OPDC
OLD OAK AND PARK ROYAL DEVELOPMENT CORPORATION

Utilities Study

LOCAL PLAN SUPPORTING STUDY

2017

MAYOR OF LONDON

53. 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; - Start competitive dialogue with potential independent distri bution 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, connect into strategic SuDs, if feasible drain into the Grand Union Canal, use on-site SuDS and if on-site, prioritise vegetated SuDS. • Recommendations from the study have been appropriately incorporated into the Infrastructure Delivery Plan (IDP).
Relations to other studies	Interfaces with the Integrated Water Management Strategy (IWMS), Development Infrastructure Funding Study (DIFS), Environmental Standards Study, Waste Management Strategy 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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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.

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, 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.

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.

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.

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.

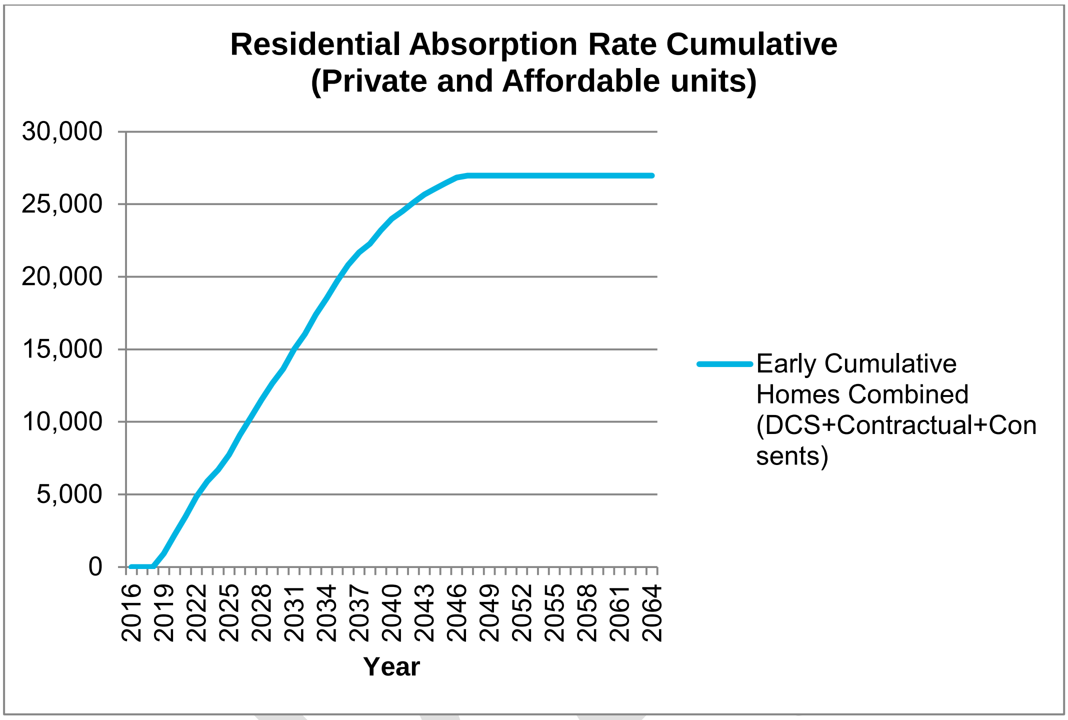

Figure 1. Anticipated Housing Growth (Draft Phasing Trajectory v7.11 - Early Scenario)

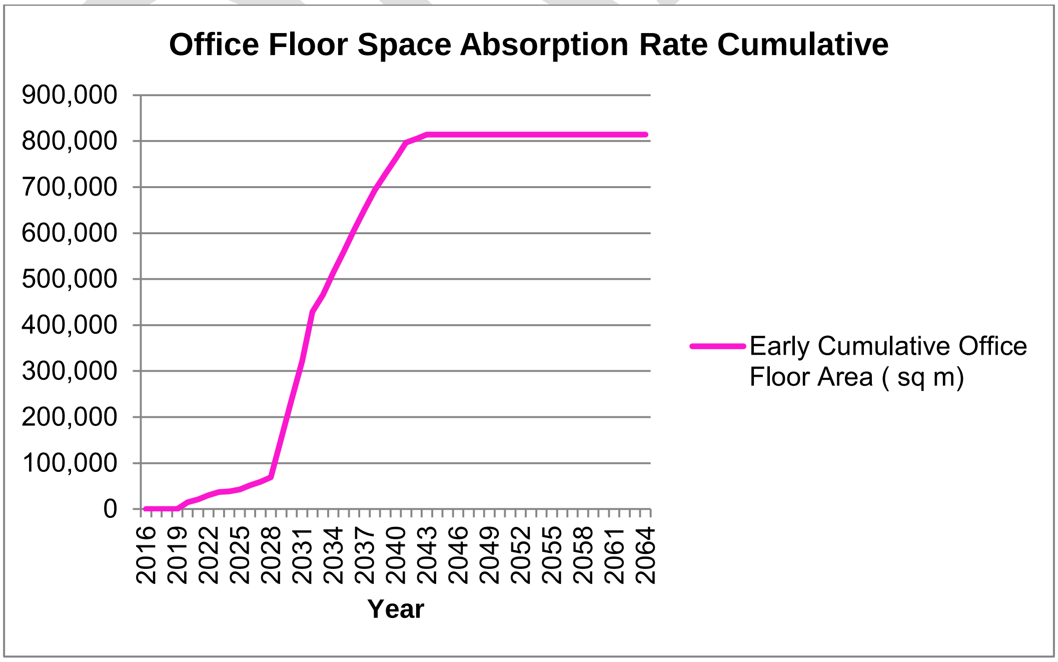

Figure 2. Anticipated Employment Growth (Draft Phasing Trajectory v7.11 - Early Scenario)

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

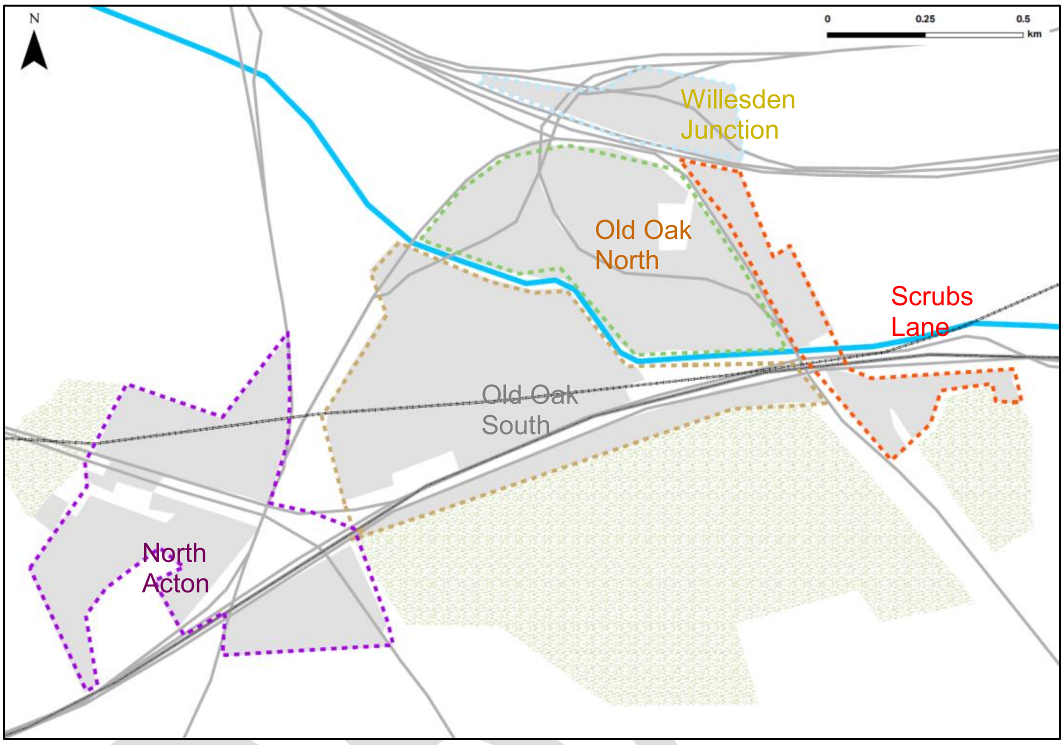

Figure 3. Old Oak Development Areas

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.

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).

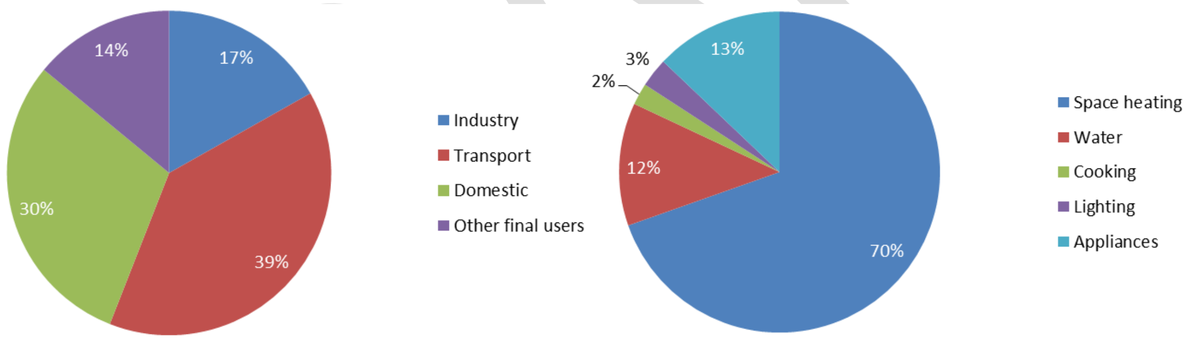

Figure 4. L – Final Energy Consumption by Sector; R – Domestic Final Energy Consumption by End Use (Existing Housing Stock)[1]

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]

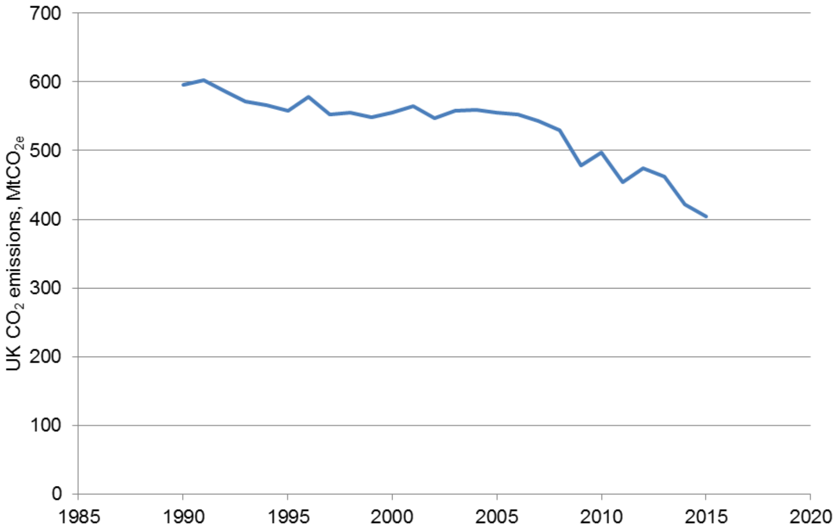

Figure 5. UK CO_2 Emissions, 1990 - 2015[2]

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.

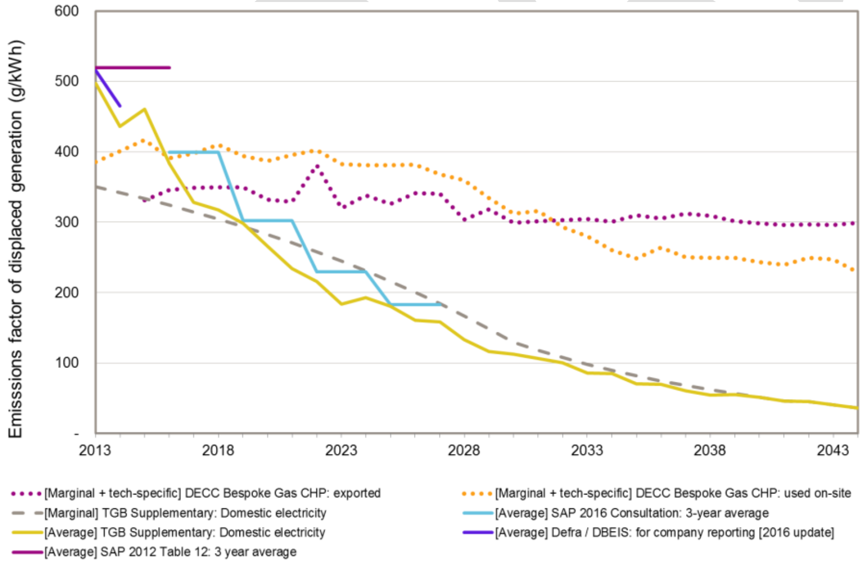

Figure 6. Projected Carbon Intensity of UK Grid Electricity

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.

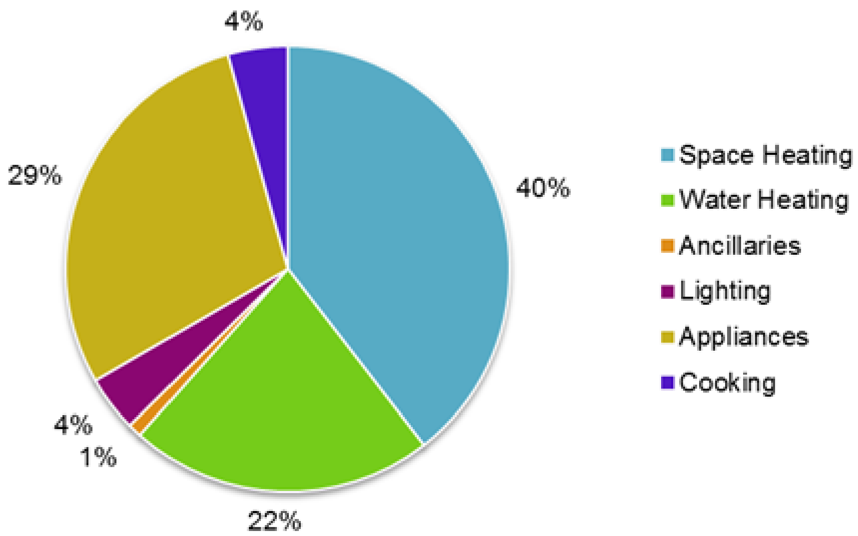

Figure 7. Energy Demand Spilt for Average Old Oak Home Complying with the Part L Target Emission Rate

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.

Electricity – Gone Green's demand components

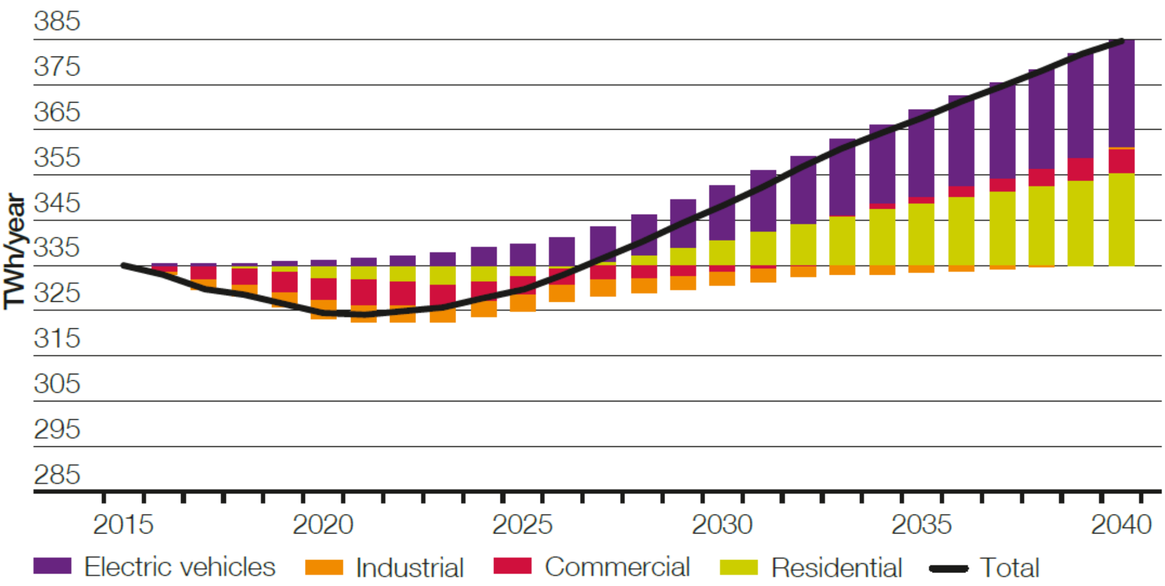

Figure 8. National Grid Projection of Growth in Transmission of Electricity for a Gone Green Scenario

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

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.

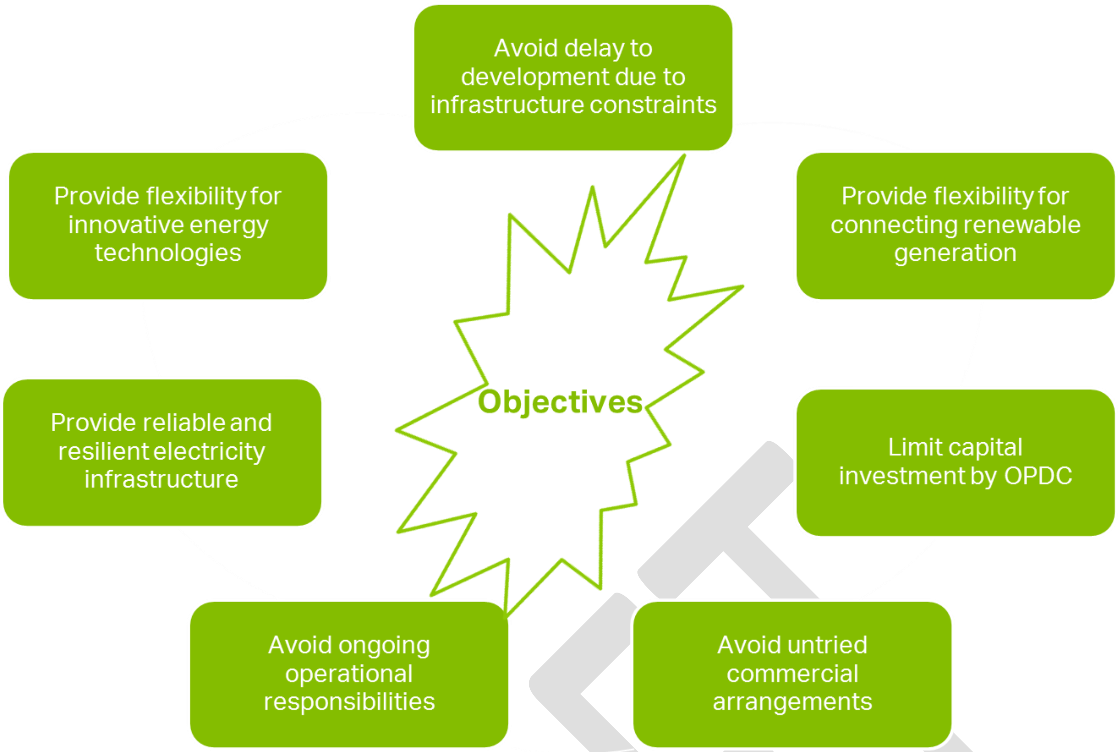

Figure 9. Electricity Strategy High Level Objectives

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.

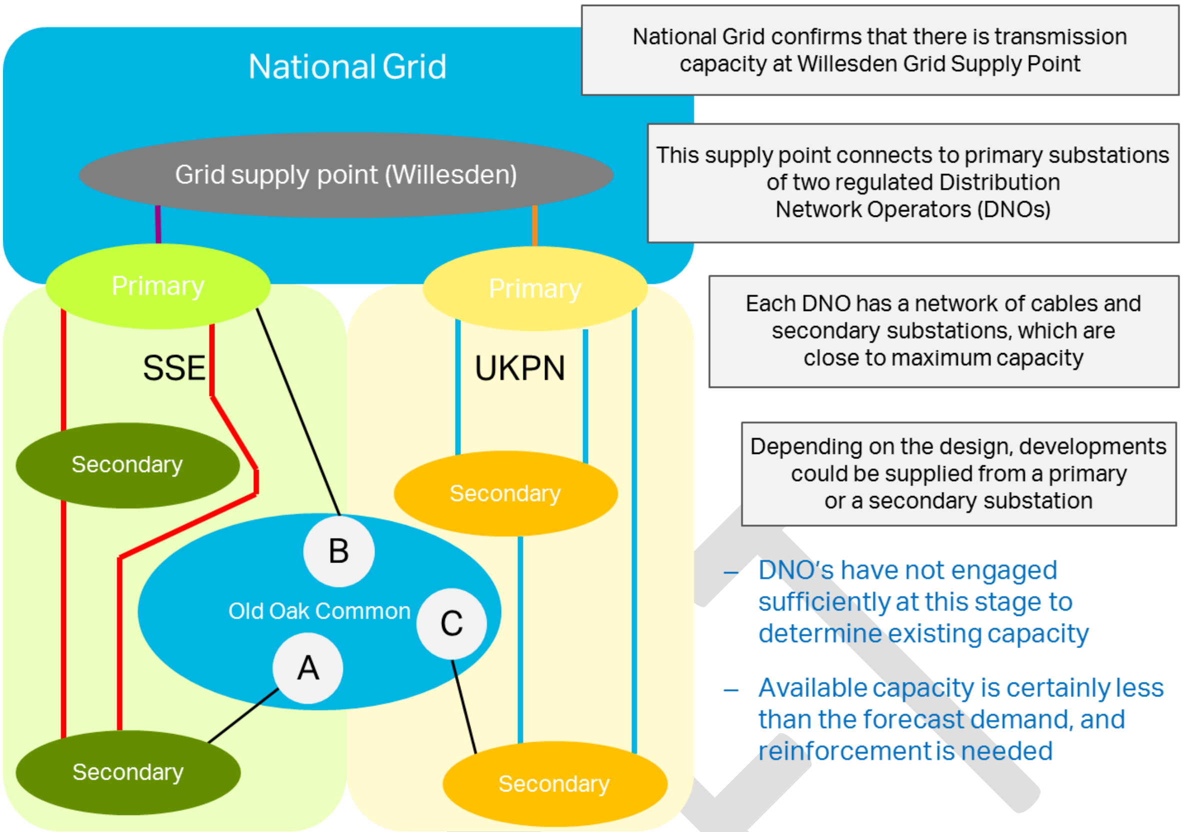

Figure 10. Current Electricity Distribution Responsibilities in Old Oak

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.

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.

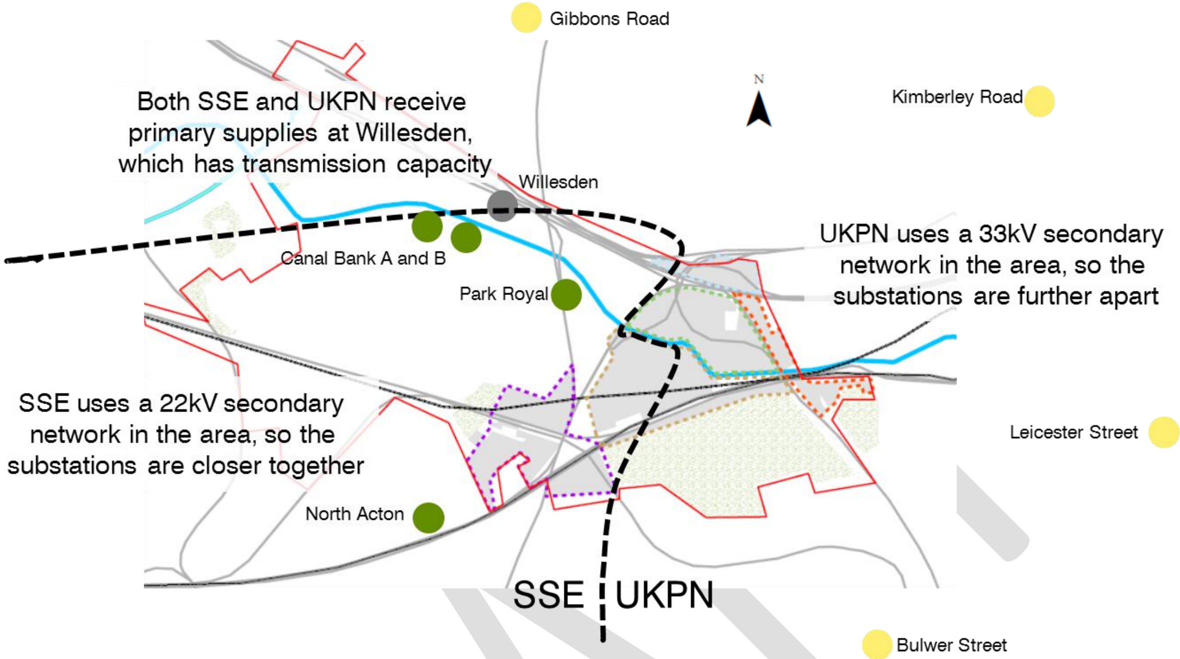

Figure 11. Current Electricity Infrastructure Supplying Old Oak

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.

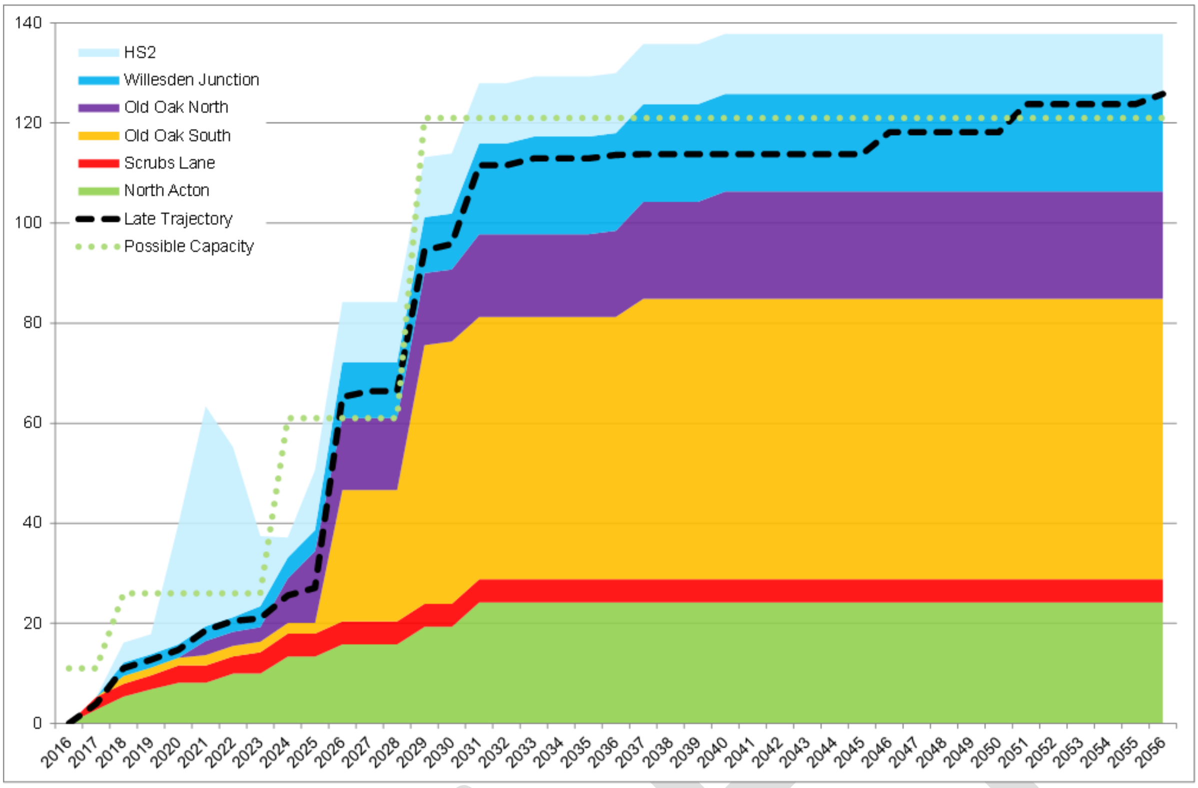

Figure 12. Build-up of Electricity Demand in Old Oak

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.

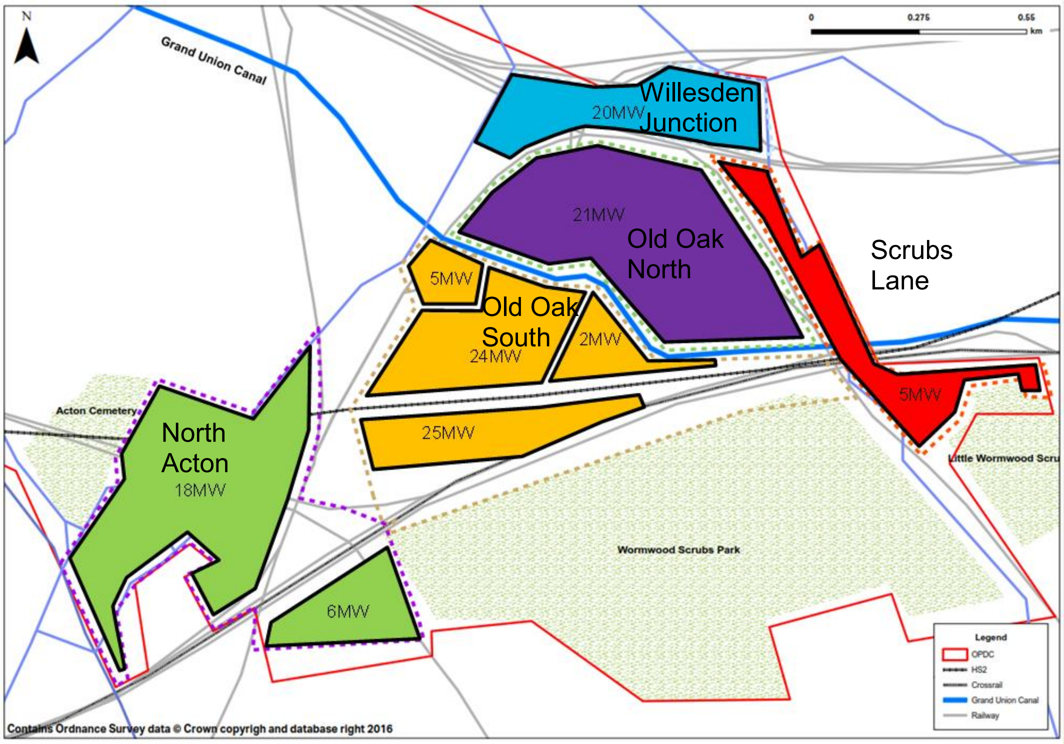

Figure 13. Estimated Peak Electricity Load by Area

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.

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.

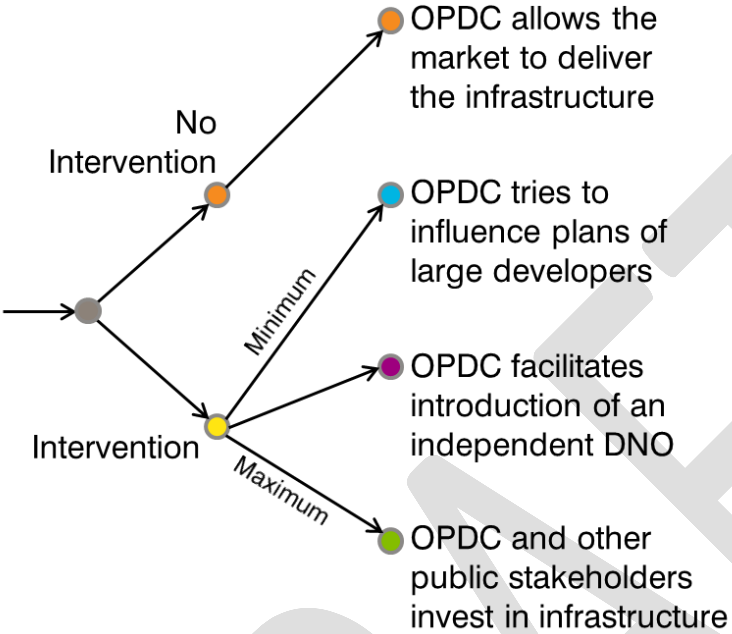

Figure 14: Varying Levels of Intervention for reinforcing the Electricity Network

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.

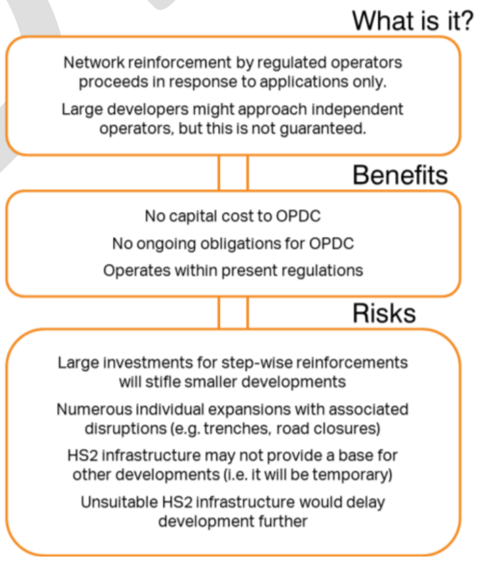

Figure 15. Anticipated Benefits & Risks Associated with No Intervention Approach

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.

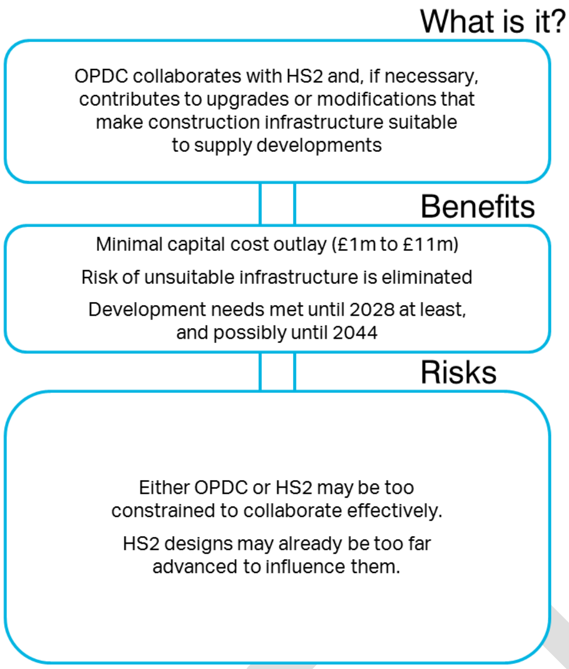

Figure 16. Anticipated Benefits & Risks Associated with Engaging Developers Controlling Large Landholdings

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.

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.

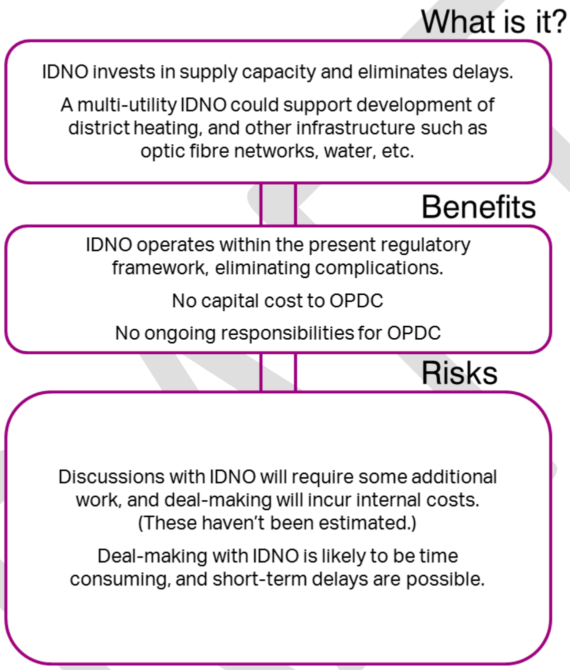

Figure 17. Anticipated Benefits & Risks Associated with Introduction of an IDNO

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.

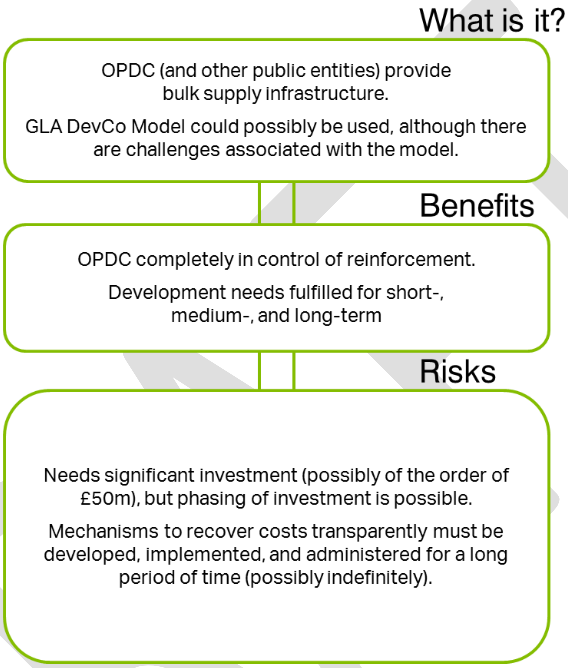

Figure 18. Anticipated Benefits & Risks Associated with Investment Ahead of Need

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.

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 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.

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.

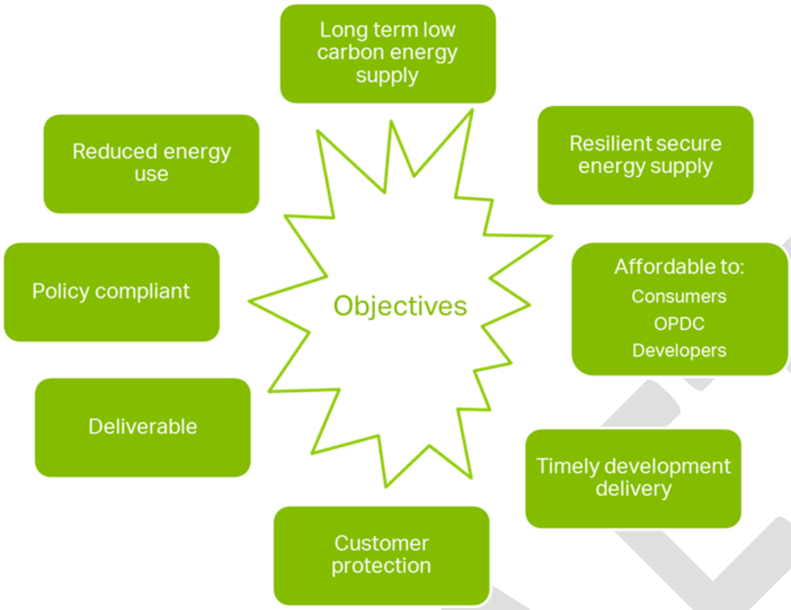

Figure 19. Objectives for the Decentralised Energy Strategy

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.

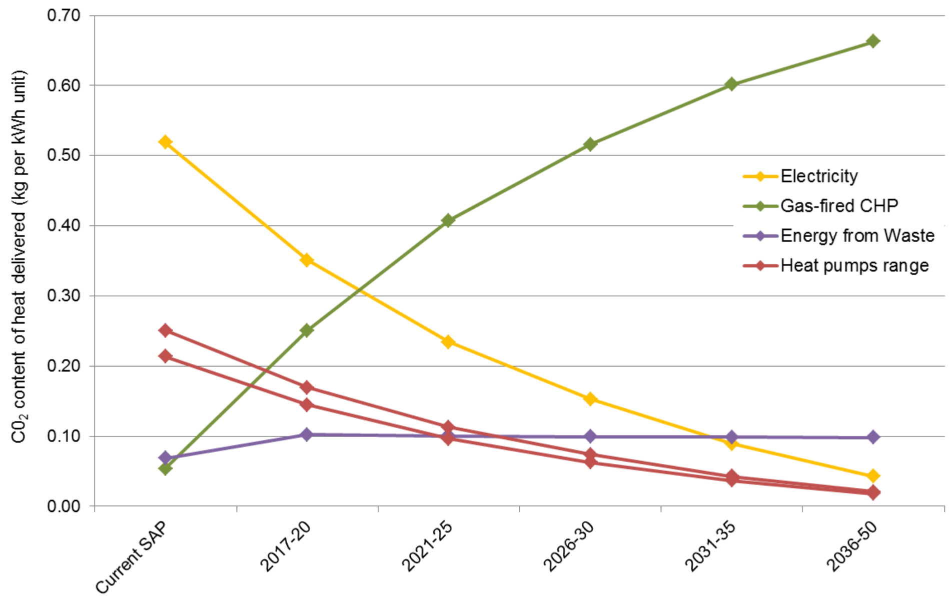

Figure 20. Carbon Intensity of Heat Generated from Different Sources[9]

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.

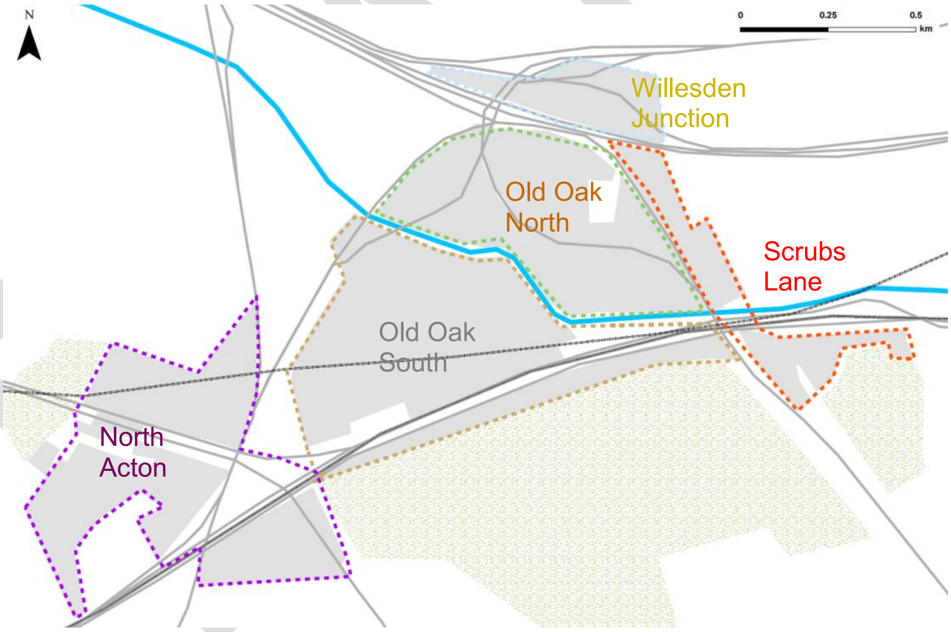

Figure 21. Five Development Clusters

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.

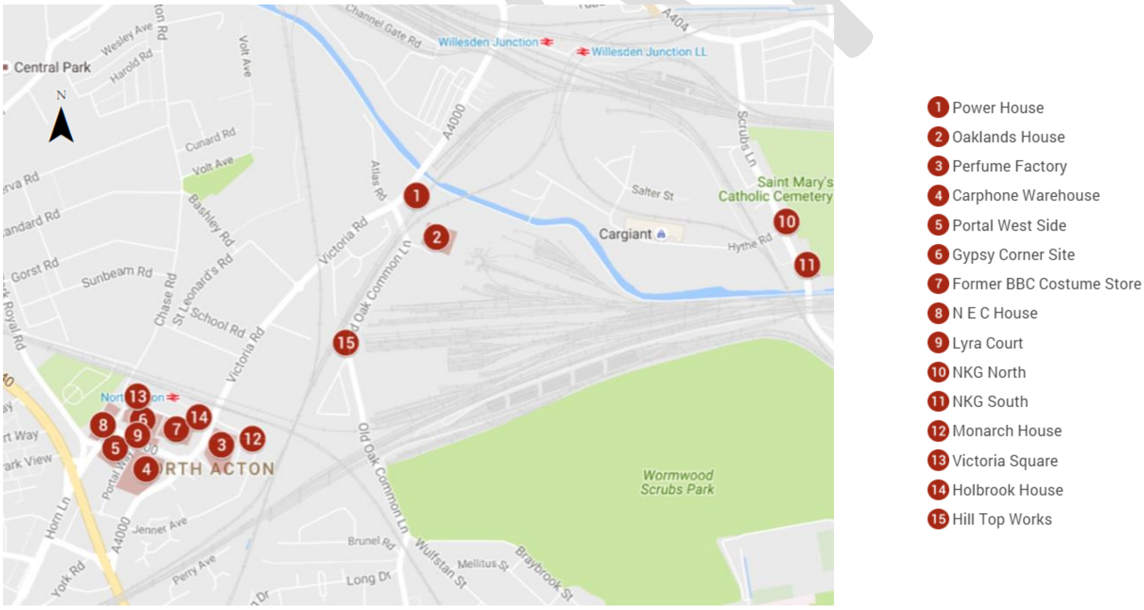

Figure 22. Existing Planning Applications

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.

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.

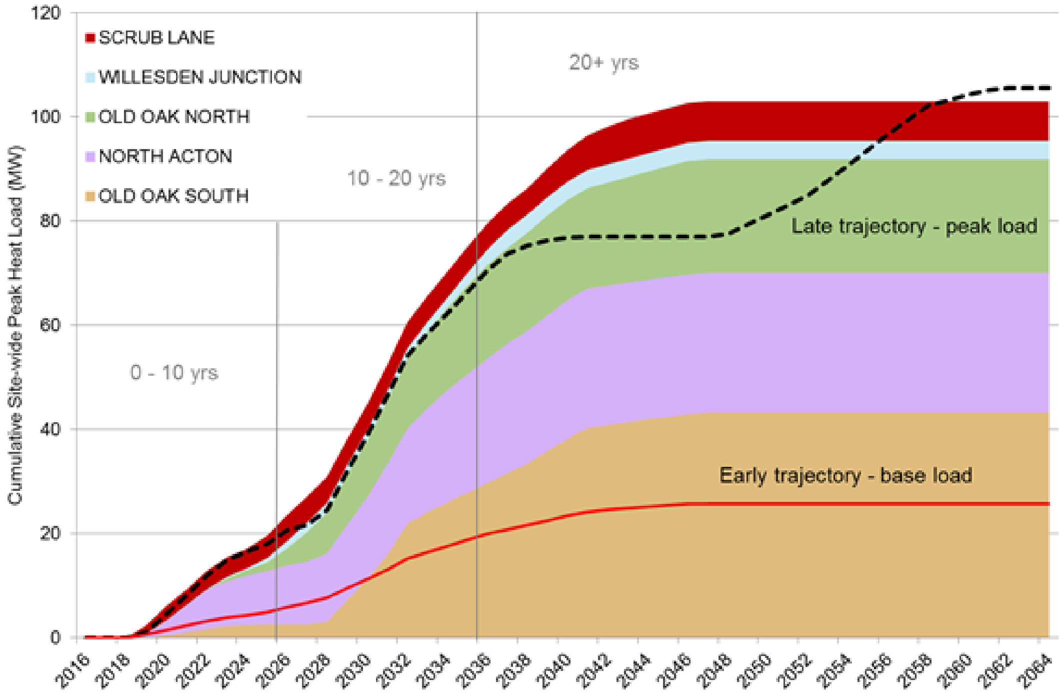

Figure 23. Heat demand build-up (at the end customer[11])

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

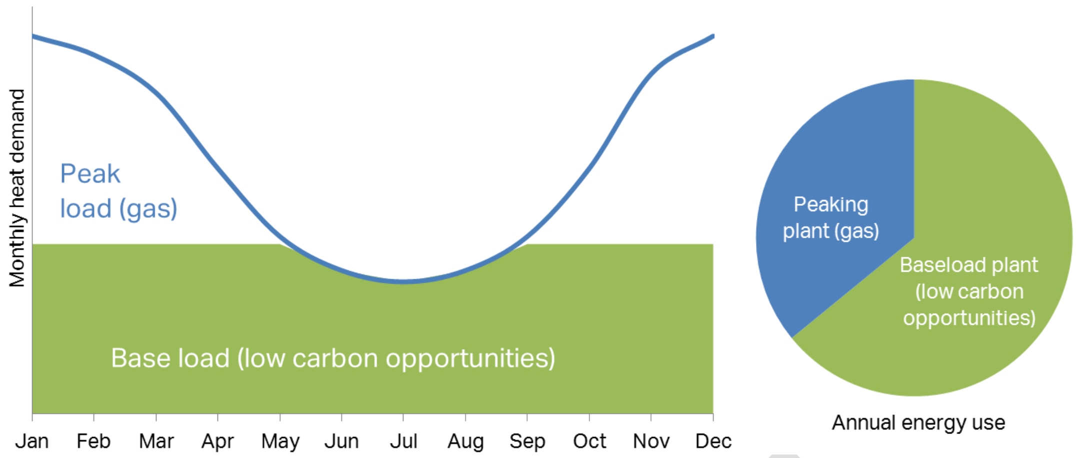

Figure 24. Relationship between Baseload and Peak Demand and Annual Energy Use

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.

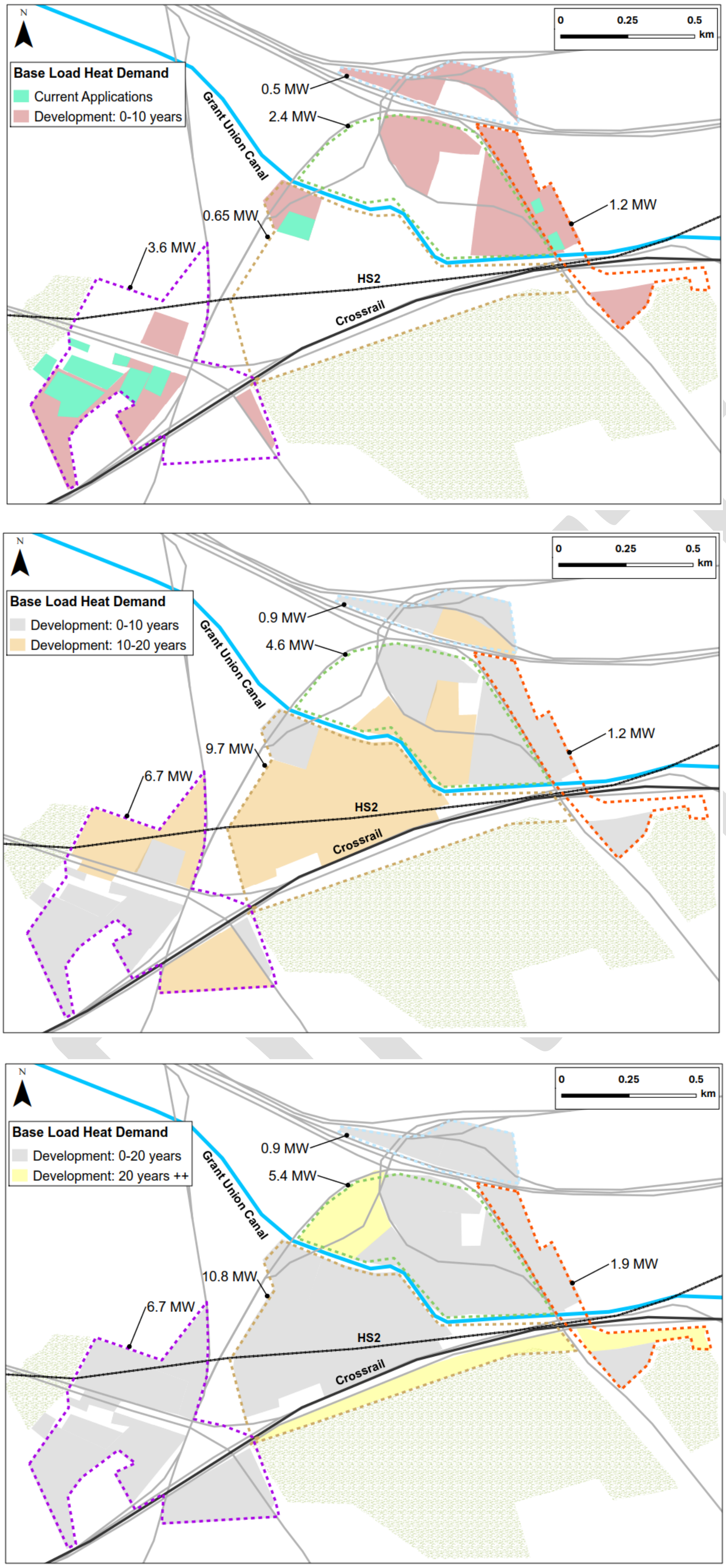

Figure 25. Phased Development and Base Heat Load. [Top: Development in 0-10 Years, incl. Current Applications; Middle: Development in 10-20 Years; Bottom: Development in 20+ Years]

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.

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.

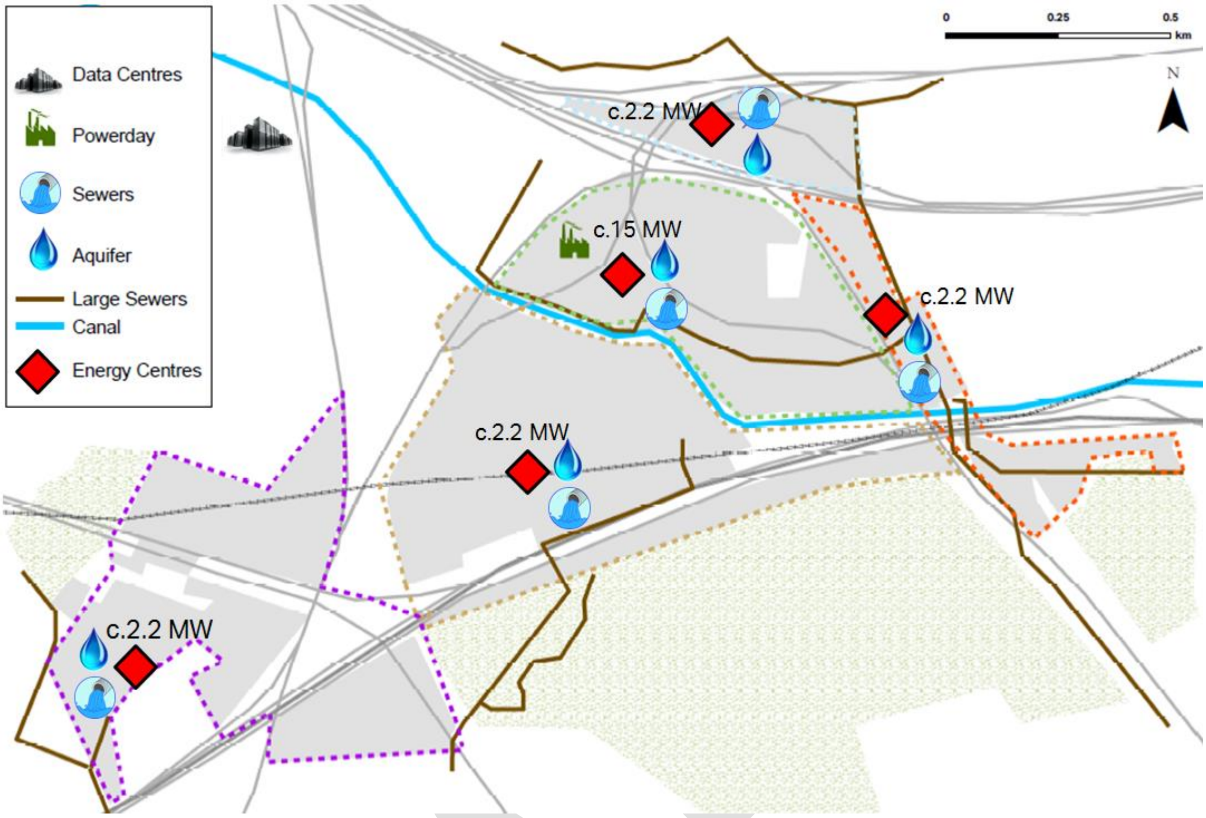

Figure 26. Notional Locations of Heat Sources

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.

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

- 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.

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

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

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.

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.

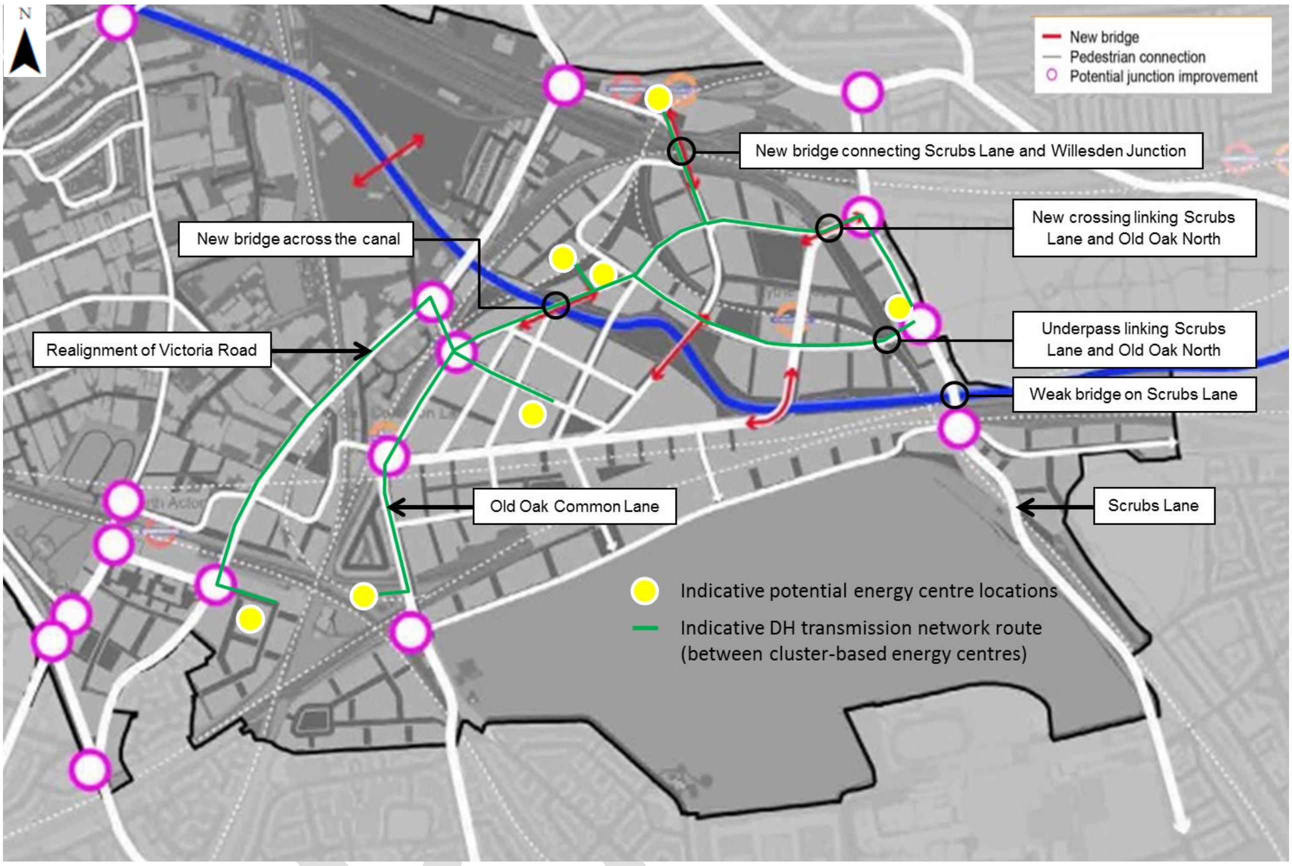

Figure 28. Indicative Route for District Heating Transmission Network and Energy Centre Locations

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.

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).

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 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.

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.

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.

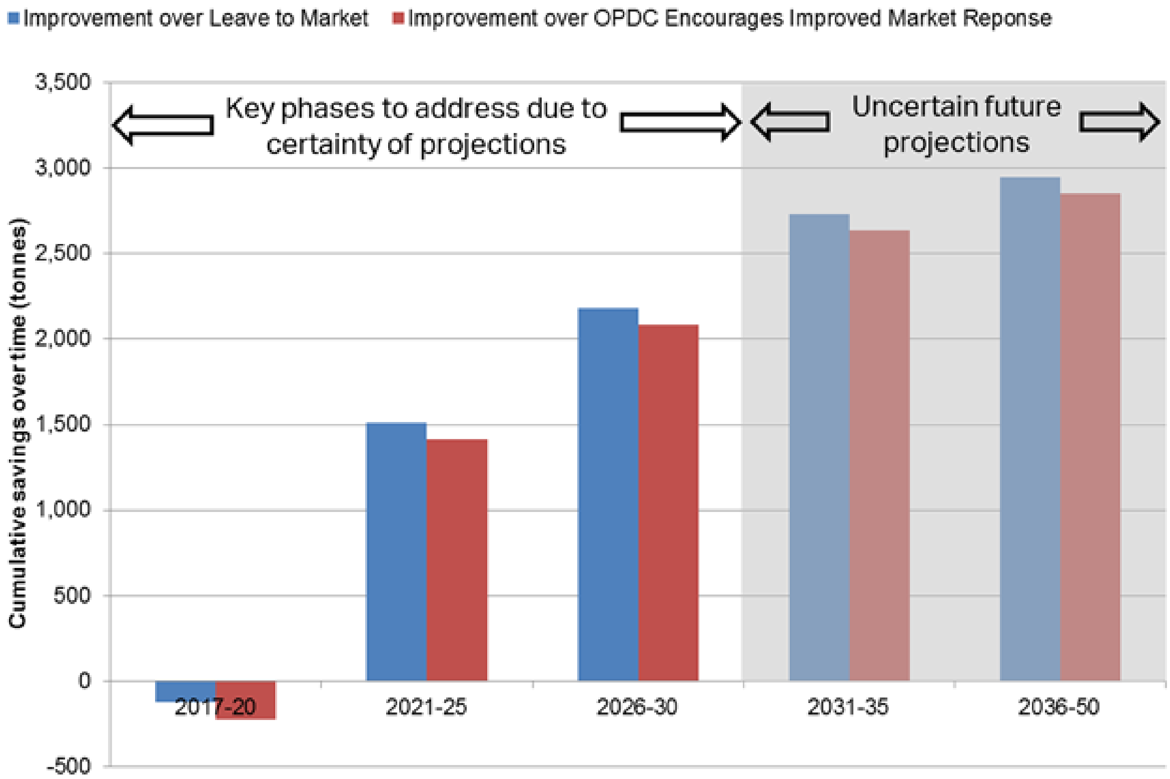

Figure 29. Cumulative Improvement in CO_2 Emissions over time from Public Sector led Network Delivery

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

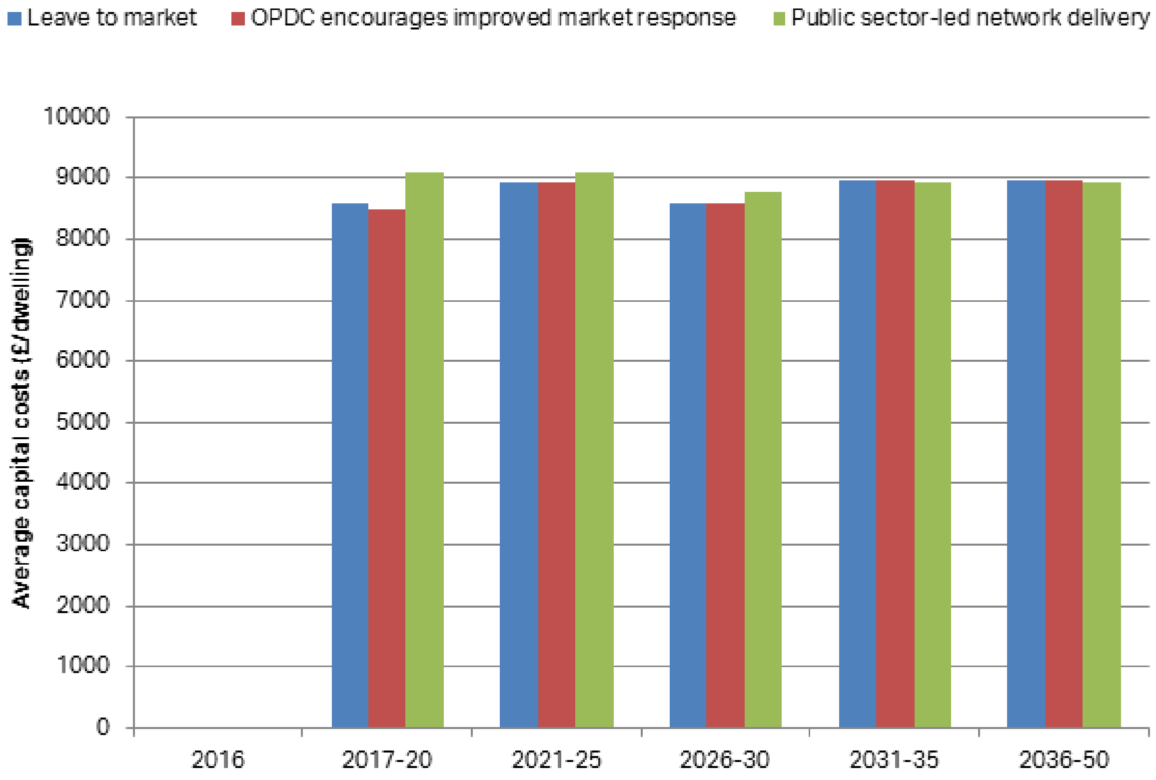

Figure 30. Indicative Capital Costs of Alternative Intervention Options

** 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.

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.

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..

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.

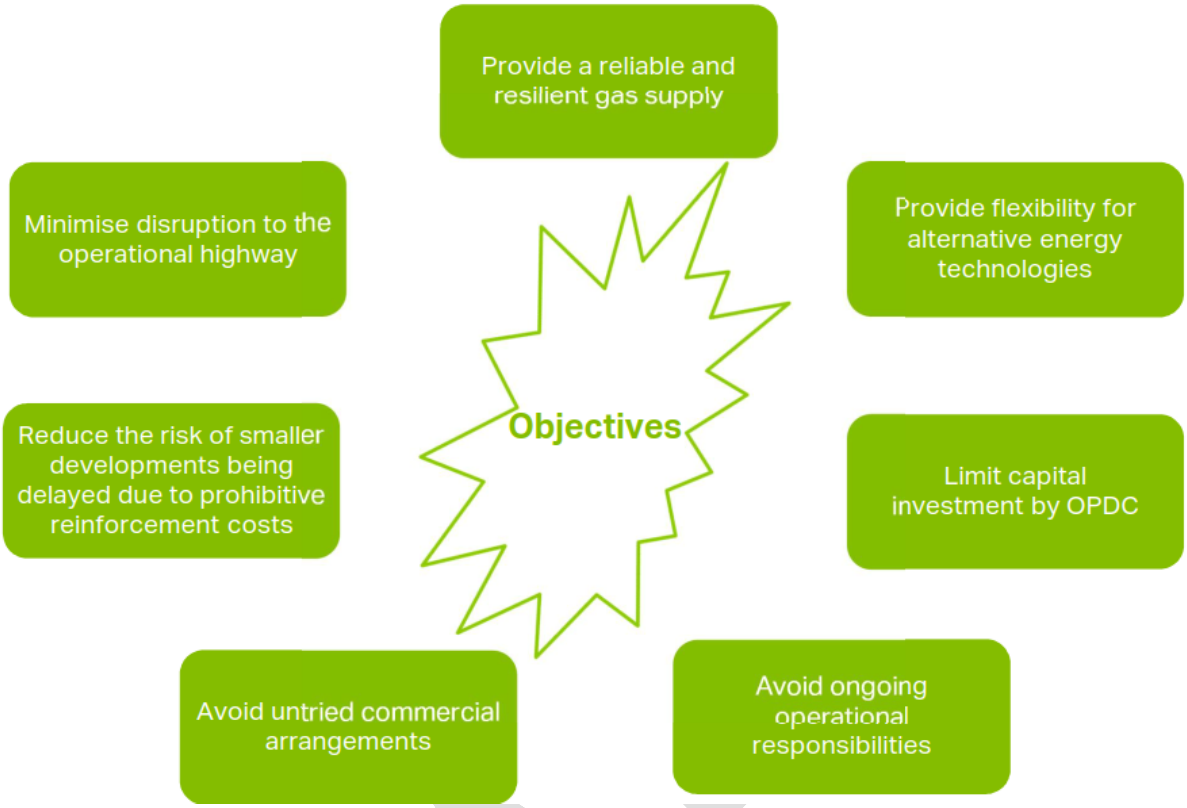

Figure 31. Objectives for the Gas Supply Strategy

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.

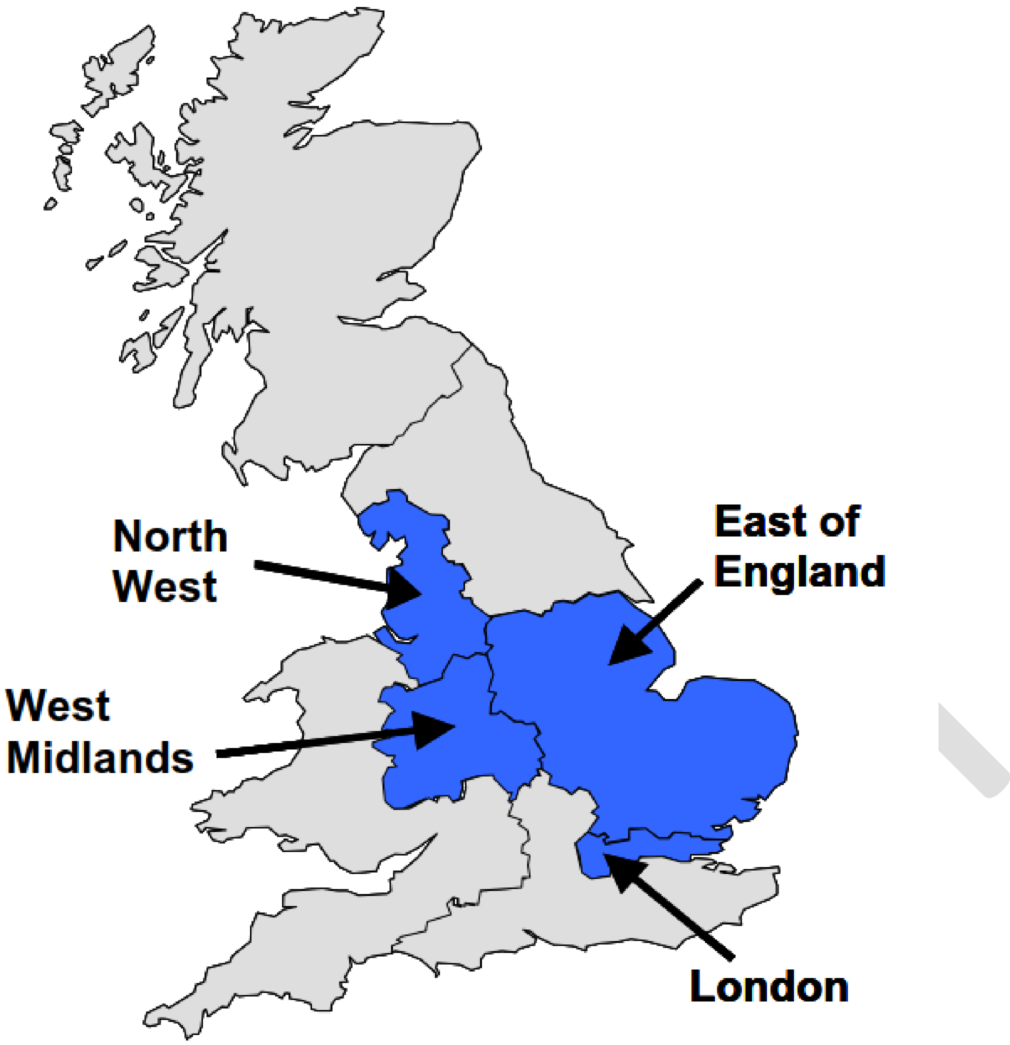

Figure 32. Geographical Layout of National Grid (Gas) Regional Distribution Networks

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.

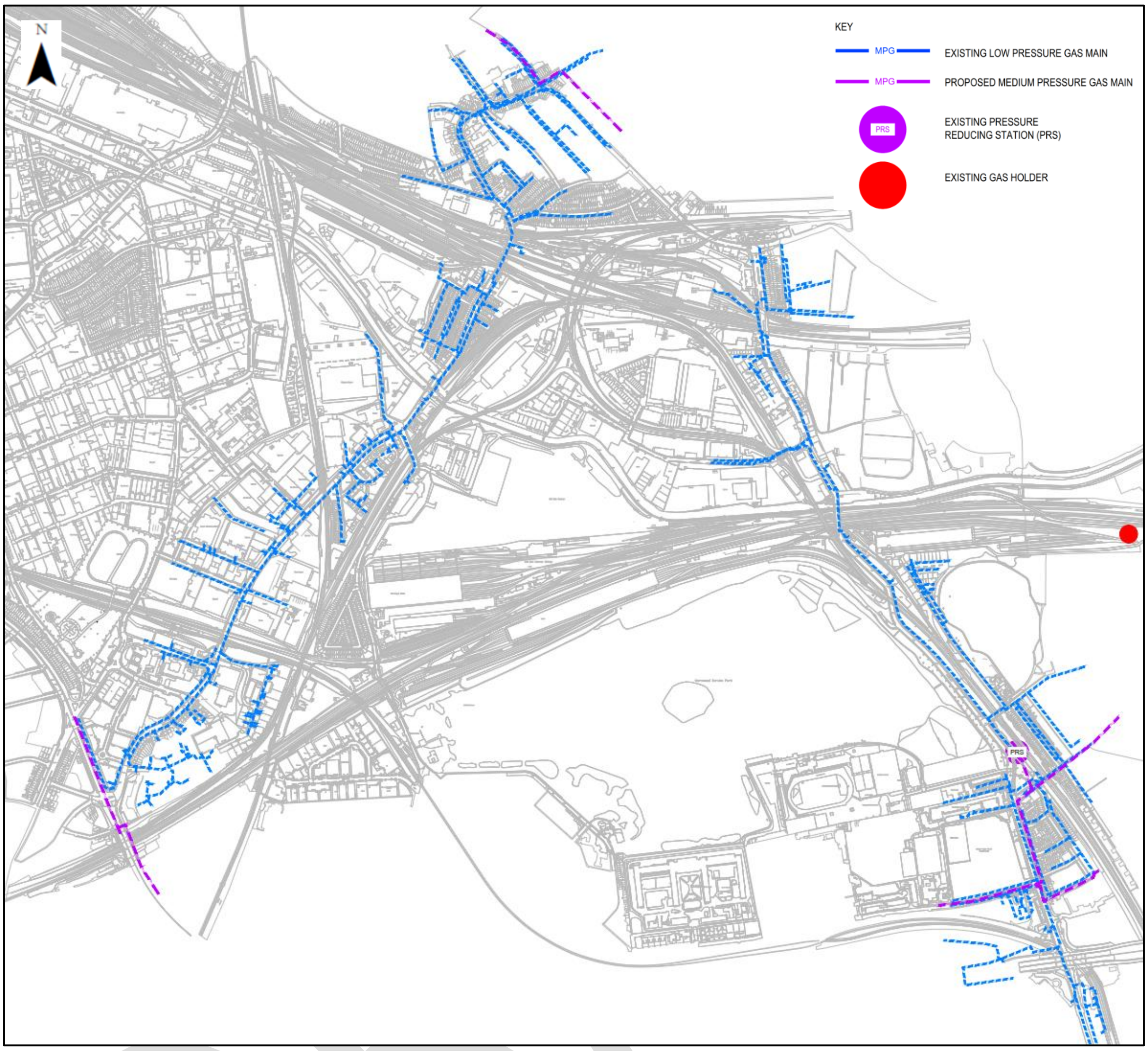

Figure 33. Plan Showing Location of Existing National Grid (Gas) Assets

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.

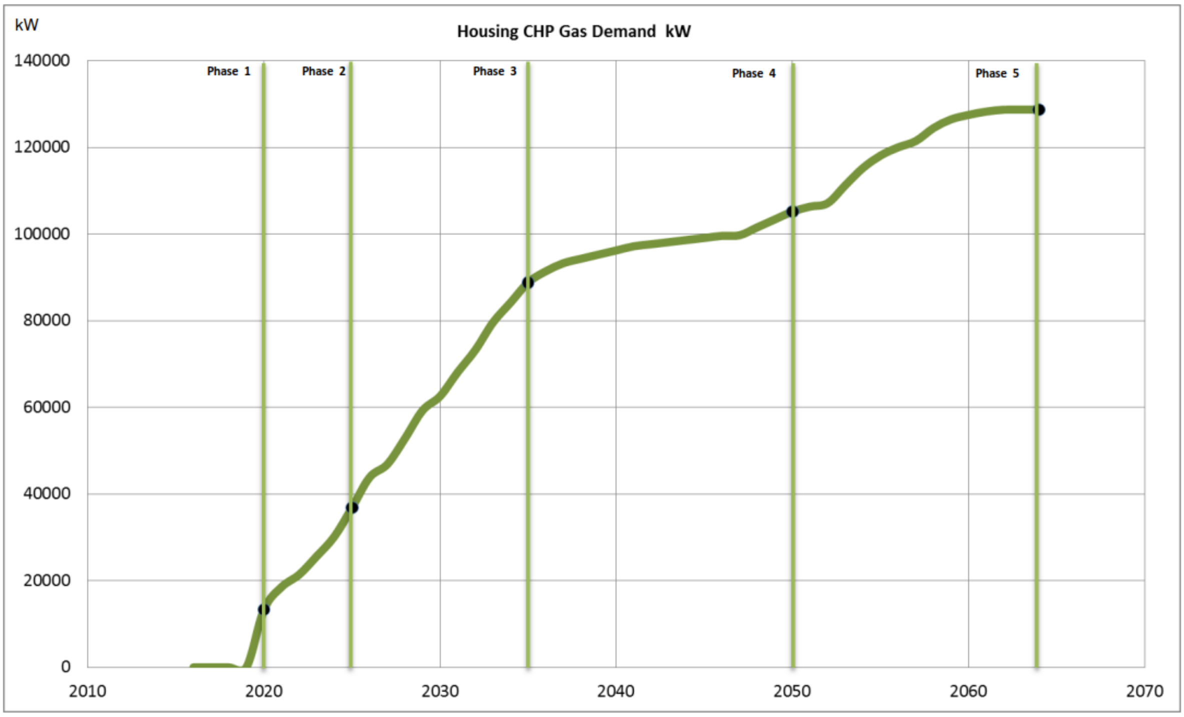

Figure 34. Gas Demand Profile

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.

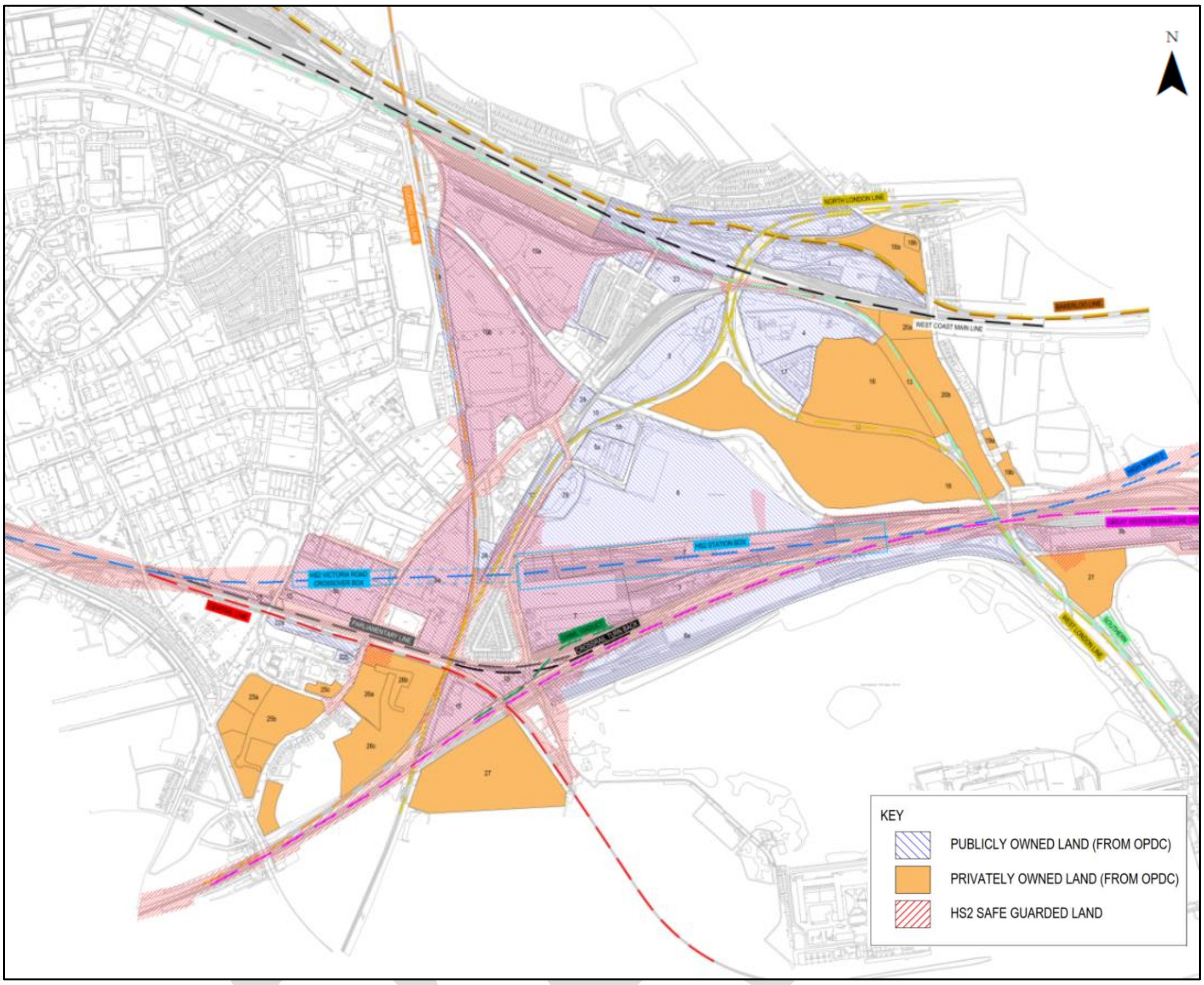

Figure 35. Land Ownership within the Old Oak Opportunity Area

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.

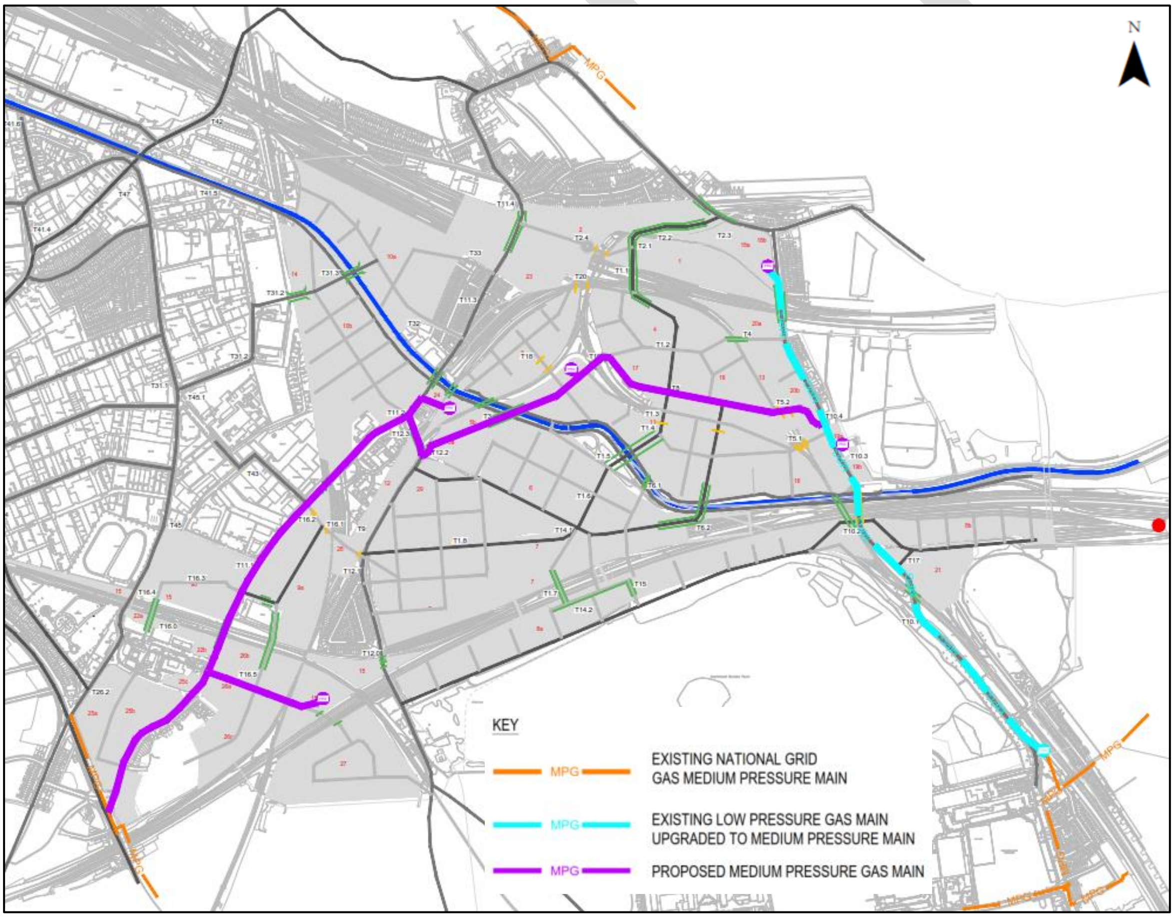

Figure 36. Potential Reinforcement of Medium Pressure Gas Networks

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.

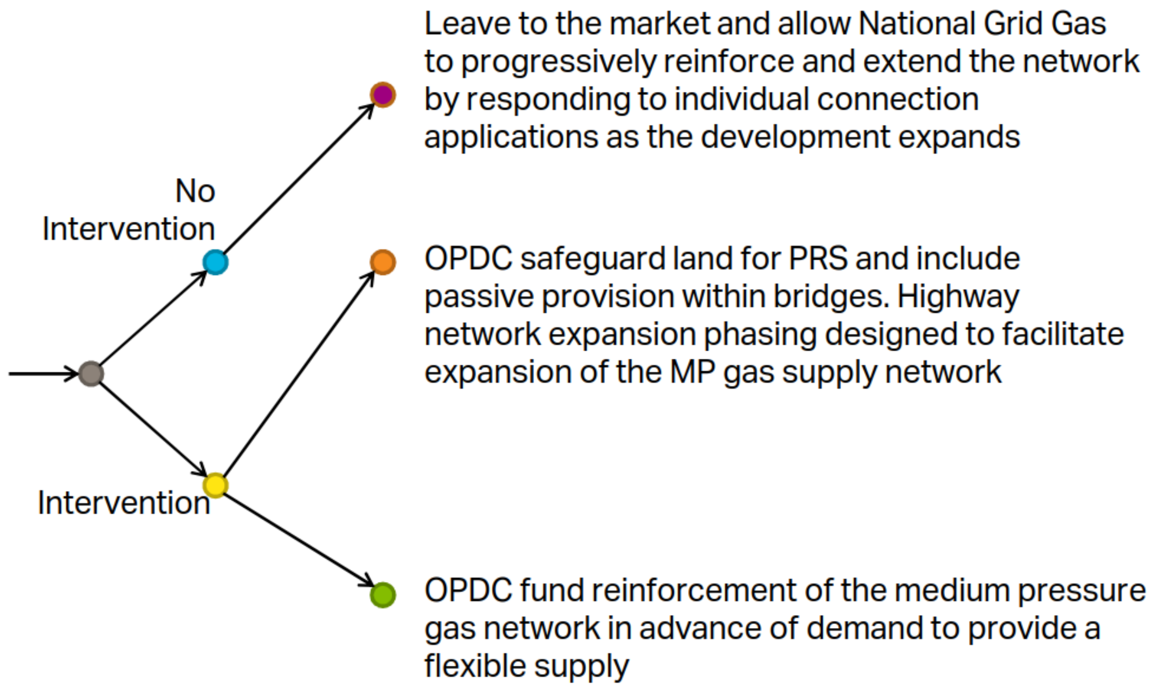

Figure 37. Varying Levels of Intervention to reinforce Gas Network

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.

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.

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.

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.

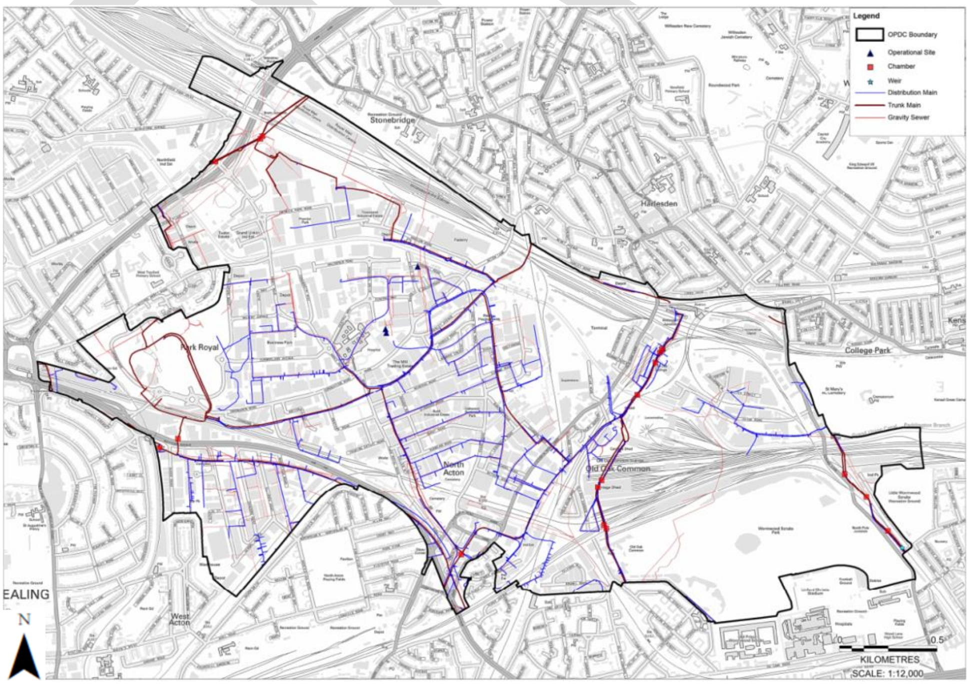

Figure 39. Thames Water Asset Location Plans

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.

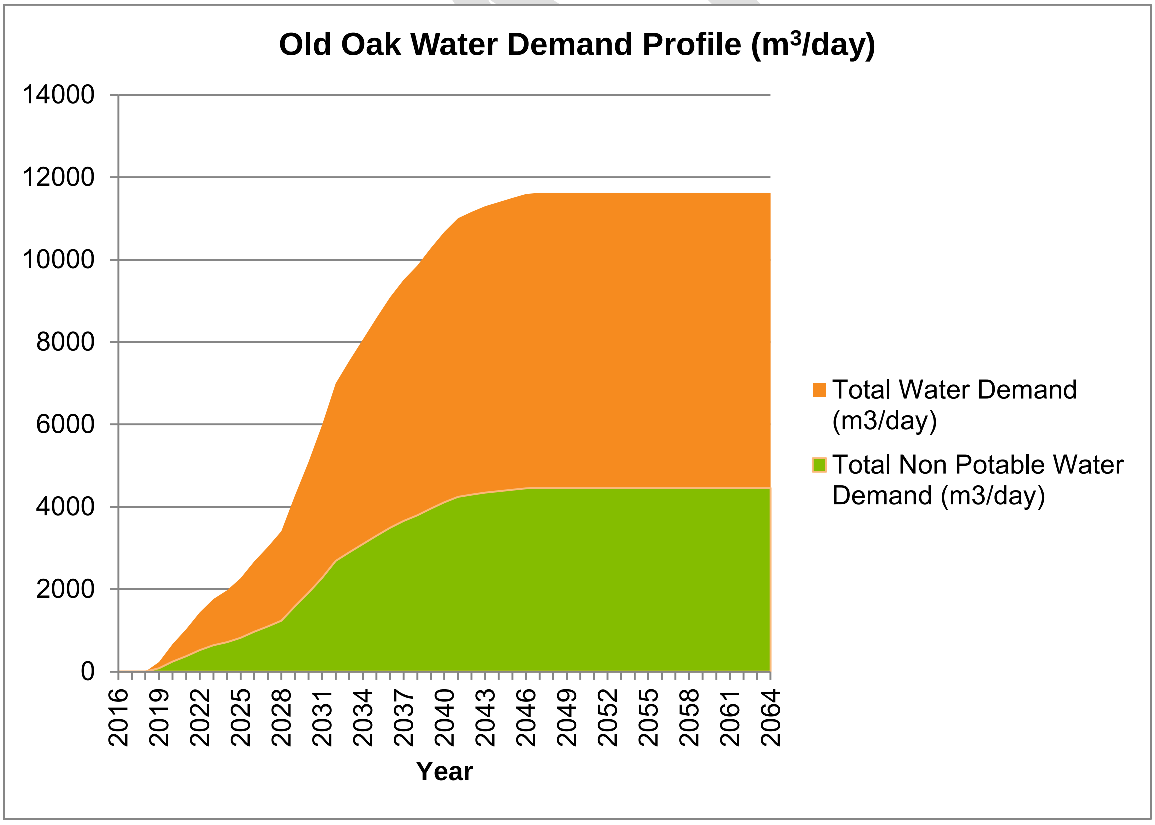

Figure 40. Potable and Non-Potable Water Demand Profile (excluding HS2)

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.

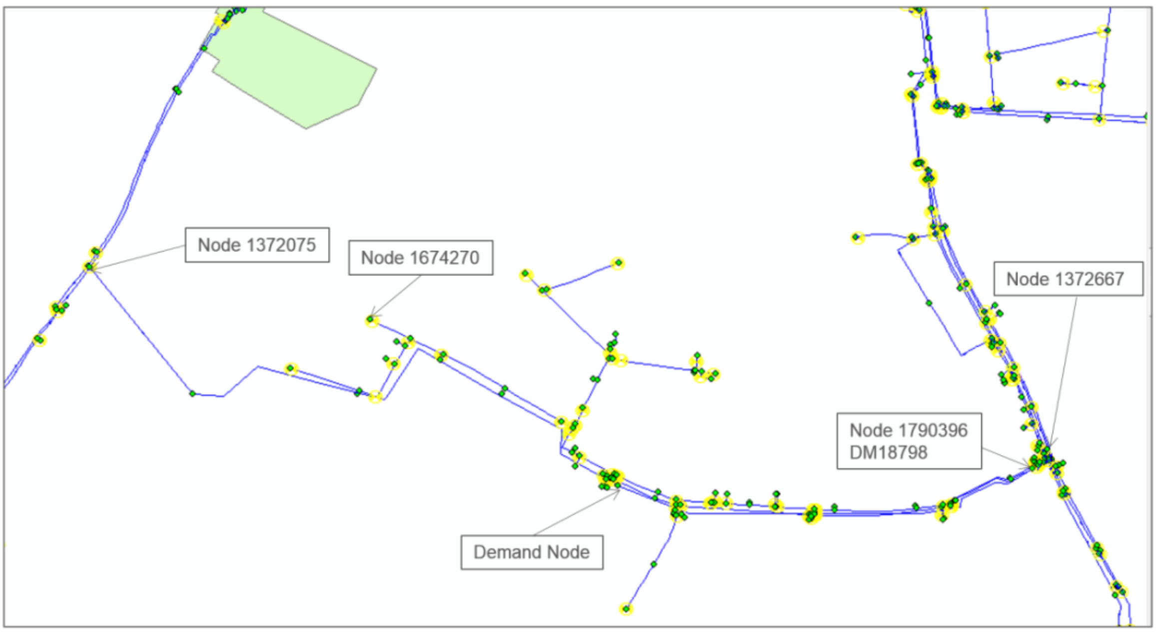

Figure 41. Extract from Thames Water Impact Assessment

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.

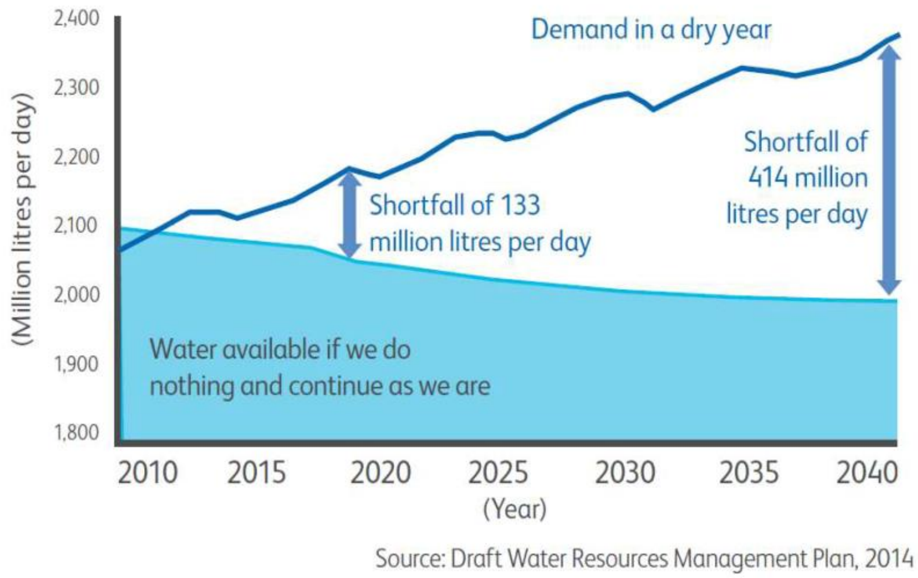

Figure 42. Thames Water Forecast Gap between Supply and Demand in London

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.

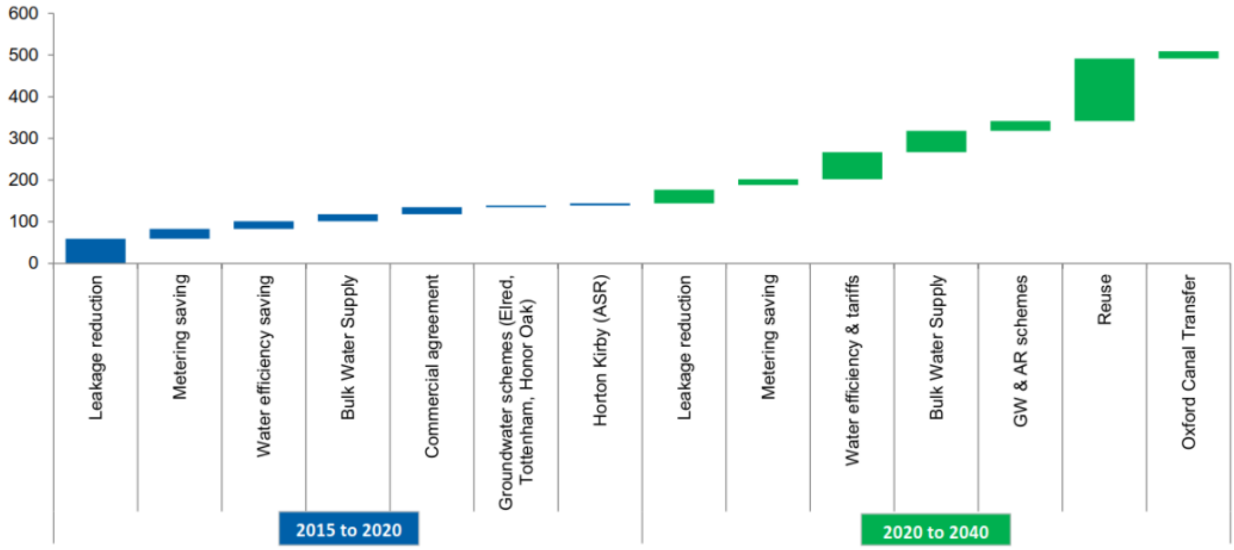

Figure 43. Thames Water Intervention Methods to Reduce Water Supply Deficit

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."

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.

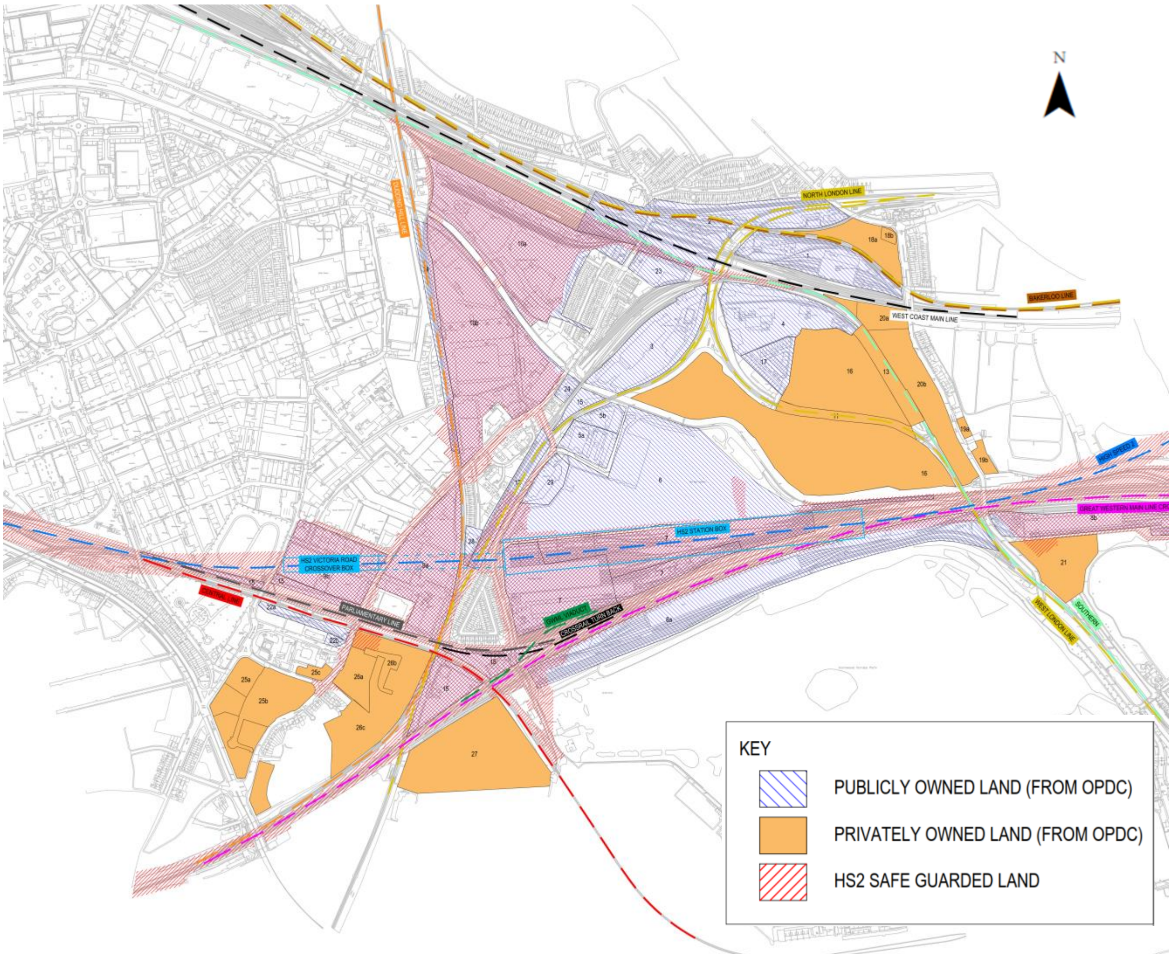

Figure 44. Land Ownership within the Old Oak Opportunity Area

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.

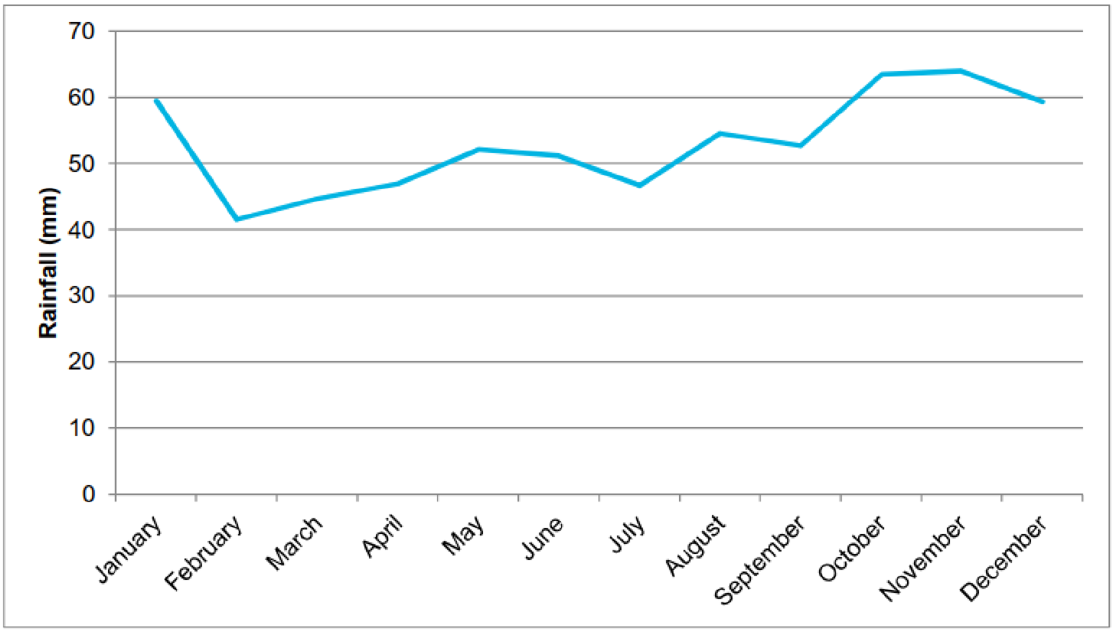

Figure 46. London Average Monthly Rainfall, as Recorded between 1960 and 2015

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.

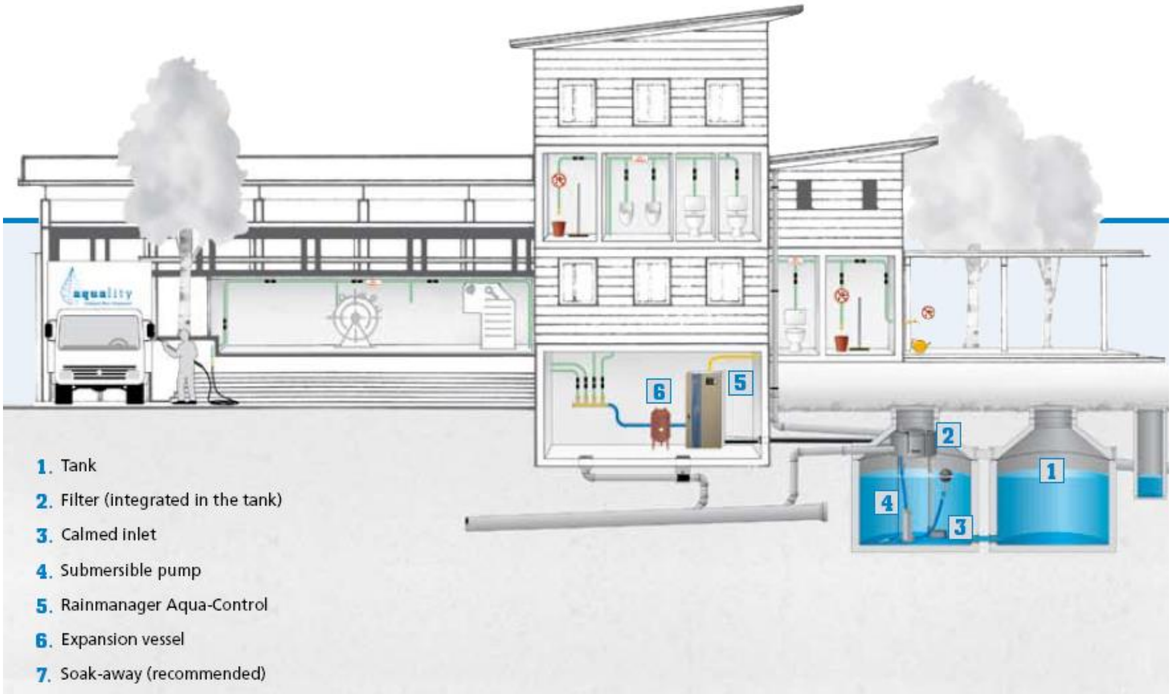

Figure 47. Typical Rainwater Harvesting System for a Large Commercial Application

(Source: Aquality)

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.

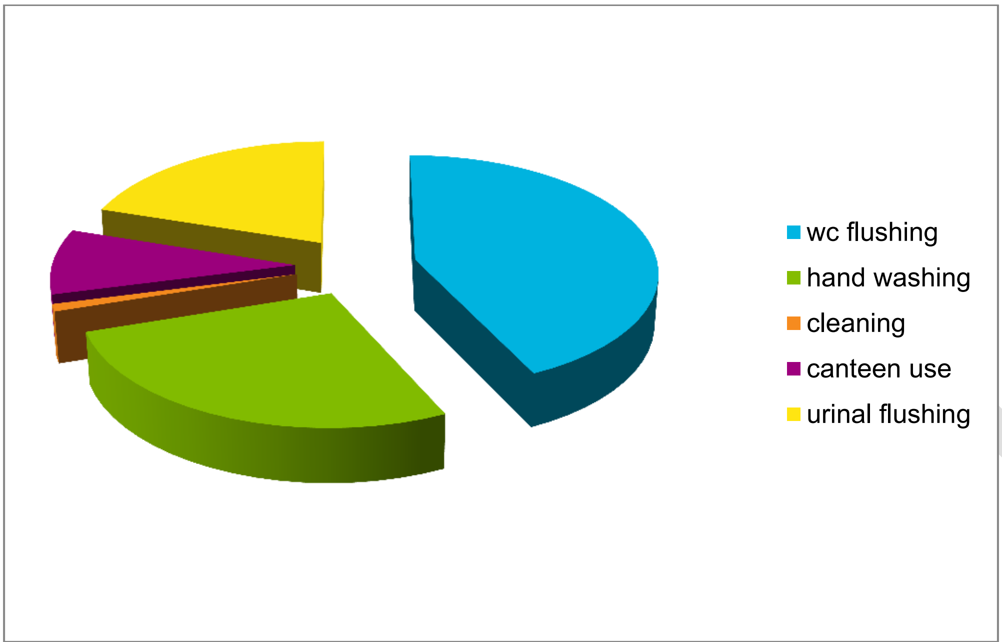

Figure 48. Water Demand in a Typical Office

(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.

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.

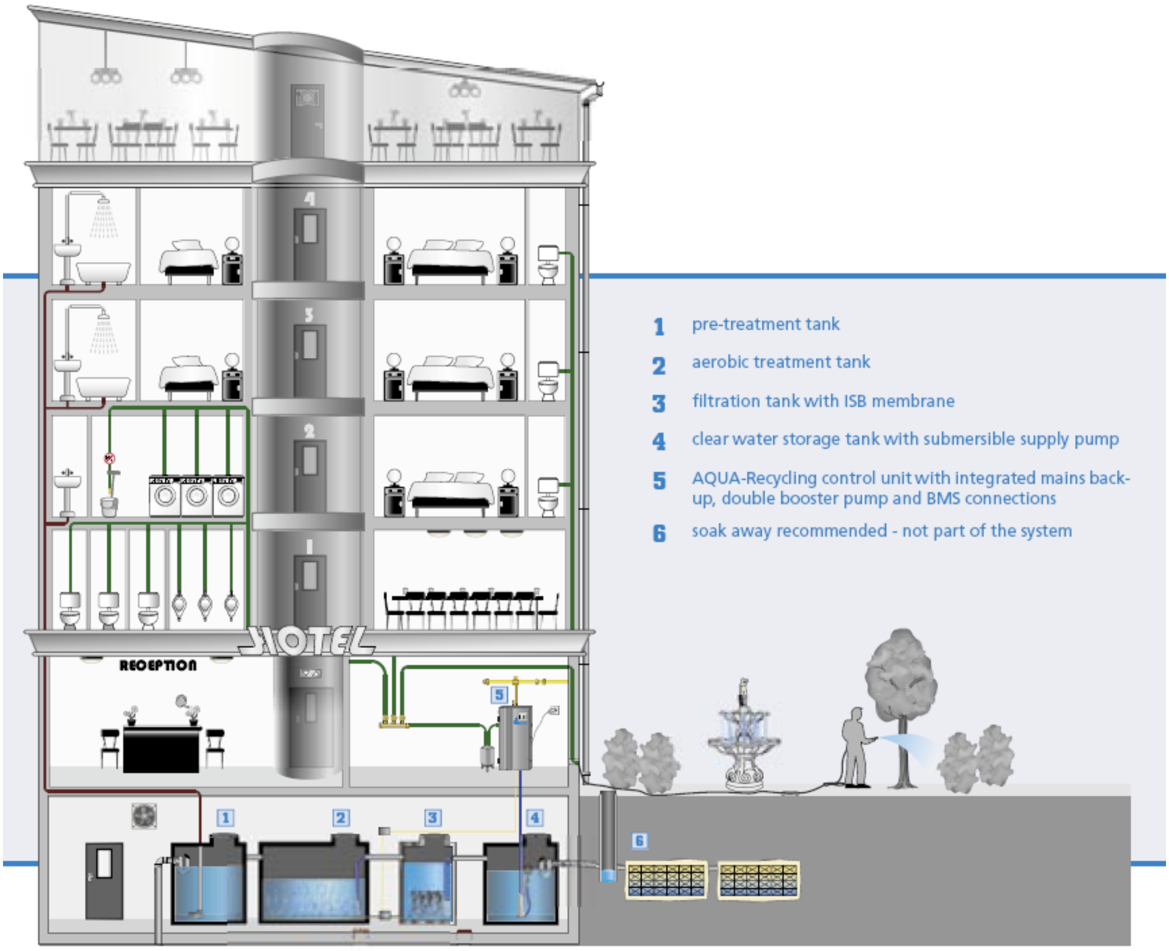

Figure 49. Typical Greywater Recycling System for a Commercial Application

(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:-

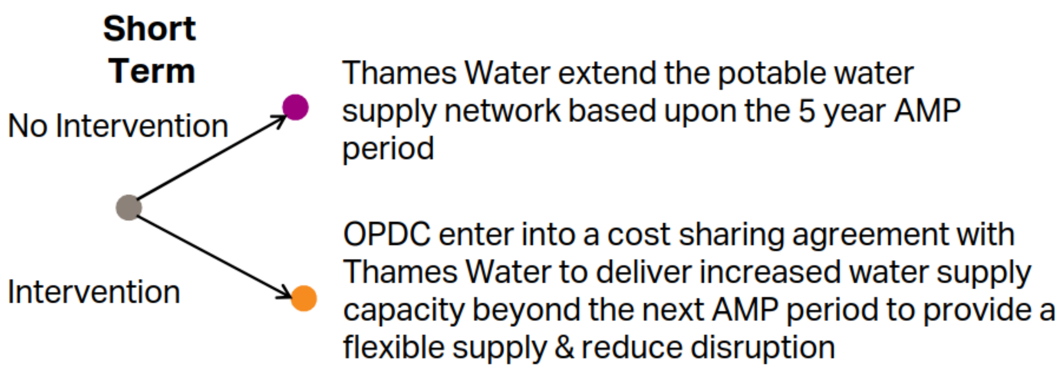

Figure 50. Varying Levels of Intervention to reinforce Water Supply Network

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:-

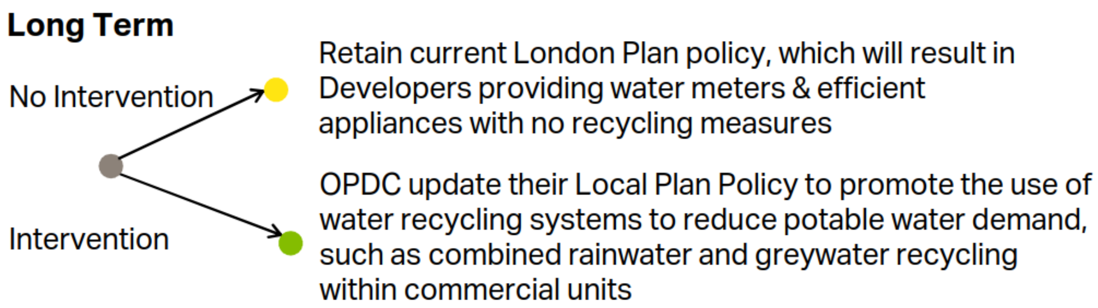

Figure 51. Varying Levels of Intervention to reduce Potable Water Demand

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 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.

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

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.

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.

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.

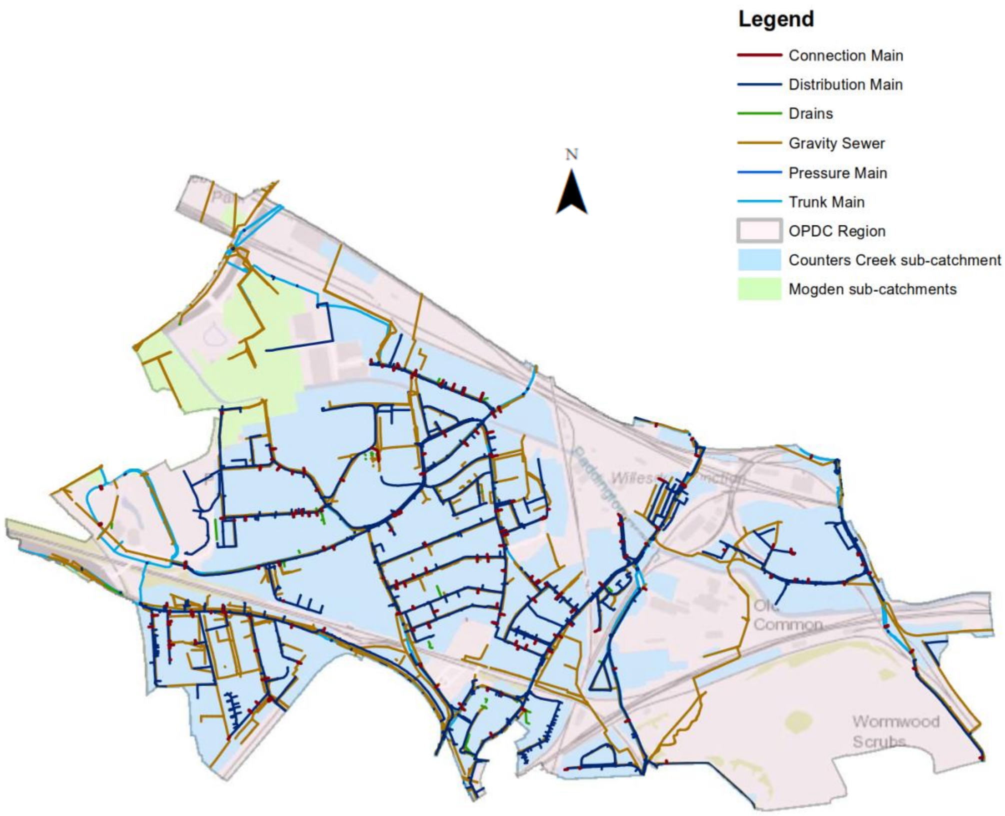

Figure 53. Existing Combined Sewers

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.

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.

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*

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 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.

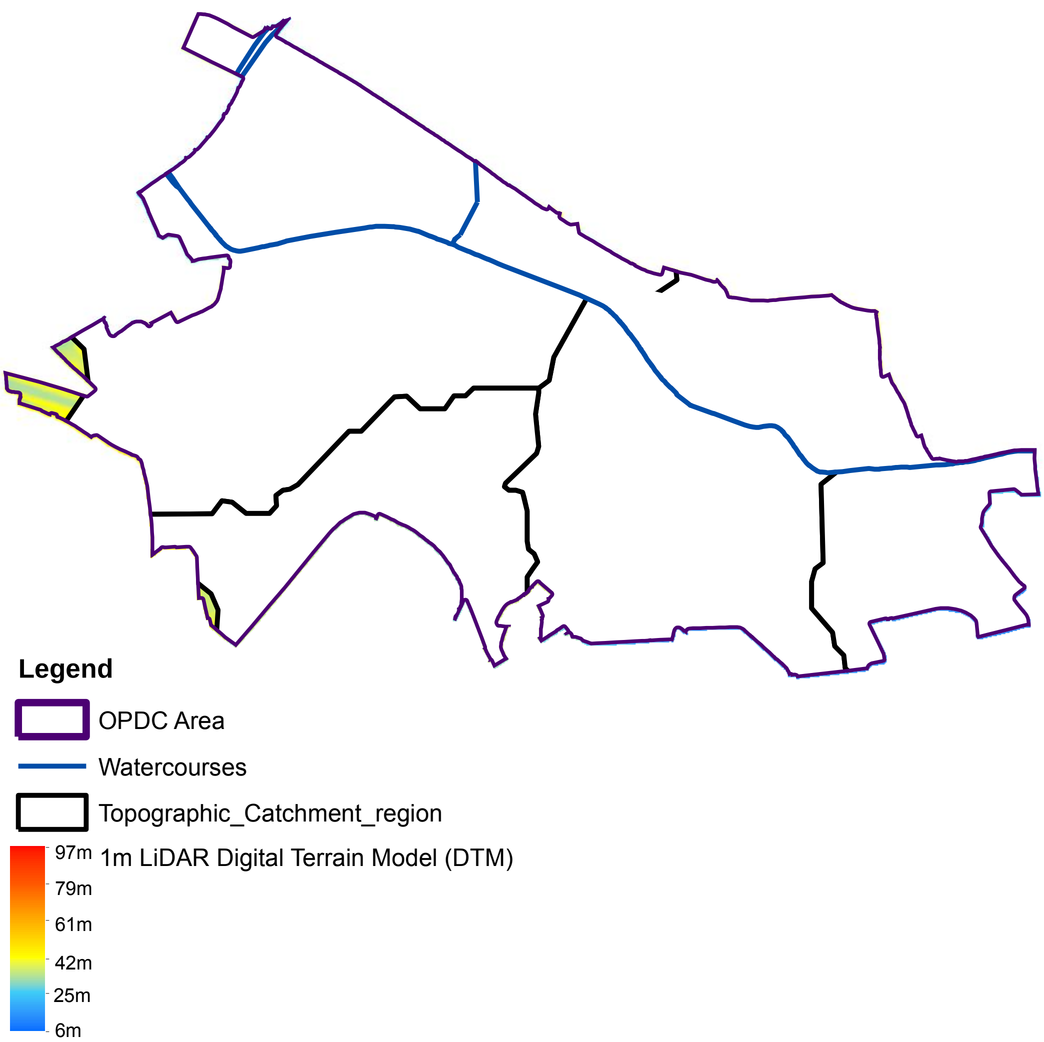

Figure 55. Surface topography and natural hydrological catchments across the Opportunity Areas

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.

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.

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

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.

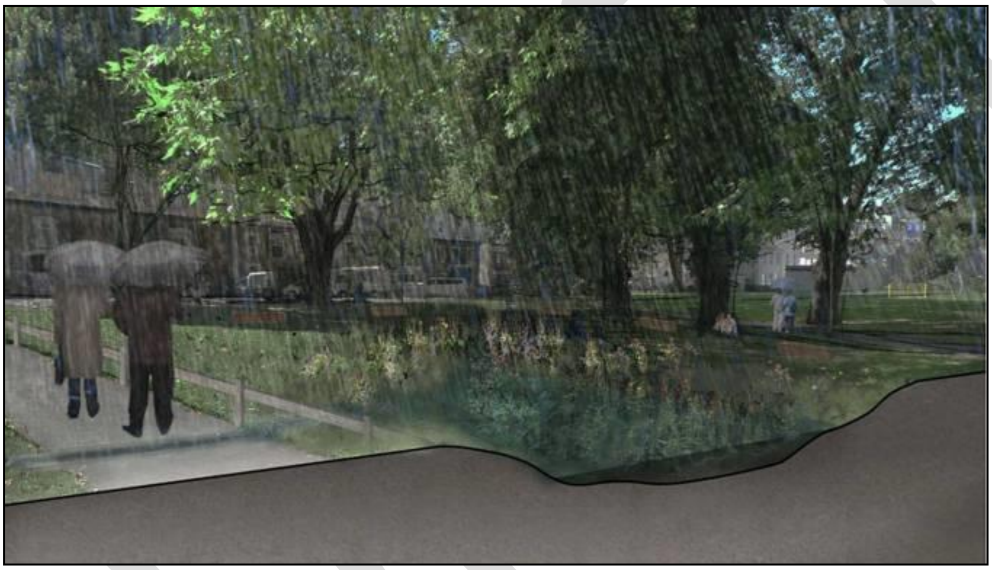

Figure 61. Detention Basin / Rain Garden within area of Multifunctional Public Open Space

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:-

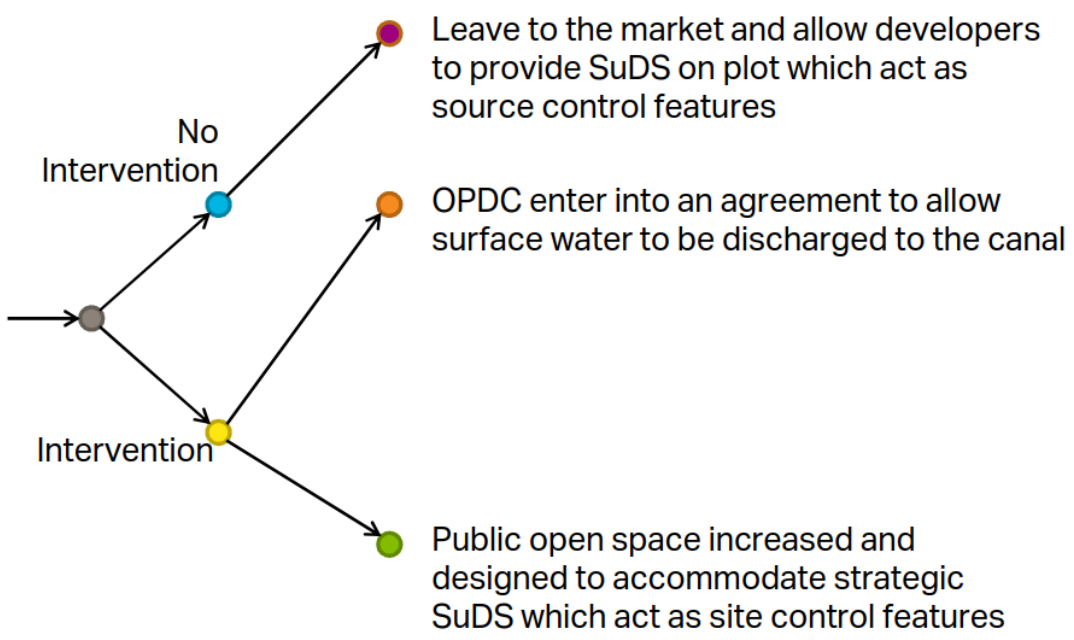

Figure 62. Varying Levels of Intervention to Manage Surface Water

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.

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

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.

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;"*

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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