance. Consideration should also be given to appropriate locations for maximising the potential of borehole heat extraction. Analysis of existing borehole records in the area suggest the potential for water extraction (and therefore heat extraction) varies considerably depending on location. Whilst extraction rates cannot be guaranteed, and investigatory boreholes will be required to determine achievable extraction rates, areas to the south and east of the Old Oak site (particularly at Hammersmith Hospital) are expected to offer the greatest opportunities for significant rates of water extraction. An abstraction and return borehole are likely to be required and these will need to be positioned a substantial distance apart to avoid thermal breakthrough between the abstraction and return water temperatures. Ground modelling will be required to explore this but separation distances of greater than 100m may be required.

For more information on these technologies, please see Appendix A of the main report.

C.3.2 Utility Requirements

In addition to the technology required to generate heat from the local low carbon heat sources, energy centres will also likely utilise gas boiler systems. These will operate as peaking plant, in order to meet loads during times of peak heating demand (e.g. during cold winter mornings, when the demand for space heating is high, and the demand for hot water services is also high). Back up plant will also be required when the main duty plant is taken out of service for planned or unplanned maintenance. Mains gas supply networks, serving the gas requirements of energy centres that host gas systems will therefore be required.

While peak and back up plant is likely to be gas boilers in the early phases, the strategy could potentially transition to electric boilers in later phases as the electricity grid decarbonises. This would be subject to the relative future cost and carbon content of gas and electricity. At present, gas has a lower cost per unit of heat output than direct-use electricity. However, in future, a greater focus on demand management could lead to more dynamic tariff arrangements, with prices being adjusted according to daily demand patterns.

A small mains water supply will also be required to serve each energy centre, in order to refill or top-up a boiler. Boilers are routinely drained for maintenance purposes, resulting in the need to refill. Typically a 15 MW energy centre would require a c.54 mm water mains.

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[3] Recovery of sewer heat: 2 case studies on a district heating and a swimming pool application, Suez, October 2016

C.4 Network Routing

Appropriate network routing design for DH pipework will need to consider a range of factors in order to maximise the potential benefits of the available low carbon heat sources. These include appraising the significant physical barriers on the site (e.g. railway lines); the effect of development phasing on heat demand (which will see loads starting from a low level and coming on line progressively as development continues); the effect of phasing on the potential development of enabling routing infrastructure (e.g. bridges over significant physical barriers such as the canal); and the coordination of routing design and installation alongside other utilities. Each of these factors are considered in turn below.

C.4.1 Physical barriers & opportunities

There are significant onsite constraints that need to be considered in developing a potential DH network on the Old Oak site. These include existing and planned infrastructure, in particular major roads and railway lines, in addition to the Grand Union canal.

Figure C.4.1 shows key existing and proposed new infrastructure on the Old Oak site, as per the OPDC Local Plan[4].

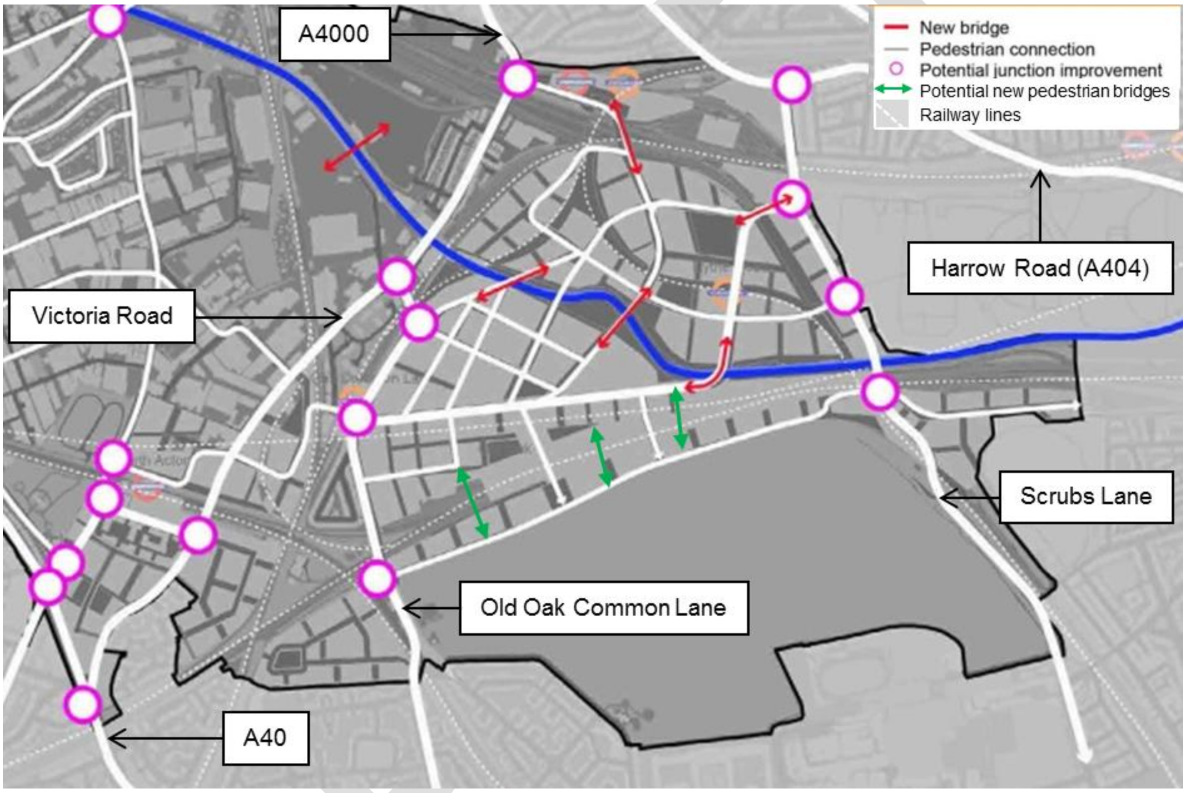

Figure C.4.1 Major Infrastructure (Existing and Planned) in Old Oak

C.4.1.1 Roads

The North Acton area is bordered to the southwest by the A40, a major 6-lane trunk road serving West London and providing direct access to Central London and the M40 motorway. To the north, the Willesden Junction area is bordered by Harrow Road (A404), another significant road linking Central London and northwest suburbs including Wembley. To the east, Scrubs Lane provides key north-south access between the A40 and Harrow Road, while in the west, the A4000, Victoria Road and Old Oak Common Lane also provide key links. See Figure C.4.1 for key road infrastructure around the Old Oak site, and expected junction improvements.

[4] Extract from OPDC Local Plan, received from OPDC 18th October 2016

While DH pipework can be routed beneath and along roads, some of these roads are such vital routes in and out of the city (particularly the A40) that obtaining permission to be able to route along or across these roads is likely to be very challenging. However, the roads likely to be key for routing DH pipework around the site are less significant, and are also likely to be upgraded, especially in order to enable the scale of development being planned for the area.

It is also understood that some of the existing bridges in the area (e.g. the bridge over the canal on Scrubs Lane) are weak and have maximum load restrictions on them.

Existing roads that are likely to be key for routing DH pipework include Victoria Road, Old Oak Common Lane and Scrubs Lane. Victoria Road in particular will be rebuilt to accommodate HS2 works and this may present an opportunity to coordinate any DH pipework installation into the proposed roadwork programme which could offer cost savings and sharing, subject to HS2 programme requirements. Other key roads that will be needed for routing the network around the site will be developed as the build out of the scheme takes place.

Since the masterplan will likely require the provision of new, rerouted or re-surfaced roads within the development area (as indicated in Figure C.4.1), there will likely be opportunities to incorporate DH networks within these new/improved roads.

C.4.1.2 Rail

Numerous railway lines (see dotted white lines in Figure C.4.1) dissect and border the site, including the main intercity lines out from Paddington towards Reading and Bristol, the Central Line, the Bakerloo Line and the Overground network. Freight lines also cross the site, while new railway infrastructure is either being constructed for Crossrail, or planned for HS2. Future stations are also planned for the area, including a future Crossrail station and Crossrail/HS2 interchange station at Old Oak.

These railway lines and stations represent significant obstacles for utilities, since crossing them or routing utilities alongside them is technically challenging and can also lead to difficulties when coordinating with Network Rail.

Options for crossing railway lines include burying pipework in roads that either bridge over or pass under the lines. Using existing bridges as a conduit to cross railway lines would likely mean that problems associated with coordinating with existing utilities, that would likely already be located in the bridge, would be encountered. There is also the potential that existing bridges are not able to carry the additional structural load, and/or are not deep enough to ensure DH pipework can be sunken within the existing surface.

Thrust boring beneath lines is also a potential option where the lines being traversed are surface lines. However, extensive consultation and design coordination with Network Rail would need to be undertaken to ensure that the works do not impact on the required railway safety standards.

The potential for using railway bridges to traverse other obstacles (e.g. the canal) may be limited by a number of factors. In addition to the ownership, access and structural concerns for existing bridges, these include the level changes between rail bridges and ground level beneath the bridge. This could be problematic, should DH pipework be directed from bridge level down to the level of the development plots below. This would likely result in exposed critical pipework infrastructure, additional heat energy losses and risk factors related to degradation of the infrastructure, although technical solutions may be available to address these issues (i.e. anti-vandalism measures and additional insulation).

Where new rail or station works are being programmed ahead of development delivery, designs should seek to facilitate any likely future provision of district energy pipework and other utilities, for example by building undertrack crossing points into the design as part of the station or rail works. This will help to avoid subsequent more challenging approvals for work around or under operational networks.

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C.4.1.3 Grand Union Canal

The canal runs through the centre of the Old Oak area, and represents a significant barrier to routing a site-wide network. Apart from a footbridge and railway crossings, there are currently no significant crossing points across the canal in the central part of the Old Oak site; however, several new bridges are identified for construction, primarily to allow better access between plots either side of the canal and improve the community connectivity in the area. See Figure C.4.1.

The canal could be traversed using thrust boring techniques similar to those discussed in relation to crossing rail infrastructure. However, this undertaking will likely need consent from the Canals and Rivers Trust (CRT).

The canal presents an opportunity for routing DH network pipework along its length, potentially buried beneath the towpath. This will require discussion with and consent from the CRT. Discussions with Car Giant's advisors Arup suggest that Car Giant may need to undertake works to the northern edge of the canal to improve amenity provisions, to re-route services and to maintain the canal wall.

C.4.1.4 New Bridge Opportunities

Given the extensive development that is planned for Old Oak, there are expected to be a number of new bridge crossings made available. The primary purpose of these bridges will be to ensure community connectivity throughout the site. However, a secondary purpose will also be to enable multiple utilities and services to reach into and around the site. See the extensive redesign of the road network around the site in Figure C.4.1.

Figure C.4.1 also shows three options for new pedestrian bridges over the new HS2 infrastructure[5]. These offer the most viable means of enabling any potential DH network to cross many of the railway lines in the area. However, effective coordination with the planning and design teams responsible for locating and designing these new bridges will be essential in order to ensure that provisions are made that enable any potential DH network to use these bridges as conduits if necessary. This need would be particularly acute were pedestrian bridges be used for this purpose, as usually these are not designed to carry structural loadings consistent with large-scale utilities. The Local Plan could respond to this likely need, by including within policy statements a requirement that any planned crossing needs to consider and be designed to accommodate utilities infrastructure. LLDC's Local Plan includes a policy of this nature.

A number of new bridges will be used to cross the Grand Union canal that dissects the site east to west. The canal creates a natural barrier that will present challenges to ensuring public access around the site, as well as to the routing of DH pipework. The planned new bridges across the canal therefore present opportunities to safeguard network route options, through early engagement with planning and design teams responsible for locating and designing the bridges, and by ensuring that provisions are made that enable any potential DH network to use these bridges as conduits for routing pipework if necessary.

C.4.2 Effect of Phasing on Routing

Phasing will have a significant effect on the options and opportunities for routing a potential DH network across the site. The optimal development and routing of the network will likely be dependent on the size and density of development in different areas of the site. For example, the detailed network plan will need to consider where development occurs at different phases of the trajectory, in addition to the type and scale of development that will be provided (e.g. residential or commercial). There may be opportunities to provide DH network services to certain plots and areas of the site in advance or on completion of the planned development; in others areas of the site, an optimal network development plan could see the planned development coming forward on the basis of local and temporary provisions of conventional heating services during an initial period prior to the extension/development of a wider DH network.

Additionally, where enabling infrastructure is being provided for those plots being developed early, consideration will need to be given to the infrastructure requirements of those plots being developed in the latter phases of programme.

[5] Old Oak Common – Footbridge Feasibility Study, Pell Frischmann, February 2016

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C.4.3 Coordination with Other Utilities

Effective coordination with existing and planned future utilities will be essential. Much of the site will likely see significant new utility provisions, including new gas networks (medium pressure and low pressure routes), mains water supplies, foul and drainage sewers, high-voltage (HV) electrical infrastructure, and telecommunications. Whilst coordination will be necessary in order to ensure that there is space provision along all required routes, there may also be a potential for cost sharing, for example through their coordinated design, installation and procurement.

An illustration of a potential coordinated design principle is shown in Figure C.4.2. A multi-utility combined trench like this is expected to be used in parts of the Vauxhall Nine Elms Battersea opportunity area; its coordinated design is likely to offer significant cost savings overall, since the cost of installation will be reduced and shared among each utility.

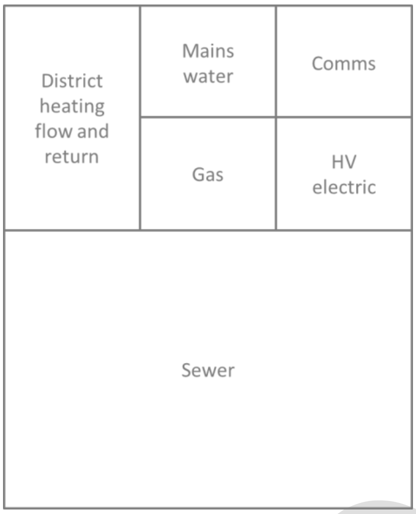

Figure C.4.2 Example of a Combined Multi-utility Trench

C.4.4 Indicative Routes

Indicative routes for the main transmission network (linking cluster-based energy centres together or major sources of heat to energy centres serving major clusters of demand) are illustrated in Figure C.4.3 and Figure C.4.4. These examples should be treated only as illustrative options. However, they have been developed through considering the factors and issues discussed above.

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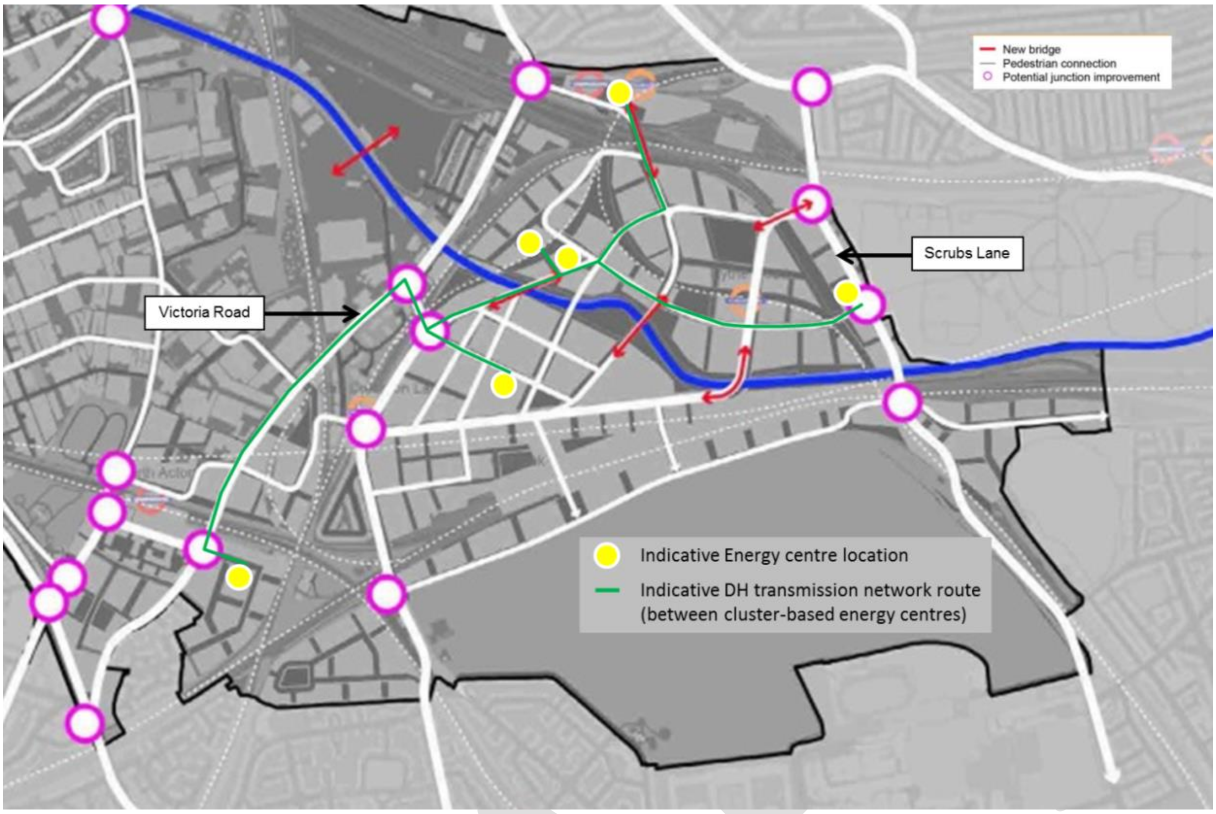

Figure C.4.3 Indicative Route for Transmission Network (Example A)

Example A in Figure C.4.3 shows the DH transmission network centred on the Powerday site and the adjacent energy centre on the western edge of the Car Giant site. The network extends northwards across the planned new bridge crossing over the railway line to the Willesden Junction cluster, and eastwards to the Scrubs Lane cluster via an improved road junction with Hythe Road.

The network extends over the canal, via a planned new road bridge over the canal immediately to the southeast of the Powerday site. Further connections to a future energy centre located in Old Oak South could be provided via new roads planned for the development on the Crossrail or HS2 sites. Routing to North Acton is indicated here to follow Victoria Road, which is expected to be reconstructed as part of the HS2 works.

The example shown in Figure C.4.4 shows an alternative route for the DH transmission network. This shows an alternative option for connecting the main areas of the site to the North Acton area and the land parcel identified as a potential location for an energy centre (see Figure C.3.1), via Old Oak Common Lane. This option could offer potential advantages compared to extending the transmission network via Victoria Road, by offering routes for connecting to plots in the southern part of the Old Oak South cluster (in particular those to the south of Crossrail).

An alternative route for connecting to the Scrubs Lane cluster is also shown, via the potential junction improvement at the northern end of Scrubs Lane.

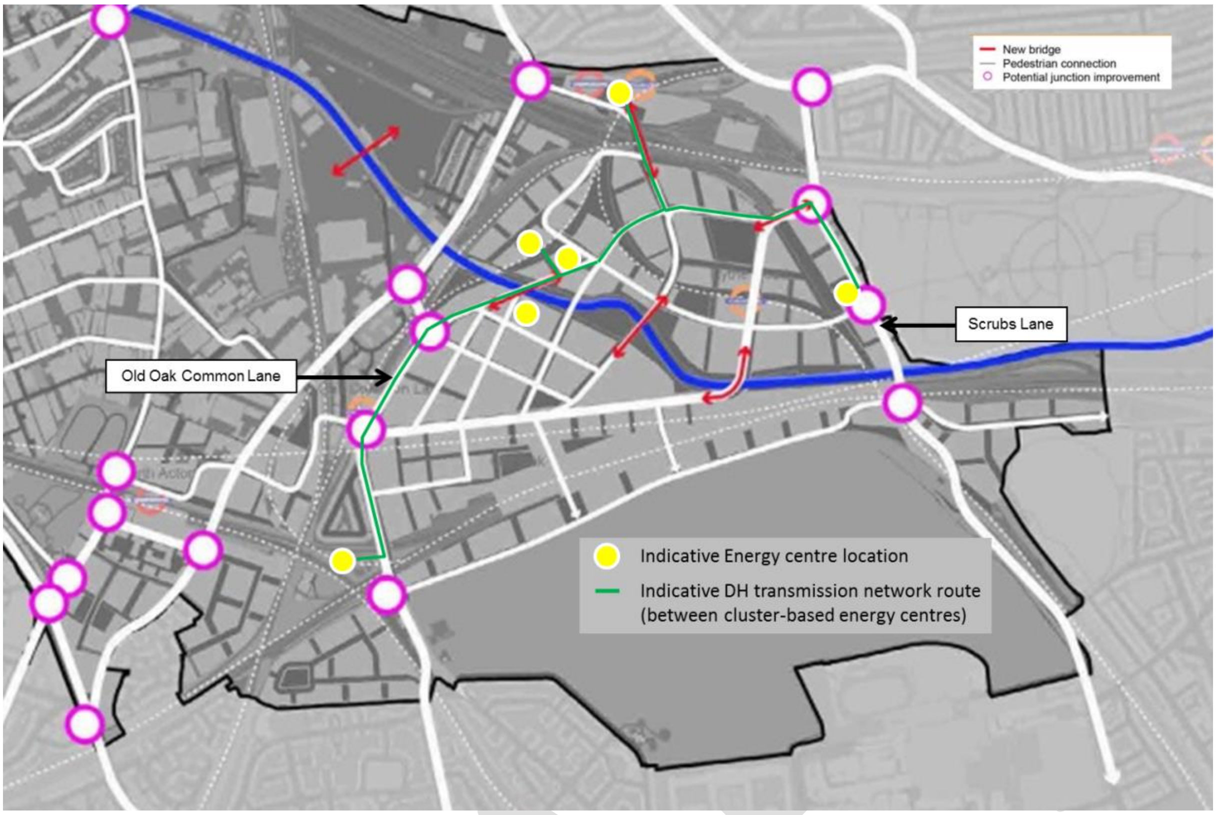

Figure C.4.4 Indicative Route for DH Transmission Network (Example B)

Note that the routes and energy centre locations shown above in Figure C.4.3 and Figure C.4.4 are indicative only, and further analysis (of the best routing options and energy centre locations) should be undertaken as part of the masterplanning stage of works. Note also that additional routes will need to be allowed for primary distribution pipework. This pipework will distribute heat from the cluster-based energy centres to individual development plot boundaries.

Key considerations for determining appropriate routes for all transmission and primary distribution networks include:

- Identifying key crossing points across the canal;
- Identifying key road crossings across railway lines to reach the Scrubs Lane and Willesden Junction clusters;
- Safeguarding these key crossings to ensure that their design can accommodate DH network pipework;
- Identifying when key crossing points would need to be delivered in order to enable expansion of the network to key demand clusters;
- Identifying energy centre locations and safeguarding access to them for construction, maintenance and network route access; and
- Identifying opportunities for coordination with the installation of other utility infrastructure, and either construction of new civil infrastructure or the upgrading of existing civil infrastructure.

C.5 Design Standards

Other considerations include ensuring that any potential DH network is designed in accordance with industry best practice guidelines as set out in the Heat Network Code of Practice CP1 (HNCoP)[2]. The HNCoP is a joint project between the Chartered Institute of Building Services Engineers (CIBSE) and the Association for Decentralised Energy (ADE), and represents the industry's coordinated approach to ensure that heat networks are designed, built and operated to a high quality that delivers customer satisfaction. Minimum and best practices standards are specified in order to provide greater confidence for specifiers and developers.

Figure C.5.1 illustrates some of the typical features needed for an efficient heat network.

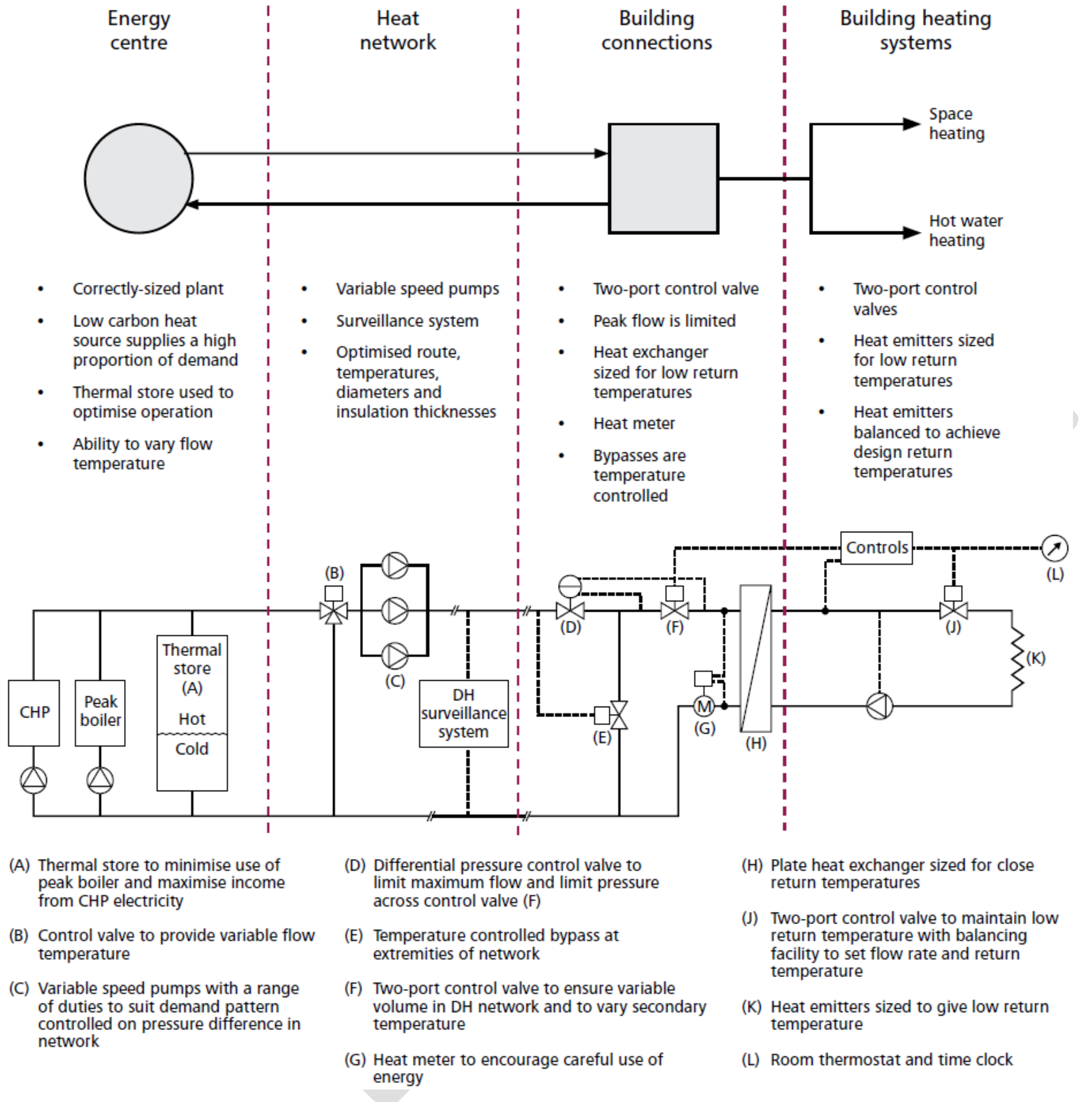

Figure C.5.1 Illustration of some Typical Features of an Efficient Heat Network with an Example Schematic Diagram (source: HNCoP[2])

Heat loss from heat networks is a key consideration that should be addressed early in the design. HNCoP recommends best practice that, for most schemes, the heat losses in a heat distribution network (up to the point of connection to each building when built out) should not exceed 10% of the sum of the estimated annual heat consumption of all connected buildings. A heat loss of 15% or more would indicate either a low density development or the need for a re-evaluation of the design and insulation specification. Since development at Old Oak is expected to be of high density (between 300 – 600 dwellings per hectare depending on location), losses from the network should be expected not to exceed 10% of the total. This means the design of the network should minimise unnecessary lengths of pipework.

Factors that will need to be considered at the design stages include ensuring pipe diameters are minimised where possible (without reducing the peak heat output and while ensuring future expansion requirements have been considered); the use of pipework insulation is maximised; and that network temperatures are optimised. For new buildings, the HNCoP recommends that flow temperatures are minimised (and do not exceed 95°C) and that return temperatures do not exceed 50°C.

Further guidance on the design of heat networks is provided in other key references, including:

- Technical Guide to Heat Networks (BRE[6], 2014)
- AM12: Combined heat and power for buildings (CIBSE, 2013)
- District Heating Manual for London (GLA[7], 2013)

The installation of heat networks is also a key cost consideration. Since many heat networks are planned for existing buildings, the cost of installation can be significant, particularly in high density urban areas. These costs can be as high as £2,000 /m in Central London, making the installation of even modestly-sized district heat networks potentially very expensive. The majority of these costs are associated with the civil component of the installation (i.e. site protection, buried services coordination and diversions and trench formation and re-instatement). Costs could be minimised for the development at Old Oak by ensuring coordination of the network design with other utilities and masterplan services such as road designs. It should also be recognised that while there is a cost for the provision of heat network infrastructure, this reduces the potential size of plant that needs to be accommodated within the buildings themselves, with costs being balanced against the costs of energy centre plant, plant space and flues within buildings. This is particularly true if the energy centres can be accommodated in locations with lower potential land values.

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[6] Building Research Establishment
[7] Greater London Authority

C.6 Summary

The high density of the planned development at Old Oak is expected to favour the utilisation of district heating; however there are a number of key challenges specific to the Old Oak area, particularly around the potential for energy centres on the site, and the physical barriers associated with major roads, railway lines and waterways in the area. The viability of DH systems to support the anticipated development at Old Oak therefore depends significantly on the feasibility of providing network infrastructure.

C.6.1 Energy Centres

A number of potential land plots have been identified for hosting energy centres in the Old Oak area. These include plots that are not being planned for development, for example the triangular plot between North Acton and Wormwood Scrubs Park, and the plot immediately south of and opposite to the Powerday site on the south bank of canal. Other potential plots include within development plots and under landscaped amenity areas to the south of the canal.

The key considerations for assessing the potential locations for energy centres include:

- Scale of energy centre proposed and the targeted low carbon energy resource;
- Proximity of the site to nearby low carbon energy resources;
- Access arrangements to the energy centre for construction, maintenance and operations;
- Viability of routing utilities (e.g. gas, water) and DH pipework to and from the site; and
- Potential flue requirements and the required flue heights relative to neighbouring buildings.

Selected plots for energy centre locations should be safeguarded in the masterplan for their construction. Additionally, the heat resources targeted for exploitation should be safeguarded in the masterplan, in order to not compromise their use.

C.6.2 Network Routing

Routing of DH networks around the Old Oak site will be subject to a number of challenges specific to the Old Oak area. Foremost amongst these are the numerous railway lines that dissect the site, including the Crossrail line currently under construction, and the HS2 line that is planned to run east-west through the site. In addition, the Grand Union canal also dissects the site, representing a further barrier to network route options.

With few options currently available for crossing these major barriers, there is, as part of the masterplan, expected to be significant investment provisions for new infrastructure that will provide a more accommodating and attractive townscape for the area (e.g. new bridges). Further investment is expected for upgrading the existing infrastructure (in particular road junctions), in order to ensure they are able to better serve the increased capacity and demand expected to result from the planned development.

These new crossings and road improvements are likely to provide opportunities for network routing. Key considerations for assessing network routing design in the masterplan include:

- The effect of development phasing on viable network routes and build-out dates;
- The potential for coordinating the design and installation of enabling infrastructure (e.g. bridges and road improvements) with network design and installation;
- The potential for early connection of buildings to the network, in order to initiate and encourage the expansion of the network, thereby providing early revenue streams for the network; and
- Ensuring developments are design to be compatible with and easily connected to the network.

Selected network routes and required enabling crossings should be safeguarded in the masterplan.

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Appendix D Review of Existing Delivery Models for Low Carbon Decentralised Energy Infrastructure

D.1 Executive Summary

This technical note was prepared in December 2016 as an interim deliverable of the stage 2 work to inform OPDC on the available models and options for district energy delivery and to inform the development of the preferred decentralised energy strategy.

There are many possible models for delivering a heat network scheme in the Old Oak area, subject to it being technically feasible, environmentally beneficial, and financially viable. Establishing the preferred delivery model broadly involves deciding on the 'delivery vehicle' and (unless scheme development and delivery is left entirely to the private sector) the 'contractual structure' for the scheme.

1. **Delivery vehicle** – Both the nature of the corporate entity that will be established to deliver the scheme and the relationship between OPDC and this 'delivery vehicle' need to be considered.

   Possible delivery vehicles cover a spectrum in terms of ownership from: **wholly public** (internal department or wholly owned municipal companies), through **hybrid**, to **fully private** sector companies (invariably **'Special Purpose Vehicles'** (SPVs), likely to be subsidiaries of specialist energy companies and often afforded exclusive rights to supply heat, e.g. through a concession). Examples of a hybrid company include: a **public sector-led SPV** (which could be: a **public + private joint venture**, or a wholly owned, arms-length **municipal limited company**); and a community-owned **mutual limited company** or **cooperative** (although community ownership is initially unlikely to suit the setting up of a large scheme serving new development).

   Opting for a publicly owned entity or public + private SPV would imply a direct and strong role for OPDC. Fully private sector delivery implies that OPDC's role would be limited to creating the necessary context (e.g. through planning, incentives, facilitation) for a viable scheme to be delivered by interested property developers and specialist energy companies.

2. **Contractual structure** – Some of the potential scheme delivery vehicles require a very specific top tier of contracts to be put in place (e.g. memorandum & articles of association for a municipal SPV or JV, master agreement for a concession). A detailed contractual structure then covers the way individual 'development works' and 'operational services' elements of the scheme are to be bundled and procured, what property-related agreements are needed, and any other necessary legal agreements between interested parties. A range of detailed contractual structures may work for a given delivery vehicle and the best fit can broadly be decided independently of, and after, the choice of delivery vehicle.

In practice, only a handful of delivery models are common (to date) or likely to work well for large schemes. These can be broadly characterised as follows:

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Model*	Originator	Owner	Vehicle	Finance**	OPDC contracts
Municipal	Public led	Public	Municipal dept. or wholly owned company	PWLB, HNIP funds	Specialist D&B contract; O&M and M&B may be in house or contracted
Municipal SPV / JV	Public led	Public / Joint	JV / SPV (limited company)	PWLB, HNIP funds, debt	Memorandum & articles of association; shareholders agreement; SPV decides contractual structure
Concession	Public led	Private***	SPV	Equity, debt	Master agreement, SLA, connection & heat supply agreements; SPV provides / procures works & services
Private	Private led	Private	SPV	Equity, debt	No contractual links with OPDC (except OPDC as heat customer)
* Delivery model names are solely for ease of reference; ** Sources of external finance not comprehensive; *** Rights of ownership transferred to the concessionaire for the term of the concession; D&B = Design & Build; HNIP = Heat Network Investment Project; O&M = Operation & Maintenance; M&B = Metering & Billing; SPV = Special Purpose Vehicle; SLA = Service Level Agreement; PWLB = Public Works Loan Board					

Table D.1.1. Outline of Common Delivery Models for Large Heat Network Schemes

The **possible role of a separate heat distribution network-owning company (PipeCo)** in the area is worth exploring, and might also influence the choice of delivery model and the role that OPDC plays in scheme development. For established parts of the scheme (generation + distribution + connected customers), a PipeCo would own just the heat distribution pipework, accepting relatively low but reliable long-term returns from 'use of system charges', and freeing up capital for the scheme owner to reinvest in expanding the network with new connections and generating capacity. The PipeCo concept is new and might need to be integrated into the delivery model from the outset if it is to be successfully applied to a scheme in the Old Oak area. It would rely, as a minimum, on strong strategic and practical support from OPDC (and potentially on financial backing to establish the PipeCo).

D.1.1 Lessons from Previous Schemes

OPDC and AECOM held three meetings with a total of six invitees with experience of five existing district heating-based decentralised energy schemes in the UK. The following stand out as lessons from those schemes with implications for the establishment of a delivery model in the Old Oak area:

1. The context of every scheme is unique and the objectives of the sponsors are different in each case leading to the adoption of a range of delivery models, all of which have been proven to work with varying strengths and weaknesses. A sustainable financial case is essential for every scheme and each model may offer opportunities to achieve viability. Schemes led by the public sector have more opportunities to access cheaper finance and grant funding to support the financial case, but the private sector can also leverage 'patient' private investment, organisational experience, multi-utility solutions and economies of scale.

2. Enabling contextual factors can be critical to the business case and should be a focus for development of the contractual structure of the scheme, e.g. for OPDC: access to surplus heat (Powerday); potentially lucrative private wire electricity sales (to HS2 and commercial sites); a supportive planning environment that contributes to reducing scheme risks (planning policy on connections (reducing demand risk), SPD including draft technical standards (reducing technical risk), designated land use for (energy from) waste site (supporting long term heat supply resilience), etc.).

3. There are emerging risks for gas-fired CHP (an inevitable long-term fall-off in carbon savings due to grid decarbonisation, with no savings projected by the early 2030s; and potential short- to medium-term headwinds in planning and Building Regulations compliance contexts when grid electricity emission factors in the National Calculation Methodologies used for Part L change). However, gas-fired CHP was essential to the technical feasibility, business case, and operational resilience of all the major heat network schemes reviewed, and invitees at the lessons learned sessions felt strongly that this will remain the case for new schemes in the near term.

4. A Multi Utility model appears to offer opportunities for high value utilities (e.g. data networks) to cross-subsidise investment in other utilities, such as heat, that offer lower returns. As such, a

decentralised energy delivery model would ideally retain the option to work as part of a multi utility solution.

5. Taking on the role of the ESCo requires a large amount of knowledge to be developed within the sponsor organisation (which needs to be retained) and setting up the contractual arrangements involves significant effort and costs.

6. Technical standards and in particular performance of the secondary network are frequently a problem in early phases of new networks and the delivery model should address this by bringing the eventual network operator on board early with a remit to control network design and construction quality.

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D.1.2 Next Steps

OPDC's **choice of delivery vehicle** is likely to be driven by:

- Strategic objectives; (and consequently)
- Appetite for control and governance of the scheme;
- Decisions on whether to carry or transfer scheme risks;
- Required / acceptable rate of return (hurdle rate);
- Available sources and costs of finance; and
- In-house technical and commercial skills (capacity that exists or can be developed).

These factors essentially point to the next steps that OPDC should take towards deciding on the delivery model through which a heat network scheme should develop in the Old Oak area:

1. Consider the strategic objectives for a potential heat network serving the Old Oak area, including the importance and relative priorities of carbon savings, developer cost savings, consumer energy prices/ bills, any system / synergistic issues such as interconnections to wider heat networks, and any other relevant issues such as the interests and potential role of neighbouring Boroughs.

2. Consider the level of control and governance over the heat network that OPDC is likely to need to achieve the strategic objectives, or that it would prefer for other reasons.

3. Undertake an initial review of scheme risks (including: presence of connectable anchor loads; heat demand evolution; broad design and construction issues; energy prices and other operational issues) and establish whether OPDC would consider carrying or would prefer to transfer each risk.

4. Establish the rate of return that OPDC would set as its own 'hurdle rate' for any financial stake in a scheme delivery vehicle (and if relevant, the rate applicable to a stake in a PipeCo).

5. Confirm the sources of finance available to OPDC (e.g. for scheme development: Heat Networks Delivery Unit, own funds; for delivery: Public Works Loan Board, Heat Networks Investment Project, Green Investment Bank, private debt), corresponding constraints (process, timescales, capital limits, etc.), and the interest rates and any other costs of accessing this finance. As part of this, consider the potential for funds to support scheme delivery to be generated through the Community Infrastructure Levy or through Section 106 as developer carbon offset payments.

6. Assess OPDC's existing in-house technical and commercial skills relative to the skills capacity needed to establish the delivery vehicle(s) that are of interest.

7. (Crosscutting:) Start to consider OPDC's level of interest in the PipeCo concept, assessing its positive potential against novelty and risk.

Before opting for a preferred delivery model for a heat network scheme serving the area, OPDC would also require initial indicative information on:

- The technical parameters of a feasible scheme (generator types and installed capacities, network length, customer mix and demand levels) given known development proposals and constraints;
- The likely range of rates return of an indicative scheme for public and private investors.

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D.2 Introduction

D.2.1 Purpose

This note explores the range of delivery models available for the development of low carbon decentralised energy (DE) infrastructure in the Old Oak area.

D.2.2 Basis, Scope, Assumptions and Terminology

The note is based on a review of published information and guidance from authoritative sources about heat network delivery. The reference material reflects the experience of the maturing DE sector in planning and delivering heat network infrastructure.

It is assumed in the note that OPDC:

- Is in the role of scheme 'originator' or 'sponsor' and would either take a direct role in the delivery of the scheme or at least ensure that a supportive planning context will be in place and facilitate development of a scheme;
- Is a 'public authority', with powers and constraints similar to Local Authorities, which have often been the sponsors of existing heat networks; and
- Has or could develop the capacity to opt for any of the range of potential delivery models.

The term 'delivery models' covers:

- The identity, corporate nature, and boundaries between key parties involved in overseeing, sponsoring, designing, building and operating the energy infrastructure in question;
- The sources and types of funding available to the parties; and
- Outline of the roles of the parties and contractual relationships between them.

The review focuses on delivery models for heat networks because the decision on whether to develop an area-wide heat network, will fundamentally shape the overall long-term energy strategy for the Old Oak area. The implications for non-network DE options should be considered further in parallel.

The term 'scheme' is used to refer to the potential heat network project developed in the Old Oak area, or in general for a network realised by a sponsor.

D.2.3 Structure and Content of the Note

The remainder of this note is structured as follows:

- Section D.3 Heat networks and the role of public authorities in delivery
- Section D.4 Common scheme delivery models
- Section D.5 Factors influencing choice of delivery models
- Section D.6 Lessons learned from case studies
- Section D.7 References

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D.3 Heat Networks & the Role of Public Authorities in Delivery

D.3.1 Heat Networks

In this paper, the term 'heat network' is taken to cover the elements illustrated in Figure D.3.1:

- Heat sources (potentially including waste heat from a power station, industry, or energy from waste plant, for example) and the energy centre(s) in which scheme heat generators and accumulators are housed;
- Primary heat transmission and distribution pipework, i.e. the larger diameter pipe network which transfers heat from the scheme energy centre(s) (and potentially also from third party heat generators supplying the scheme) to property or development site boundaries; and
- Secondary heat supply pipework up to and including the heat interface units in homes, and heat exchangers in non-domestic buildings.

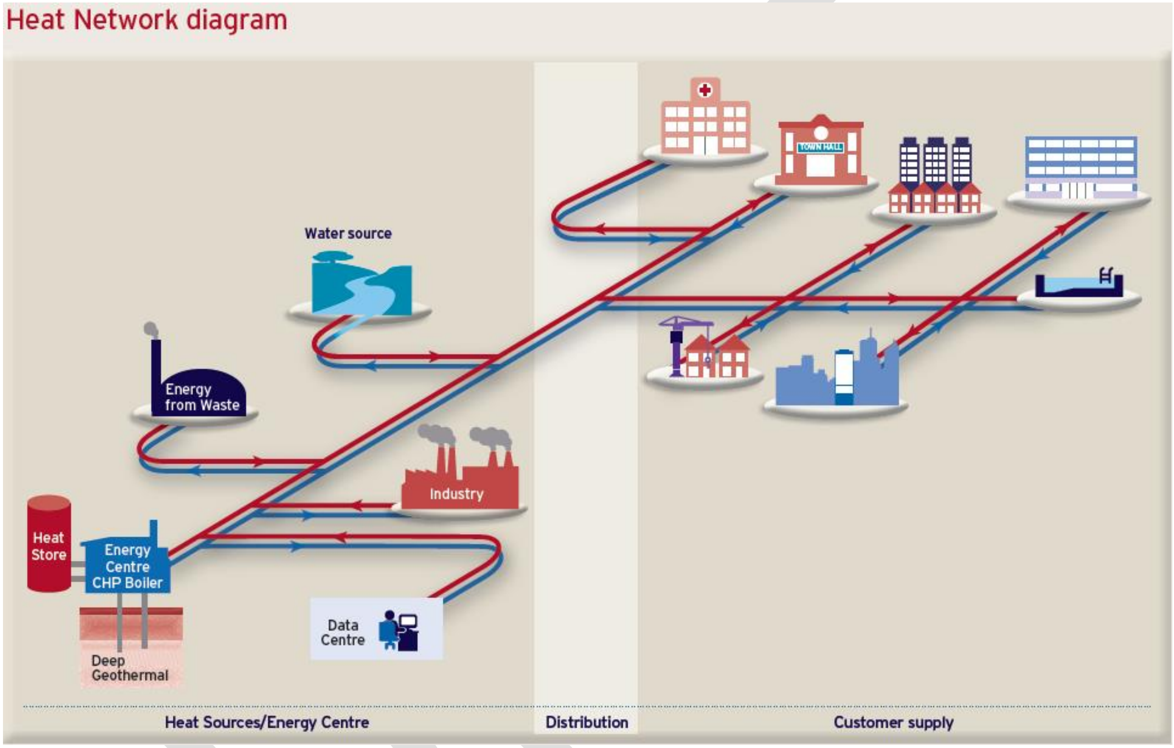

Figure D.3.1. Elements of a Heat Network Scheme
[Source: (DECC, 2015)]

Delivering such a network typically involves the 'works' and 'services' elements and property-related agreements listed in Table D.3.1.

Works elements	Services elements	Property agreements
• Design • Construction of energy centre and heat network • Connection of premises	• Energy (fuel, heat) purchase • Generation of heat and electricity • Operation and maintenance • Metering and billing • Connection of new customers • Supply of heat or heat and electricity to connected customers • Customer services	• Sale or lease of operational land and buildings • Easements, rights of way and access arrangements on private land and buildings • Street works licence

Table D.3.1. Works and Services Elements and Property Related Agreements for Scheme Delivery
Source: (GLA, 2014)

D.3.2 Stages of Development for a New Heat Network

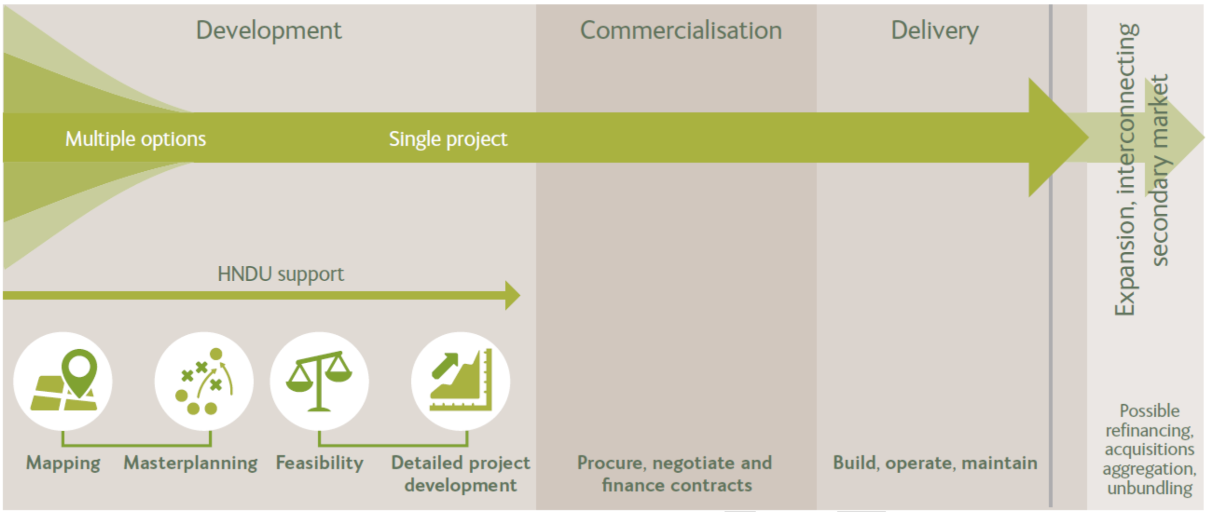

Figure D.3.2. Stages of Development for a New Heat Network
[Various sources, e.g. (Green Investment Bank)]

The creation of new heat networks generally follows an established pattern consisting of the following stages (see Figure D.3.2):

- Development – Mapping & masterplanning (to determine where heat will be generated and used and network routing options), and feasibility and detailed project development (where options are developed and iteratively tested to arrive at a deliverable project – i.e. technically feasible and economically viable).
- Commercialisation – Establishment (e.g. public SPV or JV, if not already in place) or procurement (e.g. private SPV) of the primary delivery vehicle, negotiation of top tier contracts and agreements, procurement of subsidiary works and services contracts, and securing of finance by relevant parties.
- Delivery – Building of energy centres, connection to heat sources and / or purchase and connection of heat generators; customer connections and network operation, maintenance, metering and billing. And (potentially),
- Further network development – Expansion of the network, interconnection with other existing and developing networks, and potentially: aggregation of network ownership (i.e. through acquisitions) and / or unbundling – i.e. functional separation, potentially down to separate generating companies, a PipeCo (see D.5.7), and heat supply and services companies.

D.3.3 Common Roles of Public Authorities

Public authorities generally play an important part in the development of heat networks. Figure D.3.3 illustrates the roles that they may play through the full development stages of a scheme. A public sector sponsor is more likely to fulfil the development stage roles than to take on funding and delivery of a scheme, although there are examples of local authorities taking a direct role in delivery (e.g. Woking and London Borough of Islington).

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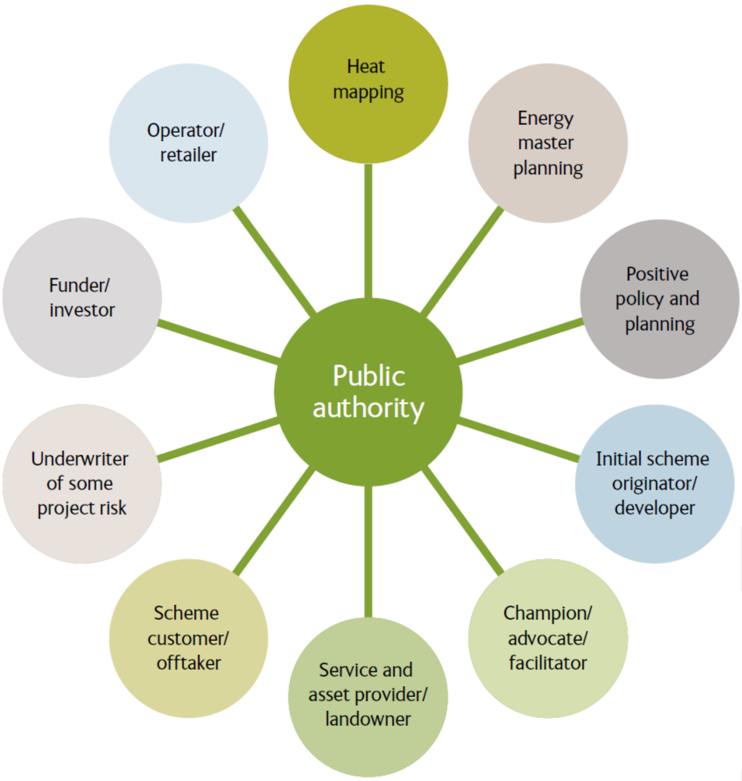

Figure D.3.3. Potential Role of Public Authorities in Heat Network Schemes

[Source: (Green Investment Bank)]

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At the ‘development’ stage, public authorities invariably act as scheme sponsors. In practice, this means taking a lead on the following issues, using the authority’s planning powers where appropriate:

- Mapping heat demands, including projecting demands for new development;
- Energy masterplanning, including identifying, facilitating and where possible securing / safeguarding locations for heat network infrastructure such as energy centre(s), and primary heat transmission and distribution pipework – with particular attention to overcoming existing infrastructure constraints, i.e. crossing road, rail, waterway and buried services routes;
- Planning policy support, which often involves a mix of directly supportive policies – e.g. expecting new developments in specified areas to connect to an existing network or to provide for future connection to planned networks – and indirectly supportive policies;
- Acting as scheme originator and developer, i.e. developing a scheme to the point that ongoing development and commercialisation is taken over by a delivery vehicle set up by the authority or procured from the private sector (or a joint venture);
- Acting as a champion for the scheme, particularly facilitating communications with stakeholders such as by brokering connections with developers and other potential customers;

At the next stages – of ‘commercialisation’, ‘delivery’ and beyond – the role of a public authority will depend on the delivery model for the scheme and context-specific things, such as whether the authority controls assets like existing property or development land. An authority with a major stake in the scheme, directly as a future heat customer, or indirectly as the owner of land for commercial and residential development, may have sufficient incentive to provide assets (e.g. land), funding, financial guarantees, and ultimately to take full or part ownership of the network delivery vehicle. The authority’s decision on whether to take on funding and delivery roles will then depend on an assessment of a range of factors, discussed further in section 0.

D.3.4 OPDC role

In terms of a heat network scheme in the area, OPDC will want to think about which of the potential roles of public authorities it would consider taking on, and subsequently how to fulfil them. The potential roles for OPDC (i.e. those listed in Figure D.3.3) are reviewed in Table D.3.2 with commentary on context-specific considerations for the Old Oak area. The roles have been reorganised to better reflect the chronology of the planning context and likely OPDC decision-making.

Potential role	OPDC capacity / appetite	Considerations
1. Positive policy and planning	High	Draft (Regulation 18) OPDC Local Plan policies (consulted on in February – March 2016) includes the following that particularly support development of heat networks: EU1: Strategic policy for the environment and utilities – Preferred Policy Option: OPDC will support proposals that: f) Support delivery of coordinated and area-wide utilities infrastructure. EU6: Decentralised energy – Preferred Policy Option: OPDC will support and facilitate: b) the provision of infrastructure to deliver a decentralised energy network; c) proposals which contribute to the delivery of a decentralised energy network subject to [conditions]; The next Draft (Regulation 19) OPDC Local Plan is scheduled for March 2017. The OPDC Community Infrastructure Levy Preliminary Draft Charging Schedule was published in October 2016. The Regulation 123 list does not include decentralised energy infrastructure. However, the document notes that "[T]he list… excludes infrastructure projects that are required to make a development acceptable in planning terms in accordance with the planning policies set out in the OPDC Local Plan… Such infrastructure will therefore be secured as part of the development through the use of planning conditions or Section 106 planning obligations… …[A] Supplementary Planning Document on Planning Obligations will be published…"
2. Energy masterplanning	High	OPDC has produced a draft Old Oak Decentralised Energy Strategy. Further energy masterplanning work is planned.
3. Heat mapping	High	Mapping and projection of demands from new development forms part of energy masterplanning, above. AECOM has submitted a proposal for additional work which includes early mapping of expected heat demands.
4. Service and asset provider / landowner	TBC	OPDC's stake as a development landowner and future scheme customer may influence its preferred scheme delivery model.
5. Scheme customer / off-taker	TBC	
6. Initial scheme originator / developer	TBC	Whether OPDCs' role is limited to scheme sponsor, or extends into delivery depends on the delivery model chosen.
7. Underwriter of some project risk	TBC	The extent of OPDC's involvement in these roles depends on the preferred scheme delivery mode which in turn will be influenced by OPDC long term remit and the funding it can access.
8. Funder / investor	TBC	
9. Operator / retailer	TBC	
10. Champion / advocate / facilitator	High	Important roles for OPDC regardless of the delivery model. Responsibility may need to be separate from any OPDC role in delivery, and this separation should be planned for.

Table D.3.2. Considerations Regarding OPDC's Role in Scheme Development and Delivery

D.3.5 Role of London Boroughs of Brent, Ealing and Hammersmith & Fulham

The Old Oak area covers land within the London Boroughs of Brent, Ealing and Hammersmith & Fulham[1]. Of immediate relevance to this paper is the potential influence of these neighbouring Boroughs on the consideration of scheme delivery models.

The plans of the neighbouring Boroughs with respect to the development of heat networks were not reviewed, nor were the Boroughs consulted on delivery models when preparing this paper. Synergies between the Borough heat plans and development of a heat network serving the Old Oak area should be considered as part of planning, heat mapping and energy masterplanning activities.

In the absence of specific information about the interests of the Boroughs, the following general points are raised for consideration:

- The Boroughs may be potential partners in a joint venture delivery vehicle, or have an interest in acquiring scheme ownership in future;
- The Boroughs may have stakes in existing or planned heat networks outside the Old Oak area and an interest in future interconnection to an Old Oak area scheme; and
- Potential anchor heat loads both within and outside the Old Oak area may already have been identified as part of Borough heat mapping activities and may be relevant to planning and delivery of a scheme.

The Old Oak Decentralised Energy study prepared by GLA's decentralised energy delivery unit (February 2016) that is part of the evidence base for the local plan recommends that opportunities to connect to nearby decentralised energy developments proposed at White City and Wembley should be considered.

The interests of the neighbouring Boroughs should be considered further as part of the study of potential delivery models and the Boroughs would ideally be consulted as part of developing a preferred model alongside future masterplanning work.

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[1] Referred to for convenience as the 'neighbouring' Boroughs.

D.4 Common Scheme Delivery Models

The delivery model for a heat network scheme broadly consist of the delivery vehicle – the corporate entity that will develop and enjoy ownership of scheme assets – and the contractual structure, i.e.: how the individual 'works' and 'services' elements of the scheme are bundled and procured, what property-related agreements are needed, and any other necessary legal agreements between parties.

D.4.1 Delivery vehicles

Possible delivery vehicles cover a spectrum in terms of ownership:

- Wholly public, e.g. internal department or wholly owned municipal companies;
- Hybrid, examples include:
  - a public sector-led SPV (which could be: a public + private joint venture, or a wholly owned, arms-length municipal limited company); and
  - a community-owned mutual limited company or cooperative (although the latter are unlikely to suit a large scheme serving new development);
- Fully private sector companies (invariably 'Special Purpose Vehicles' (SPVs), likely to be subsidiaries of specialist energy companies and often afforded exclusive rights to supply heat, e.g. through a concession).

In practice, only a handful of delivery models are common (to date) or likely to work well for large schemes and these are illustrated in Table D.4.1 (also Table D.1.1), which outlines the relationships between the scheme sponsor (outlined in green), public authority (OPDC in this case), delivery vehicle (black outline), customers, and the works and services delivery, and provides an indication of the roles typically fulfilled by (or open to) the public and private sectors (orange and blue shading respectively).

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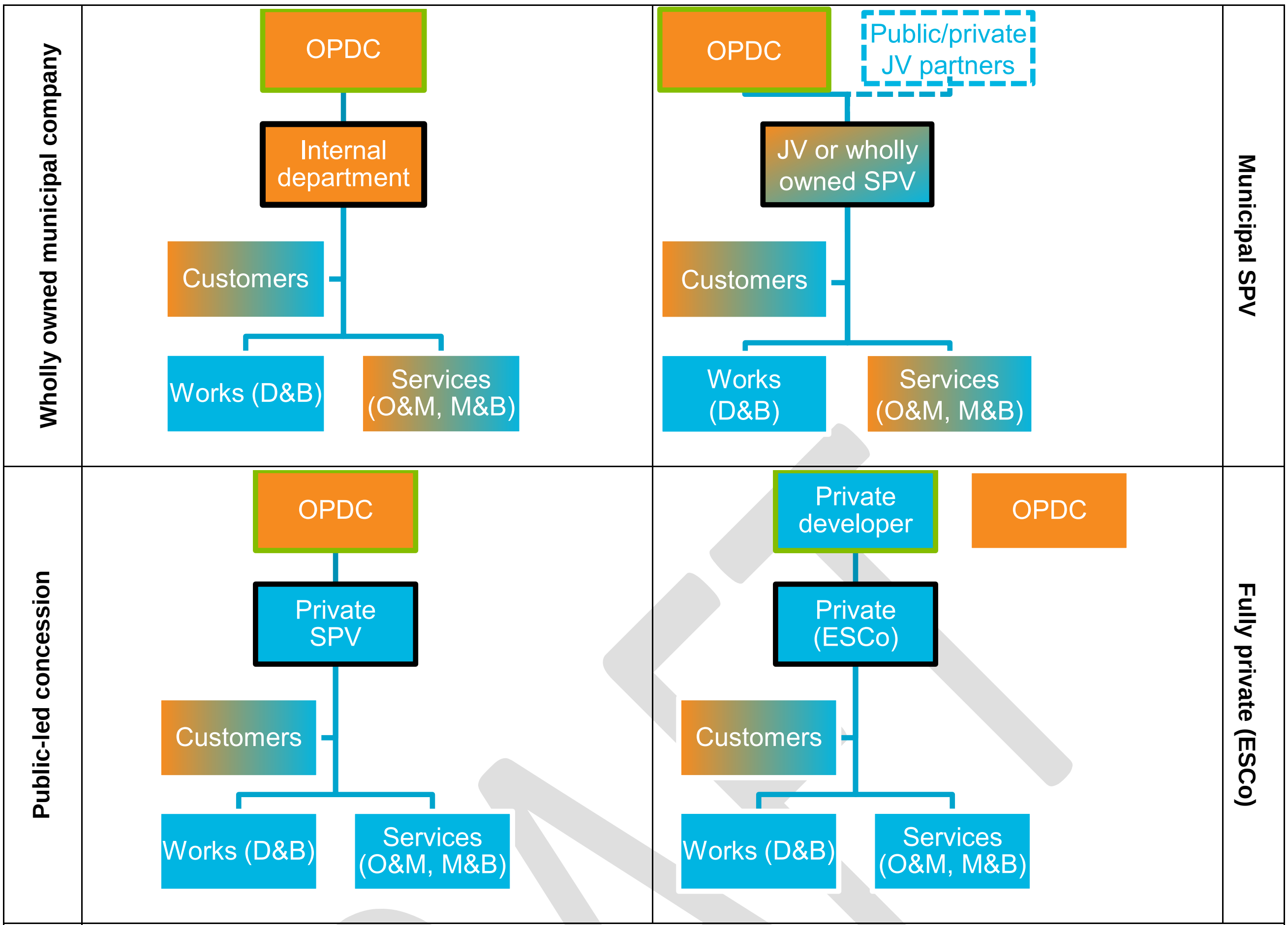

Key	**Delivery vehicle outlined in black. Colours: OPDC / public sector; private sector; boxes with gradient fill may be either public, private or mixed/joint. Dotted = optional.**

Table D.4.1. Common Delivery Vehicles, Sponsors, and Public/Private Roles

[Based on (Scottish Futures Trust, 2016)]

The choice of delivery vehicle will strongly influence the sources of finance available for scheme development and delivery. Wholly and partly public owned entities have access to public debt facilities, at lower rates of interest than will be available from commercial debt providers, and are eligible for public scheme development support (currently offered by the Heat Networks Development Unit) and grants (Heat Networks Investment Project funding to support scheme delivery is currently being piloted).

D.4.2 Contractual Structures

The choice of delivery vehicle does not necessarily constrain the approach to the contractual structure for building and operating a scheme. There are many ways that the individual ‘works’ and ‘services’ elements of a scheme could be bundled and procured, and this needs to be considered case by case.

Various options for grouping the functions involved in heat generation and supply are illustrated in Figure D.4.1, each of which would require a different set of contractual relationships between the corresponding parties. Missing from this picture are insights into asset financing and ownership, the role of the scheme sponsor, and other types of relationships and obligations – especially property-related issues.

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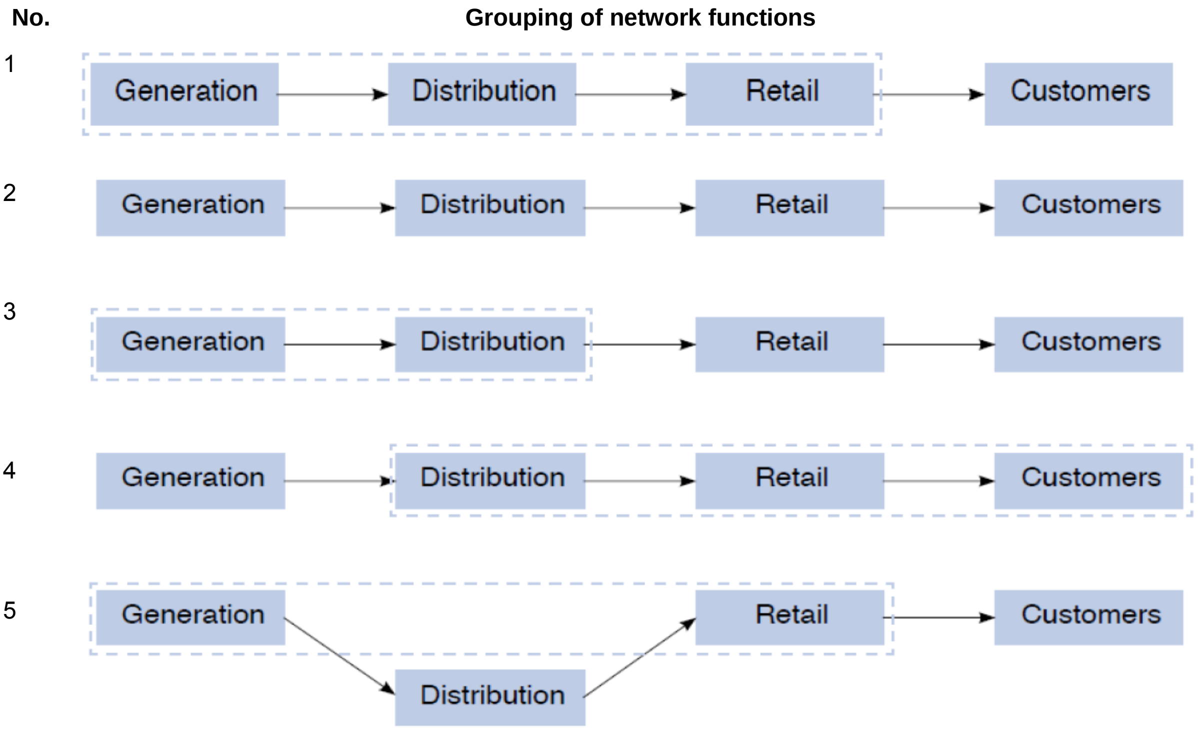

Figure D.4.1. Options for Functional Separation of Heat Network Operation
[Source: (King, 2014)]

The London Heat Manual identifies four common types of contractual approaches used for heat network schemes, as described in Table D.4.2. This perspective begins to link up the ‘type’ of delivery vehicle, its relationship with the scheme sponsor, and the specific types of contracts required between parties, including property leases – which would address issues such as obligations to connect, access for maintenance, wayleaves, etc. The last (‘Network operation’) approach in Table D.4.2 could apply, for example, to a case where a municipal company or SPV had separately procured construction of the network.

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Type	Description	Contracts required
Energy supply (ESCo)	An energy services company (ESCo) undertakes to supply heat to the customers, and for that purpose to build and operate the heat network. This could be set up with a defined set of consumer buildings to be connected, or to provide the service to developments within a defined area.	• Master agreement • Connection contract • Heat supply contract • Service level agreement (SLA) • Property leases
Wholesale supply of energy	A sponsor appoints a single contractor to design, build, own, operate and supply wholesale heat and electricity. The sponsor sells the energy retail to consumers, and may be a consumer itself. ESCos often prefer wholesale supply to multi-occupant commercial buildings.	• Master agreement or design, build, operate (DBO) Contract • Wholesale heat supply contract with SLA • Connection contract • Property leases
Network delivery and operation (DBO)	A sponsor (such as an owner of tenanted properties) appoints one or more contractors to design, build, operate and maintain a heat network but the sponsor remains the asset owner and contracts to supply heat and electricity to consumers. The sponsor may also purchase the fuel required	• DBO contract or a combination or D&B contract and O&M contract with SLA • (Metering and billing contract) • (Connection contract)
Network operation (O&M)	An operator is contracted to run a heat network that has already been constructed, for example under a main building contract. The operator may also be contracted to undertake metering and billing and customers services, if the landlord wishes to outsource these activities.	• O&M contract with SLA • (Metering and billing contract)

Table D.4.2. Commonly Used Types of Contracts for Heat Network Schemes

[Source: (GLA, 2014)]

One way to get a fuller picture of the contractual structure that might apply to an Old Oak area scheme is to draw on specific cases. Figure D.4.2 shows an example of the contractual relationships and agreement types for a 'fully private (ESCo)' arrangement (indicative of E.ON's arrangements for its Cranbrook and Skypark scheme in Exeter). This illustrates the majority of works- and services-related relationships and contracts required to build and operate a scheme.

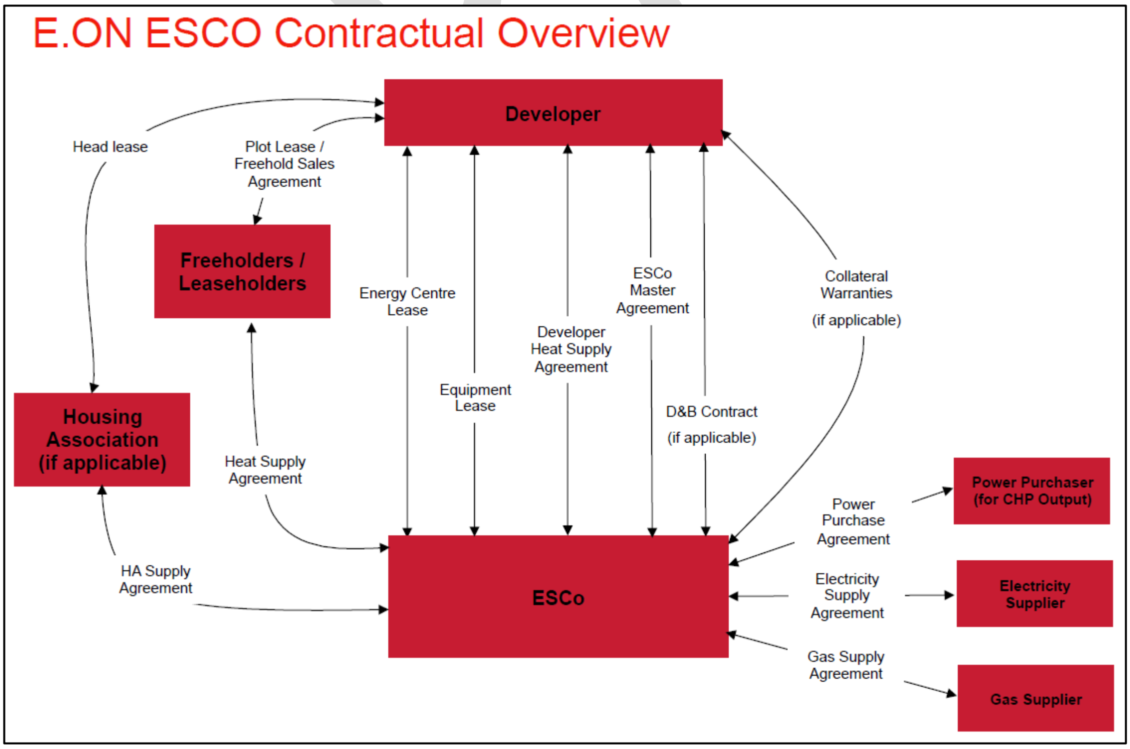

Figure D.4.2. Contractual Relationships for a 'Fully Private ESCo'

[Source: (E.ON, 2014)]

In the case of a Concession, the ‘Developer’ and ‘ESCo’ in Figure D.4.2 would be replaced by ‘Public authority (OPDC)’ and ‘Private SPV’ respectively, with the agreements needed remaining largely similar. For a municipal SPV, a third party design & build contractor would be procured to construct the infrastructure, and operation & management and metering & billing services might also be outsourced or could be delivered in-house (see Figure D.4.3). And for a wholly owned municipal company, the parties labelled ‘OPDC’ and ‘SPV’ in Figure D.4.3 would be different arms of OPDC with a degree of flexibility about how to define and regulate the internal roles and relationships.

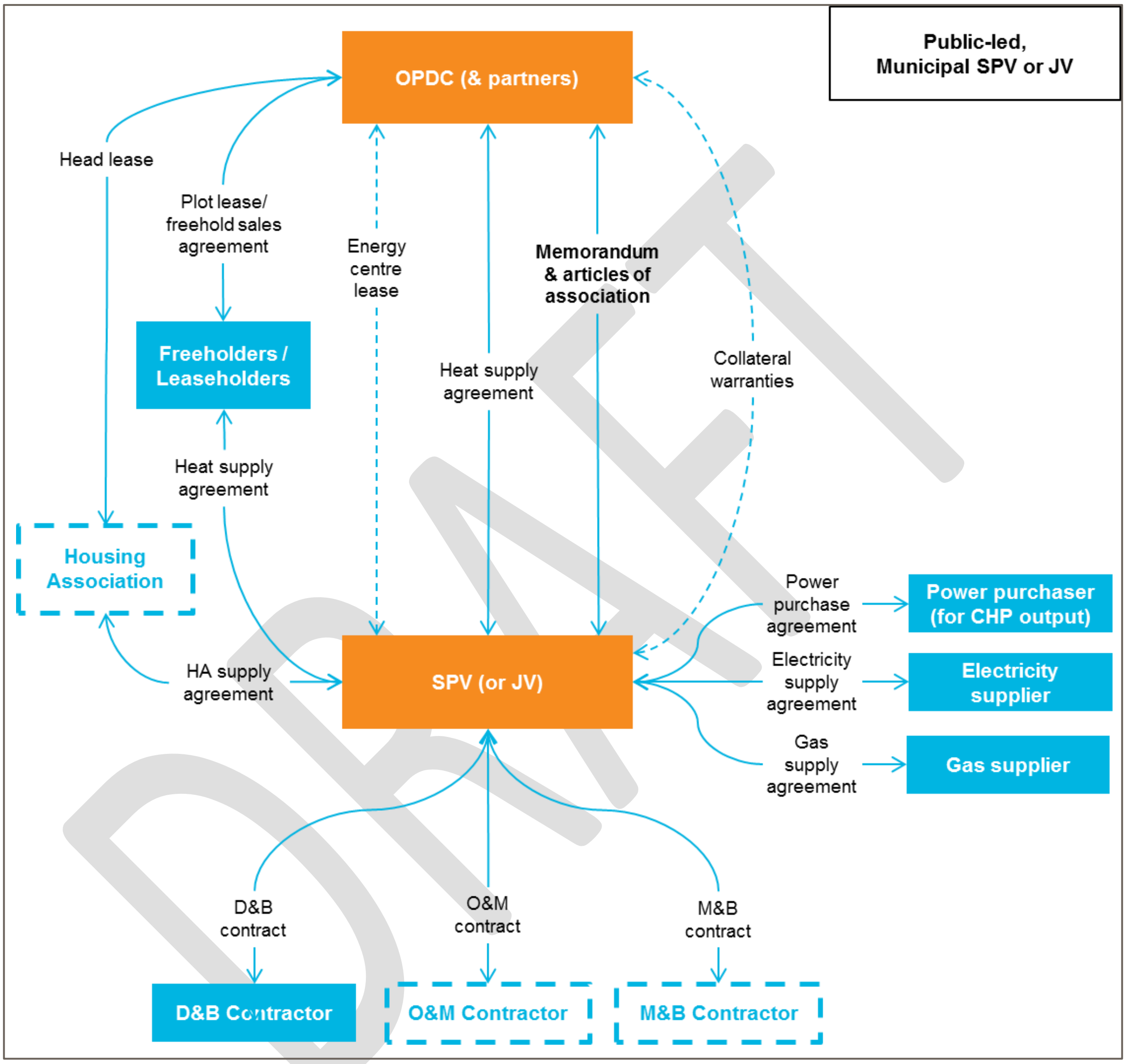

Figure D.4.3. Contractual Relationships for a ‘Fully Private ESCo’

D.5 Factors Influencing Choice of Delivery Model

Given the variety of available delivery models, OPDC needs a framework for considering its preferred model. The first priority will be deciding on the type of corporate entity, i.e. the delivery vehicle, to take forward a scheme, after which the detailed contractual structure can be progressively put in place.

OPDC's choices about how to deliver a heat network to serve the Old Oak area will depend on what it wants to achieve by developing a scheme; the financial, technical and commercial capabilities it can contribute to scheme development and the constraints it faces. The ways in which these factors may influence OPDCs choice of delivery model are discussed below under the following headings:

- Strategic objectives;
- Appetite for control and governance;
- Decisions on whether to carry or transfer scheme risks;
- Required / acceptable rate of return;
- Available sources and costs of finance; and
- In-house technical and commercial skills (capacity that exists or can be developed).

The 'PipeCo' has been conceived as a mechanism that could improve investment efficiency and unlock funding for heat network rollout in the UK. The concept is presented and its cross-cutting effects are discussed under a separate heading:

- The PipeCo concept.

D.5.1 Strategic Objectives

Heat networks provide a range of potential benefits. The strategic objectives of a scheme sponsor will primarily relate to the achievement of these benefits, and the criticality or relative priority of delivering each one.

The London Heat Network Manual (Arup 2014) provides a summary in which the potential benefits are grouped in terms of the beneficiaries, which are listed as: consumers, developers, and the environment. Summarising the suggested benefits for each group[2]:

Beneficiary	Potential benefits of heat networks
Consumers	More affordable* low or zero carbon energy supply than micro renewables (*assuming price control to this end) (With multiple heat sources:) Resilient Space efficient Low user maintenance
Developers	Lower cost of meeting planning carbon targets than micro renewables (With an attractive ESCo:) Reduced up-front capital costs and no need to engage in long term infrastructure management Reduces labour and maintenance costs as compared to individual systems. May reduce the developer's cost of compliance with Building Regulations.
Environment (and systemic)	Lower carbon emissions Durable energy centre(s) and extensible pipe network enable: use of surplus recovered heat, efficient low carbon CHP (during transition to decarbonised grid), diverse fuels and other heat sources Interconnection for greater efficiency and increased volume of low carbon heat Grows low carbon economy

Table D.5.1. Beneficiaries and Potential Benefits of Heat Networks

[Based on (GLA, 2014)]

[2] The table has been heavily summarised. The original row heading 'London and the Environment' has been replaced here by 'Environment (and systemic)'; some of the benefits listed are clearly synergistic effects or systemic benefits with the effect of increasing or extending the primary environmental benefit of reduced carbon emissions.

A scheme sponsor needs a clear understanding of its objectives if is to take effective decisions about its preferred delivery model. Delivery models where the sponsor owns and controls the delivery vehicle (fully or in part) and operates the scheme would make it inherently easier to align long term outcomes with strategic priorities. Consistent achievement of the objectives in other cases would rely on the inclusion of effective provisions in contracts governing design & build, operational services, etc. of the scheme. A sponsor then needs to negotiate contracts that aim to foresee and address predictable issues, or make contractual provisions that afford greater ongoing control and governance.

D.5.2 Appetite for Control and Governance

As noted above, OPDC's appetite for ongoing control and governance of a scheme is likely to relate to ensuring that key benefits of the network are realised. Particular areas of interest related to ongoing operation of the network are likely to be:

- Consumer prices – Price control mechanisms will be a key part of contracts under most delivery models. The balance between connection, capacity (standing), and unit charges, and the effect of network heat losses on standing charges, will influence affordability and customer perceptions of the network.
- Carbon emissions rates – determined by: fuel / heat source mix, generator efficiencies, primary and secondary heat losses; demand profile. Affects: net carbon emissions and savings relative to baseline, developers' costs and ability to meet planning and Building Regulations Part L targets and hence desirability of connecting to the network.
- Connection of new (non-gas CHP) heat generation capacity to the network in future – This will be essential to maintaining a low carbon heat supply in the medium to long term (new capacity connected from the mid-2020s onwards). There is no guarantee that lower carbon heat generation options will be cheaper by that time. The risk profile of these options, may also make them less attractive to a scheme operator making purely economic decisions.

Greater inherent control and governance can be achieved by opting for delivery models where OPDC owns and controls the delivery vehicle (fully or in part) and – for maximum control – operates the network. In other words, ranking the delivery vehicle options by inherent degree of sponsor control, the order would be as in Table D.1.1, i.e.:

1. Public led, municipal department or wholly owned company
2. Public led, municipal SPV (limited company) or JV
3. Public led, private SPV
4. Private led, private SPV

D.5.3 Allocating Scheme Risks

A heat network scheme in the Old Oak area will face a specific set of risks that will need to be identified, assessed, controlled, and reduced or eliminated where possible. A subset of these risks are common to most schemes, e.g.:

- Uncertainty about heat evolution (timing and scale of heat demands from new development and network extension);
- Construction-related risks (programme, cost and quality);
- Operation (including technology)-related risks (reliability; overall cost-effectiveness; generator efficiencies, network heat losses and fuel mix achieved and hence carbon emission rate);
- Feedstock fuel (including third-party heat) purchase prices;
- Customer credit; and
- Heat (and electricity) demand and sale prices.

These risks are presented in Figure D.5.1 along with indications of how they are commonly controlled.

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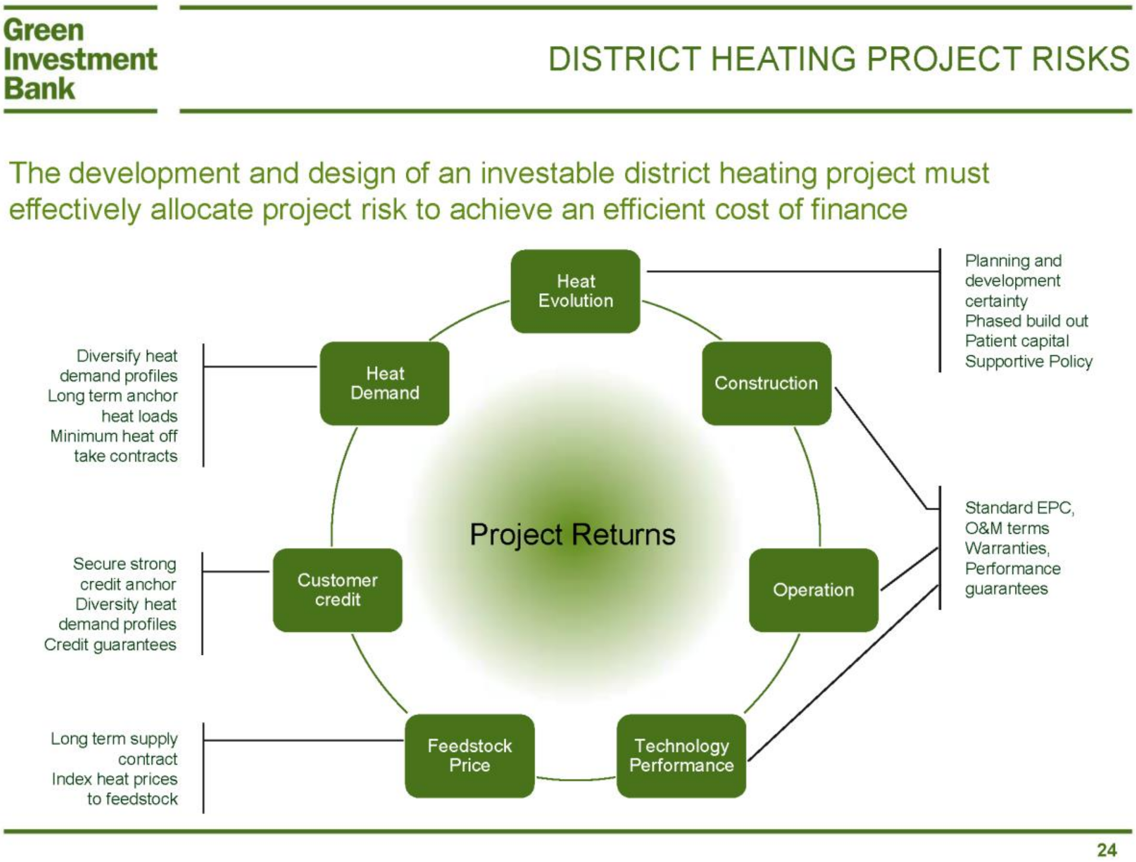

Figure D.5.1. District Heating Project Risks – Types and Controls

[Source: (Green Investment Bank)]

A key consideration will be the efficient allocation of the project risks identified for an Old Oak area scheme given the technical and organisational capability, types of finance available, and the risk appetite of OPDC as project sponsor, and of potential funders and contractors. Counterparties will expect financial compensation for the risks they take on, which will be higher for less controlled risks. Costs of finance will tend to be higher for parties taking on less controlled risks. And risk transfers to the private sector will tend to feed back in higher scheme costs due to a risk premium on the price of contracts. So overall there is a strong incentive for OPDC to understand and control project risks where it can, for example by:

- Producing and maintaining the best possible heat demand projections for new development;
- Adopting a strongly supportive planning policy framework for a heat network;
- Aggregating and guaranteeing some anchor / base heat demand (e.g. for public buildings);
- Providing (for public) or brokering (for private) customer credit guarantees.

The first step would be to assemble a risk register, which may then influence the consideration and choice of delivery model.

D.5.4 Acceptable Rates of Return

Each potential investor in a scheme will have a minimum threshold of financial return they expect from any investment, often expressed as an ‘internal rate of return’ and referred to as a ‘hurdle rate’. Private sector hurdle rates for heat network schemes at the development and commercialisation stages are likely to be in the order of 12+%. This may come down slightly if some of the risks described above are carried by the public sector, and also as scheme delivery progresses and risks have been well controlled, providing opportunities for refinancing at lower rates of interest. The hurdle rate set by public bodies for projects with societal benefits can be lower, at around 6+%, reflecting the effective underwriting of some internalised risk, a lower cost of borrowing, and less inherent need to generate a financial surplus due to the value assigned to social and environmental benefits.

D.5.5 Sources and Costs of Finance

The range of funding for the development of large scale heat networks is fairly well-defined, with the sources available to a particular scheme depending on its ownership – public, private, or joint – as summarised in Table D.5.2.

Funding sources available to…	
Private and public sectors	**Uniquely public sector**
• Equity – value of shares in the asset company held by its owner(s) • Debt – commercial loans from banks, including specialist Green Investment Bank as project finance (senior project debt) to the project delivery vehicle / SPV • Capital contributions – direct contributions from developers; indirect developer contributions via community infrastructure levy or Section 106 payments; grants from public authority local carbon offset funds	• Heat Networks Development Unit – grant funding for scheme development • Public Works Loan Board – public debt via Debt Management Office • Heat Networks Investment Project – grant funding for scheme delivery via Salix[3]

Table D.5.2. Funding Available to Public and Private Sectors for Scheme Development and Delivery

The costs of finance vary across these funding sources. It is beyond the scope of a paper at this stage to make more than general points of comparison, for example: public debt tends to be cheaper than private debt (Figure D.5.2), the administrative costs of accessing public grant funding are unlikely to impact the balance sheet but the funding itself cannot be guaranteed; and capital contributions (from developers or public authorities via CIL, S.106 or local carbon offset funds) are likely to be small relative to the total investment required.

[3] https://hnip.salixfinance.co.uk/

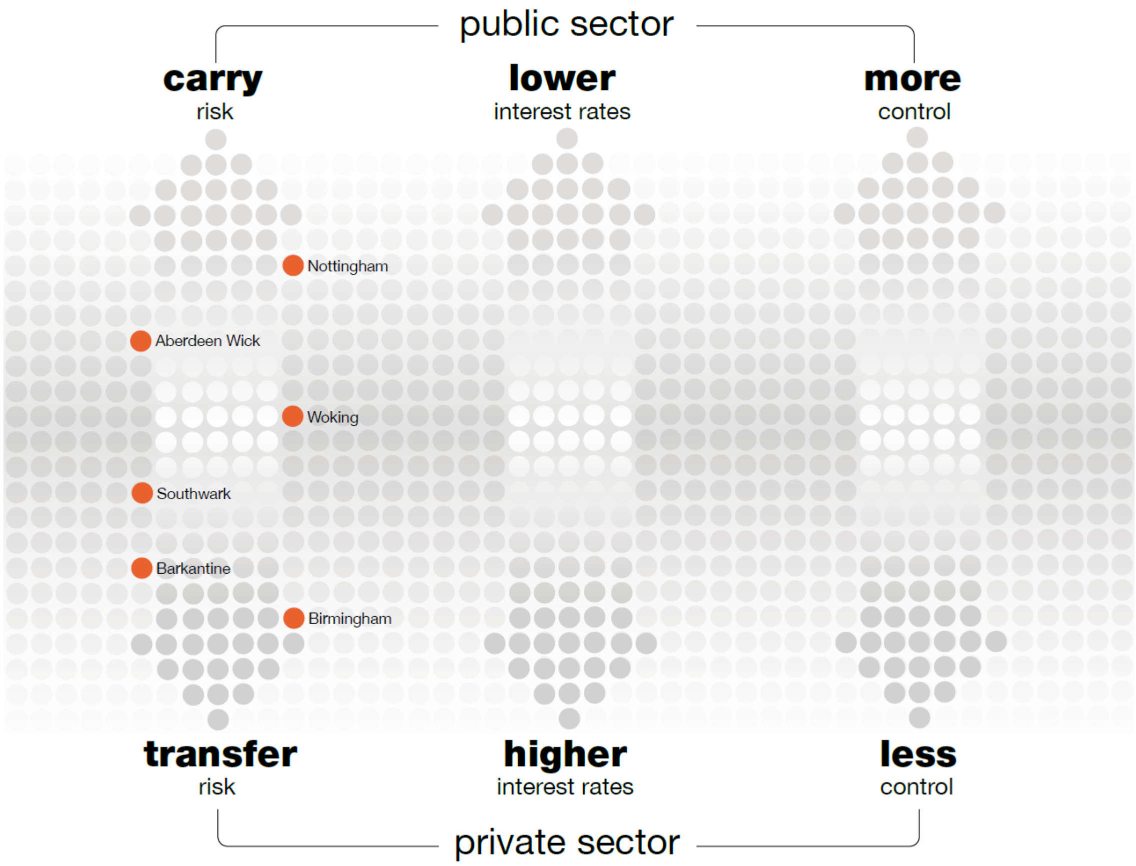

Figure D.5.2. Relationship between Risk, Control and Cost of Capital for Public and Private Sector Projects
[Source: (ADE, TCPA & LDA Design, 2010)]

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It is worth noting the current status of planning mechanisms for the Old Oak area that could potentially provide funding for a scheme:

- CIL – funding for heat network infrastructure is NOT included in the Regulation 123 list in the Draft CIL charging schedule;
- Section 106 – a Supplementary Planning Document is proposed that "will provide further advice and clarity on how CIL and s106 will interact and operate within the Old Oak area".
- Local carbon offset fund(s) – in the draft OPDC Local Plan and supporting documents, no references were found to OPDC's approach to carbon offsetting; a review of local carbon offsetting approaches in London (National Energy Foundation, 2016) indicates that Brent, Ealing and Hammersmith & Fulham are collecting offset payments related to new development;
- Developer contributions – There may be other conceivable mechanisms by which developers could be induced to contribute to the delivery of a scheme.

D.5.6 In House Technical and Commercial Capacity

With the exception of a fully privately led and delivered scheme, all of the delivery models would require OPDC to develop and maintain some in-house commercial capacity to agree and manage scheme contracts. In the case of a municipal company or SPV, an OPDC owned or controlled company could choose to develop and maintain technical staff to deliver some network services, rather than outsourcing them to the private sector.

OPDC would need to establish its inherent appetite to develop extensive technical and commercial heat network capabilities in house as well as considering the related risk and financial trade-offs.

D.5.7 The PipeCo Concept

Of potential relevance to the choice of delivery model is the idea of the ‘PipeCo’. Conceptually, once a heat network scheme is constructed and customers are connected and providing income, a PipeCo would buy the distribution pipe network. The company that made the original investment in the pipe network would immediately recoup a large part of its investment, improving cash flow and potentially freeing capital for new investment. The PipeCo is financed by institutional funds seeking low-risk investments. It levies a regular ‘use of system charge’ on those distributing heat through the network and is content to accept returns which, while relatively low, are reliable for the 50-60 year life of the network. The concept is analogous to the refinancing of infrastructure loans following the design and build phase; investors expect higher returns up to that point to compensate for the relatively high risk.

The PipeCo concept is new. There are only a few references to the approach in the literature and the main source used for this paper (Manders & Groth, 2016) acknowledges there may be only one existing example of a PipeCo in the context of property development (likely to be outside the UK) and “one major player in the UK district heating market is seriously considering setting [one] up”. However, the theoretical benefits of the approach, particularly in a context like the Old Oak area of dense development that will be brought forward over a long time scale, make it worthy of consideration.

To facilitate a PipeCo, thought would need to be applied to the contractual and financial implications of the transfer of the heat distribution pipework assets. Given the novelty of the approach, it would potentially be valuable to seek input from those promoting the concept in the UK and likely to have insights from the limited experience that is available.

Assuming initial technical options appraisal demonstrates that a district heating scheme will offer value compared with alternative dwelling or block based solutions, this input could be sought when developing a preferred district heating solution as part of the forthcoming masterplanning phase.

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D.6 Case Studies & Lessons Learned

OPDC and AECOM held three meetings with individuals representing or knowledgeable about five existing heat networks in the UK, as summarised in Table D.6.1.

Meeting	Date	Invitee & company*	Heat networks discussed
1	15/11/2016	Ian Guest – Lee Valley Heat Network Ltd Andy Kotowicz – London Legacy Development Corporation	Lee Valley HN, Enfield and Queen Elizabeth Olympic Park HN
2	17/11/2016	Paul Woods – ENGIE Michael King – Aberdeen Heat & Power Co Lucy Padfield – London Borough of Islington (apologies)	Aberdeen HN, Bunhill HN, and Queen Elizabeth Olympic Park HN
3	23/11/2016	Anthony Peter – Argent Andrew White – Metropolitan	King's Cross Heat Network
* Peter O'Dowd, Mo Williams, Dan Epstein and Alaina Tolhurst of OPDC, and Miles Attenborough and Zac Grant of AECOM also attended each of the meetings and minutes were circulated to OPDC attendees and relevant AECOM project staff.			

Table D.6.1. 'Lessons Learned' Meeting Dates, Invitees and Heat Networks Discussed

D.6.1 Case Studies

D.6.1.1 Lee Valley Heat Network

Drivers	Strategic: Regeneration in the Upper Lee Valley Opportunity Area provided a strategic focus for decentralised energy studies from which the potential to recover heat from waste management activity at Edmonton Ecopark emerged as a key opportunity. A Lee Valley Heat Network linked to the Edmonton Eco Park is one of eight planning framework objectives for the area. Local: Secure economic (inward investment, jobs, training, and energy security), social (low cost heat and community energy), and environmental (carbon reduction) benefits.
Objectives	Enfield Borough Council: Provide affordable heat to new homes, reduce fuel poverty, and cut carbon emissions. Strategic stakeholders: Same as the council, plus a long term ambition to interconnect Lee Valley, Queen Elizabeth Olympic Park and London Thames Gateway strategic heat networks.
Delivery structure	Lee Valley Heat Network Limited and subsidiary Lee Valley Heat Network Operating Company Limited established as the asset holding and operating companies respectively, wholly owned (two-tier) by Enfield.
Governance	Enfield Council controls the holding and operating companies through their Articles of Association, financing subject to approval of business plans, and appointments of directors.
Initial scheme	'Strategic network' consisting of a District Heating Energy Centre and the heat network to receive heat from a planned new energy from waste facility at North London Waste Authority's Edmonton Ecopark and supply it to 5000 new homes in the Meridian Water development. LVHN Limited is also to adopt a heat network 'Satellite scheme' serving 513 new homes, a hotel and commercial buildings completed in 2015 at Ladderswood.

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Finance	Grant funding from the London Energy Efficiency Fund, private debt in the form of commercial bank loans from the European Investment Bank, and public debt from the Public Works Loans Board, all provided via Enfield Council.
Procurement	Currently in the process of procuring: design, build and operation services for the District Heating Energy Centre for the strategic network to serve Meridian Water; a framework for the operation of Satellite Schemes, and an initial contract to operate the Ladderswood scheme; and a customer services provider for the company's heat customers.
Subsequent / planned expansion	Potential increase from 5000 to 8000 homes at Meridian Water; additional Satellite schemes at Alma Estate and New Avenue; further Satellite schemes potentially including some in neighbouring Boroughs; and interconnection of Satellite schemes to the strategic network, subject to connection of sufficient local demand.

D.6.1.2 Queen Elizabeth Olympic Park Heat Network

Drivers	Sustainability agenda for 2012 London Olympics.
Objectives	Enable the Games and Legacy Communities Scheme development to meet carbon targets.
Delivery structure	ENGIE was appointed as concessionaire to finance, construct and operate the scheme under a 40 year concession agreement.
Governance	London Legacy Development Corporation and Stratford City Development Limited are the joint employers. A concession agreement establishes expected levels of service, price controls for consumers, contractual templates for future connection agreements between ENGIE and heat and cooling customers, and controls on the cost of those connections. It also makes contractual arrangements for appointing a new concessionaire to ensure continued operation after the initial 40 year concession period.
Initial scheme	Two separate but interlinked heat networks served by Energy Centres at Kings Yard on the Olympic Park and in the Stratford City development. The heat networks are served by a combination of biomass boilers, gas CHP engines and gas boilers and the cooling networks are served by a combination of vapour compression and absorption chillers.
Finance	ENGIE invested in the construction of the heating and cooling networks and energy centres that serve them. In return for this investment ENGIE was granted exclusive 40 year rights to provide heating to developments including the Olympic Venues, the Westfield shopping centre, East Village, and all legacy development on the Olympic Park within the concession area.
Procurement	Procured by the Olympic Delivery Authority (which transferred its share of governance of the scheme to the London Legacy Development Corporation) and Stratford City Development Limited as part of the regeneration of the Olympic Park for the 2012 Olympic Games.
Subsequent / planned expansion	The heat network has been or is being extended to serve the majority of the Legacy Communities Scheme on Queen Elizabeth Olympic Park, sites at Stratford, and in some neighbouring areas subject to feasibility, including developments at Chobham Manor, East Wick and Sweetwater, the Cultural and Education District (including Stratford Waterfront), the International Quarter, and Angel Lane.

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D.6.1.3 Bunhill Heat Network

Drivers	Primary driver was to reduce fuel poverty
Objectives	Reduce fuel poverty and cut carbon emissions
Delivery structure	Project development; procurement of expert consultancy, design, build, operation and maintenance services; billing and customer services; and related legal and other services undertaken in-house by the Energy Services team and relevant departments within Islington Borough Council.
Governance	The network is run as part of the wider delivery of Council services, with the corresponding mechanisms for control and accountability. The activities and performance of third party service providers are governed by contract.
Initial scheme	Bunhill Energy Centre housing a 1.9 MWe gas CHP engine and 115 m^3 thermal store, one kilometre of trenching containing two kilometres of insulated district heating pipework serving 850 homes and two leisure centres.
Finance	£3.8 million energy centre and heat network were funded by grants secured from the Greater London Authority and the Homes and Community Agency with the remainder from Islington's own budget.
Procurement	Design and build and a 10-year operation and maintenance service were procured from the private sector.
Subsequent / planned expansion	An extension, Bunhill phase II, will serve a further 454 homes at the King's Square estate, a school, sheltered housing block, a community centre and a nursery utilising heat from a vent shaft on the Northern Line.

D.6.1.4 Aberdeen Heat Network

Drivers	Aberdeen City Council's strategic need to improve its housing stock and provide affordable, sustainable energy.
Objectives	A major improvement in the National Home Energy Rating of multi-storey flats; affordable warmth for tenants; reduction in CO_2 emissions; sustainable and affordable energy for Aberdeen City Council; improved economic returns to the Council from its housing stock; affordability to council in terms of capital outlay (Hawkey & Webb, 2014).
Delivery structure	Aberdeen Heat & Power Ltd set up by Aberdeen City Council as a 'not for profit' company in 2002 to develop and operate district heating and CHP schemes to serve multi-storey council housing.
Governance	Aberdeen Heat & Power Ltd is an independent company limited by guarantee. Board of volunteer directors consists of Council and tenant representatives and up to 6 independents with relevant expertise.
Initial scheme	Based round the Stockethill Energy Centre, with 268 homes in four blocks of flats served by a gas-fired 210 kWe / 300 kWth CHP engine and two boilers for peak loads.
Finance	The initial Stockethill scheme was financed through a mix of grant funding from the Government's Community Energy Programme (~40% of capital costs) and energy utilities via the Energy Efficiency Commitment (now superseded by ECO; ~7%), and private debt in the form of commercial bank loans (the remaining ~53%) enabled by a loan guarantee from the Council, which committed £215,000/year from the housing capital budget.

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Procurement	The company used the services of a consulting engineer to design and procure a build contract. Aberdeen Heat & Power operates and maintains the systems.
Subsequent / planned expansion	Schemes were subsequently added based round energy centres at Hazlehead, Seaton, and Tillydrone serving predominantly multi-storey housing and some commercial buildings.

D.6.1.5 King's Cross Heat Network

Drivers	Planning policy, particularly the London Plan and the energy hierarchy
Objectives	Enable the King's Cross development to meet carbon targets.
Delivery structure	Metropolitan King's Cross (MKC) set up as a private, single purpose company operated by developer Argent King's Cross (90% share) and specialist utilities infrastructure provider Metropolitan (10% share).
Governance	MKC's role is to supply heat; ensure that pricing is competitive; ensure network performance; enter into all heat contracts; and collect monies from customers. The company is signed up to the Heat Trust Scheme that sets customer service standards and customer protection requirements and provides customers free access to the Energy Ombudsman.
Initial scheme	2000 new homes, 800 student apartments, 3 million ft^2 office space, 0.5 million ft^2 retail space; served by: 1 energy centre (3x 2 MWe gas-fired CHP engines, thermal store, 3 top-up gas boilers with a total capacity of 36 MWth), a cooling pod.
Finance	Argent invested from the capital raised for the development, which includes 'patient' investment finance from the BT Pension Scheme.
Procurement	Metropolitan (part of Brookfield) was brought in as the Multi Utility Services Company providing power, gas, water and drainage, and data infrastructure, in addition to heat and cooling.
Subsequent / planned expansion	Development work on the site is ongoing and a 250 kWe to 1.4 MWe fuel cell will be added to the energy centre.

D.6.2 Lessons Learned

AECOM prepared a summary of key lessons learned as part of the minutes for each meeting. Synthesising the information from the individual sessions, the following emerge as lessons for the development of a heat network scheme in the Old Oak area:

1. The context of every scheme is unique and the objectives of the sponsors are different in each case leading to the adoption of a range of delivery models, all of which have been proven to work with varying strengths and weaknesses. A sustainable financial case is essential for every scheme and each model may offer opportunities to achieve viability. Schemes led by the public sector have more opportunities to access cheaper finance and grant funding to support the financial case, but the private sector can also leverage 'patient' private investment, organisational experience, multi-utility solutions and economies of scale.

2. Enabling contextual factors can be critical to the business case and should be a focus for development of the contractual structure of the scheme, e.g. for OPDC: access to surplus heat (Powerday); potentially lucrative private wire electricity sales (to HS2 and commercial sites); a supportive planning environment that contributes to reducing scheme risks (planning policy on connections (reducing demand risk), SPD including draft technical standards (reducing technical

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risk), designated land use for (energy from) waste site (supporting long term heat supply resilience), etc.).

3. There are emerging risks for gas-fired CHP (an inevitable long-term fall-off in carbon savings due to grid decarbonisation, with no savings projected by the early 2030s; and potential short- to medium-term headwinds in planning and Building Regulations compliance contexts when grid electricity emission factors in the National Calculation Methodologies used for Part L change). However, gas-fired CHP was essential to the technical feasibility, business case, and operational resilience of all the major heat network schemes reviewed, and invitees at the lessons learned sessions felt strongly that this will remain the case for new schemes in the near term.

4. A Multi Utility model appears to offer opportunities for high value utilities (e.g. data networks) to cross-subsidise investment in other utilities, such as heat, that offer lower returns. As such, a decentralised energy delivery model would ideally retain the option to work as part of a multi utility solution.

5. Taking on the role of the ESCo requires a large amount of knowledge to be developed within the sponsor organisation (which needs to be retained) and setting up the contractual arrangements involves significant effort and costs.

6. Technical standards and in particular performance of the secondary network are frequently a problem in early phases of new networks and the delivery model should address this by bringing the eventual network operator on board early with a remit to control network design and construction quality.

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D.7 Conclusion

The selection of a delivery model for a heat network depends on context and not least the strategic objectives of public authorities that often play a critical role as scheme sponsors. OPDC must decide the extent to which it expects to lead the development of a scheme in the area. Its role could be limited to facilitation – creating the right environment for a fully private sector solution to emerge – or extend to a part or full ownership stake in the delivery vehicle and direct involvement in scheme development, delivery and ongoing operation and governance. Work to develop and consider technical scheme options is underway. Alongside the technical studies, OPDC should take steps to define its strategic aims and objectives for a scheme and hence – alongside consideration of other key factors – its preferred delivery vehicle for a scheme.

The key points in this paper and next steps for OPDC are set out in the Summary at the start of this paper.

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D.8 References

ADE, TCPA & LDA Design. (2010). *Community Energy: Planning, Development and Delivery.* Retrieved November 3, 2016, from http://www.theade.co.uk/medialibrary/2011/11/03/796ce32b/Community%20Energy%20-%20Planning%20Development%20Delivery.pdf

DECC. (2015, November). *Investing in the UK's heat infrastructure: Heat Networks.* Retrieved November 3, 2016, from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/477898/Heat_Networks_Invest_Guide_Nov2015.pdf

E.ON. (2014, December). *Long term concession contracts.* Retrieved November 3, 2016, from http://www.heatandthecity.org.uk/__data/assets/pdf_file/0007/167056/AM6_-_Long_Term_Concession_Contracts_-_Jeremy_Bungey.pdf

Ernst & Young. (2012, March). *Financing the roll out of district heating.* Retrieved November 3, 2016, from http://www.heatandthecity.org.uk/__data/assets/pdf_file/0003/85656/Stuart_Campbell_-_Financing_the_roll_out_of_district_heating.pdf

GLA. (2014, April). *London Heat Network Manual.* Retrieved October 14, 2016, from london.gov.uk: London Heat Map - Resource library: https://www.london.gov.uk/sites/default/files/london_heat_map_manual_2014.pdf

Green Investment Bank. (n.d.). *District heating in smarter, greener cities - A guide to commercial structuring and financing.* Retrieved November 3, 2016, from http://www.greeninvestmentbank.com/media/118781/district-heating-finance-final-web.pdf

Hawkey, J., & Webb, D. (2014). *Aberdeen Heat and PowerLtd – draft Case Study for DH Delivery Structures Guidance, Scottish Futures Trust.* Retrieved from Heat and the City.

Islington Borough Council. (2014, December). *Islington DE Programme: Why a municipal energy approach?* Retrieved November 3, 2016, from http://www.heatandthecity.org.uk/__data/assets/pdf_file/0009/167058/PM3_-_Municipal_Energy_In_House_-_Islington_-_Lucy_Padfield.pdf

King, M. (2014, December). *Business models for district energy.* Retrieved November 3, 2016, from http://www.heatandthecity.org.uk/__data/assets/pdf_file/0005/167054/AM4_-_Business_models_for_district_energy_-_Michael_King.pdf

Manders, I., & Groth, T. (2016, February). *The PipeCo: an alternate approach to financing heat networks.* Retrieved November 3, 2016, from https://www.carbontrust.com/news/2016/02/pipeco-alternate-approach-to-financing-heat-networks/

National Energy Foundation. (2016, June). *Review of Carbon Offsetting Approaches in London.* Retrieved November 3, 2016, from https://www.london.gov.uk/sites/default/files/gla_cof_approaches_study_final_report_july_2016.pdf

Scottish Futures Trust. (2013, August). *Public Sector Delivery Structures for Low Carbon Investment.* Retrieved November 3, 2016, from http://www.scottishfuturestrust.org.uk/files/publications/SFT_Delivery_Structures_2013.pdf

Scottish Futures Trust. (2016). *Business models for heat networks: evolution or revolution?* Retrieved November 3, 2016, from http://www.all-energy.co.uk/RXUK/RXUK_All-Energy/2016/Presentations%202016%20Day%202/Heat/Paul%20Moseley.pdf?v=635996100399071594

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Appendix E Review of Smart Energy Technology

E.1 Executive Summary

This technical note was prepared in December 2016 as an interim Stage 2 deliverable to provide a high level review of the potential for Smart Technology to influence energy demands at Old Oak.

Smart technology has the potential to reduce the energy demand and energy infrastructure required to service buildings within the Old Oak area. A desk-based review has been undertaken of possible smart technologies that could be implemented within the development for both heating and power loads and their potential impact on energy demand and their ability to help Old Oak and Park Royal Development Corporation (OPDC) to meet both carbon reduction objectives and reduce energy infrastructure costs.

Smart technologies have the potential to reduce energy consumption in buildings through more sophisticated control systems and data analytics as well as encouraging changes to occupant behaviour. In particular, research suggests that domestic smart meters and in-home displays could achieve energy savings of 3 per cent. Research is on-going as to whether smart domestic heating controls generally save energy and, if so, by how much. It may not be possible to count the benefits of smart technologies towards meeting the Part L and London Plan targets as the associated calculation procedures do not currently allow for such technologies.

Smarter solutions are being developed to reduce peak demand on heat networks and thus reduce the size and use of more carbon intensive peak gas boiler plants. As an example, hot water priority controls are being incorporated into Heat Interface Units (HIUs) which shut off the space heating for the short period of time when domestic hot water is being drawn off and, as a result, there is no need to add the hot water demand to the space heating demand when sizing for peak loads. Another solution being trialled is looking to flatten the heat demand profile through monitoring the space heating and hot water loads for each building, forecasting demand 24-hr in advance, and adjusting heat supply as appropriate including pre-heating buildings to shift demand and using the thermal mass of the building as a thermal store. As an estimate, smarter technologies could together reduce peak heating demand by 10-20%. A potential barrier in implementing these (and other) smart solutions is resistance from engineers to adopt new design practices. Engineers are legally required to deliver to published professional standards which may not yet capture state-of-the-art innovations.

There is also significant opportunity for a more intelligent local electricity network to potentially reduce the peak capacity requirements and associated costs. This is through both: (i) demand-Side Response (DSR) which involves dynamically managing demand and any embedded generation capacity on the local network to reduce the peak load on the network, and (ii) the storage of excess renewable energy generated either from excess generation nationally or embedded generation within the local network.

- Local Generation: There is the potential of integrating any CHP engine from the district heating network with the local electricity distribution network. However, previous analysis suggests that this approach may be constrained to provide demand response primarily in the spring and autumn months. Furthermore, whilst there is the potential to use back-up generators installed in local buildings it depends on the building owners' willingness to participate and such generators tend to be diesel-powered and have relatively high carbon intensity.
- Flexible Domestic Demand: Domestic smart meters can encourage consumers to shift electricity consumption away from periods when it is most expensive to generate energy through the use of time-of-use tariffs. Trials have demonstrated this can alter patterns of energy usage during the day by up to 10%. There may be greater opportunities for DSR in the domestic sector in the future with increases in electricity use on the grid (e.g. from electric cars and heat pumps) and some flexibility around their time of use. A key challenge is likely to be the commercial arrangements to derive these benefits: (i) the electricity supplier has the relationship with the consumer and the distribution network operator (DNO) is not able to influence the tariff structure to reflect its needs, and (ii) this approach is dependent on consumers voluntarily altering their behaviour in response to financial signals (albeit this can be automated to a degree).

- Flexible Commercial Demand: It is likely that the main opportunity for DSR in commercial buildings is from shifting the Heating, Ventilation and Air Conditioning (HVAC) demand. It is both a significant contributor to the electricity load in the buildings and such loads can be interrupted temporarily with no significant impact on comfort. Again, the analysis suggests that the challenges are likely to be more of commercial viability than technical – in this case signing up sufficient commercial building owners at terms of payment that make this commercially viable for the DNO.
- Electricity Storage: An analysis has been undertaken of the opportunity for solar photovoltaics and battery storage at Old Oak. An initial high-level estimate suggests a maximum available potential of 9MWh per day in winter to 88MWh per day in summer. Furthermore, there are current trials of grid-level electrical energy storage e.g. UK Power Networks' on-going Smarter Network Storage project which is trialling the deployment of 6MW / 10MWh of lithium-ion storage. These numbers are potentially significant; the total electricity capacity requirements are around 120MVA and battery storage could potentially be used to supplement the main electricity supply. Further analysis would be needed to more accurately determine the potential supply from battery storage as well as its viability.

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E.2 Introduction

E.2.1 Purpose

Smart technology has the potential to reduce the energy demand and energy infrastructure required to service buildings within the Old Oak area. This review has been undertaken of possible smart technologies that could be implemented within the development for both heating and power loads and their potential impact on energy demand and thus ability to help OPDC to meet both carbon reduction objectives and to reduce the costs of energy infrastructure.

The Old Oak and Park Royal Development Infrastructure Funding Study [1] has already identified that there are potential benefits of a smarter local electricity grid. Indeed, it questions whether a smarter electricity network undermines the rationale for investment in a heat network highlighting factors including: (i) the reduced heat load requirements for new highly insulation buildings which can be met by electric panel heaters supplied by low-carbon electricity from a decarbonised grid and (ii) the reduced infrastructure costs for a smarter electricity distribution network through measures to reduce peak demand and thus peak capacity requirements.

The OPDC Smart Strategy Interim Report: Local Plan Supporting Study [2] was developed to inform the draft OPDC Local Plan. It highlights the need to consider: (i) smarter building management, (ii) flexible energy demand, and (iii) the potential for local energy production and storage, and its accommodation within the design of buildings and spaces.

E.2.2 Basis, Scope, Assumptions and Terminology

The note is based on a review of published information and some stakeholder engagement around smart technology. For the purpose of this review, smart technology has been defined broadly as ICT-enabled infrastructure/energy distribution and ICT enabled buildings. The focus has been on smart technology that reduces energy infrastructure, hence the review does not consider smart technology that may, for example, solely improve the customer experience.

This review assumes the development of a low carbon decentralised energy (DE) infrastructure in the Old Oak area. In particular, it has been assumed that heating for buildings will be provided through a district heat network.

The review has particularly focussed on residential development with some consideration given to non-residential buildings.

E.2.3 Structure and Content of the Note

The remainder of this note is structured as follows:

- Section E.3 Improving energy efficiency through building-level smart technology;
- Section E.4 Smarter district heat networks;
- Section E.5 Smarter local electricity networks.

[1] https://www.london.gov.uk/sites/default/files/final_old_oak_difs_141015_new_cover.pdf
[2] https://www.london.gov.uk/sites/default/files/smart_strategy_interim_report_opdc_hypercat_final_jan_2016_new_cover.pdf

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E.3 Improving Energy Efficiency through Building-level Smart Technology

E.3.1 Introduction

In recent years, both Part L of the Building Regulations and the Mayor's London Plan have been increasingly tightening the level of energy efficiency and carbon emissions in new building designs. London Plan policy 5.2B sets carbon reduction targets for new development which go beyond Building Regulations. Current policy is that new residential buildings should now be 'zero carbon' and new non-residential buildings should be 'zero carbon' from 2019.

Smart technologies have the potential to reduce energy consumption as described below. These benefits are principally delivered through more sophisticated control systems and data analytics as well as encouraging changes to occupants' behaviour in relation to energy consumption.

However it is important to recognise that it may not be possible to count the benefits of smart technologies towards meeting the Part L and London Plan targets. In both of these policies, the building's energy performance is determined using a standardised calculation methodology. In particular for residential buildings, the SAP methodology is used to assess the energy performance of buildings [3]. The SAP methodology currently does not incorporate smart technologies. Hence, it may not be possible to account for any energy efficiency benefits from smart technologies towards meeting the London Plan's targets.

E.3.2 Domestic Smart Meters and In-home Displays

The Government is committed to ensuring that every home and business in the country is offered a smart meter by the end of 2020 [4]. Domestic customers will be offered an In-Home Display (IHD) which will be connected to the smart meter through a Home Area Network (HAN) enabling them to see in real-time their energy use and cost. This system will give consumers the opportunity to engage with their energy use and make savings on the basis of better information about their consumption. Government-funded research suggests that it is reasonable to expect durable energy savings of 3 per cent (for gas and electricity) provided consumer engagement is effective, and larger savings are feasible in the future as innovation in products and services using smart meter data are developed [5]. As the efficiency gains are driven by changes in occupancy behaviour, the level of saving will vary between different households.

Heat meters are required for district heating schemes but there is currently no requirement for them to be smart – in particular, no requirement for an In-Home Display providing real-time information on energy use and cost to encourage behaviour change and demand reduction. Some manufacturers do offer In-Home Displays [6, 7]. There is little evidence of how much impact they will have on energy reduction but it seems reasonable to assume that they would achieve a similar reduction to that of smart gas meters as above. In order to enable better demand management OPDC and developers will need to mandate that Smart remotely addressable heat meters are installed to all heat network customers - this can be addressed in the local plan policy.

As highlighted in the introduction, the SAP methodology does not currently provide any benefit from the adoption of smart meters. Hence, benefits from smart meters would not go towards developers demonstrating that they have met the London Plan's CO_2 reduction targets.

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[3] http://www.bre.co.uk/sap2012/page.jsp?id=2759
[4] http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/science-and-technology-committee/smart-meters/written/32093.html#_ftn3
[5] https://www.gov.uk/government/publications/smart-metering-early-learning-project-and-small-scale-behaviour-trials
[6] http://www.ccrmagazine.com/index.php?option=com_content&task=view&id=16266&Itemid=33
[7] http://www.gurusystems.com/guru-hub/#guru_hub

E.3.3 Smart Domestic Heating Controls

There are increasing numbers of smart heating control products being offered for domestic customers. These can utilise temperature sensors in different zones, external temperature sensors, planned occupancy periods, required set point temperatures and learned heat profiles to optimise the point at which space heating and hot water systems are switched on and the flow of heat to different zones of the home [8]. There is the suggestion that automatic heating controls could save energy by, for example, turning down heating in non-occupied rooms or when the property is empty [9]. However, a literature review in 2014 suggests that few UK studies have rigorously evaluated the overall effect of providing households with technologically improved heating controls in terms of energy saved [10]. A key dependency is how the user interacts with the system which could lead to energy savings or, indeed, energy increases (e.g. if the result of the interaction with the smart controller is to increase the set point temperature). The Government is currently undertaking research to evaluate the impact of smart domestic heating controls.

SAP does account for the benefits of some heating controls which, for example, allow the occupant to manually programme the temperature at different times in different parts of the home. However, SAP does not currently account for these more sophisticated heat control systems which incorporate, for example, advanced heating algorithms that can learn occupant habits and sensors that can detect occupancy. The Government is currently undertaking a SAP consultation which includes a request for evidence on the benefits of smart heating controls on the energy performance in homes, for their potential inclusion in the SAP methodology in the future [11].

E.3.4 Non-residential Buildings

New non-residential buildings already incorporate significantly more advanced metering and control systems than residential buildings.

- Part L recommends that all buildings should have sub-metering of energy use in buildings. Sub-metering is likely to include a combination of both location-based and energy load specific measurements thus enabling assessment of the consumption of the various energy uses (e.g. lighting, power, heating and cooling energy) as well as, say, how the consumption varies by floor/commercial occupier in the building.
- Non-residential buildings already incorporate a number of control features, the benefits of which are recognised in the National Calculation Methodology (NCM) – the equivalent of the SAP methodology for non-residential buildings. These include controls for the HVAC and lighting systems in the building. Larger non-residential buildings incorporate a Building Management System, which is a computer-based control system that monitors and controls the building's mechanical and electrical equipment to run in an energy-efficient manner. The NCM includes benefits for the incorporation of specific building management features such as automatic Monitoring and Targeting (aM&T) where data from the building's energy sub-meters can be analysed to help ensure energy efficient operation and identify energy reduction opportunities.

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[8] https://www.london.gov.uk/sites/default/files/gla_migrate_files_destination/Smart%20City%20Intelligent%20Energy%20Opportunities_0.pdf

[9] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/254877/smarter_heating_controls_research_programme_overview.pdf

[10] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/277552/FINALHow_heating_controls_affect_domestic_energy_demand_-_A_Rapid_Evidence_Assessment.pdf

[11] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/566049/SAP_consultation_document__with_links_.pdf (see Proposed Amendment 19)

E.4 Smarter District Heating Networks

At present heat networks in London are typically served from centralised energy centres comprising gas engine CHP units, gas boilers providing peak capacity and standby loads and thermal stores. Heat is circulated through a flow and return heat network to supply heat demands in homes and non-residential buildings, typically via a heat interface unit (HIU) at the building. Based on early review of heat sources within the Old Oak area it may that the network will incorporate more distributed low-carbon heat generation including, for example, Energy from Waste from the Powerday site and/or using heat pumps to extract heat from the Grand Union Canal, sewers or bore-holes.

Currently the primary control of the heat network is to maintain constant flow and return temperatures sufficient to meet consumer demands and modulate flow volume (variable volume design). More sophisticated systems also allow the flow and return temperatures to adjust, in addition to flow, to reflect the changing seasonal needs of the customers. However, there is typically no link between the consumer's heating system controls and the controls in the energy centre.

Increasingly, consumer demand is being managed in a more intelligent manner through more sophisticated control systems which can reduce consumer energy demand as well as better manage peak load on the network, the latter allowing the greater and more efficient use of baseload heat generation and peak generation capacity requirements to be reduced. This is particularly relevant for OPDC to achieve its low-carbon objectives as there appears to be a number of opportunities for low-carbon heat sources to be used for baseload heat generation and by reducing peak demand it reduces the size and use of more carbon intensive peak gas boiler plants.

A key enabler of this improvement is the development of digitally controlled HIUs. This allows better control of the time and volumes at which heat is drawn from the network for use within buildings. A particular example is the integration of hot water priority into HIUs. Currently, in determining the heat demand requirement for a network, the domestic hot water (DHW) demand is typically calculated and added to the space heating demand. A diversity factor is applied to allow for the fact that domestic hot water is typically not required at the same time in all buildings, and an allowance of c2-3kW per new dwelling is typical. By contrast, a hot water priority system, shuts off the space heating when the hot water is being drawn off. As this occurs for a relatively short time in any one dwelling the internal temperature will not noticeably reduce, especially for well-insulated dwellings. As a result there is no need to add the hot water demand to the space heating demand. This reduces the peak demand depending on assumptions made on diversity, the relative demand of space and hot water heating and the location in the network. As an illustration, for the purposes of this work, a peak demand reduction was estimated of around 6% for a development of 1000 dwellings. It is assumed in this example that the energy saving reduces the peak demand and that additional space heating energy will be required subsequently to those homes where the space heating had temporarily been turned off.

More innovative solutions are currently being trialled and it would be reasonable to assume that peak generation capacity could be reduced by a further 5-10%. These solutions take further advantage of the connectedness offered by digital-controlled HIUs. As an example, PassivSystems is looking to flatten the heat demand profile through monitoring the space heating and hot water loads for each building, forecasting demand 24-hr in advance, and adjusting heat supply as appropriate including, where necessary, pre-heating buildings to shift demand and using the thermal mass of the building as a thermal store. Based on initial field research, they suggest that they achieve a 15% reduction in peak demand through this approach (including benefits of hot water priority) [12]. Other solution providers are looking to better integrate HIUs across a network to flatten the head demand. For example, Thermal Integration is currently patenting an approach for hot water priority across the heat network as a whole [13]. Hence, space heating and hot water loads are balanced across the whole network rather than on an individual building basis.

[12] Based on personal communications with Ian Rose of PassivSystems
[13] http://www.heatweb.co.uk/w/index.php?title=The_HIU_Revolution

There may be some benefit in delivering these more sophisticated control systems to distribute thermal storage through the network or in the buildings themselves. It will depend on whether both suitable locations can be identified and that the impacts on costs and space of this storage are not too high. In general, designing the building itself to be used as a thermal store, through taking advantage of its thermal mass, may be considered as an alternative solution rather than including a separate heat store. However, additional thermal storage may provide additional capacity depending on the scheme design.

There is the potential also of additional revenue streams from integration with the electricity network. Where the market conditions are favourable, the CHP engine could generate additional electricity with excessive heat stored. This is discussed further in the next section.

It is important to highlight potential barriers in implementing these (and other) smart solutions. In particular, there may be resistance from engineers to adopt new design practices. Engineers are legally required to deliver to published standards, the best currently for district heating schemes being the Heat Networks Code of Practice [14]. Such standards are typically designed to help achieve a good standard of practice across the industry but may not capture state-of-the-art innovations. This may be something to be reviewed in further detail if more innovative solutions are to be implemented in the Old Oak area.

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[14] http://www.cibse.org/Knowledge/knowledge-items/detail?id=a0q200000090MYHAA2

E.5 Smarter Local Electricity Networks

E.5.1 Introduction

The local electricity distribution networks carry electricity from the high voltage transmission grid via transformers (sub-stations) to domestic, commercial and industrial users. Currently, the primary purpose of the local electricity network is to maintain adequate supply to the various electrical demands. The Distribution Network Operator (DNO), such as UKPN, manages the local electricity distribution network.

A significant opportunity is for a more intelligent local electricity network.

- Demand-Side Response (DSR) involves dynamically managing demand and any embedded generation capacity on the local network to reduce the peak load on the network and thus the peak capacity requirements and associated costs. An important principle of DSR is that any generation and/or demand capacity need to be available and sufficiently flexible to change the electrical load on the system at points in time.
- The storage of excess renewable energy generated. This could include excess generation on the national network from, for example, intermittent wind turbines. It could also include embedded generation on the local network e.g. electricity generated from PV in the middle of the day may be more valuably used during the evening where networks principally serving residential developments tend to have peak demands.

To manage this system, greater intelligence, communications and controls needs to be integrated into the network. This is so that the system as a whole can be managed, ideally automatically, in real-time.

As part of the Low Carbon Network Fund field trials, a number of Distribution Network Operators (DNOs) undertook trials of more intelligent local networks including DSR and/or local storage such as UKPN's Low Carbon London programme [15], WPD's Falcon programme [16], and SSE's DSR programme [17]. Some DNOs are commercially deploying such solutions.

Within the rest of this section, we discuss the various opportunities for DSR and local storage.

E.5.2 Local Flexible Generation

There is the potential of integrating any CHP engine from the district heating network with the local electricity distribution network. This approach was previously evaluated by AECOM for the GLA [18]. Where the market conditions are favourable, the CHP engine could generate additional electricity with additional thermal storage likely located at the energy centre, although it could be located at building level with more limited use. In practice, CHP is likely to provide demand response primarily in spring and autumn where assets are not fully utilised but there are still significant heat loads. Only a limited response could be provided in summer, because then the thermal load is so small that if the engine is to be used it would need to use thermal storage and the heat from this would need to be discharged before the CHP could be used again to offer a demand response.. Extra electricity generation could not be provided in winter as the CHP engine could already be expected to be operating at full load 100% of the time to meet heat demands, although the electricity generation could be turned off as a demand response subject to market conditions.

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[15] http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL)
[16] https://www.westernpowerinnovation.co.uk/Projects/Falcon.aspx#FAQLink49;javascript:void(0);
[17] http://www.smarternetworks.org/Files/Honeywell_I&C_ADR_-_Demand_Response_130130162149.pdf
[18] https://www.london.gov.uk/sites/default/files/gla_migrate_files_destination/Smart%20City%20Intelligent%20Energy%20Opportunities_0.pdf

Another option is to take advantage of any significant back-up generators installed in local buildings. These are particularly likely to be installed for electricity-critical organisations, such as hospitals or data-centres. For example, in the Low Carbon London LCNF study, they used local generators, each with capacity between 1000kW and 3000kW [19]. In principal, as the generators are used rarely, there should be significant availability during the year for use with DSR. However, the Low Carbon London study suggests that only 20% of potential operators of back-up generators may be willing to participate. Furthermore, back-up generators tend to be diesel-powered and inefficient, and the resultant relatively high carbon intensity needs to be considered against OPDC’s objectives for a low-carbon energy system.

E.5.3 Local Flexible Domestic Demand

An additional benefit of domestic smart meters is that they will be able to record consumption and set separate prices for each half hourly period. This will make it possible for energy suppliers to offer time-of-use tariffs with different price periods throughout the day. Such tariffs can incentivise demand-side response, which can encourage consumers to shift electricity consumption away from periods when it is most expensive to generate energy. Research suggests that the evening peak demand is more than three times higher than the baseload. Cooking, lighting and audio-visual appliances use the largest share of peak power – however washing appliances and cold appliances also account for a significant share of the peak load, and probably offer more potential for changing the times of use [20]. Trials have demonstrated that time of use tariffs can be expected to alter patterns of energy usage during the day by up to 10% [21, 22, 23].

There may be greater opportunities for DSR in the domestic sector in the future.

- Smarter appliances such as washing machines or driers and fridge freezers may be incorporated with smart controllers which, based on tariff signals from the smart meters, will automatically take advantage of times of day with lowest energy prices e.g. operating the washing cycle overnight.
- The number of households with air conditioning may significantly increase due to rising temperatures as a result of climate change. This will significantly increase load on the electricity network and potentially some of this load can be shifted through, for example, pre-cooling homes.
- There is an expected significant increase in usage of electric vehicles. Battery storage gives some flexibility of charging time (see Section 5.5).
- If heat pumps are used as part of the heat network solution, which currently appears a possibility, thermal storage could enable electricity use to be separated from heat production (alternatively, gas could possibly be substituted for electricity at specific times).

The main challenge is likely to be the commercial arrangements to derive these benefits. Some key challenges have been identified, for example, as part of UKPN’s Low Carbon London programme.

- The approach described above relies on consumers voluntarily responding to price signals which may limit the level of participation. A more formal commercial arrangement could be implemented, but there is the challenge of upfront cost of agreeing contracts with many individually small consumers outweighing the benefits.
- The commercial relationship is currently between the electricity supplier and consumer. The electricity supplier would set any time-of-use tariffs to reflect wholesale electricity prices which may not be coincident with the times of peak load on the local network. An alternative commercial arrangement is likely to be needed to better meet the needs of the DNO.

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[19] http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL)/Project-Documents/LCL%20Learning%20Report%20-%20A7%20-%20Distributed%20Generation%20and%20Demand%20Side%20Response%20services%20for%20smart%20Distribution%20Networks.pdf

[20] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/275483/early_findings_revised.pdf

[21] https://www.ofgem.gov.uk/sites/default/files/docs/2011/06/energy-demand-research-project-final-analysis_0.pdf

[22] http://www.networkrevolution.co.uk/project-library/insight-report-domestic-time-use-tariffs/

[23] http://www.cer.ie/docs/000340/cer11080(a)(i).pdf

E.5.4 Local Flexible Commercial Demand

It is likely that the main opportunity for DSR in commercial buildings is from shifting the Heating, Ventilation and Air Conditioning (HVAC) demand. It is both a significant contributor to the electricity load in the buildings and it is possible to rapidly reduce the demand when required. Space heating, cooling and ventilation loads can be interrupted with no significant impact on comfort with the degree of turn-down dependant on factors such as the thermal mass and insulation of the building. For example, UKPN's Low Carbon London DSR trials included both hotels and offices and ran demand turn-down events in each building for an hour with an average demand reduction for hotels and offices of 230kW and 380kW respectively (note that the size of the demand reduction is dependent on the size of the buildings and the initial energy demand which is likely to be higher in older, less-efficient buildings). In practice, a longer DSR period can be achieved by turning down different buildings in sequence and pre-heating or pre-cooling the building prior to the demand-reduction event. The demand reduction potential is likely to be more significant in summer as the electrical load is likely to increase from greater use of air conditioning.

Again, the challenges are likely to be more of commercial viability than technical and would require further exploration if DSR is to be implemented. For example, DSR is currently applied nationally to help balance national grid demands and an aggregator (a company acting as an intermediary between the network operator and end-use customers to deliver demand response capacity) may sign-up commercial end-users which have a portfolio of buildings, such as a supermarket chain. Hence for a single contractual arrangement (which will take time and cost), the aggregator is able to sign-up a considerable demand reduction capacity – the combined demand reduction potential across the portfolio of buildings. In the case of a local network, it is more likely that contractual arrangement will need to be agreed one-by-one for individual buildings owners as they may well be all separate commercial entities – hence significant resources will still need to expended on contractual arrangements but the benefits are less as only gaining demand reduction capacities from one building per contract. Another challenge is whether the payments to the commercial building owners are sufficiently attractive for their participation in DSR; it may be that it is cheaper to add additional peak capacity to a new local distribution network, as well as gain the advantage of the reliability of this installed capacity rather than reliance on the commercial organisation to deliver the DSR in practice, than meet the level of fees that the commercial organisations would wish to participate in DSR.

E.5.5 Local Storage

Reducing costs for PV and previous Government incentive schemes have rapidly increased the total PV generation capacity feeding into networks. Previous national grid studies have concluded that battery storage potentially offers one of the best routes to help manage the intermittency of PV generation in relation to changing levels of sunshine and daylight. Battery storage can also help to shift the pattern of generation against demand allowing a greater proportion of the energy to be utilised within the home providing greater economic benefit to users e.g. storing solar energy during the day and used to help meet the electrical load in the home during the evening at peak prices.

Domestic electrical energy storage is a developing technology. As an example of current products available, Tesla is marketing the Powerwall [24] which provides a capacity of 14kWh, with a power output of 7kW peak / 5kW continuous, for £5400 (excluding insulation and software). PowerVault is another example of a battery storage technology being promoted to better utilise and manage PV generation.

In the context of OPDC, the opportunity for solar photovoltaics and battery storage is restricted due to the limited roof space per dwelling/apartment unit. However, it is expected that there would still be extensive application of PV. Early estimates by Atkins have suggested that 131,000m^2 of PV panel could potentially be accommodated at Old Oak with an annual energy generation of 17000MWh/yr. To estimate the maximum potential, assuming that all of the energy generated is stored by batteries with no losses and no electricity consumed within the buildings themselves, this results in around 47MWh per day being available. In practice, solar irradiance changes across the year and allowing for this, it is estimated that the total capacity per day would range from 9MWh per day in December to 88MWh per day in June. This potentially could help to reduce evening peaks which occur with residential developments, albeit there is less capacity available during winter months when the peak electrical load will be higher.

[24] https://www.tesla.com/en_GB/powerwall

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It is useful to put this into context. The total electricity capacity requirements are estimated at around 120MVA. Of this 30MVA are each spread across the SSE and UKPN patches and single client loads of around 30MVA each for HS2 Over Site Development (OSD) and Crossrail OSD. Based on the above calculations, the PV generated electricity is relatively large and could potentially be used to supplement the main electricity supply e.g. to provide additional generation during times of peak demand (i.e. 'peak lopping' or 'peak shaving'). Further analysis would be needed to more accurately determine the potential supply from battery storage as well as its viability.

The potential provision of PV at Park Royal is considerably greater. However, it would be expected to be focussed on commercial uses where there will be greater potential to utilise the power directly at the time of generation.

This technology can be taken a step further with PV generation and battery storage being linked to electric vehicle charging. Tesla has been one of the innovators in this area. Development densities, resulting lack of public space and need to promote more healthy sustainable modes of travel are likely to mean that parking provision and individual car ownership at Old Oak will need to be restricted. However, it is expected that some pooled provision of cars through car sharing operators will need to be provided. With current pressures on air quality, it is expected that this will need to be focussed around electric vehicles. While unlikely to make a substantial impact on overall energy demand, where significant numbers of electric vehicle charging points are provided, control mechanisms can be implemented to schedule charging so that peaks on the local distribution system are minimised. Furthermore, it is possible that the PV generated electricity can help manage further these reduced peaks.

Another option is the use of grid-level electrical energy storage which is connected to the distribution network. There have been a number of demonstrations projects, particularly as part of the Low Carbon Network Fund, such as UK Power Networks' on-going Smarter Network Storage project which is trialling the deployment of 6MW / 10MWh of lithium-ion storage on the distribution network. One particular benefit of grid-level storage is as an alternative more cost-effective solution to reinforcement of the grid due to increased loading. However, in the case of a new distribution network, the benefits of battery storage may be less attractive and it may be useful to discuss this with UKPN. There are other benefits of grid-level storage including helping balancing the supply and demand across the network, particularly with increased amounts of intermittent renewable generation.

Battery storage has benefits in offering near instantaneous supply in fault situations and can help with frequency response and voltage response.

E.5.6 Virtual Power Plants

A Virtual Power Plant (VPP) is a collection of distributed generated assets collectively operated via a central control mechanism. Hence, in the context of the discussion above, as an example this could include clusters of PV, CHP units, local and grid-level storage (and fuel cells if, for example, used to provide any energy production for buildings or electric vehicles).

VPPs allow for the delivery of peak load generation, as well as the ability to match generation with load. VPPs also help to smooth the intermittent nature of smaller scale renewable generation. They effectively aggregate all the generation together so that the assets behave like a centralised plant and enable the impact on the system to be managed. As local contributing generators grow, VPPs will provide a means for these assets to be integrated into the grid without disruptions, becoming part of a local power plant that is not necessarily located within the same geographical area. To enable this generation assets need to be enabled for remote monitoring and control, and an entity is required with access to multiple generation assets. The closest model to this at present is demand aggregation companies trading into grid balancing services.

Appendix F Carbon Emission Factor Projections

F.1 Background

To understand the carbon emissions over time from development in the Old Oak area, assumptions need to be made about:

1. The carbon emissions arising from the use of each kWh of electricity supplied from the national grid – referred to as the 'grid supplied electricity emission factor'; and
2. The carbon emissions avoided (carbon savings) for each kWh of electricity supplied by decentralised energy systems integrated into new development and therefore not supplied from the national grid – referred to as the 'grid displaced electricity emission factor'.

The following are outlined in this note:

1. The main types of emission factors that are used to understand the impact of grid electricity demand and savings from new development:
    a. The average emission factor for grid electricity;
    b. The marginal emission factor for grid electricity; and
    c. Technology-specific marginal emission factors for grid displaced electricity.
2. Relevant projections that are available for electricity emission factors and the key contexts in which the use of particular electricity emission factors is mandated by regulation or policy guidance, namely:
    a. Building Regulations and carbon reporting / footprinting; and
    b. Impact Assessment of Government policies and projects.

The note concludes with a recommendation on the carbon emission factors for grid supplied and grid displaced electricity to be used for OPDC scenario modelling. (The introduction of the different types of emission factors and contexts in which they are used touches on debates about the 'correct' way to account for changes in electricity use in new developments.)

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F.2 Types of Grid Electricity Emission Factors

F.2.1 Average Emission Factor (for Carbon Reporting / Footprinting)

The average emission factor for grid electricity is the total amount of carbon emissions arising from all power stations divided by the total quantity of electricity supplied to customers, typically expressed in units of $kgCO_2e/kWh$ or gCO_2/kWh. This factor will clearly change over time, as the mix of power stations supplying electricity changes from year to year. The factors used are generally based on time series of calculated historic and projected future annual averages.

The carbon emissions associated with grid electricity supplied to existing buildings for carbon reporting purposes (aka footprinting) are calculated by multiplying the average grid emission factor by the quantity of electricity demand, and this is uncontroversial in that context.

F.2.2 Marginal Emission Factors

New buildings give rise to sustained changes in the demand on the electricity grid. The change in demand from any particular new development, and even all new development in any given year, is small relative to the total demand. A general principle when considering systems is that the effects of small changes should be considered 'at the margin'. In simple, immediate terms, this means that the emission factor of an extra kWh of demand from a new development is equal to the carbon intensity of the generator that increases its output by one kWh to meet the demand. A basic application of the principle involves calculating the emissions associated with increases and savings in demand from new development based on the aggregate annual carbon intensity of just the mix of generators that serve the aggregate additional annual demand.

The concept and methodology underpinning the use of 'Long-run marginal emission factors' for electricity are described in background guidance to the Treasury Green Book supplementary appraisal guidance on energy and GHG appraisal and evaluation as follows:

> *The marginal electricity emissions factor is intended to reflect the change in emissions that would result from a small but sustained change in electricity consumption. The change in electricity consumption is assumed to be constant throughout the day and year (i.e. no differentiation is made between peak and non-peak. Figures are an average for each year).*
>
> *The marginal plant(s) refers to what energy source(s) we expect to increase or decrease when there are marginal but sustained changes to energy demand or supply. The marginal emissions factor allows us to conduct policy analysis relative to a baseline that includes implemented, adopted and planned policies and in which sufficient plant is built to meet projected demand…*
>
> *The calculations are based on the assumption that until very recently a Combined Cycle Gas Turbine (CCGT) plant was the long-run marginal electricity generation plant on the basis that it was both relatively cheap and quick to build. Therefore, the marginal emissions factor in 2010 reflects that of a typical CCGT plant (0.349 $kgCO_2e/kWh$ before taking into account distribution and transmission losses). However, going forward there are reasons to think that this may not remain the case, particularly given the policies in place to incentivise low carbon electricity generation.*
>
> *Illustrative demand reduction scenarios have been modelled in DECC using the Dynamic Dispatch Model (DDM)(6) to examine the impact of a change in electricity consumption on capital build and generation. The model predicts that CCGT plant will form a significant part of the marginal impacts, but that going forward in time, there are impacts on other plant, including low carbon technologies.*
>
> *In order not to draw overly precise conclusions from the modelling of an inherently uncertain future, the results of the demand reduction modelling have been used to inform a profile of emissions factors between the CCGT plant in 2010, and the marginal emissions factor modelled in 2030. A moving average of the results suggests broadly an increasing rate of decline in the emissions factors over this period.*

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In the longer run, uncertainties increase even further. Given that it is very difficult to identify what the marginal impacts would be, a pragmatic approach of using the projected average grid emissions factor from 2040 onwards is taken.

(6) Further information on the DECC dynamic dispatch model may be found here: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48383/5425-decc-dynamic-dispatch-model-ddm.pdf

(Department of Energy & Climate Change, 2015)

A more detailed explanation of the marginal emission factor concept and methodologies for calculating such factors is beyond the scope of this paper. The essential point to understand is that marginal emission factors tend to be a blended average of the carbon intensity of two groups of electricity generators:

1. The generator type with highly controllable variable output that for most of the year sits at the 'top' of the stack of power generating capacity (in the UK this has tended to be combined cycle gas turbine power stations with a carbon intensity of around 0.349 $kgCO_2/kWh$, before transmission and distribution losses), and
2. New generators added to the electricity system, which in the future are projected to be largely renewable, nuclear and other low carbon generators.

The marginal emission factor is currently significantly lower than the average emission factor as both CCGTs and new generating capacity have carbon intensities below the current grid average. The marginal and average factors converge over time, to parity from 2040 onwards.

F.2.3 Technology-specific Marginal Emission Factors

Specific technologies such as CHP, heat pumps and PV have (on aggregate) distinct daily and seasonal electricity supply or demand profiles. The carbon intensity of the grid changes greatly depending on the time of year and the time of day. As such, we would expect the carbon savings from displaced electricity associated with heat-led CHP (generating more electricity in winter, and morning and evenings when development heat demand and national electricity demand is high) to be different from the savings from PV (generating more electricity in summer and in the middle of the day when national electricity demand is lower). The basic marginal emission factor approach ignores these technology-specific demand profile effects. CHP advocates in particular argue that it is critical to consider the demand profile when calculating the grid displaced emission factor because a disproportionately large amount of CHP electricity is generated at times when the carbon intensity of the grid is high.

As a result of the ongoing policy agenda in support of heat networks, work for DECC (Department of Energy & Climate Change, 2015) established bespoke projections of the electricity emission factor for CHP based on modelling the effect on the electricity system of adding predetermined amounts of new CHP capacity over time. Unfortunately (to our knowledge) there has been no study to establish equivalent technology-specific factors for other important comparative technologies, notably heat pumps.

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F.3 Emission Factor Projections and Contexts in which they are Used

There are three main sources of emission factors that are relevant to the OPDC scenario modelling exercise:

1. SAP 'Table 12: Fuel prices, emission factors and primary energy factors'
2. 'Table 1: Electricity emissions factors to 2100, kgCO_2e/kWh' supporting the DECC/HM Treasury Green Book supplementary appraisal guidance on valuing energy use and greenhouse gas (GHG) emissions.
3. 'Emissions Factors for Electricity Displaced by Gas CHP' from DECC Bespoke natural gas CHP analysis.

F.3.1 SAP

SAP Table 12 emission factors are used for calculations in the context of Building Regulations compliance. Most planning policy targets are also based on the use of SAP emission factors. BRE[1] and DBEIS published a consultation on SAP 2016 in November 2016 (BRE, 2016). The consultation sets out revised emission factors for the period 2016 – 2018, and for future 3-year periods up to 2027. The revised emission factors, and the equivalent factors projected in the analogous SAP 2012 consultation (BRE, 2011) are set out in Table F.3.1.

(kgCO_2/kWh)	2013-2015	2016-2018	2019-2021	2022-2024	2025-2027
SAP 2016	0.558 (TBC*)	0.399	0.302	0.229	0.183
SAP 2012	0.522 (0.519*)	0.463	0.397	0.338	0.286
SAP 2016 values from: BRE Consultation Paper: CONSP:07 - CO_2 AND PRIMARY ENERGY FACTORS FOR SAP 2016: https://www.bre.co.uk/filelibrary/SAP/2016/CONSP-07---CO2-and-PE-factors---V1_0.pdf SAP 2012 values from: BRE Proposed Carbon Emission and Primary Energy Factors for SAP 2012: https://www.bre.co.uk/filelibrary/SAP/2012/STP11-CO204_emission_factors.pdf.					
* Final emission factors used in SAP Table 12 for Building Regulations Part L					

Table F.3.1. Proposed Electricity Carbon Emission Factors for SAP 2016 & 2012

The SAP 2016 consultation makes no change to the methodology for electricity emission factors, which is summarised in the following excerpts from the consultation documentation:

> *"2.5 Energy and emission factors are based on average values for energy sources supplied in the UK over the proposed three year compliance period.*
>
> *…*
>
> *2.6 Energy and Emissions for grid supply electricity are system average values (as against marginal values)*
>
> *System average values reflect the primary energy and emissions associated with grid supply electricity in the UK and are appropriate for measuring and reporting energy and carbon impacts. In contrast marginal emission factors are appropriate for measuring the effect of changes in demand compared to a normal or baseline situation.*
>
> *2.7 The system average value for grid supply electricity is applied to electricity exports and electricity generated using CHP*
>
> *System average values are also applied to electricity generated by the building (generally from renewable sources) which is exported to the grid. This reflects the fact that each kWh of electricity generated by a building displaces a kWh of electricity which would have otherwise had to be generated by the grid.*

[1] BRE manages SAP for government departments and other stakeholders

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For CHP the SAP calculation uses the power station displacement method to allocate emissions between electricity and heat outputs(7) so it is appropriate to apply the system average grid value.

(7) The convention assumes that the electricity generation by CHP displaces electricity generated by the grid taking into account transmission and distribution losses."

There is no additional discussion to support either of the assertions that average emission factors are more appropriate than marginal factors in general, nor that they are appropriate for electricity generation by CHP that displaces electricity generated by the grid. A stronger justification might be expected given that there were different emission factors for grid supplied and grid displaced electricity in versions of SAP used for Building Regulations between 2006 and 2010, implying that the basis for emission factors is open to argument.

Note that average emission factors are also used for mandatory greenhouse gas reporting in the context of the 'Companies Act 2006 (Strategic Report and Directors' Report) Regulations 2013' and similar voluntary carbon reporting and footprinting. In those contexts, DBEIS provides historic emission factors for UK electricity (Department for Business, Energy & Industrial Strategy, 2016). The historic factors for 2013 to 2015 published by DBEIS for company reporting do not agree very well with the 3-year average factors used in SAP. SAP emission factors are based on Updated Emissions Projections data, also produced by DBEIS. However, BRE publishes limited information on the methodology by which emission factors for SAP are derived from the UEP data. Nor is there a detailed justification of the methodology used and the results by comparison with the other main projection of average emission factors (see Treasury Green Book supplementary appraisal guidance discussed in the next section) used for policy assessment.

F.3.2 Treasury Green Book Supplementary Appraisal Guidance

Treasury Green Book supplementary appraisal guidance on energy and GHG appraisal and evaluation are used for impact assessment of policies and projects across government. This guidance mandates the use of the 'long-run marginal emission factor' for electricity when appraising the effect of small but sustained changes in electricity consumption. It provides a projection of these marginal factors, which are set out in Table F.3.2.

The TGB supplementary guidance also includes projections of average electricity emission factors. For 2010 to 2014, these agree well with the historic factors published by DBEIS for company reporting.

F.3.3 Bespoke Gas CHP Displaced Electricity Emission Factors

After the Government's heat policy publication "The Future of Heating: Meeting the challenge" identified the potential for additional natural gas fired Combined Heat & Power (CHP) plant to reduce whole system carbon emissions, DECC commissioned research to examine a range of different financial support options for CHP, which reported in December 2014. Part of the work involved electricity system modelling to establish the emission factor for electricity displaced by gas CHP up to 2044. The reporting provides a projection of these marginal factors for electricity exported to the grid and used on site, which are set out in Table F.3.2.

F.3.4 Summary of Relevant Electricity Emission Factors

The electricity emission factors from the three sources judged to be most relevant to deciding the factors to use for OPDC scenario modelling are summarised in Figure F.3.1 and Table F.3.2.

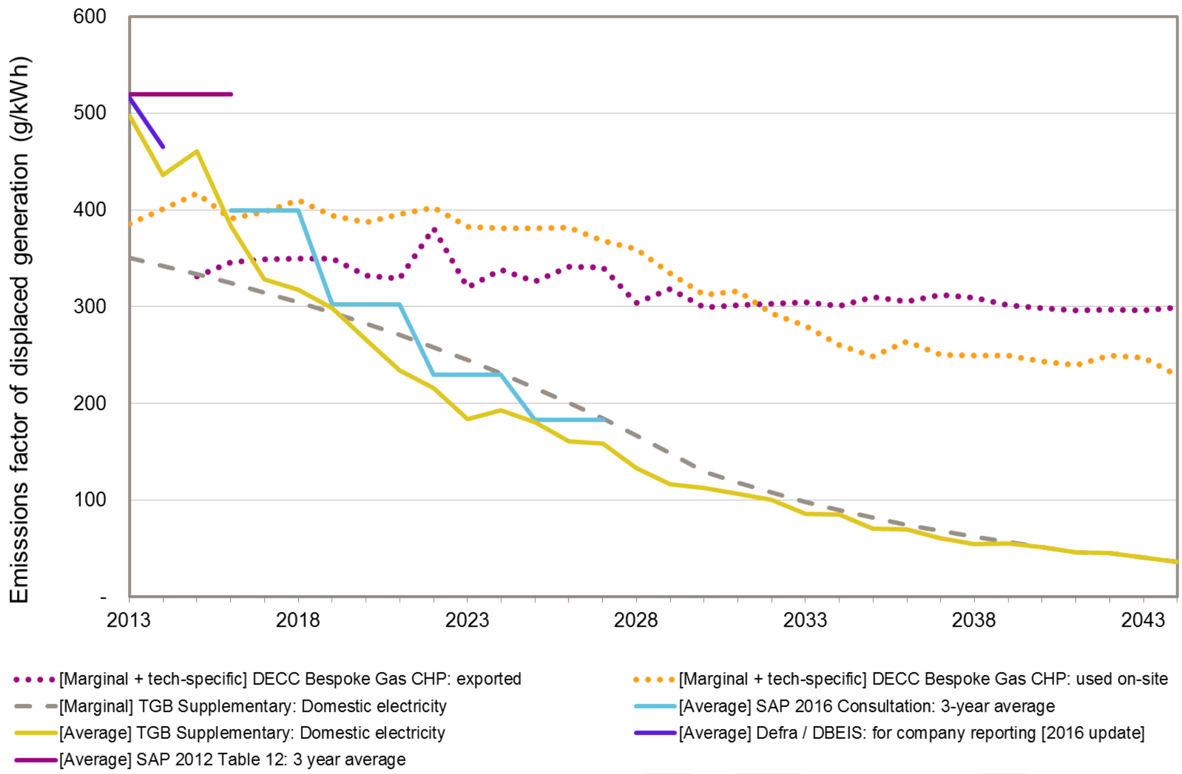

Figure F.3.1. Emissions Factors

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Notable features of the emission factor comparison are:

1. SAP 3-year average emission factors are notably higher by the end of the 3-year period than the outturn factors published by DBEIS and the average emission factor projection published in the TGB supplementary guidance.
2. In the TGB projections, marginal factors start well below the average factors, cross over in 2020, before converging by 2040, so the choice between average and marginal factors (for these projections) is not equivalent to choosing higher or lower factors.
3. DECC bespoke CHP emission factors (applicable only to displaced grid electricity) are well above all general system-wide average and marginal factors by 2020 and remain above 300 gCO_2/kWh until the 2030s
4. The DECC bespoke CHP emission factor for electricity used on site falls below the factor for exported electricity in ~2030 (as it replaces an increasing amount of electricity from renewable generators).

Year	DECC Bespoke Gas CHP: exported	DECC Bespoke Gas CHP: used on-site	TGB Supplementary: Domestic electricity - Marginal	TGB Supplementary: Domestic electricity - Average	SAP 2016 Consultation: 3-year average
2013		385	350	497	[519*] 558
2014		401	342	436	[519*] 558
2015	331	417	333	461	[519*] 558
2016	345	391	324	383	399
2017	349	398	314	328	399
2018	349	410	304	317	399

Year	DECC Bespoke Gas CHP: exported	DECC Bespoke Gas CHP: used on-site	TGB Supplementary: Domestic electricity - Marginal	TGB Supplementary: Domestic electricity - Average	SAP 2016 Consultation: 3-year average
2019	349	394	294	298	302
2020	332	387	282	265	302
2021	329	395	270	234	302
2022	381	402	258	215	229
2023	319	383	245	183	229
2024	338	381	231	192	229
2025	326	381	216	180	183
2026	341	382	200	160	183
2027	341	368	184	159	183
2028	304	359	167	133	
2029	318	334	148	116	
2030	299	312	129	112	
2031	301	316	118	106	
2032	303	293	107	100	
2033	305	280	98	86	
2034	300	260	89	85	
2035	309	248	81	71	
2036	305	264	74	69	
2037	312	250	68	60	
2038	309	249	62	54	
2039	301	249	56	55	
2040	298	243	51	51	
2041	296	239	46	46	
2042	297	249	45	45	
2043	296	247	40	40	
2044	299	229	35	35	
			36	36	
			33	33	
			30	30	
			31	31	
			28	28	
			28	28	
	* 519 is the factor used in SAP 2012 for the period 2013 – 2016, and is the value plotted in Figure F.3.1. The retrospective factor calculated in SAP 2016 for the period 2013 – 2016 is 558.				

Table F.3.2. Emission Factors

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F.4 Recommended Electricity Emission Factors for OPDC Scenario Modelling

F.4.1 Recommended Emission Factors

Recommended scenario modelling periods and corresponding emission factors for grid electricity for OPDC modelling scenarios are set out in the 'Scenario projections' columns to the right of Table F.4.1.

Emission factors for grid electricity — gCO_2/kWh

Phase	Year	Source projections: [Average] TGB Supplementary: Domestic electricity	Source projections: [Average] SAP 2012 + SAP 2016 Consultation: 3-year average	Source projections: [Marginal] TGB Supplementary: Domestic electricity	Source projections: [Marginal + tech-specific] DECC Bespoke: 50% export, 50% on site	Scenario projections: Period	Decarbonisation: Slower (All electricity)	Decarbonisation: Faster (All electricity)	Sensitivity: Gas CHP (Displaced electricity)
1	2016	383	519	324	368	Current	519	-	-
	2017	328	399	314	374	2017 - 20	351	302	367
	2018	317	399	304	380				
	2019	298	302*	294	372				
	2020	265	302	282	359				
2	2021	234	302	270	362	2021 - 25	234	201	339
	2022	215	229*	258	391				
	2023	183	229	245	351				
	2024	192	229	231	359				
	2025	180	183*	216	354				
3	2026	160	183	200	361	2026 - 30	153	136	320
	2027	159	183	184	354				
	2028	133	133**	167	331				
	2029	116	133**	148	326				
	2030	112	133**	129	305				
	2031	106		118	309	2031 - 35	89		304
	2032	100		107	298				
	2033	86		98	292				
	2034	85		89	280				
	2035	71		81	279				
4	2036	69		74	284	2036 - 50	43		270
	2037	60		68	281				
	2038	54		62	279				
	2039	55		56	275				
	2040	51		51	271				
	2041	46		46	267				
	2042	45		45	273				
	2043	40		40	271				
	2044	35		35	264				
	2045	36		36	264***				
	2046	33		33	264***				
	2047	30		30	264***				
	2048	31		31	264***				
	2049	28		28	264***				
	2050	28		28	264***				

* Note for SAP projections that the projected SAP and TGB emission factors agree closely at the start of each SAP 3-year period ** SAP projection extended to complete period based on TGB factor at the start of the SAP 3-year period *** factor assumed to remain at the 2044 value up to 2050

Table F.4.1. Recommended Emission Factors for Grid Electricity for OPDC Modelling Scenarios

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F.4.2 Rationale

The recommended emission factors for grid electricity for OPDC modelling scenarios were selected based on the following reasoning:

1. Starting in 2021, projected emission factors for scenario modelling were averaged over 5 year periods up to 2035, broadly tying in with the projected development phasing schedule, although Phase 3 (2026 – 35) was split into two emission factor periods. Rapid decarbonisation of the grid is expected over the period 2020 – 30 so a single average factor for 2026 - 35 would be a poor fit. A single factor is then proposed for the remaining 15 year period to 2050. (Little development is projected during the period from now to 2020 and it is unclear when any emission factor revisions to Part L would be introduced. If emissions for Phase 1 are modelled, average projected SAP factors for 2017 – 20 could be used.)
2. Factors were broadly based on SAP methodology – i.e. the use of average emissions factors is proposed and the same factors should generally be used for electricity supplied and displaced from the grid – and on the SAP 2016 projections as far as they are available, i.e. up to 2027. SAP emission factors are the ones commonly used in planning because it makes sense for planning targets to be set and assessed on the same calculations as eventual Building Regulations compliance. On this pragmatic basis, the debate about whether average or marginal factors are preferable was ignored. Available SAP projections end mid-way through the proposed 2026 – 30 period. Noting that for SAP projections the projected SAP and TGB emission factors agree closely at the start of each SAP 3-year period, the SAP 3-year average factor for the period 2028 – 30 is taken to be the TGB value projected in 2028 (133 gCO_2/kWh). In the absence of SAP projections beyond 2027, proposed factors for scenario modelling are based on the TGB projections from 2036 – 2050.
3. Both SAP and TGB projections are available for the period 2021 – 2035. 5-year average factors based on the TGB projections reflect faster decarbonisation to 2030 than those based on the SAP projection
4. Under the emission factor methodology used in current SAP 2012 and retained in the SAP 2016 consultation (i.e. identical factors for grid supplied and displaced electricity), the carbon savings from electricity generated by gas CHP – and therefore from the use of gas CHP overall – will reduce rapidly as the grid decarbonises. This represents a divergence in policy drivers from the DBEIS continuing support for heat networks, under which gas CHP is assumed to continue to save carbon up to the early 2030s, based on the use of gas CHP-specific emission factors for grid displaced electricity developed through the 'Bespoke natural gas CHP analysis' research (Department of Energy & Climate Change, 2015). Continued use of SAP average emission factors would constitute a significant disincentive for gas CHP in relation to GLA planning targets. Policymakers will presumably want to resolve this divergence and continue to support gas CHP, which is likely to remain key to heat network development in many cases until grid decarbonisation makes heat pumps clearly preferable. The divergence could be resolved either through changes to grid displaced emission factors in SAP / Part L or solely for planning purpose, e.g. through GLA energy assessment guidance. As such, it seems reasonable to check the sensitivity of scenario modelling results to the grid displaced emission factor assumed for gas CHP, taking the specific marginal factors projected by DECC as alternatives to the SAP average factor. The same reasoning would apply if specific marginal factors became available for heat pumps and other technologies such as PV and fuel cells, if these are expected to be widely installed.
5. TGB marginal emission factors, averaged over the proposed scenario modelling periods, lie between the SAP and TGB average factors. So using these factors offers no further insights to the scenario modelling exercise.

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F.5 Bibliography

BRE. (2011, December 12). *Proposed Carbon Emission and Primary Energy Factors for SAP 2012.* Retrieved from BRE.co.uk: https://www.bre.co.uk/filelibrary/SAP/2012/STP11-$CO_2$04_emission_factors.pdf

BRE. (2016, June 30). *Consultation Paper: CONSP:07 - CO_2 AND PRIMARY ENERGY FACTORS FOR SAP 2016.* Retrieved from BRE.co.uk: https://www.bre.co.uk/filelibrary/SAP/2016/CONSP-07---CO_2-and-PE-factors---V1_0.pdf

Department for Business, Energy & Industrial Strategy. (2016, June 1). *Government emission conversion factors for greenhouse gas company reporting.* Retrieved January 16, 2017, from GOV.UK: https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting

Department of Energy & Climate Change. (2015, July 20). *Bespoke natural gas CHP analysis.* Retrieved January 16, 2017, from GOV.UK: https://www.gov.uk/government/publications/bespoke-natural-gas-chp-analysis

Department of Energy & Climate Change. (2015, December). *Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal.* Retrieved from GOV.UK: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

LCP. (2014, December 19). *Modelling the impacts of additional Gas CHP capacity in the GB electricity market.* Retrieved from GOV.UK: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/389070/LCP_Modelling.pdf

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Appendices G to M

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Appendix G Technology Cost and Carbon Saving Comparison

G.1 Introduction

As part of the process of developing an energy strategy for proposed development in the Old Oak area, AECOM has compared carbon emission outcomes and costs for a range of energy strategy options that could be applied. The energy strategy options focus particularly on ways of reducing heat demand and supplying the remaining demand from low carbon heat sources. Key strategic questions at this stage relate to the performance and hence role of heat networks in enabling long term carbon emission savings compared to the counterfactual 'default London Plan-compliant' approach (see Box G.**1** in section G.2.2.3).

AECOM analysed 34 'Technology scenarios' and calculated the average carbon emissions of homes in each of five time periods through to full build-out and under three grid electricity decarbonisation scenarios. The assumptions and methodology for the carbon analysis, the resulting average carbon emission outcomes, capital and running cost estimates for selected technology scenarios, and a synthesis of performance metrics combining carbon emission, capital cost and running cost outcomes for the range of technical scenarios are set out in the remainder of this note in the following sections:

- G.2 Specification of Energy Technology Modelling Scenarios;
- G.3 Carbon Emissions of Technology Scenarios;
- G.4 Costs; and
- G.5 Synthesis of Carbon and Cost Results;

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G.2 Specification of Energy Technology Modelling Scenarios

This section sets out assumptions about proposed development at Old Oak and key specifications for the range of technology options evaluated for saving energy and carbon in homes.

G.2.1 Development Area & Context

G.2.1.1 Grid Decarbonisation Trajectory

The periods used for the carbon analysis were heavily influenced by the need to understand the effect of grid decarbonisation on the carbon emissions of alternate technical options. The grid is projected to decarbonise rapidly through the 2020s and early 2030s and then more slowly to the end of the analysis period. As such, it was important to look at carbon outcomes over short (5-year) periods during the stage of rapid decarbonisation. The time periods used in the carbon analysis, and the average grid electricity emission factors over those time periods under three grid decarbonisation scenarios, are set out in Table G.2.1.

Emission factors for grid electricity								gCO_2/kWh
	Source projections				Scenario projections			
	[Average]		[Marginal]	[Marginal + tech-specific]		Decarbonisation		Sensitivities
						Slower	**Faster**	**Gas CHP**
Year	TGB Supplementary: Domestic electricity	SAP 2012 + SAP 2016 Consultation: 3-year average	TGB Supplementary: Domestic electricity	DECC Bespoke: 50% export, 50% used on site	**Period**	All electricity		Displaced
2016	**383**	**519**	**324**	**368**	**Current**	**519**	**-**	**-**
2017	328	399	314	374				
2018	317	399	304	380	2017 - 20	351	302	367
2019	298	302	294	372				
2020	265	302	282	359				
2021	234	302	270	362				
2022	215	229	258	391				
2023	183	229	245	351	2021 - 25	234	201	339
2024	192	229	231	359				
2025	180	183	216	354				
2026	160	183	200	361				
2027	159	183	184	354				
2028	133	133	167	331	2026 - 30	153	136	320
2029	116	133	148	326				
2030	112	133	129	305				
2031	106		118	309				
2032	100		107	298				
2033	86		98	292	2031 - 35	89		304
2034	85		89	280				
2035	71		81	279				
2036	69		74	284				
2037	60		68	281				
2038	54		62	279				
2039	55		56	275				
2040	51		51	271				
2041	46		46	267				
2042	45		45	273				
2043	40		40	271	2036 - 50	43		270
2044	35		35	264				
2045	36		36	264				
2046	33		33	264				
2047	30		30	264				
2048	31		31	264				
2049	28		28	264				
2050	28		28	264				

Notes: Red numbers – derivation of these values involved extrapolation of the underlying data sources.

Table G.2.1. Time Periods and Corresponding Grid Emission Factors (3 Scenarios) Used for Carbon Analysis

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G.2.1.2 Phasing Trajectory

As agreed with OPDC, AECOM made assumptions about the build-out rate for dwellings based on the 'DRAFT Phasing Trajectory v7.11 Early Scenario for Planning'. Under this trajectory, development occurs from 2017 to 2047, inclusive. For the carbon emissions analysis, this trajectory was broken down into periods (see Table G.2.1), aligned as far as possible with the development phases identified and used for other ongoing studies.

The quantum of development projected to come forward in each period (based on the 'DRAFT Phasing Trajectory v7.11 Early Scenario for Planning') is set out in Table G.2.2.

Period	Affordable for Rent Units [no.]	Private Homes Units [no.]	Total Units [no.]	Total Units [%]	Net Office Floor Area [m^2]
2017 - 20	1,112	1,112	2,224	8.2%	14,999
2021 - 25	2,761	2,761	5,521	20.5%	27,869
2026 - 30	2,954	2,954	5,907	21.9%	195,776
2031 - 35	3,032	3,032	6,064	22.5%	321,601
2036 - 50	3,626	3,626	7,251	26.9%	253,779

Table G.2.2. Development Quantum Assumed in Each Time Period

G.2.1.3 Built Form

Based on the information provided through various meetings with OPDC and supported by the OPDC interactive model and map[1], it is assumed for the purpose of this evaluation that the average block height across Old Oak is 10 storeys, ranging up to 25 storeys.

Figure G.2.1. Typical Residential Block Forms within OPDC Interactive Model

Analysis of multiple existing developments of varying densities has been conducted based on previous AECOM schemes. A total of 4 developments were selected, based on the development density, as representatives of the proposed Old Oak development. The accommodation schedules were consulted for the 4 selected developments and the average number of dwellings per floor was calculated for each block in the development. An average of 12 units per storey, approximately 920 m^2 Gross Internal Area (GIA) per storey, was assumed based on these representative developments.

G.2.1.4 Scales of Technology Implementation

For most technologies, the scale of implementation affects the capital costs. For some technologies, the scale of implementation also changes assumptions about technical performance (e.g. efficiency; the area available to locate equipment, and hence the maximum installable capacity and proportion of demand met; etc.). Four implementation scales were identified as a basis for considering the effects of scale on carbon outcomes and costs:

- Unit – individual homes,
- Block – a discrete apartment block,

[1] Available at https://www.london.gov.uk/about-us/organisations-we-work/old-oak-and-park-royal-development-corporation-opdc/about-opdc/opdc-2

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- Development site – multiple blocks, and
- Cluster / area-wide – the broad areas making up the Old Oak area as a whole (North Acton, Willesden Junction, HS2, Old Oak North, and Scrubs Lane).

G.2.1.5 Typical Blocks

The 'block' scale of implementation is the one that imposes most constraints on the application and performance of technologies. The size of the roof constrains the potential for roof-mounted PV and solar hot water collectors, and the size of the plot constrains the ground area available for the borehole field of a closed loop ground source heat pump system. The most relevant characteristics of the typical block are set out in Table G.2.3.

Storeys	Units per floor	Units	Unit GIA per floor [m^2]	GIA as % of GEA	Roof area [m^2]	Plot area [m^2]
10	12	120	920	90%	1,022	1,200
Notes: GIA = gross internal area; GEA = gross external area, which is assumed to be equal to both the roof area (when calculating area available for solar technologies) and building footprint (from which the plot area available for the ground loop supplying ground source heat pumps is calculated).						

Table G.2.3. Typical Block Characteristics

Assuming an average storey height of 10 storeys, the typical block at Old Oak will consist of 120 units of 9,200 m^2 GIA.

G.2.1.6 Typical Development Site

It is assumed a typical representative development plot could consist of 4x10 storey buildings and a single 25 storey building. The energy demands and carbon emissions of homes are influenced by whether they are single or dual aspect. A ratio of 65:35 single to dual aspect dwellings was assumed for a site. Based on these assumptions, each development site consists of:

- 780 units (approximately 59,800 m^2);
- 507 single aspect units;
- 273 dual aspect units;
- 60 ground floor units; and
- 60 top floor units.

The above unit breakdown is combined with the unit sizes (in number of bedrooms) to produce a set of unit type combinations (1-/2-/3-/4-/5-bed, ground-/mid-/top-floor, and single/dual aspect) for modelling. Each unit type will have different regulated heating and electrical demands to be calculated using representative models.

G.2.1.7 The Old Oak Area and Development Clusters

It is understood that the Old Oak masterplan will be made up of 5 main development clusters: North Acton, Willesden Junction, HS2, Old Oak North, and Scrubs Lane.

A total of 26,967 homes and ~814,000 m^2 of non-domestic area are assumed to be served by the area wide heating network.

G.2.1.8 Unit Mix and Sizes

The carbon analysis assumes that the homes delivered will be a mix of 1- to 5-bed flats. The mix for affordable housing is built up from the observed mix of units offered for 'social rent', 'London Living rent', and 'shared ownership', assuming a given proportion (see Table G.2.4) of homes of each tenure type. The mix for market housing assumes 'Local Market Delivery'. The unit size assumptions are taken from the London Housing Design Guide, Minimum space standards for new dwellings. The unit mix and sizes used in the carbon analysis are summarised in Table G.2.4.

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Bedrooms	Social Rent	London Living Rent	Shared Ownership	Affordable Housing	Market Housing	GIA [m²]
1	23%	3%	19%	**14%**	**30%**	**50**
2	28%	25%	35%	**28%**	**50%**	**70**
3	34%	47%	33%	**40%**	**16%**	**86**
4	11%	19%	10%	**14%**	**4%**	**99**
5	4%	6%	3%	**5%**	**0%**	**112**
% of total	43.33%	43.33%	13.33%	**50%**	**50%**	

Table G.2.4. Unit Mix and Sizes

G.2.2 Technology Scenarios

G.2.2.1 Technology Scenario Characteristics

The technology scenarios are defined in terms of the characteristics set out in Table G.2.5.

Scenario characteristic	Options
Fabric and services specification	London Plan (LP); or Advanced Fabric (AF)
Heat network (DHN) flow and return temperatures	High – 85°C flow / 55°C return; or Low – 70°C flow / 40°C return
Fuel type of lead heat generator	Grid electricity with heat pump; direct grid electricity; waste; or gas
Lead heat generator / source and corresponding generator efficiencies	Electric storage / convection heaters; electric boilers; heat pumps- exhaust air heat recovery, ground, air, water (open loop ground), canal, or sewer source; Powerday (off-site bulk heat from waste); gas boilers; or gas-fired CHP.
Peak load heat generator / source	Direct electric secondary heating; electric boiler; gas boiler; Powerday*
Supplementary heat demand reduction	Solar hot water heating (where compatible)**
Bolt-on	Photovoltaics (where compatible)***

Notes:

* Some scenarios consider very high (70%) proportions of heat from Powerday with very low (e.g. 5%) proportions from typical peak load gas (or alternatively electric) boiler plant – in those cases, the assumption is that heat from Powerday meets a significant share of peak heat loads.

** Solar hot water was included in some technology scenarios suited to block and unit scale implementation, where it would not displace heat network base load, and when a solar thermal system was considered compatible with the main heating system.

*** Apart from competition for roof space (with solar thermal), there is no interaction between PV and the other carbon saving technologies considered. PV could be applied as a 'bolt-on' to all technology scenarios except those with solar hot water heating. The carbon savings from PV and capital costs can be considered independently of the technology scenarios.

Table G.2.5. Technology Scenario Characteristics

G.2.2.2 Technology Scenarios Evaluated

The full set of scenarios for which analysis was undertaken is set out in Table G.2.6. (For further details on assumed system efficiencies see Table G.2.7, and for proportions of heat from all heat sources see Table G.3.1.)

TS no.	Technology Scenario	Fabric & services spec.	Scenario Description	DHN flow/ return	Lead heat generator type
1	LP CHP-60 High Temp	London Plan	gas CHP (60%, η elec = 36%) + gas boiler, high temp network	85/55	gas-fired
2	LP CHP-60 Low Temp	London Plan	gas CHP (60%, η elec = 36%) + gas boiler	70/40	gas-fired
3	LP DE Storage Heater	London Plan	electric storage / convection heater	n/a	direct electric
4	LP DE Storage Heater SHW	London Plan	electric storage / convection heater + solar hot water	n/a	direct electric
5	LP GSHP Gas Boiler	London Plan	ground source heat pump (60%) + gas boiler	70/40	heat pumps
6	LP GSHP Gas Boiler SHW	London Plan	ground source heat pump (60%) + boiler + solar hot water	70/40	heat pumps
7	LP GSHP ASHP	London Plan	ground source heat pump (60%) + air source heat pump	70/40	heat pumps
8	LP GSHP ASHP SHW	London Plan	ground source (60%) + air source heat pump + solar hot water	70/40	heat pumps
9	AF CHP-60 High Temp	Advanced	gas CHP (60%, η elec = 36%) + boiler, high temp network	85/55	gas-fired
10	AF CHP-60 Low Temp	Advanced	gas CHP (60%, η elec = 36%) + gas boiler	70/40	gas-fired
11	AF DE Storage Heater	Advanced	electric storage / convection heater	n/a	direct electric
12	AF DE Storage Heater SHW	Advanced	electric storage / convection heater + solar hot water	n/a	direct electric
13	AF GSHP Gas Boiler	Advanced	ground source heat pump (60%) + gas boiler	70/40	heat pumps
14	AF GSHP Gas Boiler SHW	Advanced	ground source heat pump (60%) + gas boiler + solar hot water	70/40	heat pumps
15	AF GSHP ASHP	Advanced	ground source heat pump (60%) + air source heat pump	70/40	heat pumps
16	AF GSHP ASHP SHW	Advanced	ground source (60%) + air source heat pump + solar hot water	70/40	heat pumps
17	AF HRHP	Advanced	exhaust air heat recovery heat pump	n/a	heat pumps
18	AF HRHP SHW	Advanced	exhaust air heat recovery heat pump + solar hot water	n/a	heat pumps
19	LP 5xCluster CHP-70, Low Temp	London Plan	gas CHP (70%, η elec = 39%) + gas boiler	70/40	gas-fired
20	LP Pwrdy-70 + CHP-15	London Plan	Powerday (70%) + gas CHP (15%, η elec = 39%) + gas boiler	70/40	waste-fired
21	LP Pwrdy-55 + CHP-35	London Plan	Powerday (55%) + gas CHP (35%, η elec = 39%) + gas boiler	70/40	waste-fired
22	LP Pwrdy-40 + CHP-35	London Plan	Powerday (40%) + gas CHP (35%, η elec = 39%) + gas boiler	70/40	waste-fired
23	LP Pwrdy-70 + HPs-10 + CHP-15	London Plan	Powerday (70%) + heat pump (10%) + gas CHP (15%) + gas boiler	70/40	waste-fired
24	LP Pwrdy-55 + HPs-20 + CHP-15	London Plan	Powerday (55%) + heat pump (20%) + gas CHP (15%) + gas boiler	70/40	waste-fired

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TS no.	Technology Scenario	Fabric & services spec.	Scenario Description	DHN flow/ return	Lead heat generator type
25	LP Pwrdy 40 + HPs-30 + CHP-15	London Plan	Powerday (40%) + heat pump (30%) + gas CHP (15%) + gas boiler	70/40	waste-fired
26	LP Pwrdy 70 + HPs-10 +DEB	London Plan	Powerday (70%) + heat pump (10%) + electric boiler	70/40	waste-fired
27	LP Pwrdy 55 + HPs-20 +DEB	London Plan	Powerday (55%) + heat pump (20%) + electric boiler	70/40	waste-fired
28	LP Pwrdy 40 + HPs-30 +DEB	London Plan	Powerday (40%) + heat pump (30%) + electric boiler	70/40	waste-fired
29	LP Gas Boiler	London Plan	gas boiler	70/40	gas-fired
30	LP DE Boiler	London Plan	electric boiler	70/40	direct electric
31	LP GSHP DE Boiler	London Plan	ground source heat pump (60%) + electric boiler	70/40	heat pumps
32	LP ASHP Gas Boiler	London Plan	air source heat pump (60%) + gas boiler	70/40	heat pumps
33	LP ASHP DE Boiler	London Plan	air source heat pump (60%) + electric boiler	70/40	heat pumps
34	AF GSHP DE Boiler	Advanced	ground source heat pump (60%) + electric boiler	70/40	heat pumps
Notes: LP = London Plan 'compliant' fabric; AF = advanced fabric; SHW = solar hot water heating; DE(B) = direct electric (boiler); η = efficiency; GSHP = ground source heat pumps; ASHP = air source heat pumps; HRHP = exhaust air heat recovery heat pump					

Table G.2.6. Technology Scenarios Analysed

G.2.2.3 Counterfactual

A common, static, baseline was used to assess the carbon intensity and financial costs for applying each of the energy technologies. The carbon savings and cost uplifts are the difference from this baseline on a per unit basis.

The baseline is defined as a home with a London Plan compliant specification that has its space heating and domestic hot water requirement delivered via a high temperature heat network (85°C flow 55°C return) served by gas-fired CHP engines providing 60% of annual heat demand, with peak load gas boilers providing 40% of heat demand. A distribution loss factor of 1.3 is assumed based on primary network heat losses – between the heat generation plant and the heat substation at the development plot boundary – of 10% and 15% losses in the secondary heat network between the substation and the heat interface unit in the homes. 91% efficient gas fired boilers provide the remaining heat for the development site scenario.

- Buildings designed to meet Building Regulations Criterion 1 through energy efficient fabric and fixed services alone;
- Development-wide heat networks for each site that comes forward for planning served by gas-fired CHP housed in a central energy centre;
- Roof-mounted photovoltaics to bring on-site carbon savings to at least 35%, if required, or to the extent possible given space constraints on locations for PV panels (N.B. the counterfactual used in the evaluation assumes that **PV is NOT currently required to meet 35% on site savings** when 60% of heat is supplied by gas CHP); and
- Offsetting of residual carbon emissions off site, directly by the developer or via payment into an offset fund at the rate established by the local planning authority.

Box G.1. Counterfactual 'default London Plan-compliant' energy strategy

This counterfactual is represented by TS no. 1 in the list of technology scenarios evaluated and the 'Development' level of technology application in Table G.2.7.

G.2.2.4 Efficiency of Energy Technology Options

The appraisal considered technology options applied at 4 scales:

- Area level – district heat networks connecting the 5 Old Oak clusters;
- Development level – communal heat networks serving multiple buildings on a development site;
- Block level – communal heating within a single block;
- Unit level – each unit is served by an individual heating system.

Each option was modelled for two levels of fabric and services specifications: (i) London Plan compliant, and (ii) advanced fabric specification.

The table below shows the coefficients of performance for the technologies applied at each scale.

Technology	**Coefficient of performance**			
Level	**Area**	**Development**	**Block**	**Unit**
Powerday	heat*	n/a		
Canal heat pump	2.80			
Sewer heat pump	3.30			
Open loop borehole heat pump	3.10			
Closed loop borehole heat pump	n/a		3.10	n/a
Gas CHP	$0.39_{electical}$ ($0.38_{thermal}$)	$0.36_{electrical}$ ($0.42_{thermal}$)	n/a	
Gas boilers	0.91			
Direct electric boilers	1.00			n/a
Air sourced heat pump	n/a		2.90	
Solar hot water	n/a		heat**	
Direct electric storage	n/a			1.00
Exhaust Air Heat recovery heat pump	n/a			3.30
Notes: * Powerday is assumed to supply bulk heat. The efficiency of generating plant is reflected in the carbon intensity assumed for the heat supplied. ** The performance of solar hot water heating is accounted for in the SAP modelling and results in a reduction in residual hot water demand to be met by the other systems fitted to meet hot water demand.				

Table G.2.7: Coefficients of Performance (Efficiencies) for Heating Technology Options

Scale of application of technology options has effects beyond efficiency, which are discussed in turn below.

G.2.2.5 Capacity of Area-level Heat Sources

It is assumed that area level solutions are based on a district heat network. Table G.2.8 sets out the assumed capacity of the heat sources for the options evaluated.

Heat Source	Capacity available (MW)
Grand Union Canal serving heat pumps	1 – 3 MW varies seasonally
London aquifer serving heat pumps	5 no. 1.2 MW open loop boreholes = 6 MW
Sewage network serving heat pumps	5 no. 200m installations = 1 – 3 MW
Powerday Energy from Waste	3 – 10 MW
Total	**11 – 22 MW**

Table G.2.8. Summary of Recommended Heat Sources for Area Level Network

G.2.2.6 Area-level Heat Mix Scenarios

Three illustrative heat mix scenarios have been chosen to represent possible outcomes for heat sources for an area wide network. The scenarios are titled based on the lead heat source in the heat mix, as follows:

G.2.2.6.1 Gas CHP

A gas CHP area wide network was modelled to represent the CO_2 emissions that would likely occur for larger sites such as Car Giant if OPDC left delivery to the market and no intervention is made by OPDC. An area wide gas CHP network is also what was assumed in the GLA decentralised energy study that formed the basis of the evidence base for the draft Regulation 18 consultation for the Local Planin February 2016[2].

It is assumed that gas CHP would meet the full baseload with gas boilers providing peak. For this scenario the higher temperature network 85^{o}Cflow 55^{o}C return is assumed. Heat losses are assumed to be 10% in the primary and 15% in the secondary network with a distribution loss factor of 1.3. 70% of heat is assumed to be provided from the CHP and 30% from gas boilers.

G.2.2.6.2 Powerday

The Powerday recycling facility situated in Old Oak is considering installing energy from waste equipment to enable cogeneration on the site. Based on the availability of refuse derived fuels and solid refuse fuels on site a number of capacity options are currently being considered by Powerday (up to 5.7 MW_e) providing a potential opportunity to serve the Old Oak scheme with heat. This could potentially be increased to 10MW based on the volume of SRF currently being produced on site (approx. 100,000 tonnes per year).

The heat supplied from a potential Energy from Waste (EfW) facility has been modelled using a fuel carbon factor of 0.047gCO_2/kWh for the first ten years (SAP 2012 figure) then 0.074gCO_2/kWh for the remaining period (proposed SAP 2016 figure). It is estimated that 10MW_{th} could be available for the network. Any shortfalls occurring between the assumed EfW supply and the peak demand is assumed to be made up with gas CHP for baseload and gas boilers for peak in line with efficiency and carbon factor outlined in table 2. All top up gas boilers are assumed to have an efficiency of 91% in line with the London Plan guidance for the calculation of a site emission baseline. The resulting heat spilt serving an area wide network at full build out with a baseload demand of 20MW has been assumed to be 25% gas boilers, 40% Powerday heat and 35% gas CHP. The carbon savings for a range of heat splits have been modelled to test the impacts on CO_2 emissions of transitioning to different energy supply options over the development cycle as grid emissions fall.

The distribution network is assumed to be designed efficiently and to have a lower distribution temperature than the base case with flow of 70^{o}C and return of 40^{o}C. 70^{o}C flow will enable the system to serve both space heating and hot water. It is assumed that low temperature distribution systems are installed in all new buildings i.e. underfloor heating systems in homes. A loss factor of 1.2 is assumed, this equates to primary losses of 8% and secondary losses of 10 %.

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[2] Old Oak Decentralised Energy Strategy. Local Plan Supporting Study. Draft for Regulation 18 Consultation. 4th February 2016.

G.2.2.6.3 Powerday + Heat Pumps + Gas CHP

In this option, the district heat network is served by a combination of heat sources including up to 10MW from Powerday, 9MW from heat pump energy technologies (based on notionally 1.5MW from the canal, 1.5MW from 5No sewer installations and 6 MW from 5No open loop boreholes). And up to 5MW from Gas CHP engines which would be used to improve revenue from system balancing mechanisms and provide a back-up baseload supply. Any shortfalls between the baseload assumed supply and the peak demand is assumed to be made up with gas boilers.

The assumption has been made that at full build out 15% of heat would be provided from gas boilers, 30% from Powerday, 40% from heat pumps and 15% from gas CHP. The carbon savings for a range of alternative heat splits have been modelled to test the impacts on CO_2 emissions of transitioning to different energy supply options over the development cycle as grid emissions fall.

This scenario is intended to represent multi source heat network being operated both to maximise carbon savings but also designed to enable operators to maximum revenue streams in a more dynamic electricity market with varying price signals designed to manage demand and supply.

The distribution network is assumed to be designed efficiently and to have a lower distribution temperature than the base case with flow of 70^{o}C and return of 40^{o}C. This will enable the system to serve both space heating and hot water. It is assumed that low temperature distribution systems are installed in all new buildings i.e. underfloor heating systems in homes. A loss factor of 1.2 is assumed, this equates to primary losses of 8% and secondary losses of 10 %.

G.2.2.7 Block Level Energy Technology Scenarios

Block based solutions could be delivered as an alternative to supplying buildings with heat from area wide or development scale heat networks. The following technologies were modelled with both London Plan ‘compliant’ and advanced fabric insulation standards to explore costs and carbon savings.

G.2.2.7.1 Solar Hot Water Heating

The impact of adding solar (thermal) water heating was modelled for each of the main heating/hot water options, i.e. heat pump and direct electric systems. It is assumed that block based systems will have communal domestic hot water and space heating systems linked to a heat interface unit/meter in each flat. Energy savings were modelled based on the maximum collector area of evacuated tube solar water heating that can be accommodated within the typical block, assumed to be 25% of the roof area. Evacuated tube collectors were assumed to maximise output from the available roof area (that could otherwise accommodate PV).

G.2.2.7.2 Ground Source and Air Source Heat Pumps

For ground source systems, a closed ground loop linked to heat pumps providing as much of the space heating and hot water as possible was assumed, with space heating provided by underfloor heating systems. Separate capacity analysis of the ground loop was undertaken to provide confidence that the assumed proportion of heat and hot water supplied is reasonable. This considered the maximum closed loop system that could be delivered within the footprint of the typical block.

G.2.2.7.3 PV

PV was treated as a ‘bolt-on’ option as it does not interact with any other aspect of the technology scenarios. Potential carbon savings from PV and related costs are considered separately from the results of the technology scenarios.

G.2.2.8 Unit Level Energy Technology Scenarios

G.2.2.8.1 Direct Electric Heating

This scenario was modelled as modern, slimline combined storage + convection heaters with CELECT-type control. The system efficiency for this scenario was the default value in SAP 2012. Local hot water storage with large (at least 210 litres) storage was assumed with direct electric immersion heaters with Economy 7 controls. This option is intended to assess the carbon implications of what would be a very low cost option that is also a low carbon option once the grid has substantially decarbonised.

G.2.2.8.2 Exhaust Air Heat Pump

This system was modelled with the advanced fabric specification only. Residual space heating required is delivered through a heating coil in the whole house mechanical ventilation system. It is assumed that an ASHP would be used to serve the domestic hot water using exhaust air as its heat source. System assumptions for this scenario were a COP of 3.3, a programmer for system control, and local hot water storage cylinders in each home.

G.2.2.8.3 Solar Hot Water Heating

For both the options above the effect of adding solar thermal to serve the hot water demands of approximately 23% of units (homes on the top three floors, also capped by available collector area) was tested. Solar water heating would serve dual coil cylinders, with top up from direct electric immersion heater or exhaust air heat pump (respectively for the technology scenarios above).

G.2.3 Cooling

Under projected climate conditions and at the development densities proposed in the Old Oak area, the design of homes should consider likely demands for active cooling to prevent summer overheating.

AECOM considered whether there is a potential role for cooling networks. As with heat network, a cooling network will only be viable where there is a high and consistent (over the year) demand density, such as in a concentrated commercial zone. AECOM judges that homes, even at high density with some mix of commercial uses, will not provide the cooling demand density necessary to justify a wide area cooling network. As such, it is assumed that any cooling would be provided at a block or individual unit level.

Active cooling in buildings is generally delivered via some form of heat pump. While the efficiencies of heat pumps – and hence carbon intensity – do vary depending on the heat source (air, ground, groundwater, canal water), the differences are not as significant as those between alternative heating sources and fuels (gas, direct electric, electric via heat pumps, heat from waste). It is likely that differences due to detailed design and specification (i.e. between choosing typical and best in class equipment) would have as much influence on carbon outcomes as differences due to system type. As such, in carbon terms, AECOM concluded that the effect of adding cooling would be broadly the same across all of the technology scenarios considered in this report.

Given the considerations above, it can be seen that cooling provision is not a key factor in the choice of energy strategy, which will principally revolve around the choice of building fabric and lead heat source(s). The only effect of any cooling provision on infrastructure will be considerations relating to seasonal peak electricity demands. As with PV, cooling can be considered a 'bolt-on' to whichever preferred energy strategy emerges.

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G.3 Carbon Emissions of Technology Scenarios

G.3.1 Calculation of Current and Projected Carbon Emissions for Technology Scenarios

G.3.1.1 SAP Modelling to Determine Dwelling Energy Demands

To fully reflect the benefits of energy efficient underlying fabric and services design for dwellings, it is preferable to model real designs as similar as possible to those that are anticipated in a development under study. Dwelling designs prepared specifically for developments in the Old Oak area were not available, so flat designs from schemes recently submitted for planning in London, and for which AECOM had existing SAP model data, were selected as proxies. Ideally proxy designs would have been selected for each size of dwelling (where size is synonymous with number of bedrooms, as per Table G.2.4), and covering the nine configurational combinations of:

- Single aspect and two dual aspect units – one with main glazing facing east and the other west; and
- Ground-, mid- and top-floor units.

However, the available set of designs and models did not include enough 4- and 5-bed flats to make up a representative mix of models for those unit sizes. As such, AECOM modelled the nine configurational combinations for each of 1-, 2-, and 3-bed flats only – making a total of 27 combinations of dwelling size and configuration per technical scenario to be modelled. 4- and 5-bed flats were then assumed to have the same per-square-metre underlying annual energy demands as 3-bed flats. (A spot check using available results from past modelling of 4/5-bed flats suggested that the error involved in this assumption was small – it tends to over-estimate demands, but by <5% in the cases checked.)

AECOM undertook SAP modelling for this study using NHER Plan Assessor, which is approved SAP modelling software for the purposes of demonstrating compliance with Building Regulations Part L 2013. The use of approved SAP software is essential to establishing the correct underlying heat and electricity demands of a dwelling. The dwelling (carbon) emission rates then depends on assumptions about heat generator efficiencies and (for block heating or heat networks) heat source mix, CHP electrical efficiency, and distribution losses. Once the underlying demands are known, and given a heat splits, generator efficiencies, etc., calculating the dwelling emission rate is relatively straightforward and can be done without SAP software. Using a spreadsheet to calculate dwelling emission rates makes it easier to look at outcomes for a range of heat source mixes and generator efficiencies, which change the carbon emissions but do not change the underlying energy demands of a dwelling. Calculations outside approved SAP software are also the only way to investigate the effects of changing fuel emission factors over time.

Technical scenarios 1 to 18 in Table G.2.6 were modelled using SAP to determine underlying energy demands and current (Part L 2013) dwelling emission rates. Individual energy demands (per square metre) for the 27 unit types modelled were converted into weighted average demands (per square metre) for 1-, 2-, and 3-bed units based on the number of units of each configuration that would be present in the typical block (see section G.2.1.8).

G.3.1.2 Post-processing to Determine Current and Future Carbon Emissions

AECOM developed a post-processing spreadsheet that calculated dwelling emission rates, starting from appropriate demands established from the first 18 SAP models and applying the heat source mix and generator efficiencies corresponding to the technical scenario definition. The algorithms implemented in the post-processing spreadsheet were based on the DER worksheet set out in the SAP Technical Manual[3] and validated using the dwelling emission rate results for technical scenarios 1 – 18 from NHER Plan Assessor.

Results for future time periods for the first 18 technology scenarios were post processed. Carbon emissions for technical scenarios 19 and onward were entirely ‘post-processed’ Carbon emissions for future time periods were post-processed for all technical scenarios, based on the projected emission factors set out in Appendix F ‘Technical Note – Carbon emission factors’.

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[3] SAP 2012 version 9.92 (October 2013)

The main heat source mixes and communal system factors for each technology scenario, which represent the main inputs for the post-processing to calculate dwelling emission rates (in addition to the efficiencies set out in Table G.2.7), are set out in Table G.3.1.

Technology scenario		Fraction of space heat from system									Comm. Sys. factors		
		Secondary	Community	Main system or CHP	Gas boiler	Open loop GSHP	Canal source HP	Sewer source HP	Powerday	Electric boiler	Space heating control / charging	Hot water control	Distribution loss
1	LP CHP-60 High Temp	0%	100%	60%	40%	0%	0%	0%	0%	0%	1.05	1.00	1.30
2	LP CHP-60 Low Temp	0%	100%	60%	40%	0%	0%	0%	0%	0%	1.05	1.00	1.20
3	LP DE Storage Heater	15%	85%	0%	0%	0%	0%	0%	0%	0%	0.00	0.00	0.00
4	LP DE Storage Heater SHW	15%	85%	0%	0%	0%	0%	0%	0%	0%	0.00	0.00	0.00
5	LP GSHP Gas Boiler	0%	100%	60%	40%	0%	0%	0%	0%	0%	1.05	1.00	1.20
6	LP GSHP Gas Boiler SHW	0%	100%	60%	40%	0%	0%	0%	0%	0%	1.05	1.00	1.20
7	LP GSHP ASHP	0%	100%	60%	0.00%	40%	0%	0%	0%	0%	1.05	1.00	1.20
8	LP GSHP ASHP SHW	0%	100%	60%	0.00%	40%	0%	0%	0%	0%	1.05	1.00	1.20
9	AF CHP-60 High Temp	0%	100%	60%	40%	0%	0%	0%	0%	0%	1.05	1.00	1.30
10	AF CHP-60 Low Temp	0%	100%	60%	40%	0%	0%	0%	0%	0%	1.05	1.00	1.20
11	AF DE Storage Heater	15%	85%	0%	0%	0%	0%	0%	0%	0%	0.00	0.00	0.00
12	AF DE Storage Heater SHW	15%	85%	0%	0%	0%	0%	0%	0%	0%	0.00	0.00	0.00
13	AF GSHP Gas Boiler	0%	100%	60%	40%	0%	0%	0%	0%	0%	1.05	1.00	1.20
14	AF GSHP Gas Boiler SHW	0%	100%	60%	40%	0%	0%	0%	0%	0%	1.05	1.00	1.20
15	AF GSHP ASHP	0%	100%	60%	0.00%	40%	0%	0%	0%	0%	1.05	1.00	1.20
16	AF GSHP ASHP SHW	0%	100%	60%	0.00%	40%	0%	0%	0%	0%	1.05	1.00	1.20
17	AF HRHP	0%	100%	0%	0%	0%	0%	0%	0%	0%	0.00	0.00	0.00
18	AF HRHP SHW	0%	100%	0%	0%	0%	0%	0%	0%	0%	0.00	0.00	0.00
19	LP 5xCluster CHP-70, Low Temp	0%	100%	70%	30%	0%	0%	0%	0%	0%	1.05	1.00	1.20
20	LP Pwrdy-70 + CHP-15	0%	100%	15%	15%	0%	0%	0%	70%	0%	1.05	1.00	1.20
21	LP Pwrdy-55 + CHP-35	0%	100%	35%	10%	0%	0%	0%	55%	0%	1.05	1.00	1.20
22	LP Pwrdy-40 + CHP-35	0%	100%	35%	25%	0%	0%	0%	40%	0%	1.05	1.00	1.20
23	LP Pwrdy-70 + HPs-10 + CHP-15	0%	100%	15%	5%	10%	0%	0%	70%	0%	1.05	1.00	1.20
24	LP Pwrdy-55 + HPs-20 + CHP-15	0%	100%	15%	10%	10%	5%	5%	55%	0%	1.05	1.00	1.20
25	LP Pwrdy 40 + HPs-30 + CHP-15	0%	100%	15%	15%	15%	8%	7%	40%	0%	1.05	1.00	1.20
26	LP Pwrdy 70 + HPs-10 +DEB	0%	100%	0%	0%	10%	0%	0%	70%	20%	1.05	1.00	1.20

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Technology scenario		Fraction of space heat from system									Comm. Sys. factors		
		Secondary	Community	Main system or CHP	Gas boiler	Open loop GSHP	Canal source HP	Sewer source HP	Powerday	Electric boiler	Space heating control / charging	Hot water control	Distribution loss
27	LP Pwrdy 55 + HPs-20 +DEB	0%	100%	0%	0%	10%	5%	5%	55%	25%	1.05	1.00	1.20
28	LP Pwrdy 40 + HPs-30 +DEB	0%	100%	0%	0%	15%	8%	7%	40%	30%	1.05	1.00	1.20
29	LP Gas Boiler	0%	100%	0%	100%	0%	0%	0%	0%	0%	1.05	1.00	1.20
30	LP DE Boiler	0%	100%	0%	0.00%	0%	0%	0%	0%	100 %	1.05	1.00	1.20
31	LP GSHP DE Boiler	0%	100%	60%	0.00%	0%	0%	0%	0%	40%	1.05	1.00	1.20
32	LP ASHP Gas Boiler	0%	100%	60%	40%	0%	0%	0%	0%	0%	1.05	1.00	1.20
33	LP ASHP DE Boiler	0%	100%	60%	0.00%	0%	0%	0%	0%	40%	1.05	1.00	1.20
34	AF GSHP DE Boiler	0%	100%	60%	0.00%	0%	0%	0%	0%	40%	1.05	1.00	1.20

Notes: LP or AF = London Plan or Advanced fabric; DE(B)boiler = direct electric boiler; GSHP, ASHP, HRHP = ground source, air source and heat recovery heat pumps (HPs); SHW = solar hot water heating; Pwrdy = heat from Powerday energy from waste plant. See Table G.2.5 and Table G.2.6 for fabric specifications and full scenario descriptions.

Table G.3.1. Heat Source Mixes for Technology Scenarios (Post-processing Inputs)

G.3.2 Carbon Emission Outcomes for Technology Scenarios

G.3.2.1 Average Dwelling Emission Rates

To enable comparison of carbon emission results, the results for different dwelling sizes were combined into a single weighted average figure based on the proportion of homes of each size (see Table G.2.4). Average dwelling emission rates in $kgCO_2/m^2/year$ are set out in Table G.3.2.

G.3.2.2 Reduction in Average Dwelling Emission Rates vs the Counterfactual

Reductions in average dwelling emission rates were calculated relative to the London Plan counterfactual (technology scenario 1), and are set out in Table G.3.3.

G.3.2.3 Interpreting the Results Tables

Cell colouring in Table G.3.2 and Table G.3.3 represents the carbon emission performance relative to the counterfactual, technology scenario 1 (described earlier in Box G.1) in 2016 – unshaded neutral (white). Lower (better) emission rates are shaded green. Higher (worse) emission rates are shaded red. The darker the green or red shading, the lower or higher respectively are the emissions relative to the counterfactual.

The horizontal lines in both tables divide the technology scenarios into three groups:

1. Top group – heat pumps as lead heat generator (except 17 and 18, where they serve hot water only);
2. Middle group – direct electric storage heaters or boilers as lead heat generator; and
3. Bottom group – heat networks with defined mix of heat sources (except 29 gas boilers, included for comparison).

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The ‘Gas CHP’ decarbonisation scenario uses a higher grid emission factor for grid-displaced electricity (increasing the carbon ‘credit’ for the electricity generated by the CHP). As such, only technology scenarios that generate (and displace) grid electricity perform differently under this decarbonisation scenario.

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[$kgCO_2/m^2$/year, weighted average across units by no. of beds]

TS no.	Grid Decarbonisation Scenario > / Technology Scenario	Slower						Faster						Gas CHP					
		2016	2017-20	2021-25	2026-30	2031-35	2036-50	2016	2017-20	2021-25	2026-30	2031-35	2036-50	2016	2017-20	2021-25	2026-30	2031-35	2036-50
16	AF GSHP ASHP SHW	11.2	7.5	5.0	3.3	1.9	0.9	11.2	6.5	4.3	2.9	1.9	0.9	11.2	6.5	4.3	2.9	1.9	0.9
15	AF GSHP ASHP	12.9	8.7	5.8	3.8	2.2	1.1	12.9	7.5	5.0	3.4	2.2	1.1	12.9	7.5	5.0	3.4	2.2	1.1
8	LP GSHP ASHP SHW	14.5	9.8	6.5	4.3	2.5	1.2	14.5	8.4	5.6	3.8	2.5	1.2	14.5	8.4	5.6	3.8	2.5	1.2
17	AF HRHP	15.8	10.7	7.1	4.7	2.7	1.3	15.8	9.2	6.1	4.1	2.7	1.3	15.8	9.2	6.1	4.1	2.7	1.3
7	LP GSHP ASHP	16.4	11.1	7.4	4.8	2.8	1.3	16.4	9.5	6.3	4.3	2.8	1.3	16.4	9.5	6.3	4.3	2.8	1.3
18	AF HRHP SHW	15.4	10.4	6.9	4.5	2.6	1.3	15.4	8.9	6.0	4.0	2.6	1.3	15.4	8.9	6.0	4.0	2.6	1.3
34	AF GSHP DE Boiler	18.8	12.7	8.5	5.6	3.2	1.6	18.8	11.0	7.3	4.9	3.2	1.6	18.8	11.0	7.3	4.9	3.2	1.6
31	LP GSHP DE Boiler	25.8	17.4	11.7	7.6	4.5	2.1	25.8	15.0	10.0	6.8	4.5	2.1	25.8	15.0	10.0	6.8	4.5	2.1
33	LP ASHP DE Boiler	26.3	17.8	11.9	7.8	4.5	2.2	26.3	15.3	10.2	6.9	4.5	2.2	26.3	15.3	10.2	6.9	4.5	2.2
14	AF GSHP Gas Boiler SHW	11.9	8.9	6.9	5.5	4.4	3.6	11.9	8.1	6.3	5.2	4.4	3.6	11.9	8.1	6.3	5.2	4.4	3.6
6	LP GSHP Gas Boiler SHW	15.8	12.3	10.0	8.3	7.1	6.1	15.8	11.3	9.3	8.0	7.1	6.1	15.8	11.3	9.3	8.0	7.1	6.1
13	AF GSHP Gas Boiler	14.0	10.6	8.4	6.9	5.7	4.8	14.0	9.7	7.8	6.6	5.7	4.8	14.0	9.7	7.8	6.6	5.7	4.8
5	LP GSHP Gas Boiler	18.0	14.1	11.6	9.8	8.4	7.4	18.0	13.1	10.8	9.4	8.4	7.4	18.0	13.1	10.8	9.4	8.4	7.4
32	LP ASHP Gas Boiler	18.5	14.4	11.8	9.9	8.5	7.4	18.5	13.3	11.0	9.5	8.5	7.4	18.5	13.3	11.0	9.5	8.5	7.4
12	AF DE Storage Heater SHW	20.7	14.0	9.3	6.1	3.6	1.7	20.7	12.0	8.0	5.4	3.6	1.7	20.7	12.0	8.0	5.4	3.6	1.7
4	LP DE Storage Heater SHW	30.9	20.9	14.0	9.1	5.3	2.5	30.9	18.0	12.0	8.1	5.3	2.5	30.9	18.0	12.0	8.1	5.3	2.5
11	AF DE Storage Heater	26.9	18.2	12.1	7.9	4.6	2.2	26.9	15.7	10.4	7.1	4.6	2.2	26.9	15.7	10.4	7.1	4.6	2.2
3	LP DE Storage Heater	37.3	25.2	16.8	11.0	6.4	3.1	37.3	21.7	14.4	9.8	6.4	3.1	37.3	21.7	14.4	9.8	6.4	3.1
30	LP DE Boiler	40.5	27.3	18.3	11.9	7.0	3.3	40.5	23.6	15.7	10.6	7.0	3.3	40.5	23.6	15.7	10.6	7.0	3.3
28	LP Pwrdy 40 + HPs-30 +DEB	20.1	14.7	10.5	7.6	5.3	3.6	20.1	13.0	9.3	7.0	5.3	3.6	20.1	13.0	9.3	7.0	5.3	3.6
27	LP Pwrdy 55 + HPs-20 +DEB	17.5	13.5	10.0	7.5	5.6	4.2	17.5	12.0	9.0	7.0	5.6	4.2	17.5	12.0	9.0	7.0	5.6	4.2
26	LP Pwrdy 70 + HPs-10 +DEB	15.0	12.2	9.4	7.4	5.8	4.7	15.0	11.0	8.6	7.0	5.8	4.7	15.0	11.0	8.6	7.0	5.8	4.7
23	LP Pwrdy-70 + HPs-10 + CHP-15	9.0	10.1	10.2	10.2	10.2	10.2	9.0	10.1	10.2	10.2	10.2	10.2	9.0	9.4	8.7	8.2	7.9	7.8
24	LP Pwrdy-55 + HPs-20 + CHP-15	10.5	11.0	10.7	10.6	10.4	10.4	10.5	10.9	10.7	10.5	10.4	10.4	10.5	10.2	9.2	8.5	8.1	7.9
25	LP Pwrdy 40 + HPs-30 + CHP-15	12.1	11.8	11.3	10.9	10.7	10.5	12.1	11.6	11.2	10.9	10.7	10.5	12.1	10.9	9.7	8.9	8.4	8.0
20	LP Pwrdy-70 + CHP-15	9.5	10.9	11.2	11.5	11.6	11.7	9.5	11.1	11.3	11.5	11.6	11.7	9.5	10.4	9.8	9.5	9.3	9.3
21	LP Pwrdy-55 + CHP-35	8.6	12.0	14.0	15.4	16.5	17.3	8.6	12.8	14.5	15.7	16.5	17.3	8.6	11.2	11.1	11.0	11.0	11.5
22	LP Pwrdy-40 + CHP-35	10.7	13.6	15.6	17.0	18.1	18.9	10.7	14.5	16.2	17.3	18.1	18.9	10.7	12.8	12.7	12.6	12.7	13.1

[$kgCO_2/m^2/year$, weighted average across units by no. of beds]

Grid Decarbonisation Scenario >		Slower						Faster						Gas CHP					
TS no.	Technology Scenario	2016	2017-20	2021-25	2026-30	2031-35	2036-50	2016	2017-20	2021-25	2026-30	2031-35	2036-50	2016	2017-20	2021-25	2026-30	2031-35	2036-50
29	LP Gas Boiler	21.0	19.0	18.0	17.4	16.9	16.5	21.0	18.6	17.8	17.2	16.9	16.5	21.0	18.6	17.8	17.2	16.9	16.5
10	AF CHP-60 Low Temp	11.2	12.6	14.1	15.1	15.9	16.4	11.2	13.2	14.5	15.3	15.9	16.4	11.2	11.7	11.3	11.1	11.0	11.3
9	AF CHP-60 High Temp	11.7	13.4	15.0	16.2	17.1	17.8	11.7	14.1	15.5	16.4	17.1	17.8	11.7	12.5	12.1	11.9	11.8	12.2
2	LP CHP-60 Low Temp	13.6	17.3	20.6	22.9	24.7	26.0	13.6	18.7	21.5	23.3	24.7	26.0	13.6	16.3	16.5	16.6	16.8	17.7
1	LP CHP-60 High Temp	14.4	18.5	22.1	24.7	26.7	28.1	14.4	20.0	23.2	25.2	26.7	28.1	14.4	17.5	17.7	17.9	18.2	19.1
19	LP 5xCluster CHP-70, Low Temp	11.0	17.0	21.9	25.4	28.1	30.0	11.0	19.0	23.3	26.1	28.1	30.0	11.0	15.7	16.4	16.7	17.2	18.5

Notes: LP or AF = London Plan or Advanced fabric; DE(B)boiler = direct electric boiler; GSHP, ASHP, HRHP = ground source, air source and heat recovery heat pumps (HPs); SHW = solar hot water heating; Pwrdy = heat from Powerday energy from waste plant. See Table G.2.5 and Table G.2.6 for fabric specifications and full scenario descriptions.

Table G.3.2. Average Dwelling Emission Rates for Technical Scenarios, per Development Period & for Each Grid Decarbonisation Scenario

[% change vs. London Plan counterfactual]

Grid Decarbonisation Scenario >		Slower						Faster						Gas CHP					
TS no.	Technology Scenario	2016	2017-20	2021-25	2026-30	2031-35	2036-50	2016	2017-20	2021-25	2026-30	2031-35	2036-50	2016	2017-20	2021-25	2026-30	2031-35	2036-50
16	AF GSHP ASHP SHW	-22%	-48%	-65%	-77%	-87%	-94%	-22%	-55%	-70%	-80%	-87%	-94%	-22%	-55%	-70%	-80%	-87%	-94%
15	AF GSHP ASHP	-10%	-39%	-59%	-73%	-84%	-93%	-10%	-48%	-65%	-76%	-84%	-93%	-10%	-48%	-65%	-76%	-84%	-93%
8	LP GSHP ASHP SHW	1%	-32%	-54%	-70%	-83%	-92%	1%	-41%	-61%	-74%	-83%	-92%	1%	-41%	-61%	-74%	-83%	-92%
17	AF HRHP	10%	-26%	-50%	-68%	-81%	-91%	10%	-36%	-57%	-71%	-81%	-91%	10%	-36%	-57%	-71%	-81%	-91%
7	LP GSHP ASHP	14%	-23%	-48%	-66%	-80%	-91%	14%	-34%	-56%	-70%	-80%	-91%	14%	-34%	-56%	-70%	-80%	-91%
18	AF HRHP SHW	7%	-28%	-52%	-68%	-82%	-91%	7%	-38%	-59%	-72%	-82%	-91%	7%	-38%	-59%	-72%	-82%	-91%
34	AF GSHP DE Boiler	31%	-11%	-41%	-61%	-77%	-89%	31%	-24%	-49%	-66%	-77%	-89%	31%	-24%	-49%	-66%	-77%	-89%
31	LP GSHP DE Boiler	80%	21%	-19%	-47%	-69%	-85%	80%	5%	-30%	-53%	-69%	-85%	80%	5%	-30%	-53%	-69%	-85%
33	LP ASHP DE Boiler	83%	24%	-17%	-46%	-68%	-85%	83%	7%	-29%	-52%	-68%	-85%	83%	7%	-29%	-52%	-68%	-85%
14	AF GSHP Gas Boiler SHW	-17%	-38%	-52%	-62%	-69%	-75%	-17%	-44%	-56%	-64%	-69%	-75%	-17%	-44%	-56%	-64%	-69%	-75%
6	LP GSHP Gas Boiler SHW	10%	-15%	-31%	-42%	-51%	-57%	10%	-21%	-35%	-44%	-51%	-57%	10%	-21%	-35%	-44%	-51%	-57%
13	AF GSHP Gas Boiler	-3%	-26%	-41%	-52%	-60%	-66%	-3%	-32%	-46%	-54%	-60%	-66%	-3%	-32%	-46%	-54%	-60%	-66%
5	LP GSHP Gas Boiler	25%	-2%	-20%	-32%	-42%	-49%	25%	-9%	-25%	-34%	-42%	-49%	25%	-9%	-25%	-34%	-42%	-49%

[% change vs. London Plan counterfactual]

	Grid Decarbonisation Scenario >	Slower						Faster						Gas CHP					
TS no.	Technology Scenario	2016	2017-20	2021-25	2026-30	2031-35	2036-50	2016	2017-20	2021-25	2026-30	2031-35	2036-50	2016	2017-20	2021-25	2026-30	2031-35	2036-50
32	LP ASHP Gas Boiler	29%	0%	-18%	-31%	-41%	-48%	29%	-7%	-23%	-34%	-41%	-48%	29%	-7%	-23%	-34%	-41%	-48%
12	AF DE Storage Heater SHW	44%	-3%	-35%	-58%	-75%	-88%	44%	-16%	-44%	-62%	-75%	-88%	44%	-16%	-44%	-62%	-75%	-88%
4	LP DE Storage Heater SHW	115%	45%	-3%	-37%	-63%	-82%	115%	25%	-17%	-44%	-63%	-82%	115%	25%	-17%	-44%	-63%	-82%
11	AF DE Storage Heater	87%	26%	-16%	-45%	-68%	-85%	87%	9%	-28%	-51%	-68%	-85%	87%	9%	-28%	-51%	-68%	-85%
3	LP DE Storage Heater	159%	75%	17%	-24%	-55%	-79%	159%	51%	0%	-32%	-55%	-79%	159%	51%	0%	-32%	-55%	-79%
30	LP DE Boiler	182%	90%	27%	-17%	-51%	-77%	182%	64%	9%	-26%	-51%	-77%	182%	64%	9%	-26%	-51%	-77%
28	LP Pwrdy 40 + HPs-30 +DEB	39%	2%	-27%	-47%	-63%	-75%	39%	-10%	-35%	-51%	-63%	-75%	39%	-10%	-35%	-51%	-63%	-75%
27	LP Pwrdy 55 + HPs-20 +DEB	22%	-6%	-31%	-48%	-61%	-71%	22%	-16%	-38%	-51%	-61%	-71%	22%	-16%	-38%	-51%	-61%	-71%
26	LP Pwrdy 70 + HPs-10 +DEB	4%	-15%	-35%	-49%	-59%	-67%	4%	-23%	-40%	-51%	-59%	-67%	4%	-23%	-40%	-51%	-59%	-67%
23	LP Pwrdy-70 + HPs-10 + CHP-15	-38%	-30%	-29%	-29%	-29%	-29%	-38%	-29%	-29%	-29%	-29%	-29%	-38%	-34%	-40%	-43%	-45%	-46%
24	LP Pwrdy-55 + HPs-20 + CHP-15	-27%	-24%	-25%	-26%	-27%	-28%	-27%	-24%	-26%	-27%	-27%	-28%	-27%	-29%	-36%	-41%	-44%	-45%
25	LP Pwrdy 40 + HPs-30 + CHP-15	-16%	-18%	-21%	-24%	-26%	-27%	-16%	-19%	-22%	-24%	-26%	-27%	-16%	-24%	-33%	-38%	-42%	-44%
20	LP Pwrdy-70 + CHP-15	-34%	-24%	-22%	-20%	-19%	-18%	-34%	-23%	-21%	-20%	-19%	-18%	-34%	-28%	-32%	-34%	-35%	-35%
21	LP Pwrdy-55 + CHP-35	-40%	-17%	-3%	7%	14%	20%	-40%	-11%	1%	9%	14%	20%	-40%	-22%	-23%	-24%	-23%	-20%
22	LP Pwrdy-40 + CHP-35	-26%	-5%	9%	18%	26%	31%	-26%	1%	13%	20%	26%	31%	-26%	-11%	-12%	-12%	-12%	-9%
29	LP Gas Boiler	46%	32%	25%	21%	17%	15%	46%	29%	24%	20%	17%	15%	46%	29%	24%	20%	17%	15%
10	AF CHP-60 Low Temp	-22%	-12%	-2%	5%	10%	14%	-22%	-8%	1%	6%	10%	14%	-22%	-18%	-21%	-23%	-24%	-22%
9	AF CHP-60 High Temp	-19%	-7%	5%	13%	19%	24%	-19%	-2%	8%	14%	19%	24%	-19%	-13%	-16%	-17%	-18%	-15%
2	LP CHP-60 Low Temp	-6%	20%	43%	59%	72%	81%	-6%	30%	50%	62%	72%	81%	-6%	13%	15%	16%	17%	23%
1	LP CHP-60 High Temp	0%	29%	54%	72%	85%	96%	0%	39%	61%	75%	85%	96%	0%	21%	23%	25%	27%	33%
19	LP 5xCluster CHP-70, Low Temp	-23%	18%	52%	76%	95%	109%	-23%	32%	62%	81%	95%	109%	-23%	9%	14%	16%	20%	29%

Notes: LP or AF = London Plan or Advanced fabric; DE(B)boiler = direct electric boiler; GSHP, ASHP, HRHP = ground source, air source and heat recovery heat pumps (HPs); SHW = solar hot water heating; Pwrdy = heat from Powerday 's proposed energy from waste plant. See Table G.2.5 and Table G.2.6 for fabric specifications and full scenario descriptions.

Table G.3.3. Reduction in Average Dwelling Emission Rates for Technical Scenarios, per Development Period & for Each Grid Decarbonisation Scenario

G.3.3 Commentary on Carbon Emission Outcomes

The carbon emission outcomes for the technology scenarios studied confirm many of the prior expectations of the study team based, on a general understanding of the current relative performance of technologies and the trends in emission factors (particularly for grid electricity):

1. Gas CHP (as main heat source) falls precipitously from being among the best carbon saving options deliverable now to definitively the worst of the options studied by 2021 – 25 under all the emissions scenarios considered. While the use of bespoke gas CHP marginal emission factors reduces the calculated emissions (‘Gas CHP’ grid decarbonisation scenario), this does not alter the relative ranking of the technology choices.

2. Heat pumps supplant gas CHP as the main heat source providing the lowest carbon emissions from the start of the 2020s.

3. Heat pump and direct electric options have the best carbon outcomes in the long term but in the short term either have the worst carbon outcomes (direct electric), which will not meet London Plan carbon targets (and may not enable homes to meet Building Regulations Part L) or are relatively costly to install (ground source heat pumps), as will be discussed later.

The results also help to draw out the following insights:

1. Heat from a proposed Energy from Waste facility appears critical to any heat network in the Old Oak area. It enables the carbon intensity of a heat network to remain somewhat competitive (in terms of emission rates) with unit- and block-scale electric heating options into the 2030s.

2. Scenarios including infrastructure scale heat pump options (open loop ground, canal, and sewer source) are the only ones near the top on carbon outcomes throughout the periods considered. Previous work established the capacity of the heat resource for these options of around 10 MW, i.e. approximately 10% of peak heat load at full build out (~100 MW) and perhaps half of the base load for the first 20 years.

3. Scenarios based on heat networks offer the best carbon outcomes in the short term. Electricity-based heating systems (which in practice would be block and unit scale, with no heat network) have the best long term outcomes. There is little common ground between these options and therefore it is not obvious how an energy strategy would transition smoothly from one solution to the other.

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G.4 Costs

This section below provides a comparison of the capital costs and occupant running costs for the alternative energy strategy options being considered for the proposed development in the Old Oak area.

G.4.1 Capital Costs

G.4.1.1 Introduction

The capital costs of delivering energy and CO_2 reduction targets impact scheme viability and are therefore an important consideration for developers. Indicative capital costs have been produced to enable energy technology scenarios to be compared, alongside their estimated CO_2 savings and running costs for occupants. The estimates include costs for individual technology components, associated plant and site infrastructure, as well as building systems and/or services within dwellings where these varied across options.

The comparative costs are presented relative to the counterfactual 'default London Plan-compliant' scenario with gas-CHP as the low carbon heat source for each of the development parcels.

Please refer to section G.2.2.3 for further details on the counterfactual 'scenario and the alternative technology scenarios modelled.

G.4.1.2 Methodology, Data Sources and Limitations

The cost estimates are derived based on a bottom up analysis using a combination of published reference sources and internal AECOM data from previous projects. High level estimates have been developed for system sizes taking into consideration the site context, housing densities and projected heat demand profiles. For certain cost items, such as indicative length of primary pipework for district heating network, estimates are based on AECOM experience from schemes with similar housing densities.

Table G.4.1 below summarises the cost items that were included in the comparative analysis.

Scale	Cost components
Development scale 'market delivery' option	Heat generation plant (gas CHP and ancillaries) Gas boilers to meet peak demand Energy centre, assumed to be located in basement for smaller plots, standalone building for large development parcels (i.e. Old Oak North and Old Oak South), excludes land costs Primary district heating pipework Block level heating sub-stations Secondary distribution pipework Heat interface units (HIUs) within dwellings Heat emitters (radiators) London Plan compliant fabric specification
Cluster level options	Heat generation plant (gas CHP and ancillaries/ heat pump technologies) Connection to Energy from Waste (EfW) plant Gas boilers to meet peak demand Standalone energy centre building District heating transmission network connecting energy centres in each cluster Primary district heating pipework to plot boundary Block level heating sub-stations Secondary distribution pipework HIUs within dwellings Heat emitters (radiators/ low temperature underfloor heating depending on network flow and return temperatures) London Plan compliant fabric specification

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Scale	Cost components
Block level options	Heat generation plant (ground source/ air source heat pumps/ direct electric) Block level energy centre Secondary distribution pipework HIUs within dwellings Heat emitters (low temperature underfloor heating) Solar water heating for specific options London Plan compliant/ advanced fabric specification
Unit level options	Heat generation technology (exhaust air heat pumps/ electric storage heaters) Solar water heating for specific options Hot water cylinder in dwellings London Plan compliant/ advanced fabric specification

Table G.4.1. Cost Components for Technology Scenarios

The cost estimates reflect 1st Quarter 2017 prices and do not reflect anticipated changes or inflationary increases in technology and infrastructure costs over time. Costs include prelims, overheads and profits. No allowance has been made for professional fees and contingencies. It is worth noting there is a high level of uncertainty associated with capital cost estimates at design development stage. The uncertainty comes from a whole host of variables, such as technical assumptions around system sizes and specifications, lack of reliable cost data for newer technologies that are not mainstream in the UK (such as sewer based heat pumps or advanced fabric specification in high rise construction), site-specific variables and risks (e.g. cost implications of routing district heating pipework under railway lines or other obstructions), as well as the impact of delivery and procurement routes (for instance the ability to combine district heating infrastructure with other ground infrastructure).

Specifically on the additional cost of delivering an advanced energy efficiency fabric specification relative to a London Plan compliant specification, this is based on estimates produced by Zero Carbon Hub (Feb 2014) for a low rise block of apartments, which is adjusted using AECOM's Building Cost Index to indicatively bring it to current prices. There is limited published data currently on cost implications of delivering advanced and/or PassivHaus standard for high rise apartments in the UK. The additional cost can vary depending on the construction system used, glazing ratios, baseline ventilation strategy, and other variables.

The current comparative analysis is based on total capital costs associated with alternative strategy options. The net cost to the developer can also vary depending on the procurement strategy for energy infrastructure, e.g. ESCo equity contributions. These could potentially reduce the upfront cost burden for developers with the area wide options expected to benefit most from this (because of the scale and potential commercial attractiveness to ESCos), and to a lesser extent the development scale options.

G.4.1.3 Comparative Capital Costs of Alternative Energy Strategy Options

The estimated percentage uplift in capital costs for alternative energy technology scenarios relative to the development scale 'market delivery' option are set out in Table G.4.2 below. These indicate that:

- The alternative district heating options at cluster level are broadly comparable in cost to the development scale 'market delivery' option. The additional investment in primary distribution pipework and transmission network for the cluster level options is offset by efficiencies in delivering 5 large energy centres as opposed to a number of smaller energy centres at development scale. These efficiencies are reflected in a reduction in cumulative footprint for the energy centres, reduction in back-up plant capacity, as well as lower unit costs of MW scale gas-CHP plant. Cluster level options also create opportunities to tap into Powerday's proposed 'Energy from Waste' plant, connecting to which is a relatively low capital cost investment in comparison to gas CHP as the baseline technology.

- Ground source heat pumps with direct electric top up at block level are also broadly comparable in costs to the development and cluster level DH options. This technology scenario is however expected to have implications for electrical infrastructure costs at the block level which are not quantified as part of this current comparison and will need further analysis. Heat pump technologies at both block and unit level end up with much higher capital costs in comparison when combined with advanced fabric specification.
- Dwelling based direct electric heating technologies have the lowest costs in comparison, though these start to become comparable to the development scale 'market delivery' option and cluster level options when combined with solar water heating and advanced fabric specification.

TS no.	Technology scenario*	Fabric specification	Scale	Capital cost** uplift (approx.)	Annual running cost uplift (approx.)
12	Direct electric storage heater + solar hot water	Advanced	Unit	-5%	-35%
4	Direct electric storage heater + solar hot water	London Plan	Unit	-45%	-20%
11	Direct electric storage heater	Advanced	Unit	-20%	-40%
3	Direct electric storage heater	London Plan	Unit	-60%	-20%
18	Exhaust ventilation air heat recovery heat pump + solar hot water	Advanced	Unit	55%	60%
17	Exhaust ventilation air heat recovery heat pump	Advanced	Unit	40%	50%
34	Ground source heat pump (60%) + direct electric boiler (40%)	Advanced	Block	45%	-30%
31	Ground source heat pump (60%) + direct electric boiler (40%)	London Plan	Block	5%	-15%
1	Gas CHP (60%; **η elec = 36%) + gas boiler (high temp network)**	**London Plan**	**Development**	**0%**	**0%**
25	Powerday (40%) + heat pump (30%) + gas CHP (15%) + gas boiler (15%)	London Plan	Cluster	5%	-5%
22	Powerday (40%) + gas CHP (35%, η elec = 39%) + gas boiler (25%)	London Plan	Cluster	0%	-5%
19	Gas CHP (70%, η elec = 39%) + gas boiler (30%)	London Plan	Cluster	5%	-5%
28	Powerday (40%) + heat pump (30%) + direct electric boiler (30%)	London Plan	Cluster	0%	-5%
23	Powerday (70%) + heat pump (10%) + gas CHP (15%) + gas boiler (5%)	London Plan	Cluster	0%	-5%

* Please refer to Table G.2.5 and Table G.2.6 for a description of the technology scenarios and their characteristics.
** Cost comparison does not include cost for roof mounted PVs for the development level counterfactual scenario or where this technology may be compatible with any of the others scenarios being analysed.

Table G.4.2. Comparative Costs of Energy Technology Scenarios

When comparing capital costs, it is worth noting that each of the energy strategy options are not directly comparable in terms of the CO_2 impact, and fare better or worse relative to the development scale' market delivery' option at different points in time in the future. Similarly, the impact on heating energy bills for occupants also varies for the alternative options, which is discussed further in Section 0.

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G.4.2 Running Costs for Occupants

A key consideration in arriving at an optimum energy strategy is the impact on running costs for occupants. It is important that the strategy does not lead to unacceptably high costs for occupants relative to other widely available alternatives. This is even more critical given the high proportion of affordable housing to be delivered in the Old Oak area and the mayor's aspiration to increase affordable housing provision.

The sub-section below outlines some of the challenges in comparing heating bills for district heating and dwelling based systems. To enable a like for like comparison across technology scenarios, it makes a case for comparing the total cost for the occupant of owning, operating, maintaining and replacing the systems over its life. Sections G.4.2.2 and 0 set out the comparative figures for the alternative energy strategy options along with a brief discussion of how these are expected to change in the future.

G.4.2.1 District Heating versus Dwelling-based Systems

Comparing running costs for district heating (DH) and communal systems with dwelling based systems on a like-for-like basis is not without its challenges. The occupant's perception of the 'cost of heating' is often based on the bill that lands at their door. This typically consists of a variable cost calculated based on a unit cost of heat or fuel, and fixed charges that are independent of consumption. The differences in annual heating bills for occupants connected to a district heating systems versus dwelling based systems stem from how both these cost elements are calculated and, in particular, the inclusions and exclusions.

In general terms it is typical for larger market-led DH schemes to set the total cost of heat (including variable and fixed charges) to the occupant to be no higher (or marginally lower) than the cost of owning, operating, maintaining and replacing a conventional gas boiler heating system. With this parameter essentially fixed it then determines the financial return for the DH scheme and whether it will be economic to invest in and operate.

In determining the cost of heat, the heat network operator will take into account the price the occupant would pay for heat (including both variable charges and utility standing charges) as well as anticipated annual service costs, maintenance costs and replacement costs for the boiler. In reality many occupants do not take out a service contract on their boiler, often choosing to pay to have the boiler repaired or replaced when and if it breaks down. Their annual energy bill when connected to district heating will therefore seem much higher than the energy bill for a conventional gas heating system. In effect though the costs involved in owning, maintaining and replacing the conventional dwelling based system have been deferred to future years and often incurred as a lump sum.

To add to the complexity, data from operational district heating schemes indicates a huge variation in heat costs charged to consumers. The cost variation comes from differences in how the schemes are developed and financed (e.g. where these have benefited from significant capital grants), ownership models (for instance, where schemes have adopted existing assets thereby negating the need to recover upfront investment through heat sales) and other priorities (e.g. local authority led schemes where mitigating fuel poverty is high on the agenda).

An AECOM study for DECC[4] (2015) that looked at heat price data from 7 operational DH schemes indicated a price range of 4.64 – 9.88 p/kWh. Non-bulk schemes supplying heat directly to the end residential consumer typically sit at the upper end of this range. The study estimated that in comparison the total cost of heat for the counterfactual gas boiler system would translate to just over 10p/kWh for a small efficient dwelling with a low annual heat demand (such as a new build flat) with around 4.6p/kWh of that being attributable to the boiler ownership costs (i.e. maintenance and replacement).

A *Which?* Report (March 2015)[5] suggested a broader range of heat costs for district heating customers based on data collected from 40 metered schemes including both private and social housing. To enable a comparison of the cost of heat across these schemes, the unit rates and fixed charges were translated into an aggregate p/kWh figure using annual space heating and hot water demand for a typical new built 2-bed flat. This gave a total cost of heat ranging between ~5.5 -15p/kWh, with the average figure of around 11p/kWh. The estimated counterfactual cost of between 9.55 -11.60p/kWh for the gas boiler system compares well with this average figure.

[4] DECC, Assessment of the costs, performance, and characteristics of UK heat networks, 2015
[5] Which?, Turning up the heat: Getting a fair deal for district heating users, March 2015

The figures from the DECC and *Which?* reports suggest that heat costs for currently operational district heating schemes are on average broadly comparable to the total cost of owning, operating, maintaining and replacing a conventional gas boiler system for smaller new build dwellings (such as would be the case for proposed development in the Old Oak area). Typically the lower annual heat demand baseline for flats means the fixed costs when connected to a DH scheme are a significant proportion of the total bill, close to around 50%.

For comparison, the heat tariffs for residential consumers on the Queen Elizabeth Olympic Park are set out in the table below alongside the figures from the DECC and *Which?* reports. The Olympic Park offers a useful comparator because of the scale and the London location. Assuming a heat demand of 5000 kWh per annum (the figure used in the DECC report for a small efficient dwelling), the heat costs and billing and metering charges for consumers on the Olympic Park translate to 7.5p/kWh, somewhat higher than the 5.7p/kWh fuel costs and standing charges for the counterfactual system as estimated in the DECC and Which? reports.

	Total cost of heat for DH schemes	**Estimated counterfactual costs for small efficient dwelling with gas boiler (p/kWh)**
DECC (2015)	4.64 – 9.88 p/kWh Average cost 6.43 p/kWh	10.24 p/kWh, broken down as 5.68 p/ kWh for fuel costs and standing charges [4.2 p/kWh for fuel costs alone] 4.57 p/KWh for boiler maintenance and replacement
Which? (2015)	5.51 – 14.94 p/kWh Average cost 11.04 p/kWh	9.55 – 11.60 p/kWh, broken down as 5.73 p/kWh for fuel costs and standing charges 3.18 - 5.23 p/KWh for boiler maintenance and replacement
Queen Elizabeth Olympic Park	Unit cost of heat 5.49 p/kWh Metering and billing 99.85 £/year Availability charge 22.84 £/year per kW heat capacity Additional variable charge where secondary distribution losses > 15%	Not known

Table G.4.3. Total Cost of Heat for District Heating and Individual

The huge range in cost of heat in the figures above highlights instances where district heating consumers may be paying significantly lower or higher for their heat in comparison. Greater transparency on charging structures and costs, e.g. through voluntary initiatives such as the Heat Trust[6], will ensure that consumers energy bills remain broadly comparable with other widely available technology options.

Experience from the Olympic Park and other operational schemes suggests that consumers may also incur additional charges for distribution losses where these exceed set thresholds, for instance, in case of Olympic Park where the secondary pipework losses exceed 15%. This highlights the need for ensuring that district heating systems are designed, operated and managed efficiently to minimise the impact on consumer energy bills, and emphasises the importance of defining the key technical requirements for design of the secondary network to facilitate this.

Most existing district heating networks in the UK are served by gas boilers and gas CHP engines, and occasionally biomass boilers or waste heat sources. The historic charges reflect the fact that it is possible to create viable networks that can compete on price when operating on these heat sources. Our analysis of carbon emissions shows that as the electricity grid decarbonises it will become favourable to shift from gas CHP based systems to electric heat pumps or direct electric boilers. Given the relatively high cost of electricity compared with gas this is likely to increase the operational costs for the heat network operator, which in turn would either increase the energy cost to the consumer or reduce the internal rate of return to

[6] The Heat Trust is a voluntary standard that sets out the quality and level of service heat suppliers should provide to customers. It also provides an independent process with the Energy Ombudsman for settling complaints between the customers and their heat supplier, which is a free service for customers to access. For more details see www.heattrust.org

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the investor/operator. Carrying out a full financial appraisal of the various heat network technology options is beyond the scope of this current work, though any future business case assessment for heat networks utilising alternative low carbon heat sources will need to appraise whether sufficient returns can be obtained to enable economically viable operation while retaining affordable bills for residents.

An assessment for DECC (2016)[7] on the potential for heat pumps to serve district heating networks found that although the technology offers large CO_2 reduction potential alongside a decarbonising electricity grid, the price premium for delivered heat is in the range of 35% -74% at current costs (relative to a counterfactual of DH schemes operating on gas CHP or gas boilers). This is attributed to a combination of factors including high capital costs, high electricity price compared to gas price, and lost revenue from electricity sales compared to schemes with gas-CHP. This price premium for heat is unlikely to drop in future years based on DECC's projected retail fuel costs in the 2020s and 2030s. Refer to section 0 below for further discussion on future cost of heat.

As the UK increasingly shifts to electric heating systems the counterfactual against which district heating costs are benchmarked could also be expected to change.

G.4.2.2 Running Costs for Alternative Energy Strategy Options

Table G.4.1 above sets out the indicative 'running cost' for alternative energy strategy options considered for the Old Oak area. The running cost comparison includes the fuel/ heat bills, any fixed annual charges (such as the utility standing charges or charges for billing and metering) plus the annualised cost to the occupant of owning, maintaining and replacing the system.

The fuel bills for the dwelling based technologies have been estimated based on the current electricity unit prices and standing charges for domestic consumers in London[8]. Economy 7 tariffs have been used for electric storage heaters assuming between 90- 93% off peak usage in line with SAP[9] assumptions. While less efficient, storage heaters were selected in preference to direct electric heaters as they offer greater scope for shifting demand. Replacement costs for storage heaters and/or heat pump options have been converted to equivalent annual costs using a 3.5% discount rate and a 15 year service life. An estimated annual maintenance/ servicing cost is added to this to arrive at the total annual running cost for the technology options. The maintenance costs are assumed to be negligible for storage heaters. For heat pumps, the cost of an annual servicing contract from a prominent heat manufacturer has been used as an estimate.

For the block-based GSHP option, current electricity tariffs for small to medium sized non-domestic consumers in London[10] are used, which were then assumed to be passed down to individual occupants accounting for any secondary distribution losses, along with an annual billing and metering charge. As for dwelling based systems, replacement costs have been converted to equivalent annual costs using a 3.5% discount rate. An estimated annual O&M cost is added to arrive at a total annual running cost figure.

For the district heating options at both development and cluster level, the annual heat bills are estimated based on the current unit price of heat and the billing and metering costs being charged for residential customers connected to the Olympic Park DH scheme. The total running costs are then worked up based on the annualised replacement costs and the cost of an annual servicing contract for a gas boiler as the counterfactual system. Replacement and servicing costs and service life for gas boiler are based on figures from DECC (2015)[11].

Compared to the development scale 'market delivery' option, the running costs are marginally lower for the cluster level, low temperature, district heating options due to reduction in distribution losses.

Block based heat pumps and dwelling level electric storage options fare the best, with the running costs dropping by a quarter relative to the market delivery option when combined with solar water heating and/or advanced fabric specifications. Total running costs are highest for the dwelling based heat pump options primarily due to the high annualised cost of replacement.

[7] DECC, Heat Pumps in District Heating, 2016
[8] BEIS Quarterly Energy Prices, Dec 2016
[9] SAP (Standard Assessment Procedure) is used for building regulation compliance for new dwellings in England.
[10] BEIS Quarterly Energy Prices, Dec 2016
[11] DECC, Assessment of the costs, performance and characteristics of UK heat networks, 2015

G.4.2.3 Future Projections of Cost of Heat

The DECC projections (September 2015)[12] on retail fuel prices indicate that the comparative figures for the variable cost of heat will largely remain unchanged in 2020s and 2030s, though electricity based systems could be marginally worse off. Electricity prices see a marginally higher increase, around 19% by 2030 compared to a 13% increase in gas prices over that timeframe.

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[12] DECC, Valuation of energy use and greenhouse gas emissions for appraisal- Data tables, September 2015

G.5 Synthesis of Carbon and Cost Results

Dwelling emission rates for selected technology scenarios are shown alongside corresponding capital cost and annual running cost results in Table G.5.1.

Table G.5.2 presents this information in terms of percentage uplift relative to the counterfactual for the different technology scenarios.

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Technology Scenario				Scenario emissions, weighted average per unit [kgCO$_2$/m^2/year]							Cost uplifts [£/unit]	
TS no.	Fabric Specification	Technology Specification	Scale	2016	2017-20	2021-25	2026-30	2031-35	2036-50	Overall average 2017 - 50	Capital cost [/m^2]	Annual bill + cost of owning system [/m^2/year]
12	Advanced	Direct electric storage heater + solar hot water	Unit-based	20.7	14.0	9.3	6.1	3.6	1.7	5.7	£112	£5.87
4	London Plan	Direct electric storage heater + solar hot water	Unit-based	30.9	20.9	14.0	9.1	5.3	2.5	8.5	£63	£7.61
11	Advanced	Direct electric storage heater	Unit-based	26.9	18.2	12.1	7.9	4.6	2.2	7.4	£95	£5.66
3	London Plan	Direct electric storage heater	Unit-based	37.3	25.2	16.8	11.0	6.4	3.1	10.2	£46	£7.47
18	Advanced	Exhaust ventilation air heat recovery heat pump + solar hot water	Unit-based	15.4	10.4	6.9	4.5	2.6	1.3	4.2	£186	£14.91
17	Advanced	Exhaust ventilation air heat recovery heat pump	Unit-based	15.8	10.7	7.1	4.7	2.7	1.3	4.3	£169	£14.11
34	Advanced	Ground source heat pump (60%) + direct electric boiler (40%)	Block-based	18.8	12.7	8.5	5.6	3.2	1.6	5.2	£171	£6.31
31	London Plan	Ground source heat pump (60%) + direct electric boiler (40%)	Block-based	25.8	17.4	11.7	7.6	4.5	2.1	7.1	£122	£8.00
1	**London Plan**	**Gas CHP (60%; η elec = 36%) + gas boiler (high temp network)**	**Development-based**	**14.4**	**18.5**	**22.1**	**24.7**	**26.7**	**28.1**	**25.0**	**£119**	**£9.34**
25	London Plan	Powerday (40%) + heat pump (30%) + gas CHP (15%) + gas boiler (15%)	Cluster-based	12.1	11.8	11.3	10.9	10.7	10.5	10.9	£122	£9.02
22	London Plan	Powerday (40%) + gas CHP (35%, η elec = 39%) + gas boiler (25%)	Cluster-based	10.7	13.6	15.6	17.0	18.1	18.9	17.2	£116	£9.02
19	London Plan	Gas CHP (70%, η elec = 39%) + gas boiler (30%)	Cluster-based	11.0	17.0	21.9	25.4	28.1	30.0	25.8	£123	£9.02
28	London Plan	Powerday (40%) + heat pump (30%) + direct electric boiler (30%)	Cluster-based	20.1	14.7	10.5	7.6	5.3	3.6	7.2	£120	£9.02
23	London Plan	Powerday (70%) + heat pump (10%) + gas CHP (15%) + gas boiler (5%)	Cluster-based	9.0	10.1	10.2	10.2	10.2	10.2	10.2	£116	£9.02

Table G.5.1. Carbon Emissions and Cost /m^2 Results Summary for Selected Technology Scenarios

Technology Scenario				Scenario emissions, weighted average per unit						[%]	Cost uplifts	[%]
TS no.	Fabric Specification	Technology Specification	Scale	2016	2017-20	2021-25	2026-30	2031-35	2036-50	Overall average 2017 - 50	Capital uplift (approx.)	Annual uplift (approx.)
12	Advanced	Direct electric storage heater + solar hot water	Unit-based	44%	-3%	-35%	-58%	-75%	-88%	-61%	-5%	-35%
4	London Plan	Direct electric storage heater + solar hot water	Unit-based	115%	45%	-3%	-37%	-63%	-82%	-41%	-45%	-20%
11	Advanced	Direct electric storage heater	Unit-based	87%	26%	-16%	-45%	-68%	-85%	-49%	-20%	-40%
3	London Plan	Direct electric storage heater	Unit-based	159%	75%	17%	-24%	-55%	-79%	-29%	-60%	-20%
18	Advanced	Exhaust ventilation air heat recovery heat pump + solar hot water	Unit-based	7%	-28%	-52%	-68%	-82%	-91%	-71%	55%	60%
17	Advanced	Exhaust ventilation air heat recovery heat pump	Unit-based	10%	-26%	-50%	-68%	-81%	-91%	-70%	40%	50%
34	Advanced	Ground source heat pump (60%) + direct electric boiler (40%)	Block-based	31%	-11%	-41%	-61%	-77%	-89%	-64%	45%	-30%
31	London Plan	Ground source heat pump (60%) + direct electric boiler (40%)	Block-based	80%	21%	-19%	-47%	-69%	-85%	-51%	5%	-15%
1	**London Plan**	**Gas CHP (60%; η elec = 36%) + gas boiler (high temp network)**	**Development-based**	**0%**	**29%**	**54%**	**72%**	**85%**	**96%**	**74%**	**0%**	**0%**
25	London Plan	Powerday (40%) + heat pump (30%) + gas CHP (15%) + gas boiler (15%)	Cluster-based	-16%	-18%	-21%	-24%	-26%	-27%	-24%	5%	-5%
22	London Plan	Powerday (40%) + gas CHP (35%, η elec = 39%) + gas boiler (25%)	Cluster-based	-26%	-5%	9%	18%	26%	31%	20%	0%	-5%
19	London Plan	Gas CHP (70%, η elec = 39%) + gas boiler (30%)	Cluster-based	-23%	18%	52%	76%	95%	109%	80%	5%	-5%
28	London Plan	Powerday (40%) + heat pump (30%) + direct electric boiler (30%)	Cluster-based	39%	2%	-27%	-47%	-63%	-75%	-50%	0%	-5%
23	London Plan	Powerday (70%) + heat pump (10%) + gas CHP (15%) + gas boiler (5%)	Cluster-based	-38%	-30%	-29%	-29%	-29%	-29%	-29%	0%	-5%

Table G.5.2. Carbon Reduction and Cost Uplift %Results Summary for Selected Technology Scenarios

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G.5.1 Commentary on Carbon Emission and Cost Outcomes

The following summarises the analysis undertaken for carbon and costs performance of the different solution investigated.

1. Heat networks reliant on gas CHP engines as the main heat source are expected to result in the highest calculated carbon emissions. From 2021 onwards, this solution is predicted to result in the highest calculated CO_2 emissions. This makes this solution unattractive for any development post 2021. It also appears unattractive for development pre-2021 as the gas CHP engines will be expected to run for 15-20 years and the calculated cumulative emissions over this period will be higher than most, if not all, other options.

2. A multi-sourced low temperature heat network, where the main heat source is from the proposed Powerday EfW facility, is necessary for any large scale heat network in the Old Oak area. It enables the carbon intensity of a heat network to remain competitive (in terms of emission rates) with unit- and block-scale electric heating options into the 2030s. This would be expected to be integrated with infrastructure scale heat pump options (open loop ground, canal, and sewer source). In later years, direct electric boilers can be included to replace more carbon intensive sources (such as any supporting gas CHP engines or gas boilers). It should however be recognised that not all this benefit may be realised due to the lead in time for the Powerday plant itself, which would not be operational until 2021 at the earliest when the heat loads that can utilise it may be limited due to lack of development coming forward prior to this date. This could potentially be overcome if heat were supplied to wider developments such as North Acton, where loads are expected to build up more quickly, but where at present it may be difficult to deliver an area wide heat network due to the multiple land ownerships and need to agree multiple connection agreements. The benefit of a multi sourced low carbon heat network is dependent on the permitting and planning approval for heat offtake from Powerday's EfW plant. The risks associated with this require further evaluation.

3. Block and unit scale electricity-based heating systems have the best long term CO_2 outcomes. In particular block-level ground source heat pumps (GSHP) with advanced insulation standards are relatively attractive from 2021 onwards. All other block-level GSHP options and unit-level electric storage heating options are relatively attractive from 2021 onwards when the vast majority of the development will be built out. In general, the electricity-based heating options are competitively priced compared to heat network alternatives, both in terms of capital cost and cost to the consumer. However, such options go against London Plan policy which promotes heat networks. These solutions will also require greater electrical infrastructure.

4. If it is necessary to adopt the current London Plan policy, and the need to maintain the ability to deliver a 35% reduction in carbon, the most favourable strategy at least in the early phases would be to deliver area wide heat networks if these could utilise heat from Powerday initially and then increasingly from heat pumps drawing low grade heat from the canal, sewers and the aquifer, and potentially in the later phases from electric boilers.

5. Based on the findings from this study, a multi sourced low carbon heat network could meet OPDC's strategic objectives for the decentralised energy strategy in terms of policy compliance, long term carbon savings and secure energy supply, assuming that Powerday can be utilised.

6. For later development clusters, such as Old Oak South (Crossrail and HS2) that could potentially be delivered much later in the programme (mostly after 2030), it is possible that London Plan policy will change to reflect the observed change in electricity emission reductions. For development clusters delivered after the 2030's flexibility would ideally be retained to deliver block or unit based solutions in place of heat networks, as these would be expected to offer lower carbon emissions at lower cost to consumers and at around the same overall total capital cost.

7. It should be recognised that there are some limitations in looking at the overall costs of delivery for the alternative options. One of these is that the costs will fall to different parties depending on the option chosen and the method of procurement. For example while the overall costs of ground source heat pumps (TS 31) are shown to be only slightly higher than the heat network option (TS 25), in reality it may be possible to get a 3rd party ESCO to partially fund the heat network option, so

the capital delivery cost to the Developer may be lower for the district heating option, particularly if it can be delivered at scale.

The analysis presented here indicates that heat networks are likely to be a technically viable solution to ensure low carbon heat supplies are provided to development at OPDC. Initial high level analysis has been carried out to consider some of the opportunities and issues the masterplanning team will need to consider in terms of potential energy centre locations and the likely routes for the primary heat network. This is set out in Appendix C.

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Appendix H Electricity Network Improvements

See drawing overleaf.

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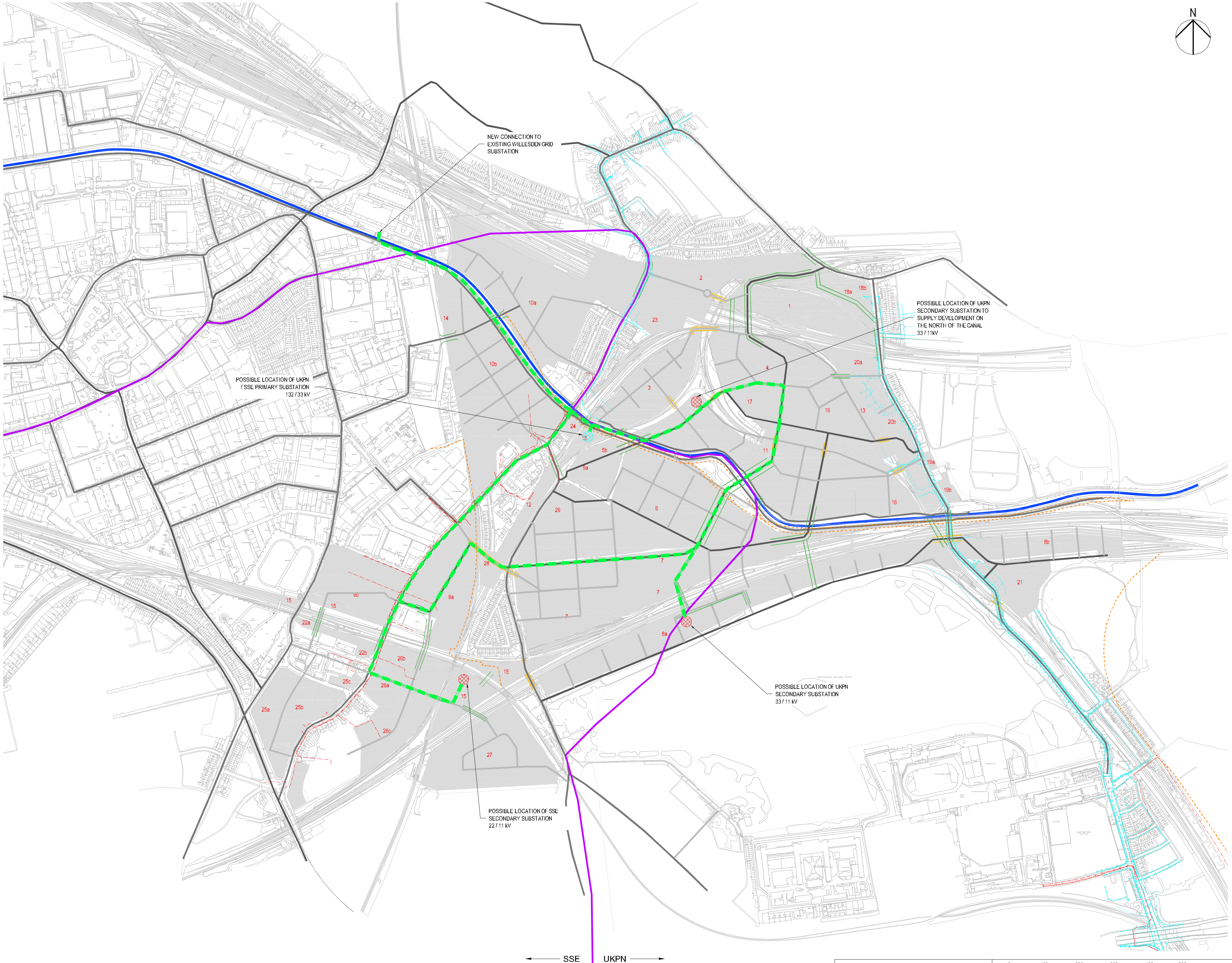

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KEY

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- SSE/UKPN BOUNDARY
- NATIONAL GRID ELECTRICITY CABLES
- UKPN ELECTRICITY CABLES (HV)
- PROPOSED HV MAIN (APPROX 50kg/m)
- POSSIBLE PRIMARY SUBSTATIONS
- POSSIBLE SECONDARY SUBSTATIONS

BRIDGES, HIGHWAYS AND CONSTRAINTS

- PROPOSED BRIDGES
- PROPOSED UNDERPASSES
- MAJOR ROADS
- SECONDARY ROADS
- MINOR ROADS
- PADDINGTON BRANCH OF GRAND UNION CANAL

Revision Details	By / Check	Date	Suffix
ASSET REFERENCES REMOVED	MH / JR	30.03.17	P3
MINOR REVISIONS	MH / JR	17.02.16	P2

Purpose of issue

DRAFT

Client

OLD OAK AND PARK ROYAL DEVELOPMENT CORPORATION

Project Title

OLD OAK COMMON

Drawing Title

OLD OAK COMMON ELECTRICITY SUPPLY STRATEGY

Designed	Drawn	Checked	Approved	Date
AW	MH	JR	BM	DEC 2016

AECOM Internal Project No. 60495203

Suitability

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Appendix I Gas Network Improvements

See drawing overleaf.

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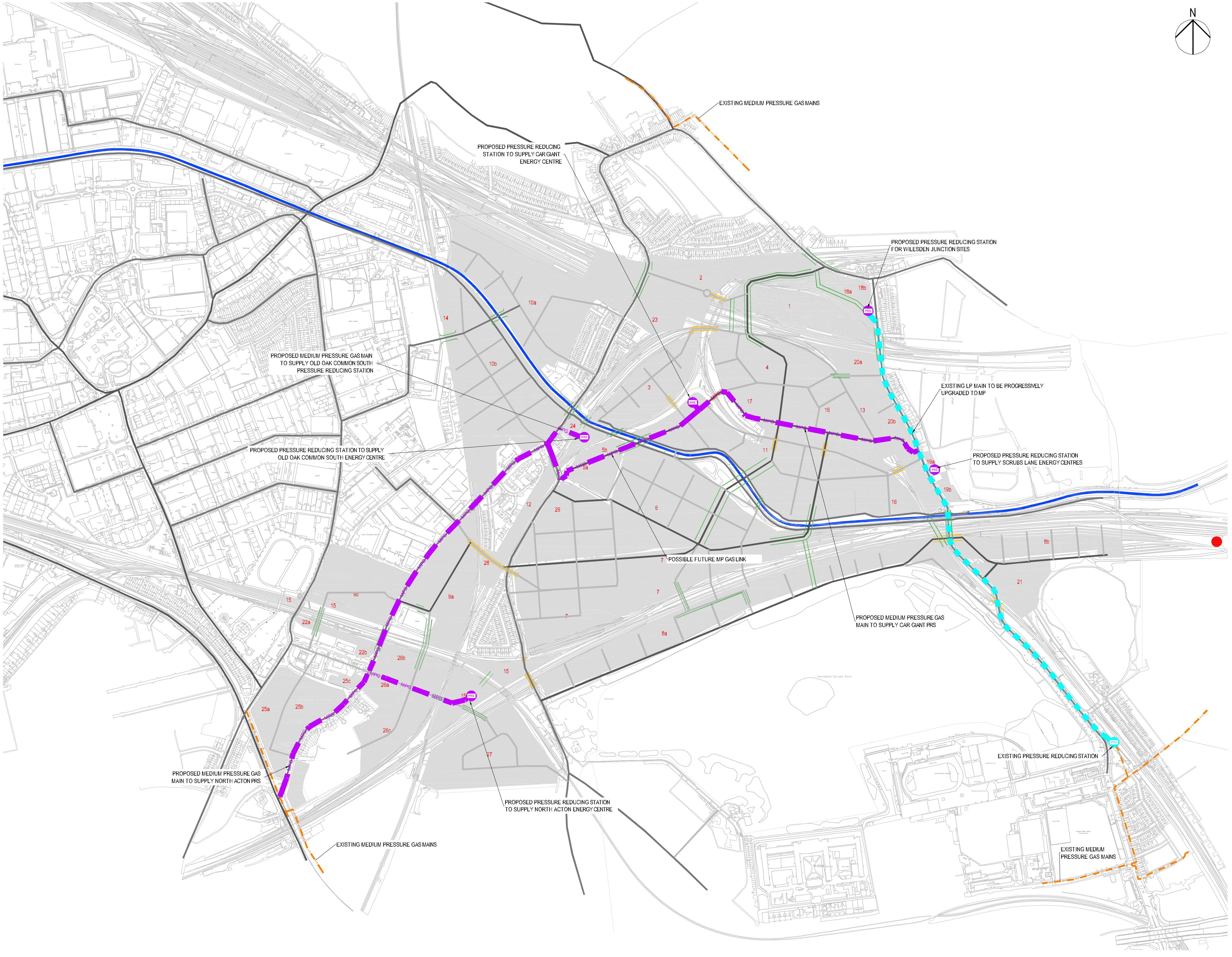

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KEY

GAS SUPPLY STRATEGY

- MPG — EXISTING NATIONAL GRID GAS MEDIUM PRESSURE MAIN
- MPG — EXISTING LOW PRESSURE GAS MAIN UPGRADED TO MEDIUM PRESSURE MAIN
- MPG — PROPOSED MEDIUM PRESSURE GAS MAIN
- PRS — PROPOSED PRESSURE REDUCING STATION (PRS)
- PRS — EXISTING PRESSURE REDUCING STATION (PRS)
- EXISTING GAS HOLDER

BRIDGES, HIGHWAYS AND CONSTRAINTS

- PROPOSED BRIDGES
- PROPOSED UNDERPASSES
- MAJOR ROADS
- SECONDARY ROADS
- MINOR ROADS
- PADDINGTON BRANCH OF GRAND UNION CANAL

Revision Details	By / Check	Date	Suffix
ASSET REFERENCES REMOVED	MH / JR	30.03.17	P5
MINOR AMENDMENTS	MH / JR	17.02.17	P4
MINOR AMENDMENTS	MH / JR	04.01.17	P3
MINOR REVISION TO NOTES	MH / JR	23.12.16	P2

Purpose of issue

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Client

OLD OAK AND PARK ROYAL DEVELOPMENT CORPORATION

Project Title

OLD OAK COMMON

Drawing Title

OLD OAK COMMON GAS SUPPLY STRATEGY

Designed	Drawn	Checked	Approved	Date
JR	MH	BM	BM	23.12.16

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Appendix J Thames Water Potable Water Network Impact Assessment

See overleaf.

DRAFT

THAMES WATER UTILITIES LTD

WHOLESALE WATER SPA - WATER MODELLING GROUP

Old Oak Redevelopment – Modelling Impact Assessment - Interim Report

Draft Report – March 2017

Company Confidential

Document history

Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
Rev 1.0	First Draft for Comment	Rob Dixon	Julie Reynolds	Paolo Teixeira		17/03/2017

This Modelling Study is Valid for a Period of 18 Months from the Date of Authorisation

Contents

FIGURES

Tables

1 Introduction

Developer Services requested a modelling study to investigate the impact of the Old Oak Common redevelopment located in North Acton, North West London, on the distribution network and resource availability of Barrow Hill and Shoot Up Hill Zones.

Old Oak redevelopment site incorporates the Car Giant development site; and together these are part of the wider Old Oak and Park Royal Development Corporation (OPDC) site. The OPDC redevelopment site is bounded by Scrubs Lane to the east, North Circular (A406) to the west and Western Avenue (A40) to the south near North Acton and Park Royal (Figure 1).

The Old Oak development comprises of five phases commencing from 2020 for 20 plus years. The total development will comprise of 27,014 residential units and 720,000 m2 of office floor space.

The demand used in this assessment is a daily demand of 9 Ml/d and peak instantaneous demand of 353.6 l/s for 2040.

No data on the distribution of this demand has been provided at this stage and the point of connection (POC) for the development has been modelled at a single location.

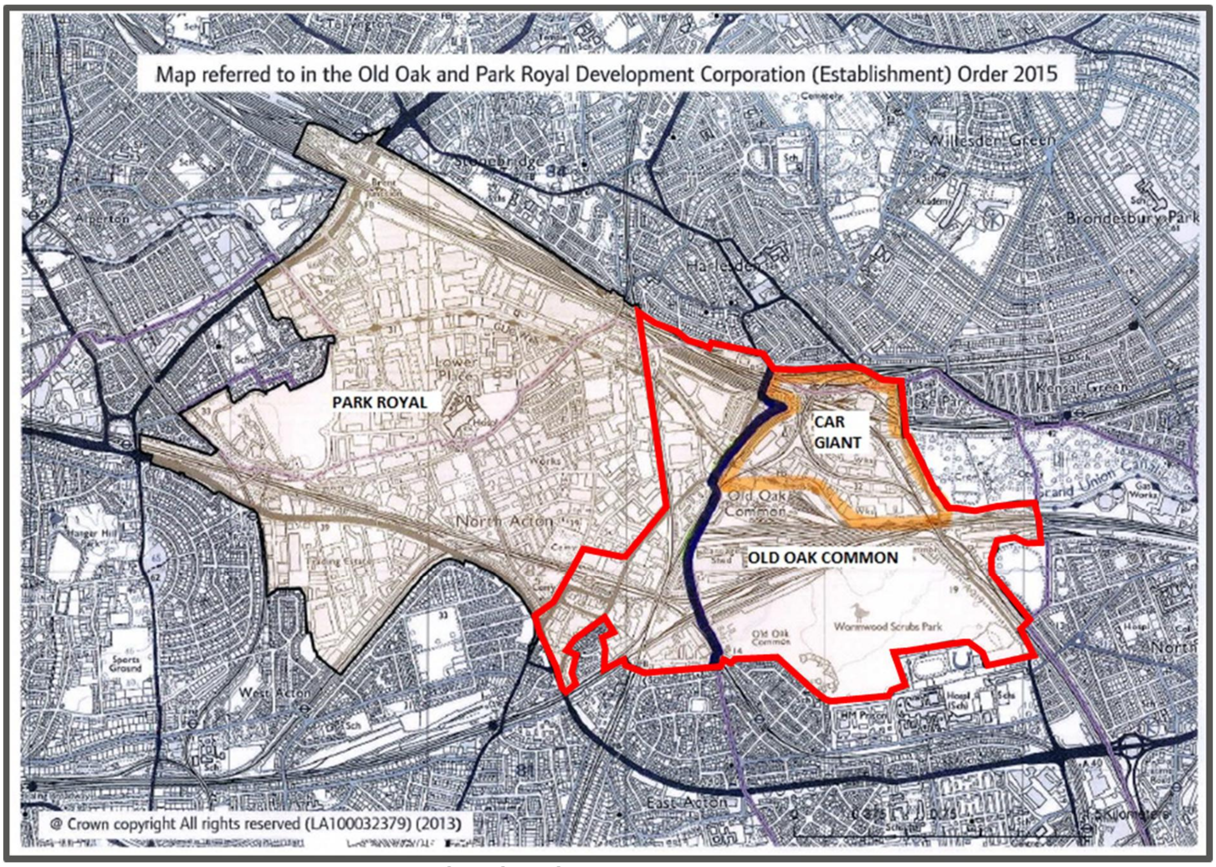


FIGURE 1 – OLD OAK COMMON RE-DEVELOPMENT SITE

1.1 Supply Configuration

The Old Oak Common site geographically extends over three zones: Barrow Hill, Shoot Up Hill and Kempton Flow Monitoring Zones (FMZ). However a review of the network showed that the most suitable trunk mains for supplying the site are in Shoot Up Hill and Barrow Hill zones.

The Barrow Hill and Shoot Up Hill zones are located in North West London and predominantly cover an urban area. The two zones are currently interconnected and are supplied from a variety of sources:

1. Thames Water Ring Main (TWRM) at:
   - Barrow Hill Shaft
   - Holland Park Shaft
   - Park Lane Shaft

2. Hammersmith Pumping Station (PS) located in the south west of the zone, which draws water from Barnes Tank (supplied from the TWRM and Ashford WTW).

3. Infusion from the Kempton 48” trunk main at Cricklewood (ZM13119, ZM13120) which supplies water into the north of Shoot Up Hill zone via 42” twin trunk mains.

4. Willesden Reservoir (Top Water Level (TWL) = 57.52 mAOD) has a bi-directional flow into Barrow Hill and Shoot Up Hill zones, it also provides the suction to Willesden Boosters which supply Bishops Wood Zone.

5. Dollis Hill Reservoir (TWL = 78.73 mAOD) provides water storage for the Shoot Up Hill zone.

6. Barrow Hill Reservoir (TWL = 57.31 mAOD) is located in Barrow Hill Zone

The current average daily demand for ZBARHT and ZSUHIL FMZ’s is 116.58 Ml/d and 100.91 Ml/d respectively.

The area schematic for the Barrow Hill FMZ is shown in Figure 2 below.

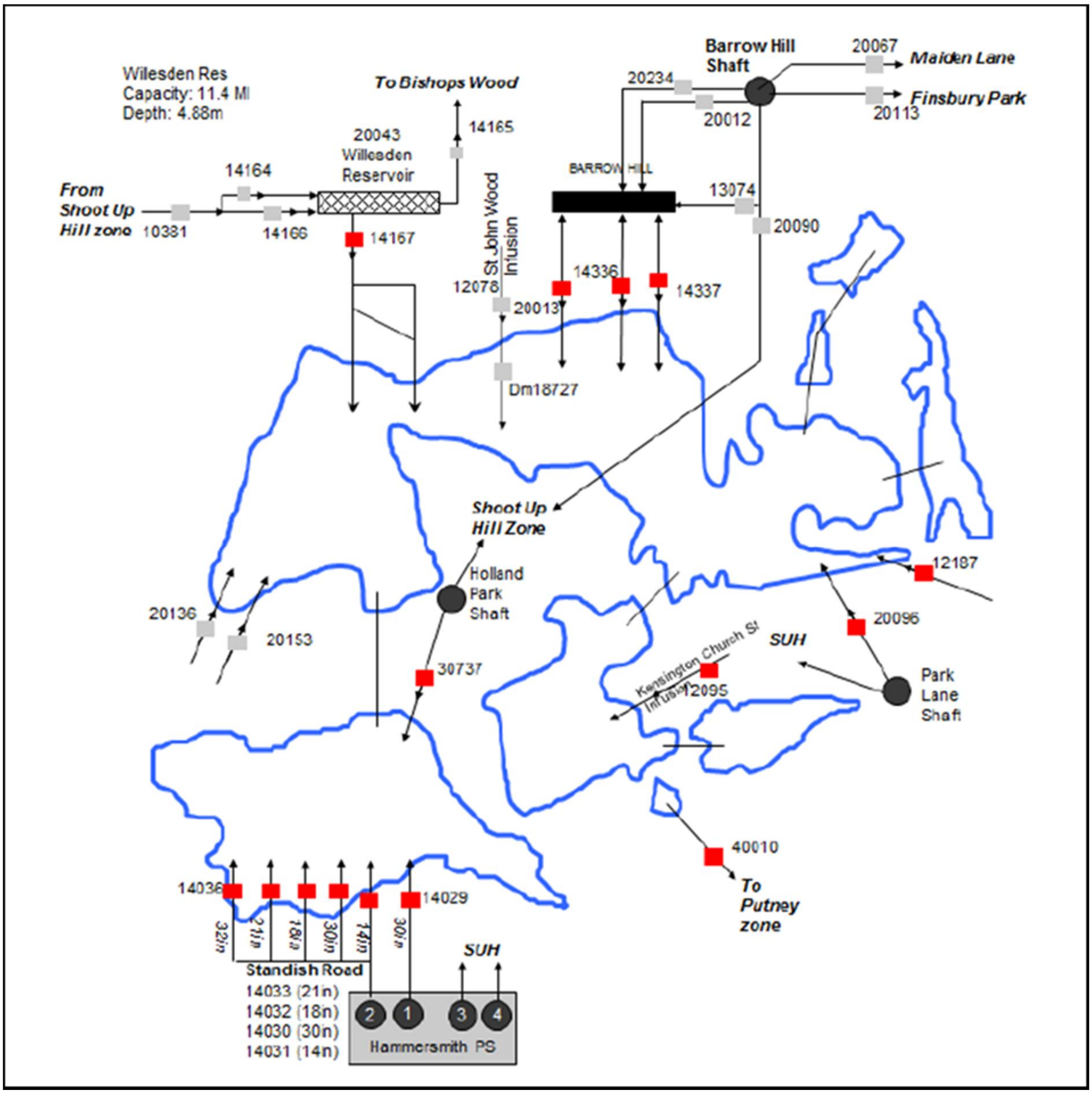


FIGURE 2 – BARROW HILL AREA SCHEMATIC

The area schematic for the Shoot Up Hill FMZ is shown in Figure 3 below.

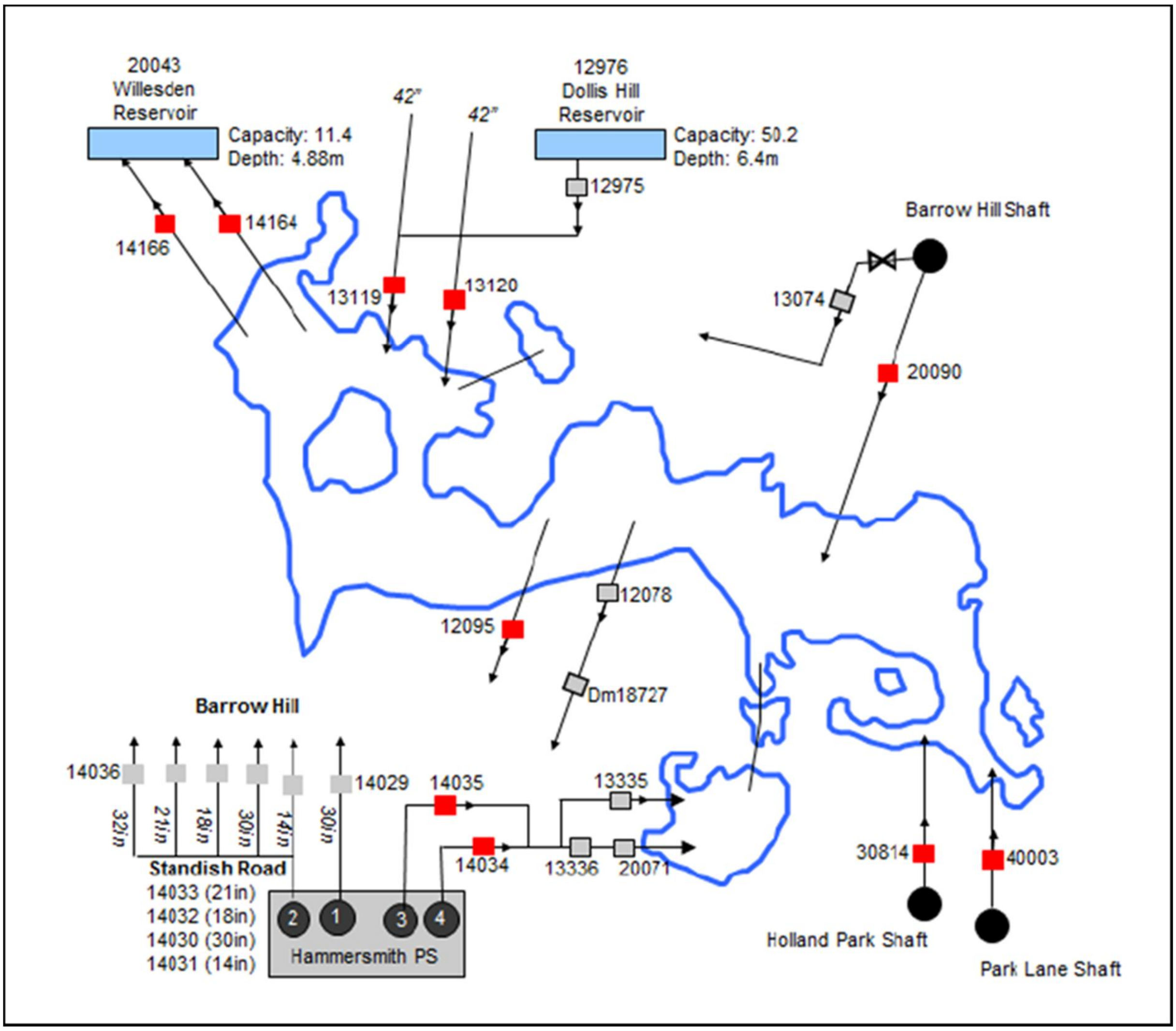


FIGURE 3 – SHOOT UP HILL AREA SCHEMATIC

2 Scope of Work

This study is for the Old Oak Common redevelopment in North West London. The proposed development is constructed over five phases between years 2020 – 2040. The total development will comprise of 27,014 residential units and 720,000 m2 of office floor space.

The aims of this study are:

- To assess the impact of the development on the distribution network for the 2040 demand scenario.
- To review the resource available in North West London to supply the development.
- Provide solution options for new infrastructure, if necessary.

3 Methodology

3.1 Resource Availability

A supply/demand balance has been carried out to determine the availability of water for the final 2039/40 planning period for a Dry Year Critical Period Peak Week with Headroom scenario (DYCP PW + HR).

3.2 Network Impact

The hydraulic analysis of the impact of the proposed development was carried out using the Barrow Hill and Shoot Up Hill FMZs 'all mains' model. The impact of the development on the water distribution network was evaluated in conjunction with Dry Year Critical Period Peak Day with Headroom (DYCP PD + HR) 2039/40 demand scenario, by comparison of network pressures with and without the proposed development incorporated.

4 Development Site

4.1 Site Supply

The location and full phasing of the Old Oak developments are shown in Figure 4. The development site geographically covers Barrow Hill, Shoot Up Hill and Kempton FMZ's. The site is bounded by Scrubs Lane to the east, Willesden Junction Station to the north, North Circular (A406) to the west and the A40 (West Acton) to the south and is sited on the areas of Park Royal to the west and Old Oak Common to the east.

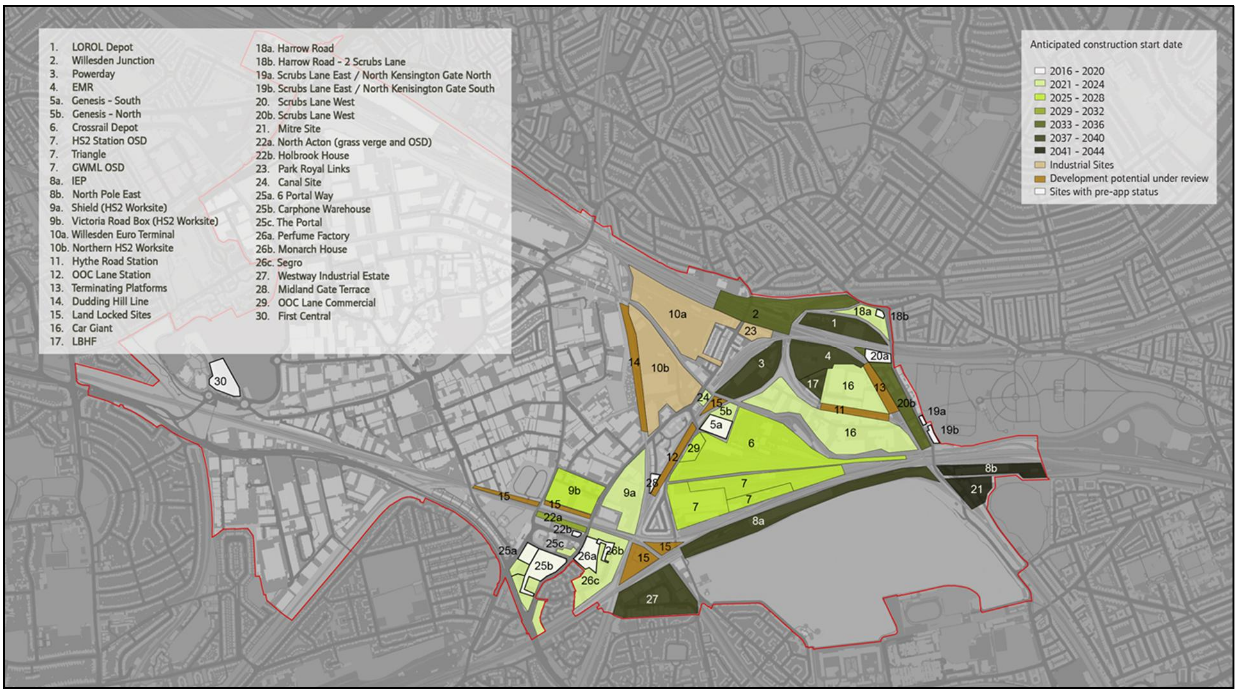


FIGURE 4 – DEVELOPMENT SITE

The proposed POC was selected at a node downstream of District Meter 18798 (DM18798) which is the current connection for Car Giant in Hythe Road see Figure 5.

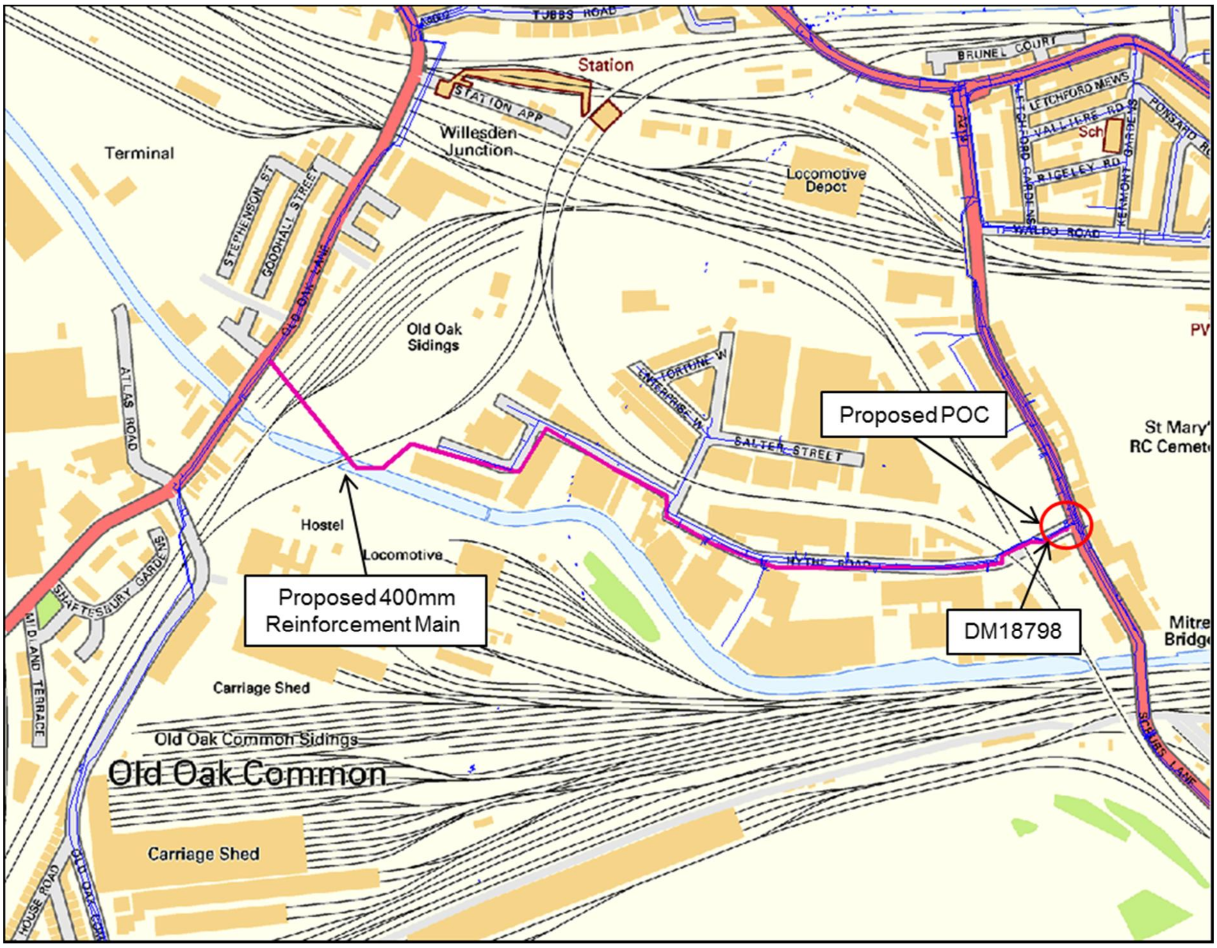


FIGURE 5 – PROPOSED POC LOCATION

The conclusion from the previous Car Giant detailed development study (November 2016), indicated the proposed development would have a significant impact on the pressures in the local area without any enhancements to the network. The Car Giant development is phase 2 of the Old Oak Development (phase 2 = 2025 – 2030)). Option 2B was recommended to maintain the 2025 modelled level of service and resilience. The proposals were:

The proposed POC at the existing supply site, DM18798 originally fed off the 21" Cast Iron (CI) main at the junction of Hythe Road and Scrubs Lane, would be connected into the 16" Barrow Hill main in Scrubs Lane instead.

A rezone of the boundary of Shoot Up Hill onto Barrow Hill between the 21" and 16" CI mains running along Scrubs Lane and a 16" cross connection between these two mains.

A new reinforcement main with a diameter of 315 mm PE100 SDR17 and length of 1.13 km to be connected to the Shoot Up Hill 30" CI main in Old Oak Lane, and to be laid across the Car Giant site to DM18798, see Figure 6.

A new district meter on the new reinforcement main at the POC with the Shoot Up Hill 30" main

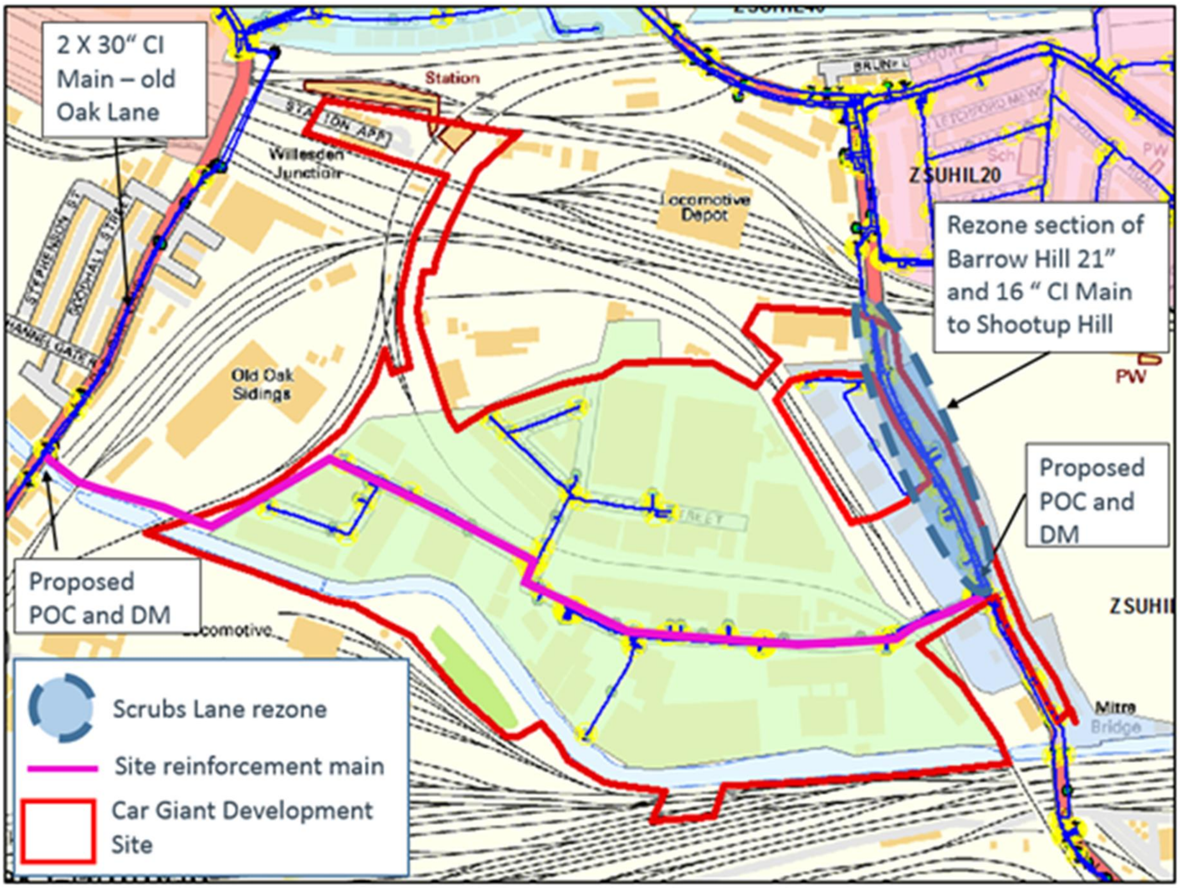


FIGURE 6 – CAR GIANT OPTION 2B

5 Supply and Demand Data

5.1 Development Demand Data

Details on the proposed development have been supplied together with the general layout as shown in Figure 7.

FIGURE 7 – PROPOSED DEVELOPMENT PHASES

The supply requirement has been based on the total of the 5 phases. Table 1 details the timescales, residential units and commercial area of each phase.

Phase	Plots	Year	Residential units	Office/Retail area Sq/m
1	0 - 5 years	2020 - 2025	4,914	51,000
2	5 - 10 years	2025 - 2030	6,449	80,000
3	10 - 15 years	2030 - 2035	5,538	561,000
4	15 - 20 years	2035 - 2040	4,346	14,000
5	20 years ++	2040 -	5,767	14,000
		Total	**27,014**	**720,000**

Table 1 – Phasing Numbers

Table 2 below gives a summary of the demand for the proposed development site.

	2040	
	Daily Demand [Ml/d]	**Peak Morning [l/s]**
Old Oak Development	9	353.62

Table 2 – New Development Demand

5.2 Supply Demand Balance

The supply/demand balance was completed with the latest demand forecasts (v8.3) for the North-West London network. The development daily demand figure of 9 Ml/d was split between Barrow Hill & Shoot Up Hill zones for the 2040 scenario. The supply/demand balance illustrates that there are the resources available from the ring main shafts to meet the additional daily demand. It should be noted that although pumping from the shafts have been increased to the near limits of the pumps. It is the capacity of the network to supply the peak demand, which will be the main constraint.

Appendix B shows the 2039/2040 DYCP PW + HR supply/demand mass balance, with the development demand included.

6 Hydraulic Network Modelling

The hydraulic analysis to assess the impact of the proposed Old Oak development was carried out using the InfoWater model for the area “ZBARHTZSUHIL_CAL_OCT2015_V1”.

Scenario A1 (Base 2040 Peak Day model) this model has been created by factoring the demands using the latest Demand Forecast Data, v8.3. The pump sets have been adjusted to meet the 2040 increase in zonal demand.

Scenario A2 (Impact model) the model was then subsequently created by adding the Old Oak development demand on node 1372540 downstream of DM18798.
The pump sets have been set up to represent the supply/demand balance results and meet the additional 9 Ml/d demand increase for the Old Oak development:

Barrow Hill Zone

- Holland Park pumps set to 40 Ml/d
- Barrow Hill pumps set to 30 Ml/d
- Hammersmith pumps set to 40 Ml/d

Shoot Up Hill Zone

- Holland Park pumps set to 23 Ml/d
- Barrow Hill pumps set to 75 Ml/d
- Hammersmith pumps set to 34 Ml/d

Scenario A3 (Solution Model) the network was updated with the development site’s POC re-sited onto the 30” CI main in Old Oak Lane on Shoot Up Hill Zone to the west of the site rather than from Barrow Hill and with a 400 mm PE100 SDR17 main running through the site to the

16" CI Barrow Hill Main in Scrubs Lane. The 16" CI Barrow Hill zone main in Scrubs Lane needs to be rezoned onto Shoot Up Hill zone (see Figure 6).

Scenario A4 all the other known new developments were added to scenario A3 model.

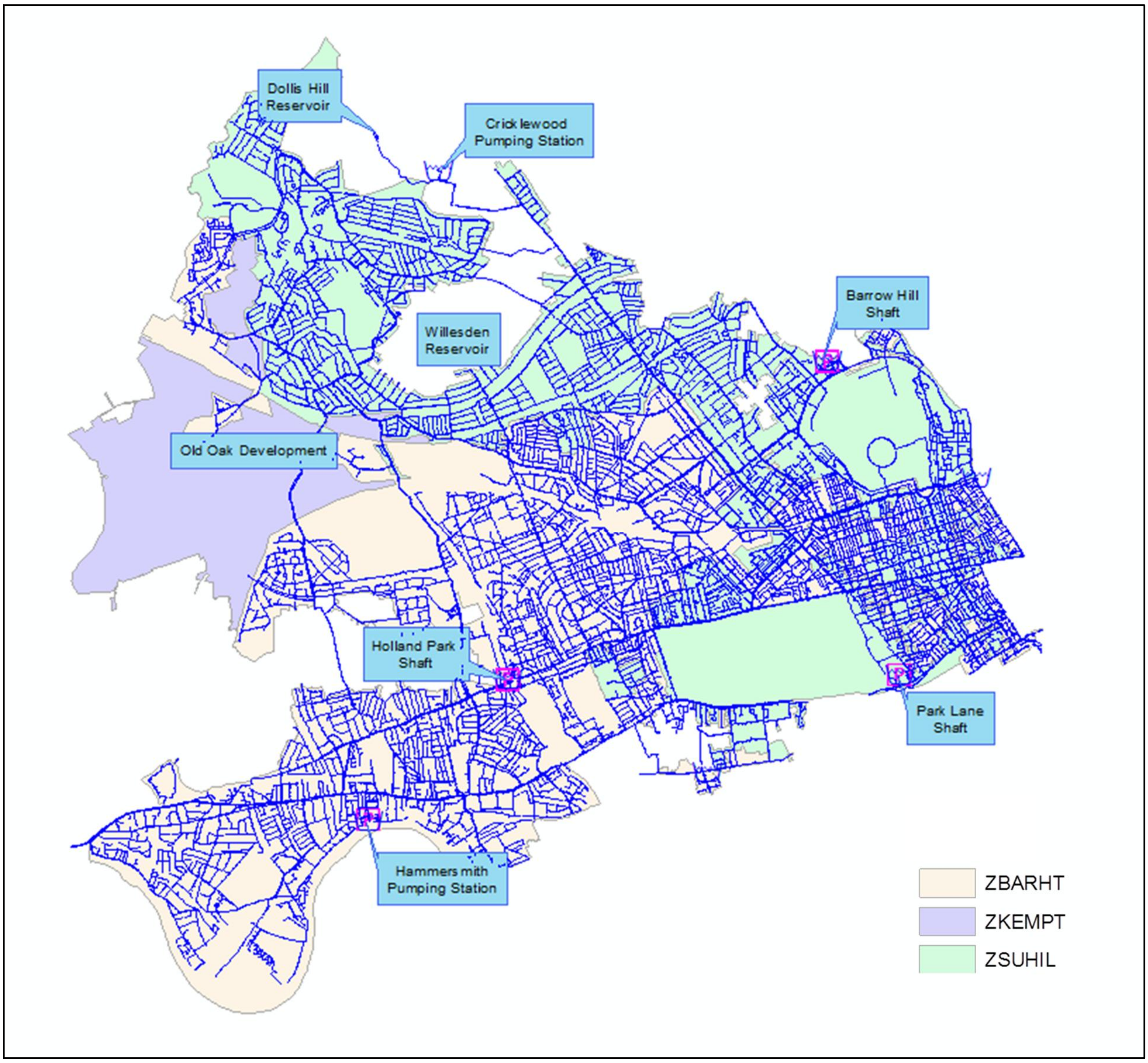


FIGURE 8 – INFOWATER MODEL OF BARROW HILL & SHOOT UP HILL

7 Model Results & Discussion

7.1 Existing Supply & Network Configuration

7.1.1 Baseline Model: Scenario A1 - 2039/40 DYPD Demand – Pumps Adjusted

The model predicts that for the 2039/40 DYCP_PD+ HR demand scenario the instantaneous peak hour minimum pressure at the proposed POC is 13.3 m.

7.2 Impact Assessment of Development

7.2.1 Impact of Development: Scenario A2 – With Old Oak Development

The model predicts that for the 2040 DYCP_PD+ HR demand scenario the instantaneous peak demand hour, minimum pressure at the proposed POC is sub atmospheric. There is a widespread impact on pressures in Barrow Hill FMZ, where a drop in pressure of approximately 7 m is seen at the Critical Press Point 290 (CPP_290) in Barrow Hill.

7.2.2 Peak Day Model with Development

The following mains reinforcement and network changes were required to provide adequate pressure within the proposed development and throughout the existing network see figures 6, 9 and 10:

- Supply the site from the Shoot Up Hill FMZ on the western side from the 30” CI main in Old Oak Lane with a 400 mm (351.2 mm ID) PE100 SDR17 main running through the site to the 16” CI Barrow Hill Main in Scrubs Lane.
- Rezone the boundary between the Barrow Hill and Shoot Up Hill zones southwards in Scrubs Lane, requiring the following valve changes:

1. 6988889 Open
2. 6988886 Closed
3. 6989458 Closed

- Lay a new 16” cross connection 3m in length between 21” CI and 16” CI mains in Barrow Hill Zone
- Extend the connection for DM18798 from the 21” Barrow Hill Zone to the 16” Shoot Up Hill ‘rezoned’ main.

7.2.3 Peak Day Model with Development plus Other Developments

The Barrow Hill pump sets at Hammersmith PS were adjusted to provide adequate pressure within the proposed development and throughout the existing network.

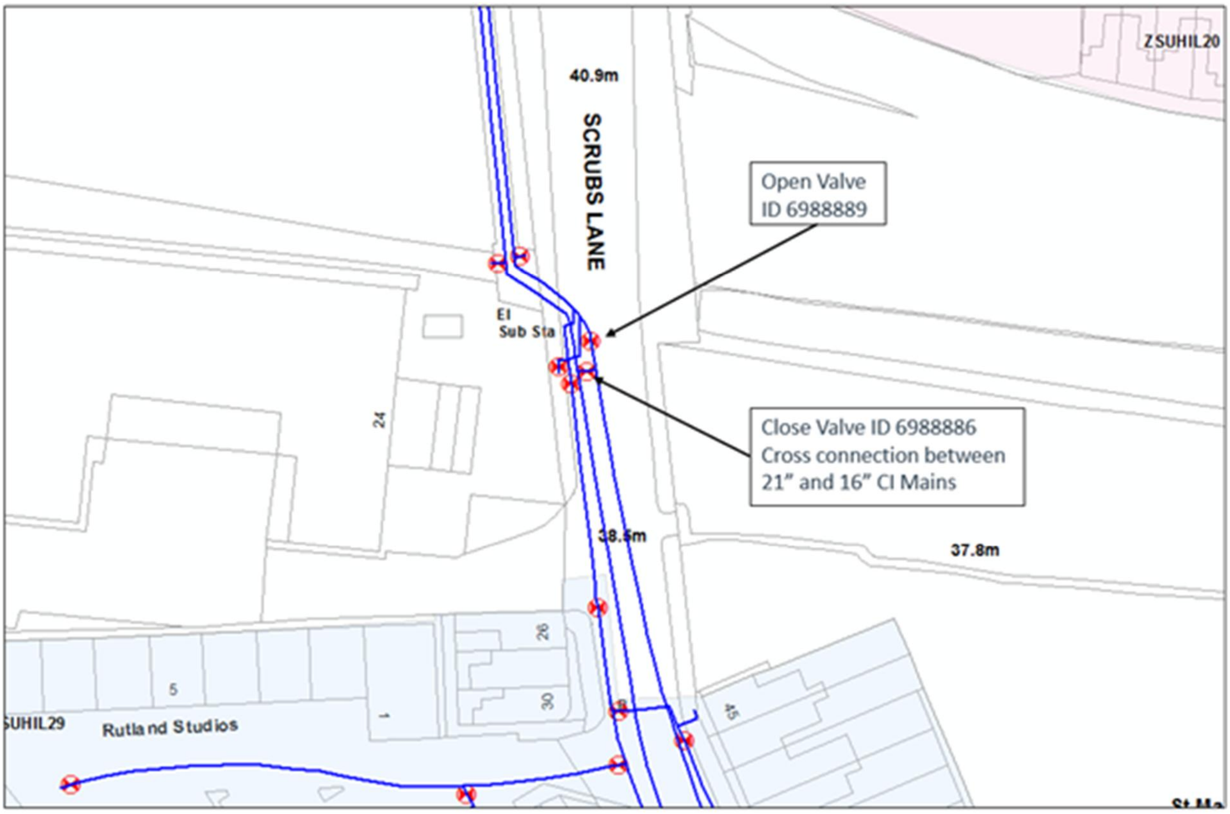


FIGURE 9 - REZONE SCRUBS LANE

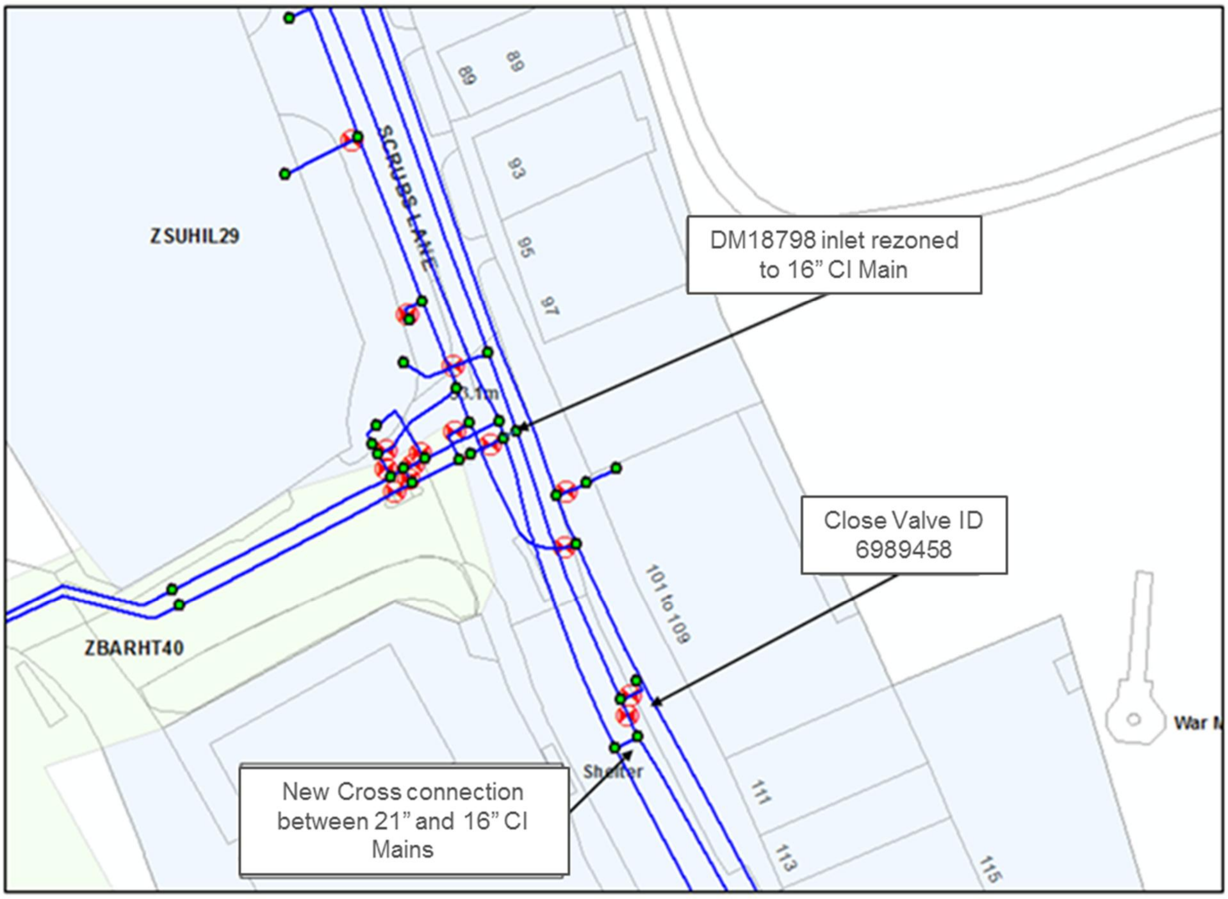


FIGURE 10 - REZONE SCRUBS LANE

7.3 Upgraded Network

7.3.1 Impact of Development: Scenario A3 – With Old Oak Development

The model predicts that for the 2040 DYCP_PD+ HR demand scenario the instantaneous peak demand hour minimum pressure at the proposed POC is 25.2 m, as the development is subjected to Shoot Up Hill FMZ pressure. Across both FMZs the pressures are within 1 m of those seen under scenario A1.

7.3.2 Impact of Development: Scenario A4 – Plus Other Developments

The model predicts that for the 2040 DYCP_PD+ HR demand scenario the instantaneous peak demand hour minimum pressure at the proposed POC is 25.19m. Pressures in the wider network are impacted on by just over 1m in Barrow Hill FMZ. The impact of all developments in Barrow Hill FMZ will need further reinforcements/enhancements to maintain the 2040 level of service.

		MODEL SCENARIO PRESSURE @ 06:15			
LOCATION	**ZONE**	**A1**	**A2**	**A3**	**A4**
POC East- D/S DM18798	ZBARHT	13.34m	0m	25.17m	25.19m
POC West – Old Oak Road	ZSUHIL	40.81m	40.74m	40.89m	40.91m
ZM14337 – Barrow Hill Shaft	ZBARHT	9.34m	3.06m	9.45m	8.28m
ZM20090 – Barrow Hill Shaft	ZSUHIL	26.8m	27.59m	27.78m	27.77m
ZM14164 – Willesden Reservoir	ZSUHIL	18.56m	18.46m	17.99m	17.99m
CPP_297	ZSUHIL	16.76m	16.76m	16.76m	16.76m
CPP_3590	ZSUHIL	32.38m	32.29m	31.84m	31.85m
CPP_290	ZBARHT	26.63m	19.63m	26.75m	25.45m

Table 3 - Predicted Pressures

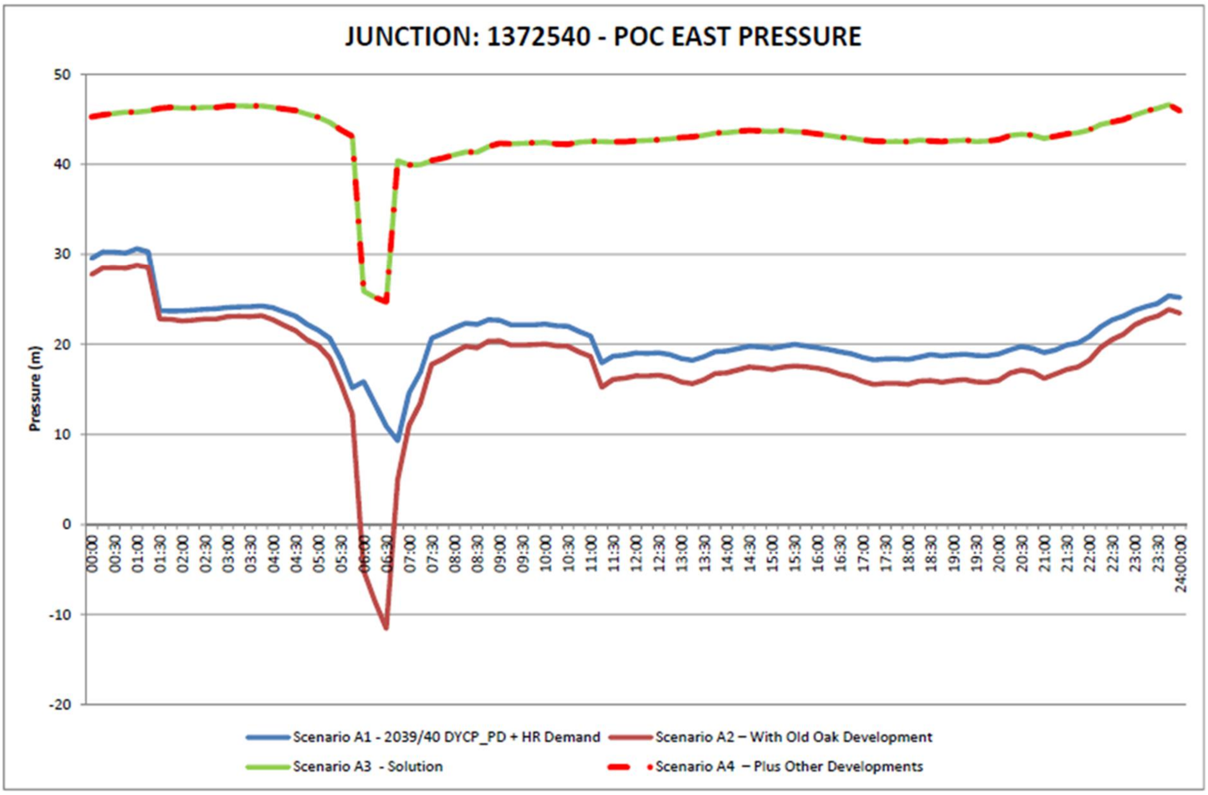


FIGURE 12 - PREDICTED PRESSURES AT THE POC EAST

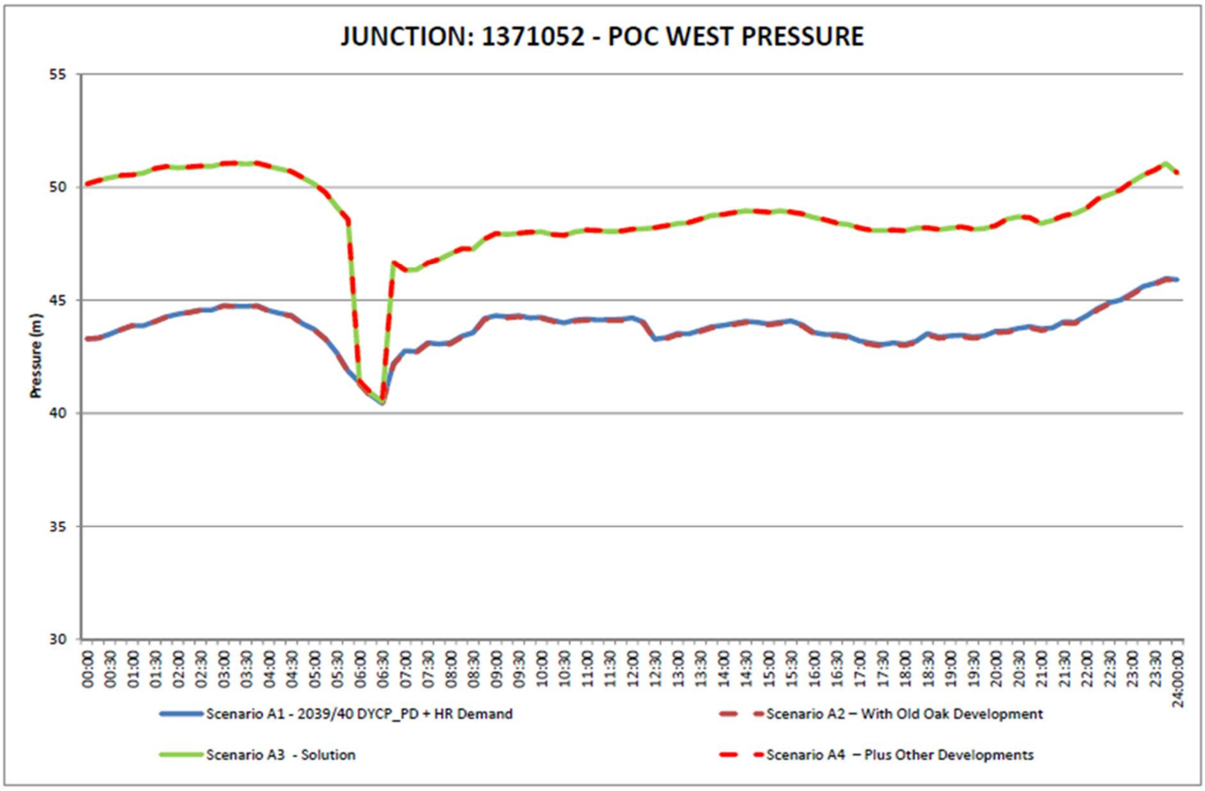


FIGURE 13 - PREDICTED PRESSURES AT THE POC WEST

8 Conclusion

In summary the model predicted that the proposed Old Oak development will have a significant impact on pressures and supply in the Barrow Hill FMZ. Network enhancements are required as pressures at the proposed POC will drop to below zero by 2040.

The supply/demand balance indicates that additional pumping will be required to feed Barrow Hill and Shoot Up Hill FMZ from Holland Park and Barrow Hill TWRM shafts, and from Hammersmith pumping station to meet the additional 9 Ml/d demand. This can be achieved by using full capacity of existing pumps.

To resolve the low pressure issues caused by the addition of the new development the following option was recommended:

- Supply the site from the Shoot Up Hill FMZ on the western side from the 30" CI main in Old Oak Lane with a 400 mm (351.2 mm ID) PE100 SDR17 main running through the site to the 16" CI Barrow Hill Main in Scrubs Lane.

- Rezone the boundary between the Barrow Hill and Shoot Up Hill zones southwards in Scrubs Lane, requiring the following valve changes:

4. 6988889 Open
5. 6988886 Closed
6. 6989458 Closed

- Lay a new 16" cross connection 3m in length between 21" CI and 16" CI mains in Barrow Hill Zone.

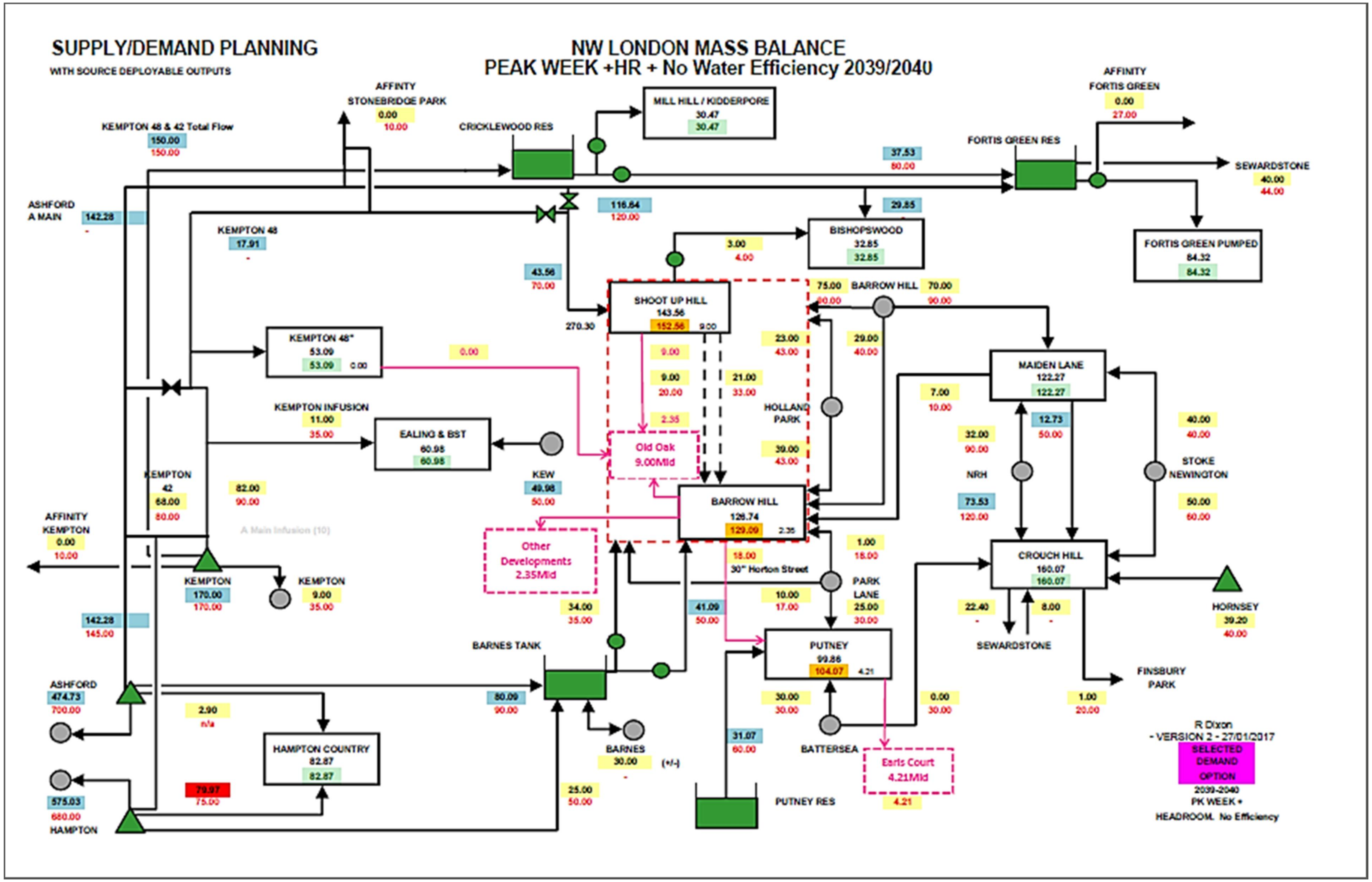
- Extend the connection for DM18798 from the 21" Barrow Hill Zone to the 16" Shoot Up Hill 'rezoned' main.

With the addition of further developments in Barrow Hill Zone, further strategic reinforcements or pumps may be required to maintain the 2040 level of service.

Appendix A – GLOSSARY OF TERMS

NETBASE	TWUL's Database of Network Information, with analysis and reporting functionality
OMS	TWUL's Operational Management System
PIWADIS	TWUL's District Meter Area Database
WMG	Water Modelling Group, TWUL Asset Management
ADD	Average Day Demand, based on annual consumption figure
ADPW	Average Day Peak Weak
DBV	District Boundary Valve
DIM	Distribution Input Meter
DM	District Meter
DMA	District Meter Area
d/s	Downstream
DTM	Digital Terrain Mapping
DYAA	Dry Year Annual Average
DYCP	Dry Year Critical Period
DYCP – PW	Dry Year Critical Period Peak Week equivalent of ADPW
DYPW – PD	Dry Year Critical Period Peak Day equivalent of PDPW
FMZ	Flow Monitoring Zone
GIS	Geographical Information System
GPS	Global Positioning System
GWW	Ground Water Works
l/p/d	Litres per property per day
l/s	Litres per second
LMC	Large Metered Customer
m	Metres
m/km	Meters per kilometre
m/s	Metres per second
m3	Cubic metres
Mld	Mega Litres per day
NRV	Non-Return Valve
PBV	Pressure Boundary Valve
PDPW	Peak Day Peak Week
PMA	Pressure Managed Area
POC	Point of Connection
PRVPMA	Pressure Reducing ValvePressure Managed Area
PSPRV	Pumping StationPressure Reducing Valve
PSVPS	Pressure Sustaining ValvePumping Station
SRPSV	Service ReservoirPressure Sustaining Valve
TMSR	Transmission MainService Reservoir
TWTM	Thames WaterTransmission Main
u/sTW	UpstreamThames Water
WTWu/s	Water Treatment WorksUpstream
ZBVWTW	Zonal Boundary ValveWater Treatment Works
ZMZBV	Zonal MeterZonal Boundary Valve
ZPAZM	Zonal Performance AssessmentZonal Meter
ZPA	Zonal Performance Assessment

Appendix B – Supply / Demand Balance 2040 DYCP PW + HR



Appendix K Potable Water Network Improvements

See drawing overleaf.

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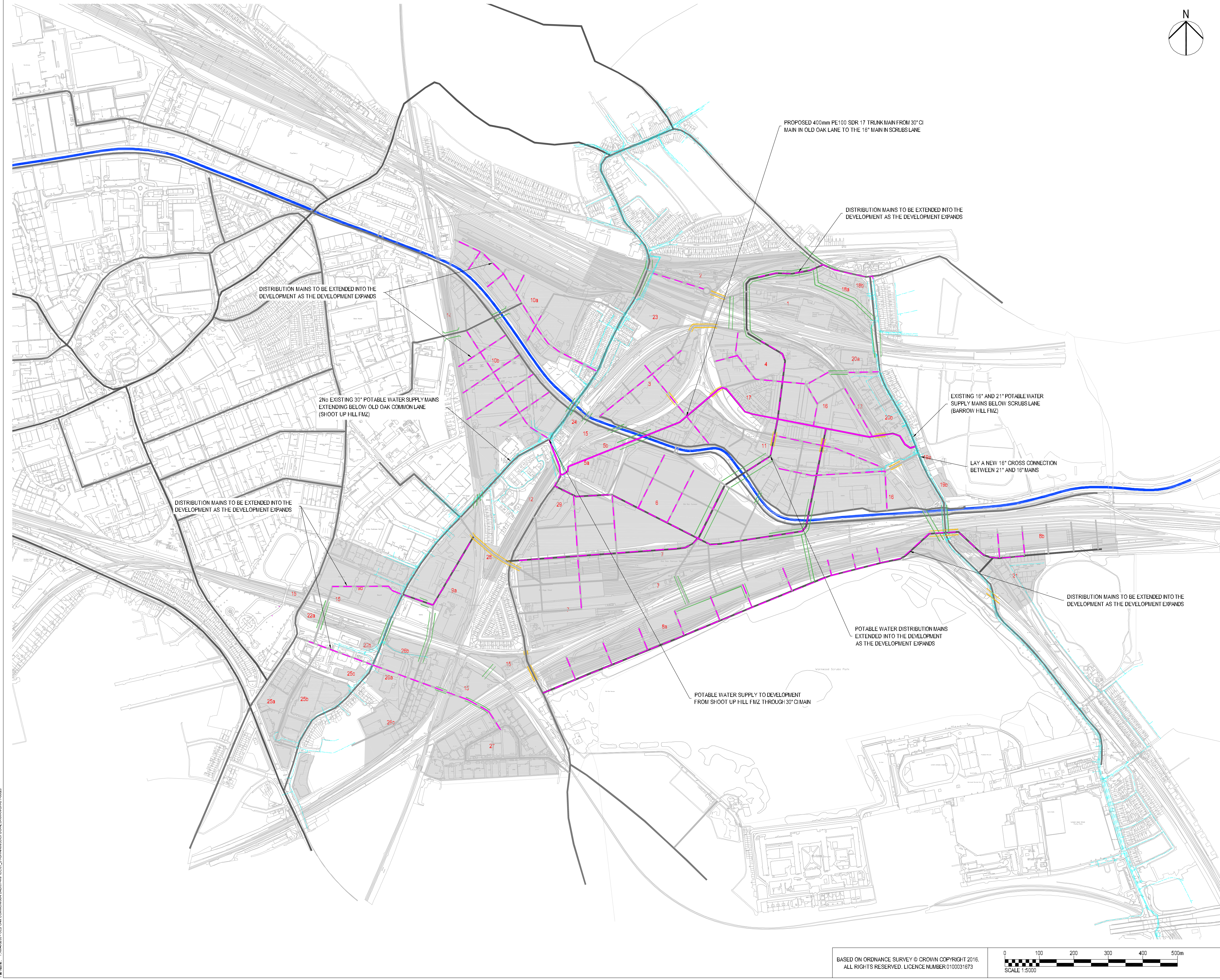

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CONSTRUCTION RISKS	MAINTENANCE / CLEANING RISK	DEMOLITION RISKS

In addition to the hazard/risks normally associated with the types of work detailed on this drawing take note of above. It is assumed that all works on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

This drawing is for preliminary purposes only and is subject to amendment during design development. UNDER NO CIRCUMSTANCES MUST THIS DRAWING BE USED FOR CONSTRUCTION PURPOSES

NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS, ENGINEERS,SERVICES AND SPECIALIST DRAWINGS AND SPECIFICATION.
2. ANY DISCREPANCIES IN DIMENSIONS OR DETAILS ON OR BETWEEN THESE DRAWINGS SHOULD BE DRAWN TO THE ATTENTION OF THE ARCHITECT AND/OR THE ENGINEER FOR CLARIFICATION.
3. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE.
4. DO NOT SCALE THIS DRAWING.
5. THE WATER SUPPLY STRATEGY PRESENTED ON THIS DRAWING WILL BE VERIFIED ONCE THAMES WATER COMPLETE THE STRATEGIC NETWORK IMPACT ASSESSMENT AND WHEN THE CANAL AND RIVER TRUST COMPLETE THE GRAND UNION CANAL ABSTRACTION ASSESSMENT. THESE STUDIES MAY INTRODUCE A REQUIREMENT FOR OFFSITE REINFORCEMENT WORKS.
6. THIS STRATEGY ASSUMES THAT WATER RECYCLING MEASURES WILL BE PROVIDED ON PLOT BY INDIVIDUAL DEVELOPERS.

KEY

POTABLE WATER INFRASTRUCTURE

- POT — EXISTING POTABLE WATER MAINS
- PROPOSED POTABLE WATER DISTRIBUTION MAIN
- PROPOSED POTABLE WATER TRUNK MAIN

BRIDGES, HIGHWAYS AND CONSTRAINTS

- PROPOSED BRIDGES
- PROPOSED UNDERPASSES
- MAJOR ROADS
- SECONDARY ROADS
- MINOR ROADS
- PADDINGTON BRANCH OF THE GRAND UNION CANAL

Revision Details	By / Check	Date	Suffix
REVISED TO MATCH TW IMPACT ASSESSMENT	MH / JR	31.03.17	P2
FIRST ISSUE	MH / JR	23.12.16	P1

Purpose of issue

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Client

OLD OAK AND PARK ROYAL DEVELOPMENT CORPORATION

Project Title

OLD OAK COMMON

Drawing Title

OLD OAK COMMON POTABLE WATER SUPPLY STRATEGY

Designed	Drawn	Checked	Approved	Date
JR	MH	BM	BM	DEC 2016

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Appendix L Canal & River Trust Discharge Assessment

See overleaf.

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Canal & River Trust

OLD OAK COMMON SWD INITIAL FEASIBILITY ASSESSMENT

21 February 2017

Client:	Utilities Team
Contact:	Nick Pogson
Issue:	External
Date of Issue:	21st February 2017
Prepared By:	Sarah Richards (Hydraulic / Hydrological Modeller)
Checked By:	Mat Wells (Principal Hydrologist)
Authorised By:	Adam Comerford (National Hydrology Manager)

1. OVERVIEW

Water Management has been asked by the Utilities team to assess the feasibility of a new surface water discharge into the Paddington Arm of the Grand Union Canal, located within a long 43 km pound. The “Long Pound” functions as a reservoir to feed water through Lock 1A Hampstead Road Lock to the Regents Canal and through Lock 90 Hanwell Top Lock to the Norwood flight. There is only one principal source of water to the pound, namely lockage and bypass flows at Lock 89, Cowley Lock. The proposed site is Old Oak Common (NGR TQ 22122 82239), which will be redeveloped to accommodate a mixed use development with approx. 27,000 residential dwellings and 814,000 m^2 of commercial floor space. The proposed site is approximately 24 km along the canal from Lock 89 Cowley, and 8 km above Lock 1A Hamsptead Road Lock.

AECOM (the external client) estimates the catchment size to be 26.55 ha and that the maximum un-attenuated post development peak discharge rate is 10.7 m^3/s (1:100 + 20% CC + 10 % UC). Greenfield runoff is estimated to be 0.1 m^3/s. They acknowledge that the calculations are based on limited information, therefore no detailed design of the site’s drainage systems or the duration of various flows have been modelled at this stage. Both are clearly important when evaluating the ability of the canal to accommodate an increase in discharge.

The purpose of this assessment is to evaluate the viability of putting flood waters from the development site to the canal, and to appraise potential engineering measures that could help to accommodate an increase in flow, (including a rough estimation of costs). Although the initial calculations provide some indication of potential flood mitigation for a range of flows, for a development of this scale, such mitigation can only be derived from detailed hydraulic modelling. This is beyond the scope of this initial assessment.

The initial findings conclude that there are several existing structures in the Long Pound, as well as a few downstream, that may be able to accommodate additional flows from the site. The construction of a new by-weir downstream is also a possibility. The exact scale of the flows which can be accommodated (and associated costs) will be dependent on the type of mitigation measures carried out. The feasibility of the proposed schemes will need to be appraised in a detailed hydraulic assessment.

2. RISK REGISTER ASSESSMENT (STANDARD CRT METHOD)

A bespoke spreadsheet “risk register” tool is used by the Trust to assess if a new surface water discharge is acceptable. It calculates if an increase in the maximum peak discharge causes an unacceptable increase in flood risk. Flood risk can be mitigated by extending waste flood structures/weirs. The amount of additional weirage required to reduce the risk to an acceptable level can also be estimated with this tool.

Table 1 summarises the amount of additional weirage that would be required to accommodate a range of peak maximum flows at Old Oak Common:

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Table 1: Output of CRT "Risk Register" analysis showing the amount of additional weirage required to mitigate the flood risk caused by the increase in maximum peak discharge at Old Oak Common

Maximum discharge rate m^3/s	Additional Weirage Required (m)
0.1	2
0.5	10
1	20
1.5	30
2	40
2.5	50
5	100
10.7	210

Even for the lowest amounts modifications to the canal flow regime are required to mitigate the flood risk.

The scale of mitigation required for a maximum peak discharge of 10.7 m^3/s is higher than the current total amount of fixed weirs in the Long Pound (144m, see below).

The above figures should be considered indicative only, and have been calculated using a conservative approach. Critically, this feasibility does not take into account:

(i) Flood storage (along the 43 km canal pound)
(ii) Hydraulic gradients between flood discharge to flood weirs
(iii) The duration of the storm being considered (i.e. flood volume)

Considerations of these elements are imperative when considering a development of this scale, and can only be undertaken with detailed hydraulic modelling. The detailed modelling of the canal to accommodate these considerations (and reduce the scale of mitigation works) is estimated to be of the order of £20k.

3. POTENTIAL ENGINEERING WORKS TO ACCOMMODATE ADDITIONAL FLOW

Various engineering measures may mitigate the impact of the additional flow from the development site. As well as typical fixed side weirs these include:

- Crenulation of existing waste weir crests within the pound
- Crenulation of by-weir structures downstream (Regents Canal)
- Construction of new structures downstream e.g. a new byweir or sluice at Lock 1A Hampstead Road Lock
- Installation of tilting gates on existing waste weir crests

3.1 Crenulation of existing weir crests

The Long Pound where Old Oak Common is located already has a total of 144m of weirage, provided by 6 waste weir structures of various sizes and designs. Photos of 4 of the weirs can also be seen in the appendix (Figures 1-4). Figure 7 (see appendix) shows where these structures are located relative to the development site.

In 2013 CRT accommodated a new discharge into the Regents Canal by crenulating the crests of 8 transverse byweir structures, for an example of these works see Figure 5 in the appendix. These modifications increased the volume of discharge that could be accommodated by around an additional 50%. The costs of these works was in the region of £600,000.

None of the 6 waste weirs in the long pound have been crenulated as yet, so there is a possibility that additional flow from Old Oak Common could be accommodated by crenulating part or all of the crest of one or more of these structures. A detailed hydraulic assessment of the weirs is required to determine precisely how much additional flow could be accommodated, (as this is determined by the length of the crest that is crenulated, the depth of the crenulation, and the structural readiness of the weir to carry additional flows from the canal to the receiving watercourses). Costs may vary considerably from structure to structure, depending on the level of engineering works required. Consent from the Environment Agency to discharge higher volumes of flood water to the receiving water course will also be required.

It may also be possible to crenulate 3 downstream by-weir structures downstream at Lock 2 Hawley (NGR TQ 28814 84170), Lock 3 Kentish Town (NGR TQ 28900 84151) and Lock 4 St. Pancras Locks (NGR TQ 29925 83597), which are located between 8.4 –9.7 km downstream of Old Oak Common. However, the amount of additional flow that be accommodated further downstream is limited. Hydraulic modelling undertaken for the 2013 works referenced above confirmed that the bottom of the Regents Canal will only be able to receive an additional 0.22 m^3/s from new upstream discharges.

3.2 Construction of new flood mitigation structures

At present there is no by-weir structure at Hampstead Road (Camden) Lock (NGR TQ 28678 84079), where (despite limited physical space), there may be potential to construct one. Although structurally there may also be potential to construct a sluice the restriction of downstream flows to 0.22 m^3/s means that further works would also need to be undertaken downstream to benefit from this. The design and capacity of the by-weir structure could be explored further in a more detailed hydraulic study. It is known that there is limited space for construction works at this site, so it is anticipated that a significant sized pipe or culvert will need to installed if a byweir is constructed, and that there will be restricted access for plant and materials. Due to these constraints a very rough estimation of the costs of the works (based on general knowledge of the site, rather than a site survey) is £500,000. More precise costs for such works can only be estimated after detailed hydraulic modelling is undertaken.

3.3 Installation of Tilting Gates

To accommodate high flow rates and volumes crenulation alone is unlikely to be a feasible solution. Installing tilting weir gates at one of more of the existing flood weir structures in the long 43 km pound is a flexible solution that would allow much greater volumes of discharge to be accommodated. For example, Bulls Bridge weir (the lowest and controlling weir for the pound) is divided in to 9 sections by concrete pillars, so gates could be installed in some of all of the sections. The Trust has already installed tilting gates on structures on the Gloucester & Sharpness Canal, for example an 8m broad crest weir was completely replaced by two 4m titled gates at Purton in 2007 (see Figure 6 in the appendix). Costs include the hardware, installation of electrical equipment to control the gates remotely, and there are also operation and maintenance costs. For the above project the costs of the initial installation were c. £310,000 in 2007, and it is estimated that the same project would cost c.£390,000 in 2017. The weir was installed at a rural site with unrestricted access, however additional costs may be incurred for similar works in more built up. Operating and maintenance costs are estimated to be c.£500, however these costs can vary from site to site.

Detailed hydraulic modelling of suitable flood weir structures will need to be undertaken to determine how much additional flow could be accommodated if tilting gates are installed.

4. WATER QUALITY – ENVIRONMENTAL APPRAISAL

The development site is to be comprised of 27,000 residential dwellings and 814,000m^2 of commercial floor space. There are also to be a number of energy centres (details not submitted).

4.1 Operational phase of the development

a. Under our Local Operational Control (LOC) for Discharges to CRT Waterways, the operational phase of the development would be classified as being of medium risk, given its scale and residential/commercial nature. The nature of the commercial activities is not described in the application and I have assumed that there is the potential for certain commercial activities to involve goods vehicle parking and/or vehicle manoeuvring. For medium risk sites, CRT requires that a Class 1 oil interceptor be installed prior to each discharge point into the waterway.

b. We require the applicant to adhere to the Environment Agency's PPG3 guidance note on oil separators: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/290142/pmho0406biyl-e-e.pdf . Although PPG3 has been withdrawn by the EA, we still regard it as constituting best practice, and therefore require prospective dischargers to CRT waterways to adhere to it. The applicant needs to ensure that the separators are sized in accordance with PPG3 and the applicant also needs to account for how silt storage is to be provided for.

c. The applicant needs to provide sufficient access points in the design to allow for inspection and cleaning of the internal chambers.

d. The applicant must undertake to label the oil separator(s) as per PPG3 and to show their presence on drainage plans.

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e. The applicant needs to submit a maintenance procedure for the oil separator(s) that encompasses the maintenance requirements of PPG3.

f. The application states that measures will be provided to prevent pathways between the canal and potential sources of existing ground contamination, as surface water drainage systems and Sustainable Drainage Systems will be lined. This undertaking should form part of any agreement.

4.2 Demolition & construction phase of the development

a. The application states that a ground investigation has not yet been undertaken, as this initial enquiry is provided to determine whether it will be feasible to discharge surface water to the Grand Union Canal. In the absence of any data to demonstrate that the soil and groundwater on-site is **not** contaminated, a precautionary approach is required. This will mean that no discharge of collected rainwater, rainwater run-off or extracted groundwater/perched water from dewatering works etc. will be accepted into the CRT waterway during construction works i.e. any temporary surface water drainage system in place during construction works should not discharge to the CRT waterway.

5. SUMMARY

This assessment concludes that it may be possible to accommodate additional surface water discharge from the Old Oak Common development site into the Paddington Arm, however the amount of additional discharge that is feasible can only be determined by undertaking in-depth hydraulic modelling. Various engineering works could mitigate the flood risk from the additional discharge, ranging from the crenulation of weir crests to the installation of tilting weir gates. The Trust has previous experience and detailed knowledge of how to successfully undertake both types of works. There are several existing structures in the Long Pound where Old Oak Common is located that have the potential to be modified. The impact of building a new structure or modifying by-weirs along the Regents Canal is also possible, but at present limited by the amount of additional discharge that can be accommodated further downstream.

The scale of mitigation for this site would be without precedent compared to any discharge that have previously been accepted across the Trust's 2,000 mile network. An estimation of the maximum post development peak discharge has been provided, but this is based on limited information and will need refining once details such as the number of discharge points are known. Detailed hydraulic modelling will help to determine the amount of additional discharge that the proposed engineering works can accommodate, and allow more accurate cost estimations to be provided. The detailed study should also take in to account the impact of additional flows on the receiving watercourses beyond the Trust's network. It is estimated that a detailed modelling of the canal would be of the order of £20k. This should provide the detail of the mitigation works required for the range of discharges being considered and would include due consideration of the considerable attenuation that may be provided by the 43km canal pound.

DRAFT

APPENDIX

I. **Figure 1: Court Lane Road Waste Weir**

II. **Figure 2: River Pinn Waste Weir**

III. **Figure 3: Bulls Bridge Weir**

IV. **Figure 4: Southall Fixed Weir**

DRAFT

V. **Figure 5: Crenulation of a transverse by-weir crest on the Regents Canal**

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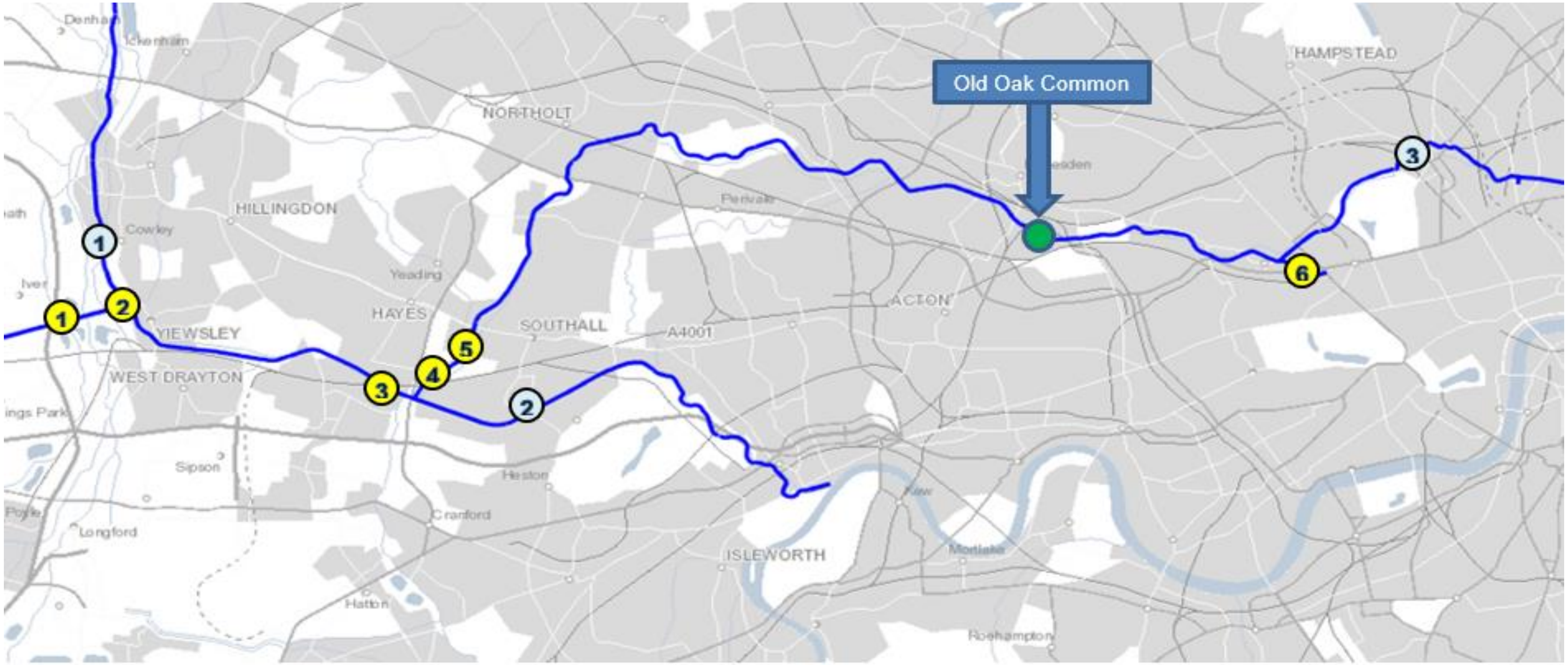
VI. Figure 6: Tilting weir gate – Purton Weir on Gloucester & Sharpness Canal

Canal & River Trust

VII. Figure 7: Map of the 43 km pound where Old Oak Common is located, (including flood weir structures and lock flights)



(1) Court Lane Road Weir (NGR TQ 04367 80661), 13 m crest (2) River Pinn Weir (NGR TQ 05560 80896), 27 m crest
(3) Bulls Bridge Weir (NGR TQ 10456 79226), 30 m crest (4) Southall Fixed Weir (NGR 11546 79875), 55 m crest
(5) Brick Weir (NGR 11608 80291), 6 m crest (6) Travis Perkins Weir & Sluice (NGR TQ 26447 81696), 13 m crest

(1) Cowley Lock (NGR TQ 05156 82258) (2) Hanwell Lock (NGR TQ 13688 79371) (3) Hampstead Rd Lock, top of Regents Canal (NGR TQ 28667 84076)

Appendix M Surface Water Drainage

See overleaf.

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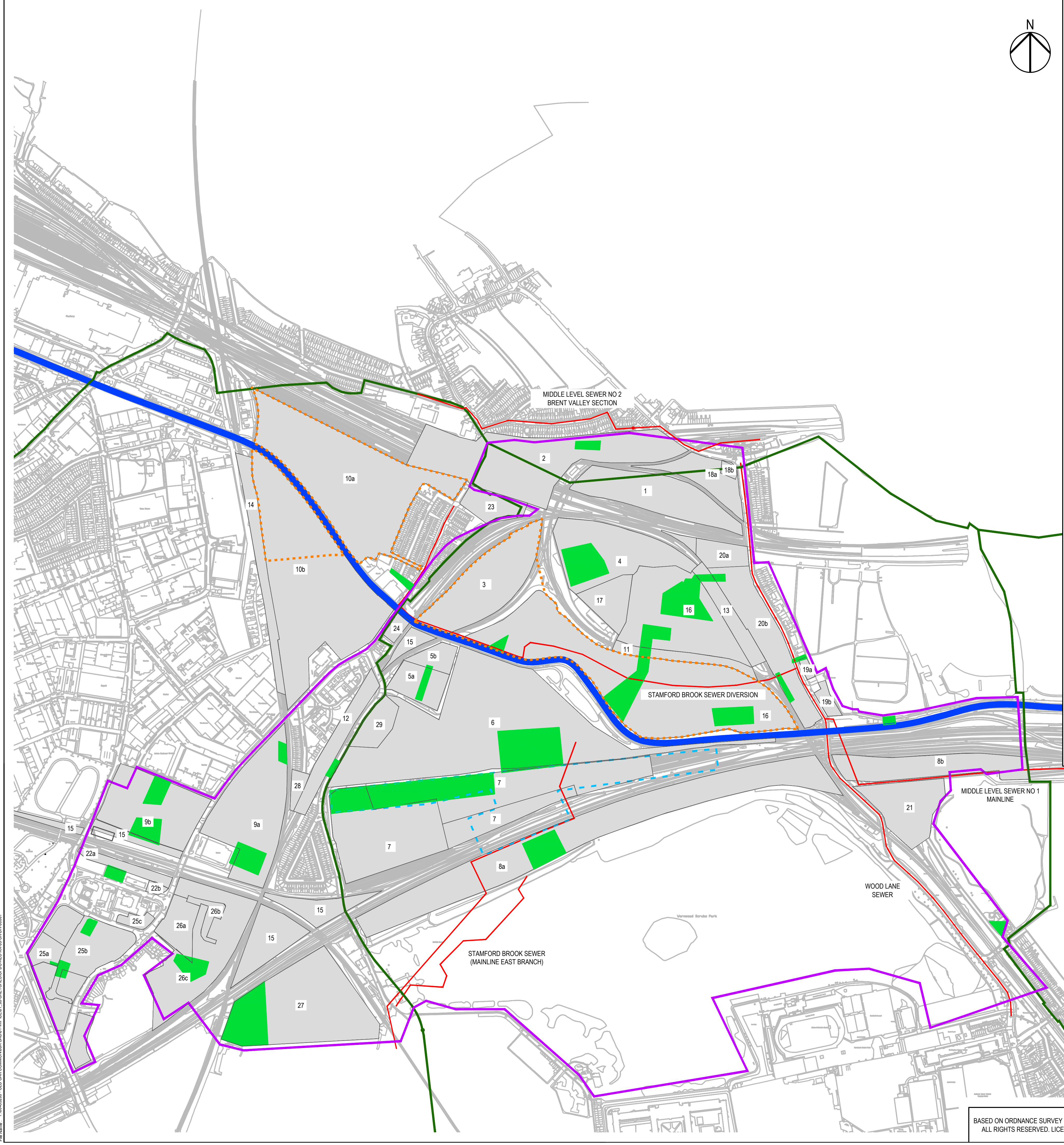

PLOT NAME	PLOT No.	TOTAL PLOT AREA (ha)	PERMISSIBLE RUN OFF RATE WITHIN WHOLE SITE BASED ON 1:100 YEAR GREENFILED RUNOFF RATE (l/s)	APPROXIMATE VOLUME OF ATTENUATION STORAGE REQUIRED WITHIN SITE (m^3)
LOROL DEPOT	1	3.19	15.50	2639
WILLESDEN JUNCTION	2	6.93	33.60	5734
POWERDAY	3	3.73	18.1 *	3082 *
EMR	4	3.73	18.10	3083
GENESIS - SOUTH	5a	1.12	5.40	929
GENESIS - NORTH	5b	0.59	2.90	487
CROSSRAIL DEPOT	6	13.03	63.30	10779
HS2 STATION OSD / TRIANGLE / GWML OSD	7	11.17	54.20	9239
IEP	8a	8.72	42.30	7214
NORTH POLE EAST	8b	2.62	12.70	2166
SHIELD (HS2 WORKSITE)	9a	4.71	22.90	3899
VICTORIA ROAD BOX (HS2 WORKSITE)	9b	3.59	17.40	2967
WILLESDEN EURO	10a	8.82	42.8 *	7296 *
NORTHERN HS2 WORKSITE	10b	9.83	47.7 *	8129 *
HYTHE ROAD STATION	11	0.83	4.10	689
OOC LANE STATION	12	1.38	6.70	1142
TERMINATING PLATFORMS	13	1.01	4.90	832
DUDDING HILL LANE	14	1.51	7.30	1248
LAND LOCKED SITES	15	3.43	16.70	2840
CAR GIANT	16	15.64	75.9 *	12939 *
LBHF	17	1.12	5.40	925
HARROW ROAD	18a	1.39	6.80	1151
HARROW ROAD - 2 SCRUBS LANE	18b	0.12	0.60	100
SCRUBS LANE EAST / NORTH KENSINGTON GATE NORTH	19a	0.12	0.60	96
SCRUBS LANE EAST / NORTH KENSINGTON GATE SOUTH	19b	0.28	1.40	229
SCRUBS LANE WEST	20a	0.76	3.70	627
SCRUBS LANE WEST	20b	3.02	14.70	2499
MITRE SITE	21	2.22	10.80	1839
NORTH ACTON (GRASS VERGE AND OSD)	22a	0.55	2.70	458
HOLBROOK HOUSE	22b	0.12	0.60	95
PARK ROYAL LINKS	23	0.96	4.70	793
CANAL SITE	24	0.24	1.20	199
6 PORTAL WAY	25a	1.55	7.50	1287
CARPHONE WAREHOUSE	25b	1.92	9.30	1589
THE PORTAL	25c	0.25	1.20	208
PERFUME FACTORY	26a	1.01	4.90	838
MONARCH HOUSE	26b	0.37	1.80	304
SEGRO	26c	4.05	19.70	3348
WESTWAY INDUSTRIAL ESTATE	27	6.03	29.30	4984
MIDLAND GATE TERRACE	28	0.28	1.40	232
TOTAL		131.94	640.90	109134

NOTE:- * - PEAK DISCHARGE RATE MAY BE INCREASED SUBJECT TO AGREEMENT FROM THE CANAL AND RIVER TRUST

TABLE DEFINING PERMISSIBLE SURFACE WATER DISCHARGE RATES AND ATTENUATION VOLUMES

CONSTRUCTION RISKS	MAINTENANCE / CLEANING RISK	DEMOLITION RISKS

In addition to the hazard/risks normally associated with the types of work detailed on this drawing take note of above. It is assumed that all works on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

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4. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH DRAWING REFERENCES OPDC-AEC-XX-05-SK-DR-00002 AND 00003 WHICH SHOW TYPICAL DETAILS OF SUSTAINABLE DRAINAGE SYSTEMS

KEY

- OPDC OLD OAK COMMON BOUNDARY
- LONDON BOROUGH BOUNDARY
- DEVELOPMENT AREAS
- 2 PLOT REFERENCE NUMBER
- FUTURE AREA FOR OLD OAK COMMON RAILWAY STATION
- PADDINGTON BRANCH OF THE GRAND UNION CANAL
- PROPOSED NEW OPEN SPACES WHICH HAVE POTENTIAL TO ACCOMMODATE STRATEGIC SUDS
- EXTENT OF SITE WITH POTENTIAL TO DISCHARGE SURFACE WATER TO THE GRAND UNION CANAL BY GRAVITY SUBJECT TO CONSENT FROM THE CANAL AND RIVER TRUST
- EXISTING COMBINED SEWERS WHICH FORM OUTFALL FOR ATTENUATED RUNOFF FROM DEVELOPMENT PARCELS THAT DO NOT DISCHARGE SURFACE WATER TO THE GRAND UNION CANAL

Revision Details	By / Check	Date	Suffix
FIRST ISSUE	MH / JR	24.02.17	P1

Purpose of issue
FOR INFORMATION

Client
OLD OAK AND PARK ROYAL DEVELOPMENT CORPORATION

Project Title
OLD OAK COMMON

Drawing Title
SURFACE WATER DRAINAGE PERMISSIBLE RUNOFF RATES AND ATTENUATION STORAGE VOLUMES

Designed	Drawn	Checked	Approved	Date
JR	MH	JR	BM	24.02.17

AECOM Internal Project No.: 60495203
Suitability: FOR INFORMATION
Scale @ A1: 1:5000

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Drawing Number: OPDC-AEC-XX-05-SK-DR-00001
Rev: P1

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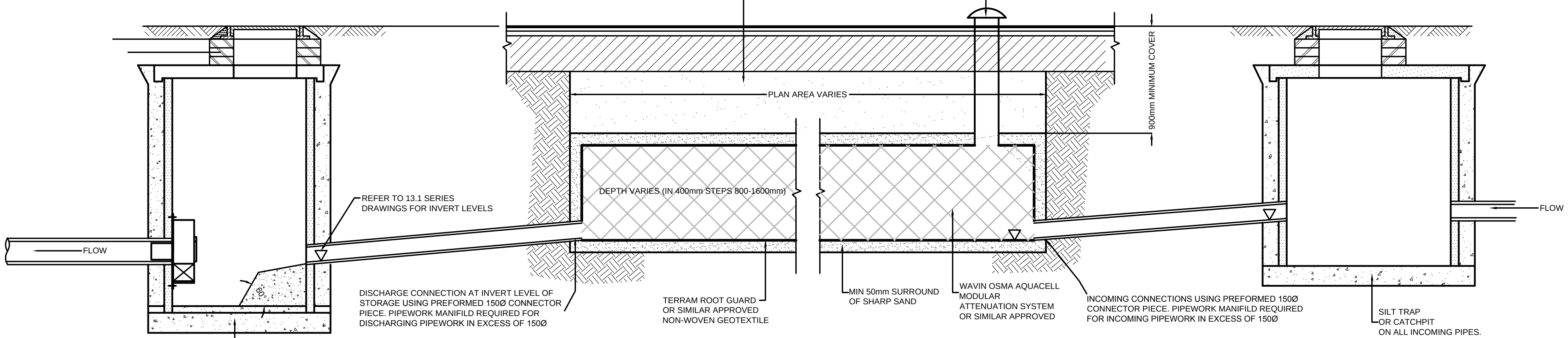
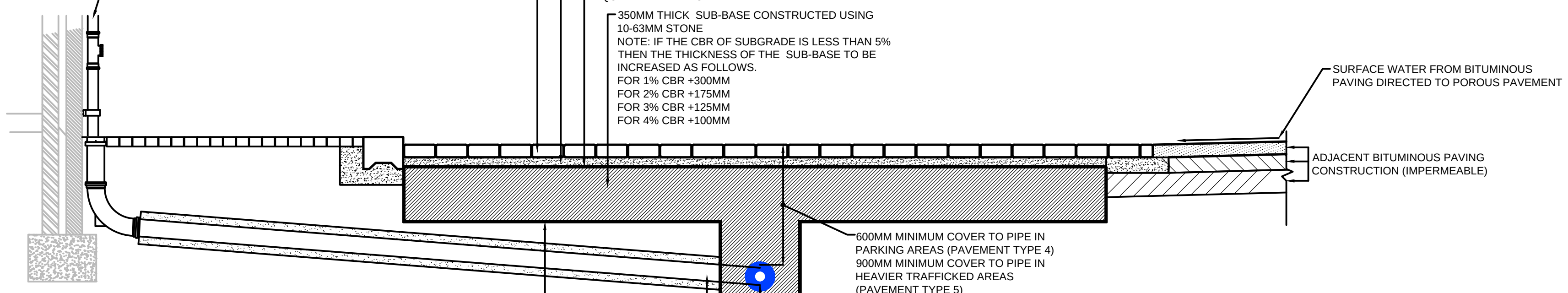
1 : 5000
100m 0 100m 200m 300m 400m 500m



TYPICAL DETAIL SHOWING UNDERGROUND GEOCECULLAR STORAGE



TYPICAL DETAIL SHOWING POROUS PAVEMENT CONSTRUCTION

CONSTRUCTION RISKS	MAINTENANCE / CLEANING RISK	DEMOLITION RISKS

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Purpose of issue

FOR INFORMATION

Client

OLD OAK AND PARK ROYAL DEVELOPMENT CORPORATION

Project Title

OLD OAK COMMON

Drawing Title

TYPICAL DETAILS OF SUITABLE SUSTAINABLE DRAINAGE SYSTEMS SHEET1

Designed	Drawn	Checked	Approved	Date
JR	MH	JR	BM	24.02.17

AECOM Internal Project No.	Suitability
60495203	S1-CO-ORDINATION

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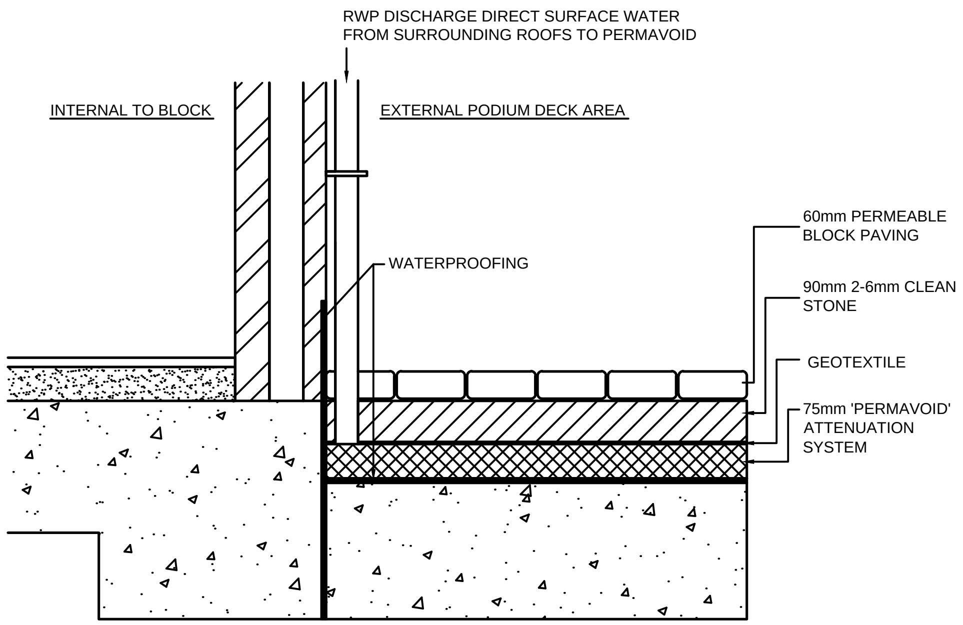
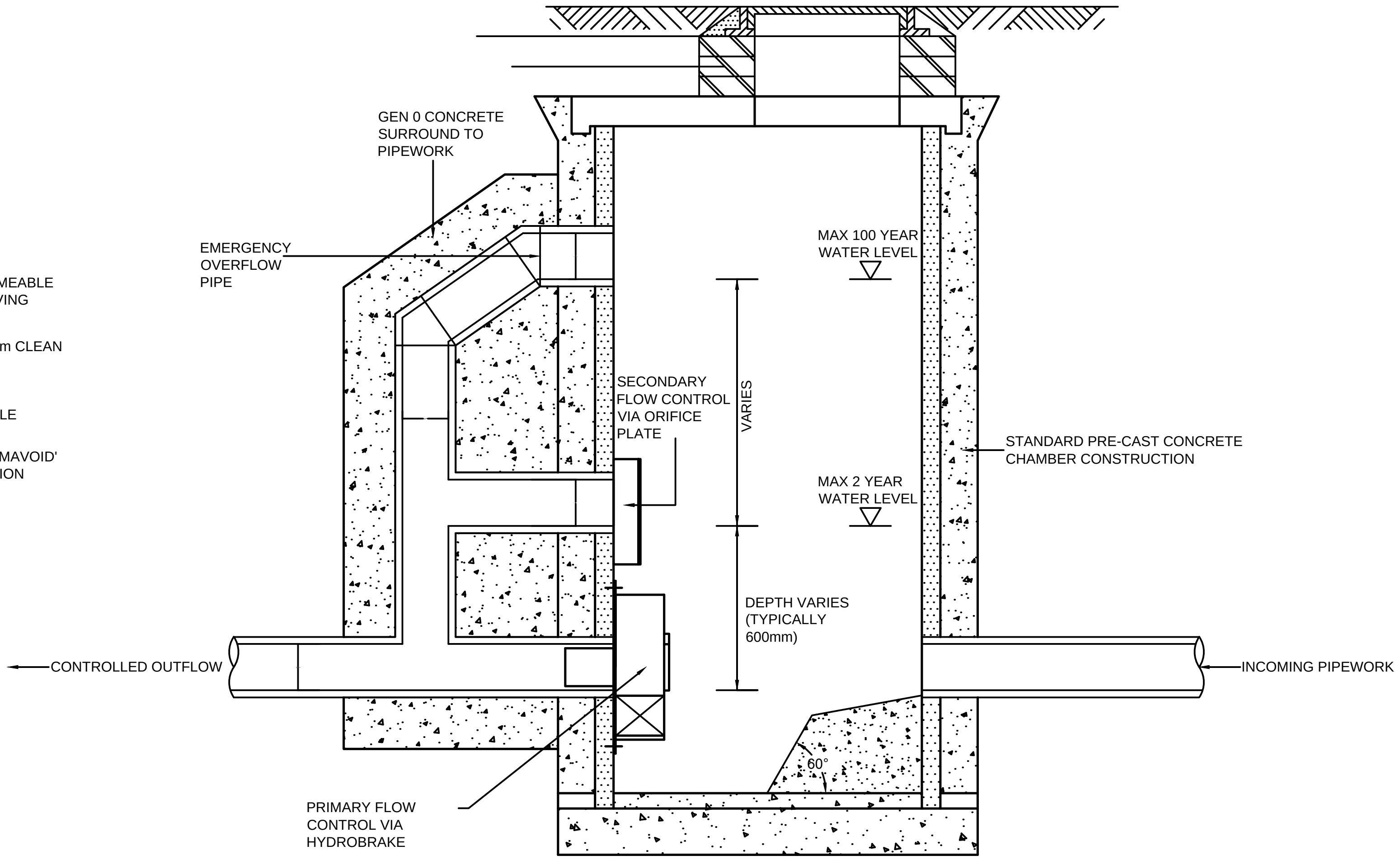


TYPICAL DETAIL SHOWING PERMAVOID STORAGE PROVIDED ON PODIUM DECK TO ALLOW SURFACE WATER TO BE ATTENUATED AT SOURCE



TYPICAL COMPLEX FLOW CONTROL DETAIL REQUIRED DOWNSTREAM OF UNDERGROUND STORAGE TO RESTRICT THE PEAK SURFACE WATER DISCHARGE TO GREENFIELD RATES

CONSTRUCTION RISKS	MAINTENANCE / CLEANING RISK	DEMOLITION RISKS

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Project Title

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Drawing Title

TYPICAL DETAILS OF SUITABLE SUSTAINABLE DRAINAGE SYSTEMS SHEET 2

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AECOM Internal Project No.	Suitability
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