

OPDC
OLD OAK AND
PARK ROYAL
DEVELOPMENT
CORPORATION

Utilities Study

Appendices A to F

2017



MAYOR OF LONDON

Appendix A Potential Heat Sources at Old Oak

A.1 Executive Summary

This technical note was prepared in December 2016 as an interim deliverable to inform the development of the strategy set out in the main body of the Stage 2 report. It summarises the low carbon heat sources that could potentially supply district or communal heat networks serving planned development at Old Oak.

Development in the Old Oak & Park Royal opportunity area could deliver approximately 26,970 new homes and over 800,000 m² of new non-domestic floor area. Development is expected to be multi-phased and capitalise on the significant transport infrastructure improvements planned for the area. Development of this scale will result in a significant demand for energy, in particular heat energy to service space heating and domestic hot water loads. Although improvements in building fabric standards continue to reduce the demand for energy in new buildings, it is expected that the development will exhibit high demand for heating, led primarily by hot water demand. An initial calculation of heat demand for the scheme at full build out indicates a peak heat load of c.100 MWth. A thermal profile of this scale and type, including appropriate levels of thermal storage, would likely mean a base heating load of 20 – 30 MWth.

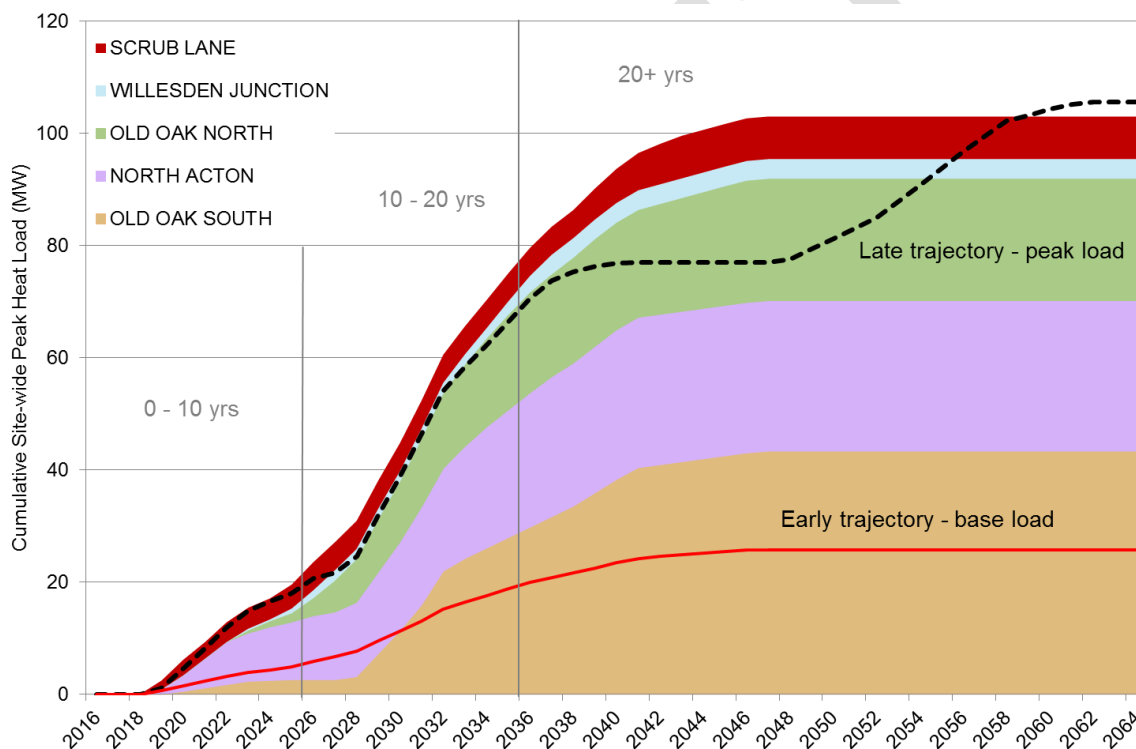


Figure A.1.1. Projected Peak Heat Demand

(Source: 'Phasing Trajectory v7.11_Early Scenario for Planning')

This compares with a recent report by Atkins¹ which estimates that the annual thermal energy requirement for residential buildings to be between approximately 64,000 – 127,000 MWh/year, and 11,000 – 81,000 MWh/year for the office and retail buildings, giving a total of between 75,000 – 208,000 MWh/year for the scheme as a whole. Appropriate sizing of thermal storage would indicate a baseload of approximately 15 – 35 MWth. A further report by Arup² indicates that the total heating energy use in the Old Oak and park Royal development is expected to be 180,000 MWh/year, which, should appropriate thermal storage be used, provide a base load of approximately 30 MWth.

¹ OPDC Environmental Target-Setting and Delivery Study, Atkins, September 2016

² OPDC & LWARB Circular Economy Scoping Study for Old Oak and Park Royal, Arup, December 2016

The density of development being planned for the area could potentially limit the viability of providing low carbon heating services via block (individual apartment building) or dwelling based solutions, due to space constraints or the visual and noise impacts of large numbers of individual heating units. It is likely therefore that a rationalised approach for the Old Oak area would include provision of centralised generation of low carbon heat and distribution to individual units via an area-wide heat network. This is also the strategy that would be required by London Plan policy. However, the long term case for an area-wide heat network, in terms of ensuring it remains a strategy that enables developments to continue to reduce their CO₂ emissions, is dependent on it being able to continue being served by low carbon heat sources.

The current outcome of London Plan policy is that in many cases small (50-300kW) gas-fired Combined Heat and Power (CHP) engines are installed to serve communal heating systems in individual developments. Gas-fired CHP has traditionally been an effective low-carbon heat supply option. This is due to local gas CHP electricity generation displacing higher carbon electricity that would otherwise come from the grid. However, as the grid decarbonises (as a result of increased penetration of renewable energy technologies, new nuclear generation, and the decommissioning of ageing coal-fired power plants), the carbon emissions benefits associated with CHP will reduce dramatically. While CHP currently provides net carbon savings compared to gas-boiler heating, it is expected that CHP will stop offering net carbon emissions reductions by the early 2030's (based on bespoke marginal emissions factors for CHP deployment). However, the calculated savings in national Part L calculation methods could start to show no saving much earlier due to the use of average rather than marginal grid electricity emission factors for these calculations. Some projections and methodologies show that CHP will no longer offer carbon savings by 2021-2022³.

Alternative dwelling or block based strategies for ensuring the low-carbon supply of heat include renewable energy sources such as solar thermal or PV systems, air source heat pumps and ground source heat pumps. However, the density of the planned development (expected to be around 300-600 dwelling per hectare) may constrain the potential of some of these options for very tall buildings. For example, the capacity of solar thermal systems and solar photovoltaics could be constrained by the proportion of unshaded roof and façade area in relation to the overall development floor area. Similarly, the large-scale deployment of air source and ground source heat pumps could be limited by the available footprint and roof area in relation to building height and density. It is therefore expected there will be merit in utilising district energy networks, where these can be served by local low carbon heat sources of sufficient capacity. If necessary, local low carbon heat sources could be supplemented with gas CHP to provide a multi-source strategy for resilient heat generation.

A.1.1 Available Heat Sources to Serve District and Communal Systems

A number of large potential local heat sources have been explored. These are shown geographically in Figure A.1.2, and include:

- Water sources (including the London Aquifer and the Grand Union Canal);
- Taylor's Lane Power Station (possibility of recovering heat from an existing power station);
- Powerday (potential waste to energy plant);
- Heat recovery from the sewage network;
- Heat recovery from transport tunnels (including from ventilation shafts, tunnel linings and water drainage from HS2 tunnels); and
- Heat recovery from data centres.

Table A.1.1 provides a high level summary of the findings for each heat source, based on stakeholder discussions, and a conventional gas CHP comparator, including:

- An initial estimate of the available heat capacity that could be delivered to a heat network;
- The relative carbon intensity of the heat source (kg CO₂ per kWh of heat delivered, excluding network losses) based on current SAP 2012 emission factors and for proposed SAP 2016 emission factors;

³ An Operational Lifetime Assessment of the Carbon Performance of Gas Fired CHP and District Heating, CIBSE Technical Symposium, ARUP, April 2016

- A relative rating of the likely capital and operational costs; and
- Anticipated delivery constraints.

A red, amber, green assessment has been applied to show their relative merits against these issues.

Heat sources shown red for deliverability are considered unlikely to make a contribution to meeting Old Oak's heat demands. All other sources explored are considered to have potential to serve heat networks at Old Oak and are considered further below.

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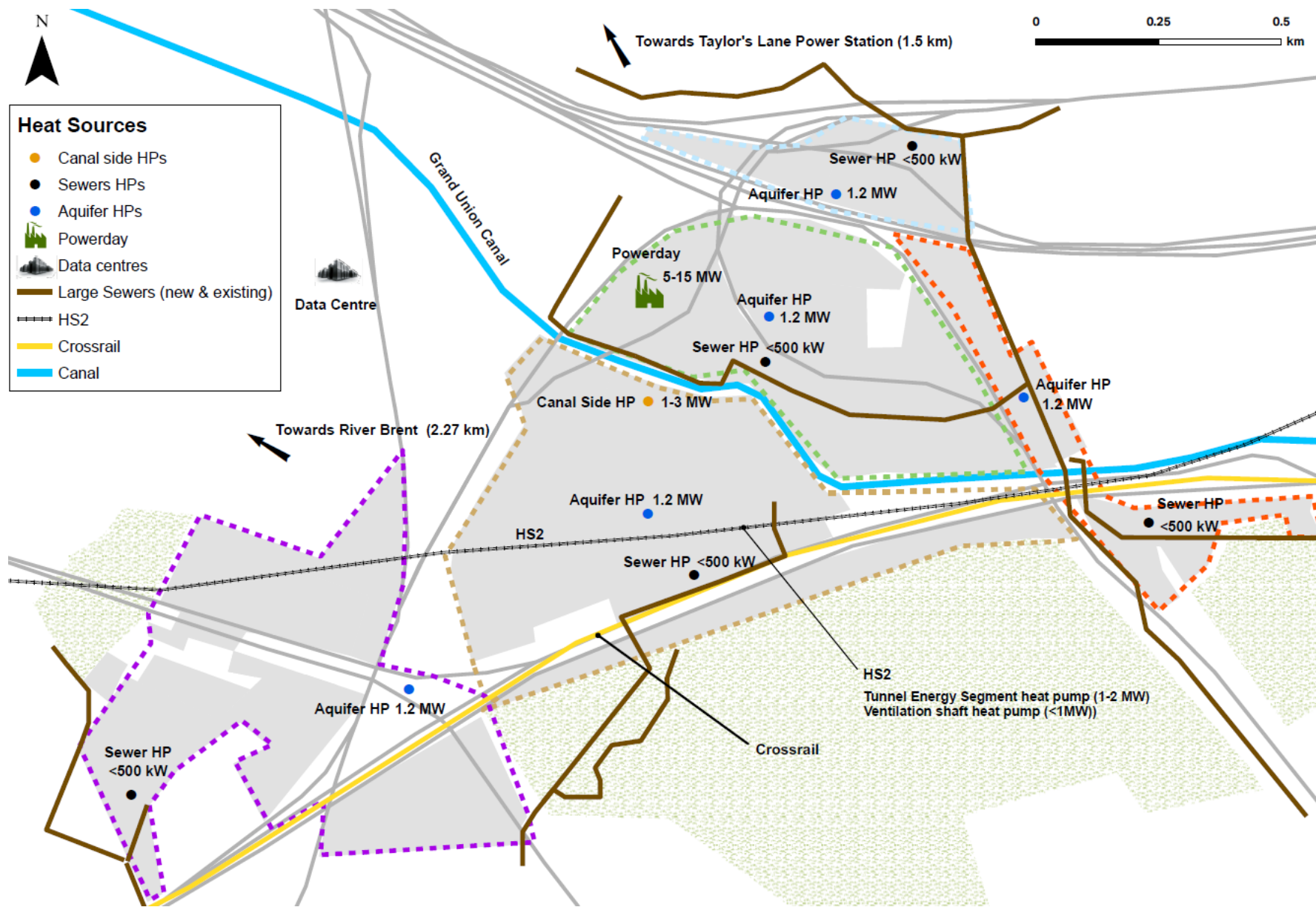


Figure A.1.2. Potential Heat Sources

Heat source	Delivered Heat MWth	Carbon intensity of heat generated (kgCO ₂ /kWh)		Relative Capital Cost	Relative Opex	Deliverability
		SAP 2012	Proposed SAP 2016			
Grand Union Canal heat pump	1 – 3 MW	0.251	0.192	Medium	Medium	Heat or cooling extraction from the canal appears a deliverable option that would be supported by the Canals & Rivers Trust (CRT). Water abstraction infrastructure will be needed adjacent to the canal and necessary licenses obtained and renewed
London aquifer heat pump	<1 (per borehole)	0.227	0.174	High	Medium	Extraction of water from the aquifer will require sinking boreholes to a depth of c.100m. Extraction rates will be uncertain until boreholes are sunk, but this is a potentially deliverable source of heating and cooling that has been exploited elsewhere in London. Necessary licenses would need to be obtained and renewed.
Taylor's Lane Power Station heat recovery	-	0.083	0.063	High	Low	This option is not deliverable. E.ON have confirmed this plant is only licensed to operate as a peaking plant 100 hrs p.a. E.ON have no immediate plans to provide alternative plant.
Energy from Waste	5 – 10 MW (potentially more)	0.069	0.103	Low	Low	This option is reliant on third party provision of an energy from waste facility and a successful planning consent and permitting. Thrust boring under railway lines to distribute heat and identifying an entity to purchase and supply heat would be required. While this creates some uncertainty it appears possible that this option could be delivered.
Sewage network heat pump	200 – 500 kW (per installation)	0.214	0.164	Medium	Medium	This is a relatively novel technology for the UK but has been delivered successfully by Suez and others in Europe. Thames water is positive about a potential pilot, but this will depend on commercially attractive terms. 6 number of 200 m length heat recovery installations could be provided.
Ventilation shaft heat pump	<1	0.242	0.186	Medium	High	The Bunhill heat network has shown that tunnel heat recovery is possible to deliver, however, the main HS2 tunnel vent shafts are outside the Old Oak area and station vent shafts would more logically supply loads within HS2 rather than a wider network.
Tunnel Energy Segment heat pump	1 – 2 MW	0.241	0.185	High	Medium	This option would be reliant on HS2 for its delivery, discussion with HS2 confirm there is no plan to install this technology.
Tunnel drainage heat pump	Negligible	0.265	0.203	High	High	This option would be reliant on HS2 for delivery, water is expected to flow to tunnel vent shafts outside the Old Oak area and hence considered undeliverable
Data centres heat recovery	TBC	0.200 (summer) 0.265 (winter)	0.154 (summer) 0.203 (winter)	Medium	Medium	The deliverability of this option is unknown and would require further discussion with the operator. Heat pipework would need to cross land outside the development delivery parcels. However it is in relatively close proximity to a planned HS2 logistics tunnel.
Gas-fired CHP comparison	Any capacity	0.054	0.216	Low	Low	Delivery within control of OPDC or private developers will require medium pressure gas supply but this is required for resilience for all other options. Will need to comply with London Plan air quality standards.

Table A.1.1. Summary Table of Potential Heat Sources at Old Oak

A.1.1.1 Thermal Capacity of Available Heat Sources

Overall, there are a number of potential heat sources that could be used and should be investigated further. It can be seen from Table A.1.2 that if all could be delivered they could meet most of the expected baseline heat demand of 20 – 30 MW. The potential heat output from the data centre will depend on a detailed investigation of the technical challenges of implementation and the interest of the operator in enabling heat recovery.

The potential availability of significant low-carbon heat sources supports the case for developing a district energy solution as part of the masterplanning work.

Heat Source	Viable heat source (MW)
Grand Union Canal serving heat pumps	1 – 3 MW varies seasonally
London aquifer serving heat pumps	5 no. 1.2 MW open loop boreholes = 6 MW
Sewage network serving heat pumps	5 no. 200m installations = 1 – 3 MW
Energy from Waste	3 – 10 MW (potentially more)
Total	11 – 22 MW

Table A.1.2. Summary of Recommended Heat Sources

A.1.1.2 Carbon Content of Heat

Of the heat sources explored, waste heat from an EfW facility would offer the lowest carbon heat source in the short to medium term, and potentially the lowest cost, although this would be subject to negotiations with the EfW operator. Low temperature heat sources serving heat pumps are more carbon intensive than EfW, but would quickly become less carbon intensive than gas CHP and the carbon content of the heat they provide will continue to fall as grid electricity emission factors fall, meaning they would be future proofed for long term carbon savings. The higher the temperature of the heat source the higher the efficiency of the heat pump and the lower the carbon emissions per unit of heat delivered. The chalk aquifer and sewers are expected to have higher temperatures than canals in winter and hence slightly improved carbon emission factors.

The carbon content figures shown in Table A.1.1 assume that technologies will be serving heat networks with current typical operating temperatures of 80°C flow and 60°C return. However, industry best practice encourages lower circuit temperatures and larger temperature differences between supply and return (delta T of 30°C recommended). The carbon content for all heat pump technologies will reduce if serving low temperature district heating networks of 70°C flow, 40°C return. As the majority of low carbon heat sources identified rely on heat pumps for their exploitation there is a strong argument for exploring the use of low temperature district heating networks at Old Oak.

A.1.1.3 Costs and Deliverability

Heat offtake from an EfW facility could have relatively low costs both in capital and running costs terms, relative to other heat sources, as the heat generation capital and maintenance costs would potentially be met by the EfW provider. A tariff would however need to be paid for the heat. Most of the heat pump sources will require investment in related infrastructure, for example: construction of boreholes to reach the aquifer, construction of a leat and associated water filtration to extract water from the canal, or implementation of heat exchangers and modification of the sewer - all of these are likely to have higher capital costs than conventional gas CHP solutions.

It is assumed in all cases that the heat supply plant would be located in an energy centre building which would require medium pressure gas supplies as gas boilers are expected to be required for backup or peak demands in all cases.

A.1.2 Findings and Recommendations

A.1.2.1 Geographic Distribution of Heat Sources

Phasing of infrastructure investment against phasing of planned development, means it is likely that a number of energy centres will be required serving the different areas within Old Oak. These can seek to exploit the available local heat sources and be delivered to suite the specific phasing of development.

Having reviewed the available heat sources there are some notable geographic and phasing considerations. Old Oak North and the Car Giant Site are well served by heat sources, having potential access to heat from EfW, the canal, sewers and from the chalk aquifer.

Old Oak South could access heat from the canal or boreholes and, assuming a primary heat network extension across the canal, could utilise heat from an EfW facility, although the heat demand for Old Oak North could potentially absorb a large proportion of the available heat from EfW.

The only alternative low carbon heat sources identified locally to development in North Acton would be open loop boreholes and possibly sewer heat extraction. Any work to develop a network in these areas should seek to test the viability of utilising these sources, to avoid locking the development into a gas-CHP only solution.

While each development area should seek to exploit the sources available locally, there will be potential merit in terms of resilience in seeking to link up local networks over time. Creating a district wide network would also enable sharing of available low carbon sources over a wider area.

A.1.2.2 Heat Source Summary of Findings

A.1.2.2.1 Energy from Waste

The most attractive of the low carbon heat sources is considered to be an EfW facility proposed by Powerday and located in Old Oak North. Powerday plans to install a medium-size EfW plant on their site (potentially offering up to 5 MWth of heating capacity). There would be potential for this capacity to be increased to 10MWth based on current waste throughputs, or up to c.50% of the total anticipated base load).

The carbon intensity of the available heat is expected to be very low and to remain low into the future. Additionally, the temperature offtake of any EfW heat export is expected to be high enough to serve a heat network without the need to use heat pumps to raise temperatures to those useful for a heat network. Powerday has significant time remaining on their lease, meaning they could remain a reasonably long-term energy supplier subject to a supportive planning framework, successful permitting applications, and appropriate contractual arrangements. In addition, the proximity of the proposed EfW facility to the development around Old Oak, means the costs of connecting low carbon heating infrastructure to nearby buildings is likely to be low.

With some of the earliest development coming forward now (e.g. Genesis and North Acton), low carbon heating from an EfW facility could form part of the masterplan energy strategy from the outset. Although subject to programme constraints, the upgrade and realignment of Victoria Road (linking the Old Oak site to North Acton) that is planned as part of the HS2 works offers a potential opportunity for installing DH pipework along this route as part of the works. Powerday has confirmed their interest in serving part (or more) of the new development. Initial calculations suggest that EfW could meet most of the baseline heat demands of the Car Giant site.

The potential air quality impacts and odours resulting from the proposed EfW facility will need to be considered further during the masterplan phase. However, OPDC should seek to protect Powerday as a potential heat source by ensuring any future planning approval for an EfW facility is conditional on there being a heat offtake and on the use of an advanced thermal technology rather than incineration. OPDC could also help protect the long term use of the site for waste treatment operations through a suitable land designation within the local plan.

A.1.2.2.2 Sewer Heat Recovery

There are potentially large heat resources available in the local sewer network. This technology would use heat exchangers laid on the floor of sewers to extract heat from the sewerage flow, with heat pumps operating to increase the low-grade temperature. Although this would act only as an indirect heat source, requiring heat pumps to increase the temperature of a secondary loop to those required by an area-wide heat network, the warm source temperature (of the sewerage) would provide a significant source of low grade heat. It is anticipated that up to 3 MW would be available, should installations of heat recovery systems of the type used in France by Suez be deployed. (It is noted that other sewer heat recovery technologies are under development and trialled, which could potentially mean more heat could be recovered.) However, in order to maximise the potential of this resource, a number of local heat substations/energy centres would need to be installed around the Old Oak site. This is because the technology currently limits the length of heat exchangers arranged in series to approximately 200 m (in order to avoid hydraulic and pumping problems). Each 200 m length of heat exchangers is expected to produce 200 – 500 kW of heat. The heat capacity estimates provided in this note assume that 5 installations would be created close to energy centres delivered to serve each main phase of development. There is potential for greater implementation possibly directly serving individual development blocks. The commercial and contractual arrangements for exploiting such sources have yet to be tested in the UK. Thames Water is supportive of the principle of working with OPDC to pilot this technology at Old Oak.

A.1.2.2.3 Open Loop Boreholes

Another potential large heat resource is the London Aquifer. The aquifer is a large reservoir trapped in porous rock (e.g. chalk) deep underground, at a depth of c.100m. An open loop system could be installed in boreholes that allow water from the aquifer to be brought to the surface. This water (typically at c.14°C) would be used as a source medium for water-sourced heat pumps to elevate temperatures in a secondary circuit up to temperatures suitable for an area-wide heat network. In order to maintain aquifer water levels, the extracted water would need to be reinjected back into the reservoir after heat exchange has been undertaken. Similarly, in order to maintain aquifer temperatures, the temperature change of reinjected water, relative to the extracted water, would need to be limited to c.10°C. Similarly, there would likely be limitations to the total amount of heat that could be extracted throughout the year. If abstraction rates of c.20 l/s per borehole were obtained, it is expected that up to c.1.2 MW of heat could be provided to a heat network via a heat pump. However, in order to avoid thermal short-circuiting of the aquifer reservoir, borehole pairs would need to be spaced significant distances from each other. This limits the potential use of the aquifer as a heat source, and would require borehole pairs to be spaced out across the Old Oak site. It is assumed that at least 5 borehole pairs could be accommodated and delivered close to energy centres or major load centres. In combination these could potentially deliver up to 6MW of heat based on water extraction rates obtained for other nearby boreholes. However, the water abstraction rate cannot be guaranteed until the borehole has been sunk, and this could significantly impact on estimated heat extraction should abstraction rates prove low.

A.1.2.2.4 Grand Union Canal

The Grand Union Canal can also be used as a significant low-grade heat source. Discussions with the Canals & Rivers Trust (CRT), and research into government sources⁶, indicate that between 1 – 3 MW of heat can be extracted from the canal as a source medium for a water source heat pump. In the same way that the London Aquifer is used as a heat source, water would be extracted from the canal in order to extract heat from it, via a water source heat pump, before being pumped back into the canal at a lower temperature. Limitations on the temperature changes that CRT would allow in the canal will limit the amount of heat that could be extracted from the canal throughout the year. The use of this source will require an energy centre site to be safeguarded close to the canal as well as work to the canal wall to create a leat to house the water off-take equipment.

A.1.2.2.5 Heat Recovery from Data Centres

Heat recovery from nearby data centres (in particular the large Powergate facility to the immediate west of the Old Oak site), could be used as another low grade heat source. The high electrical loadings of data centres mean they often experience significant cooling loads, and therefore require significant heat rejection equipment. This low grade heat could be recovered for use as a source medium for heat pumping to serve an area-wide heat network. Although the greatest opportunity for heat recovery is during summer (when the opportunities for free cooling in the data centre are limited, and the ambient conditions could allow recovery

of heat to occur at higher temperatures and therefore higher heating efficiencies), this is also when the demand for heat at Old Oak will be at its lowest. This non-coincidence between load and opportunity may be balanced however, if heat can be extracted efficiently during summer months and stored in seasonal storage facilities for use during winter months. A potential tie-up between heat recovery at the data centre/s and a ground source system such as the London Aquifer could provide an opportunity to maximise the use of these two technologies. This could involve excess heat being recovered from the data centre during the warm summer months, and stored underground in the aquifer for reuse during subsequent winter months. This could potentially increase the efficiency and scale of the aquifer's use as a heat resource during winter, while also maximising the efficiency of heat recovery from the data centre in the summer. However, such an approach would be subject to further detailed discussion with the Environment Agency (EA), on successful ground source water abstraction and rejection rates and close management of water and environmental temperatures. It is further noted that the potential heat recoverable from the data centre will depend on a detailed investigation of the technical challenges of implementation and the interest of the operator in enabling heat recovery.

As noted above many of these heat sources are low temperature sources that act as a source medium for heat pumps to elevate temperatures up to the operating temperature of a local heat network. In order to maximise the efficiency of the heat pumps, it would therefore be beneficial to reduce the operating temperatures of the heat network (typical operating temperatures of heat networks in the UK are c.80/60°C; reducing these to c.70/40°C would increase network and heat generation efficiencies). This would likely require significant intervention from OPDC and require standards to be set for the mechanical design for development coming forward, in order to ensure compatibility between the buildings and a low temperature network.

A.2 Introduction

A.2.1 Context

The scale of the development projected to occur in the Old Oak area of West London is expected to have significant demands for energy, and in particular demand for heat for space heating and hot water. This Technical Note provides a high level assessment of the projected heat demand and discusses the strategies that could be deployed to service this demand. Potential strategies include:

- Traditional dwelling-based solutions (e.g. gas boiler systems);
- Block or plot based solutions (e.g. communal boiler systems); or
- Area-wide solutions (e.g. District Heat (DH) networks).

Traditional dwelling-based solutions in the UK utilise individual gas-fired boilers in each dwelling, providing space heating and domestic hot water. Because of the historically high carbon content of grid electricity, this strategy has offered a lower carbon strategy than grid electricity-driven heating systems (e.g. wall-mounted electric radiators or storage heaters). However, as the carbon content of grid electricity is being reduced rapidly, the advantage of individual gas-fired boilers over electrically-driven systems is being reduced.

In response to the priority of reducing carbon emissions, other lower carbon heating technologies have been deployed in recent years. The historically high carbon content of grid electricity, relative to natural gas, has meant gas fired Combined Heat and Power (CHP) provides a lower-carbon solution to gas boilers (because the electricity generated displaces high carbon electricity that would otherwise have to be supplied from the grid). CHP is best deployed at large scale (due to the increases in electrical generation efficiency and plant utilisation that comes with scale), so they have often been deployed for block/plot based solutions or in area-wide DH networks.

However, the reducing carbon content of grid electricity is now leading to the carbon saving benefits of gas CHP being eroded. A typical CHP-led district heating system is expected to generate heat with the same carbon intensity as that from a typical individual gas boiler when the carbon intensity of grid electricity falls to 0.341 kgCO₂/kWh⁴. For context, the current Building Regulations assume a carbon intensity for grid electricity of 0.519 kgCO₂/kWh. Although grid electricity carbon intensity fluctuates, depending on the load on the grid and the mix of generation technologies being deployed at any one time (e.g. wind, coal-fired power stations, nuclear), the value assumed for current Building Regulations is considered to be significantly higher than the current average year-round intensity. The Department for Business Energy and Industrial Strategy (BEIS) has recently launched a consultation on proposed changes to SAP (the Building Regulations compliance methodology for dwellings) including a proposal that the average grid CO₂ emissions factor is reduced from 0.519 currently to 0.398 kgCO₂/kWh.

Projections by a number of bodies suggest that the carbon intensity of grid electricity will continue to reduce significantly in the future. See Figure A.2.1 for projections through to the early 2040s. For more details and discussion of this analysis, please see *Technical Note – Carbon Emission Factor*, which is appended to the main report as Appendix F.

Analysis by Arup³ (and quoted in Atkins' report¹) indicates that the decarbonisation is expected to result in CHP ceasing to be a carbon saving technology by the early 2020's. This is in line with our own findings of the savings that would be reported in planning calculations, but it is important to recognise these calculations are based on grid-average carbon intensity for electricity. Government guidance⁵ for appraisal of publicly funded projects is that when assessing the carbon savings arising from gas-fired CHP bespoke marginal carbon emission factor projections should be used for the electricity generated by CHP, not electric grid-average carbon intensity projections. This is to account for the anticipated interaction with the grid-based generators, whereby gas-CHP is expected to displace generation from gas-fired Combined Cycle Gas Turbine (CCGT) facilities rather than a weighted average of all generators (as implied by using grid-average figures). Using bespoke carbon intensity projections in the calculation of carbon emissions relating to gas-fired CHP is expected to delay the point at which gas-fired CHP becomes ineffective in reducing carbon

⁴ Assuming gas boiler efficiency of 90%; CHP electrical efficiency of 38%; CHP thermal efficiency of 40%; district heating distribution losses of 10%; and gas carbon intensity of 0.216 kgCO₂/kWh (current Building Regulations).

⁵ Bespoke Gas CHP Policy: Summary of Analysis Results & Conclusions, Department of Energy & Climate Change, December 2014

emissions until approximately 2032. It could be later depending on the mix of marginal plant that is required to meet changes in electrical demand as the grid decarbonises.

The SAP emission factors for future compliance periods are based on a projection made by BRE in the recent SAP 2016 consultation. This sets a projection for emission factors applying to three year periods.

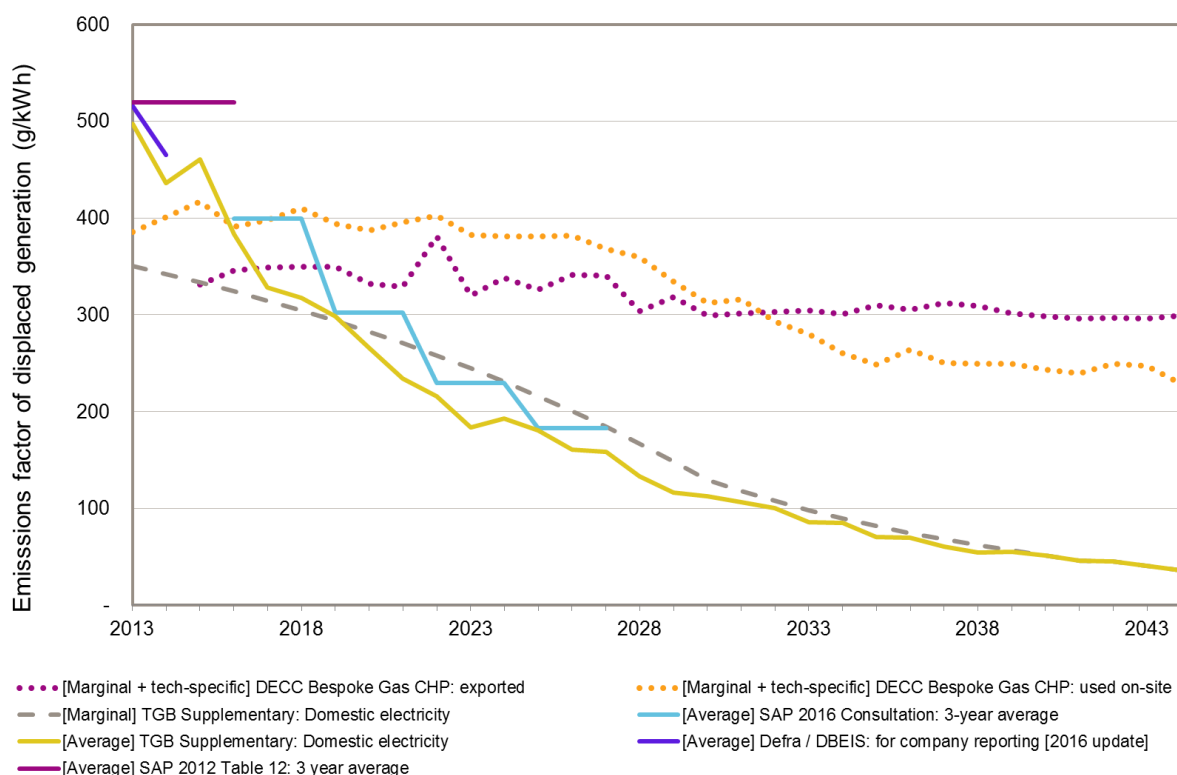


Figure A.2.1. Projected Carbon Intensity of Grid Electricity

Decarbonisation of the electricity grid will lead to significant changes in the carbon intensity of available technologies that could be deployed to provide heating services to the development at Old Oak. Heat from electrically-driven systems (e.g. heat pumps) is expected to naturally decarbonise over time in line with grid decarbonisation, while heat from gas CHP will become more carbon intensive over time. Conventional gas boiler heating systems are expected to stay roughly stable (ignoring any potential decarbonisation of the mains gas supply due to increased injection of renewable gas supplies).

For these reasons, alternative heating strategies and heat sources need to be investigated in order to ensure the development at Old Oak future-proofs the low carbon supply of heating services as grid emission factors change. Part of this analysis needs to consider whether upfront investment in district energy solutions is expected to increase or reduce flexibility for maintaining cost effective provision of low carbon heat.

A.2.2 Projected Heat Demand

The demand for heat for anticipated development at Old Oak is expected to be significant. At full build out (using the development trajectory “v.7.11_Early Scenario for Planning”), the development will host 26,967 new dwelling units and approximately 814,000 m² of new commercial office accommodation. Although not defined in the development trajectory received by AECOM, the scheme is also expected to host additional facilities, including retail, leisure and community facilities, in addition to healthcare centres.

In order to accurately determine the impact of low carbon strategies and heat sources, detailed modelling of the heat loads encountered in each building type and their profiles will be required. However, to provide context for assessing the likely heat demands and the relative contribution that different heat sources could make to these, a high-level assessment of the expected heat loads has been made here.

The received development trajectory has been used to establish an approximate heat load build up over time. Please see Figure A.2.2. (Note that the load estimates account only for dwellings and commercial office space. It is expected that the total heat load, including all additional usage types, could be significantly larger than that shown in Figure A.2.2.)

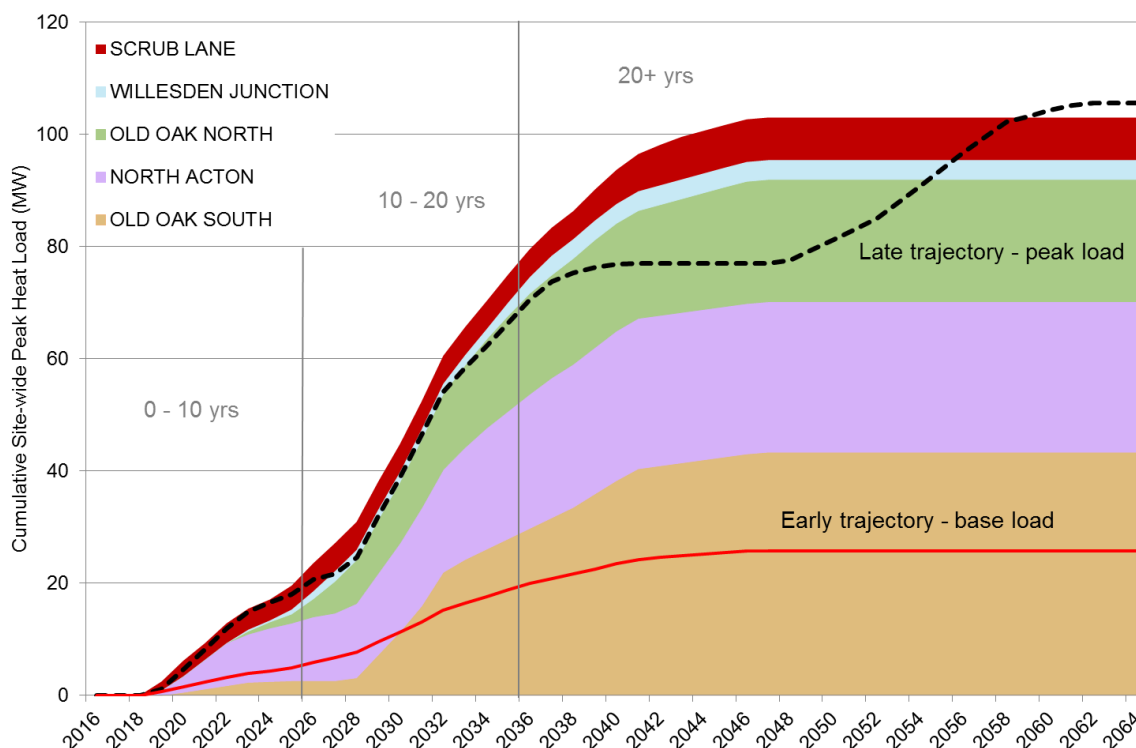


Figure A.2.2. Projected Peak Heat Demand

(Source: 'Phasing Trajectory v7.11_Early Scenario for Planning')

The load estimates have been calculated using the following high level assumptions for expected peak load conditions, and also accounts for simple diversity (the effect of not all customers requiring peak load services simultaneously).

- Dwellings: 40 kW peak provision for domestic hot water (DHW) heating

6% diversity for domestic hot water coincident loads

Space heating assumed not to be coincident with domestic hot water loads

Load requirement for space heating of c.35W/m² and 80% coincident diversity

- Offices: Space heating peak load of 70 W/m²

70% coincident diversity

DHW heating load not considered

It is estimated that the Old Oak scheme will have a peak heat demand of 90 – 100 MW at the point of use (excl. non-office and non-residential accommodation), and an expected base load of 20-30 MW. Losses in distribution networks are expected to increase the demand for heat from thermal generators to above c.100 MW as shown in Figure A.2.2. Note that this demand assessment represents a worst case and makes no allowance for improved insulation standards over time. This is broadly in line with the analysis presented by Atkins¹.

The following outlines the available heating strategies.

A.2.3 Heating strategies

A.2.3.1 Demand Reduction

A number of strategies are available to ensure the development is provided with low carbon heating services. On the demand side, design specifications can impact significantly the demand for and consumption of heat. For dwellings, design and construction standards that meet Passivhaus standards (which require high levels of insulation and air tightness in excess of those required by Building Regulations) can reduce the demand for space heating significantly. While a typical high density development would expect annual space heating demand to be between 30 – 40 kWh/m², Passivhaus standards require a maximum of 15 kWh/m² (effectively more than halving the allowable demand for space heating). Passivhaus also requires the overall heating system energy input to be no greater than 10 kWh/m² (which effectively requires the use of systems such as heat recovery units to reduce the demand on the heating services). Passivhaus does not require limitations on the demand for domestic hot water.

Although building all Old Oak dwellings to Passivhaus standards would significantly reduce the demand for heat, requiring all new build dwellings to be built to the necessary standards would have significant cost impacts. There is, however, likely to be a case for improving efficiency standards to some degree.

On the supply side, conventional options for localised dwelling or block/plot based systems include Air Source Heat Pumps (ASHP), Ground Source Heat Pumps (GSHP), Solar Hot Water (SHW) systems, and solar Photovoltaic (PV) systems. A high level assessment of the likely applicability of these systems to the expected high density development of Old Oak is set out below.

A.2.3.2 Air Source Heat Pumps

ASHPs will inherently benefit from the future decarbonisation of grid electricity, with the carbon intensity of the heat provided reducing naturally as the electrical input to the system (mostly for operating the compressor) becomes less carbon intensive.

However, although ASHPs could be used on a per-dwelling basis, this would require fan-based evaporator units to be located on the façade of each dwelling. This is unlikely to be aesthetically acceptable, and is not expected to be an attractive solution for such a high-density scheme.

The use of ASHPs on a block/plot-based system is potentially viable, although there will be planning, architectural, and general arrangement challenges regarding where to locate the large evaporator units that would be required.

Owing to the size of the array that would be needed to provide significant quantities of heat, ASHPs are also not well suited to use on area-wide DH networks, where land will be at a premium, as energy centres would need to be much larger to accommodate the required evaporators.

A.2.3.3 Ground Source Heat Pumps

In much the same way as for ASHPs, GSHPs will also benefit from the future decarbonisation of grid electricity. However, the potential deployment of GSHPs could be constrained by the available land area, relative to the floor area of and number of homes being planned. For the taller buildings this may limit the proportion of the heat load that can be served, requiring back up from other systems potentially including gas or electric boilers.

GSHPs could contribute to a block/plot based system or DH network.

A.2.3.4 Solar Hot Water

Although SHW would also benefit from the decarbonisation of grid electricity, the Coefficient of Performance (CoP) of the system is so high that it is already a near-zero carbon heat source. While heat pumps operate compressors to generate heat, SHW systems are passive and require only a simple pump to circulate water around the panel and storage vessel.

In the UK well designed systems can typically meet around 50% of annual domestic hot water use although the actual utilisation will depend on occupant behaviour and the timing of hot water use.

Roof mounted SHW systems could be deployed on a per dwelling basis, although they would need to be located close to each dwelling in order to reduce the pipe lengths from the solar collectors to the thermal storage tank. This would likely limit their use to apartments near the top of buildings, or provide only a small proportion of the heat demand if linked to a communal system.

Façade mounted evacuated tube solar collectors (see Figure A.2.3 for an example of façade-mounted solar thermal collectors in Sweden) could also be viable for unshaded south facing or south-west or south-east facing façades, but would require careful integration from an aesthetic and architectural perspective. SHW systems are best suited to low density development. While they could be deployed at Old Oak to meet the hot water needs of the upper floors of blocks or to apartments adjacent to unshaded south facing façades, their contribution to meeting overall heat demands may be constrained by the available area of unshaded roof and wall areas relative to the overall scale of development. Serving more than the upper floors from roof mounted panels can become inefficient and costly due to pipe lengths between the heat generation and supply point, and the significant riser spaces required to accommodate these pipes. While solar water heating should be encouraged, an additional system for meeting the majority of hot water demands will be required..



Figure A.2.3. Evacuated Tube Solar Thermal Collectors on Unshaded Facade (Western Harbour, Malmö, Sweden)

Some schemes have used ground-based solar collectors to provide hot water to communal heating systems or district heat systems. Work by Atkins to develop Environmental and Sustainability standards for OPDC has demonstrated that Old Oak is likely to have a relatively low proportion of open space. It is therefore unlikely that space would be available for ground based solar water heating panels directly feeding into district heating networks.

While the application of solar water heating is likely to be limited, ideally delivery models for Old Oak should seek to identify a model that would not preclude the use of low carbon renewable heat sources to provide at least part of the load.

A.2.3.5 Solar Photovoltaic

Although solar PV is a zero carbon technology, the carbon benefits of solar PV will reduce over time, as the grid decarbonises. This is because the electricity generated by PV will be displacing electricity that becomes increasingly less carbon intensive. However, while the contribution that a given capacity of PV will make to meeting London Plan CO₂ reduction targets will reduce, it will remain a beneficial technology in terms of supplying local low carbon electricity.

While solar PV is not typically deployed directly for providing heating services, some system providers have utilised PV for hot water heating to exploit loopholes in the way Feed in Tariffs are administered. For smaller installations, payments for exported electricity are not metered and are based on typical assumed export rates based on the capacity of the system installed. These payments can effectively be supplemented by dumping the generated electricity into hot water heating via an immersion heater rather than exporting it as the tariff payment assumes. This effectively results in an additional income by reducing payments for DHW heating. As the grid decarbonises in the longer term, and there is a greater shift to electric-based heating, power generated from electricity could increasingly support heating. Currently it is typically fed into landlord supplies to maximise its use on site and to displace costly grid supplied electricity, but it could in future supply heat pumps and other electrically based heat sources. Development in cost effective battery storage could also increase the proportion of PV generated electricity that could be utilised on site rather than being exported.

Like solar water heating the contribution that PV can make to demands at Old Oak is expected to be limited by the available unshaded roof or façade area in relation to the overall development density. This will limit the contribution to either electrical or heating demands that building-integrated or roof-mounted PV could make. However, work by Atkins has estimated that around 20 MW_{peak} of PV might be integrated into buildings at Old Oak.

Expected cost reductions for PV manufacture and developments in thin film technologies (which have better generating properties in diffuse light) may increase the potential application of PV, with a greater ability to apply PV cost effectively to vertical facades or as an integrated film on the surface of glazing systems. These however would be subject to aesthetic and architectural considerations.

Overall, the expected physical constraints on dwelling-based and block/plot-based low carbon heating solutions are likely to favour area-wide DH solutions that can remove roof top and other plant from the buildings, provided they can be supplied by low carbon heat sources at a sufficiently low cost to be affordable to residents. In order to safeguard and future-proof the development for low-carbon heat solutions, alternative heat sources therefore need to be identified that could replace or operate alongside gas CHP as the carbon benefits of gas CHP decline.

A.3 Potential Local Heat Sources For Communal or District Heating Schemes

The potential heat sources investigated in this Technical Note are:

- Water sources, including the:
 - London Aquifer;
 - Grand Union Canal and River Brent;
- Taylor's Lane Power Station;
- Powerday renewable fuels;
- Heat recovery from the sewage network;
- Heat recovery from transport tunnels, including:
 - Ventilation shafts;
 - Tunnel linings;
 - Water drainage from London Underground or other transport tunnels; and
- Heat recovery from data centres.

Where applicable, these heat sources are shown in Figure A.3.1.

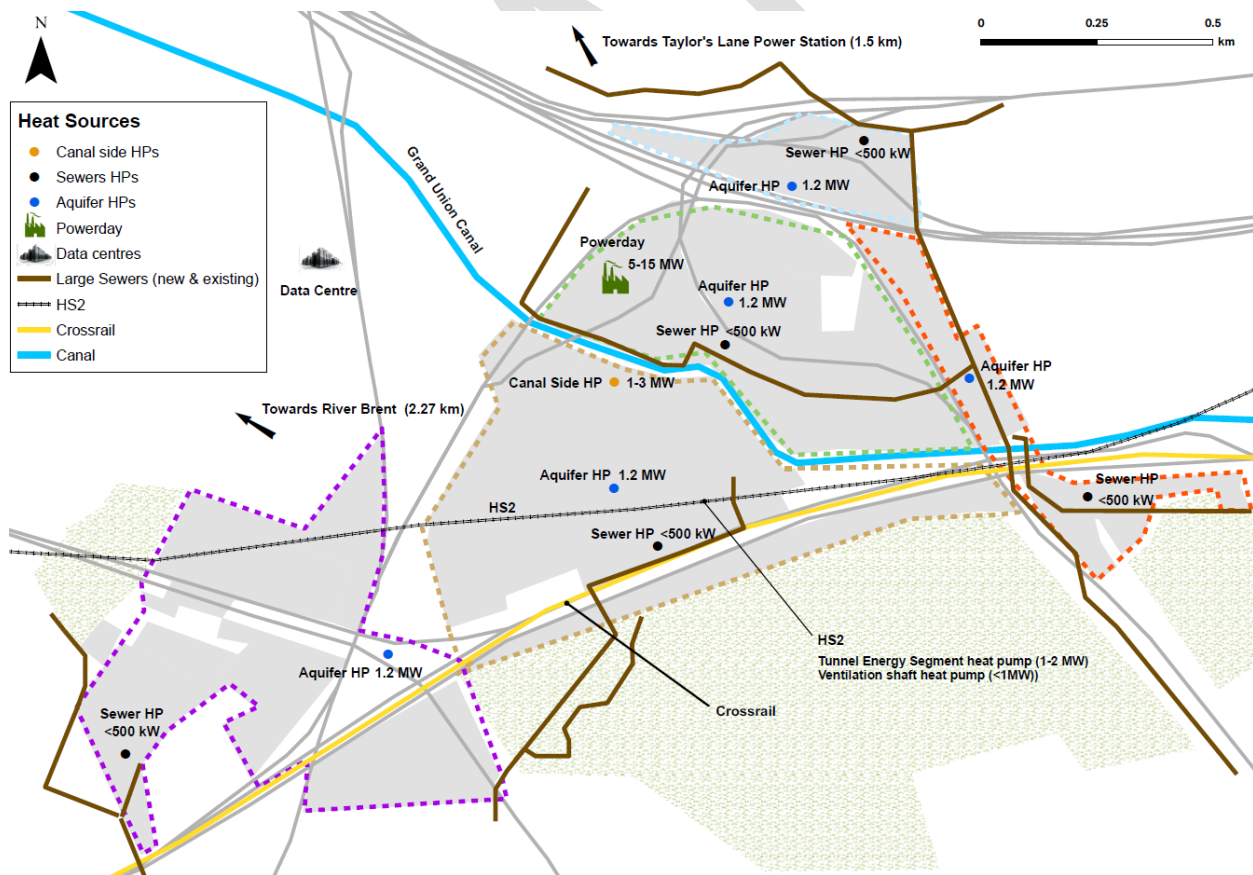


Figure A.3.1. Potential Heat Sources

The following sections discuss each technology in detail. The summary section at the end of this Note outlines the likely capacity of each of these potential heat sources, and the viability of their use, including the expected carbon content of the supplied heat and a qualitative high level assessment of their likely relative costs.

A.3.1 Water Sources

Heat pumps are electrically driven systems which raise the temperature from that of a heat source to a desired temperature which can be used to provide heating. They are typically used to service space heating systems, but can also be used to supply domestic hot water. The efficiency of heat pump systems are inversely proportional to the temperature 'uplift' achieved (i.e. the greater the uplift from the source temperature to the supply temperature, the less efficient the system).

Water source heat pumps (WSHP) utilise a large body of water as the heat source. The size and ability of the body of water to replenish any extracted heat via WSHP systems determines the thermal capacity (both the peak MW extraction, and the annual MWh extraction limits) which the WSHP can operate at.

The key water source options in the area include both surface water and sub-surface water.

A.3.1.1 Surface Water Abstraction for Heat Pumps

On the surface, the River Brent runs to the west of Park Royal industrial estate, while the Grand Union Canal runs through the northern half of the Old Oak site. Heat extraction from these resources would be undertaken using open-loop heat exchangers. This technology would extract water from the canal/river, in a process called abstraction. The water would then be pumped to a nearby heat exchanger, which would transfer heat from the water into a closed-loop circuit. The water would then be pumped back into the canal/river. The closed-loop circuit is then used as a heat source for the evaporator side of a heat pump serving the primary circuit of a DH network.

In addition to planning consent, the use of these resources as a source of heat would be conditional upon obtaining both an abstraction licence (for taking water from the canal/river) and an environmental permit (to enable discharge back into the canal/river). Abstraction licences and environmental permits can be obtained from the Environment Agency (EA). The EA develops Catchment Area Management plans typically on a 12 year cycle and licenses are therefore time limited and will need to be renewed. Possible reasons for non-renewal may include the licensee having a poor record of maintaining required water quality or temperature limits, or if the catchment area is being over exploited. The risk from the latter should to some extent be managed by the EA not offering licenses where they would be expected to have a detrimental impact on the water catchment.

There are a number of examples of using surface water resources such as rivers and canals as heat sources in the UK. While many of these examples utilise large rivers (e.g. the Thames), the most relevant example for Old Oak is the use of the Grand Union Canal to provide cooling for GlaxoSmithKline (GSK) at their headquarters building in Brentford. This scheme abstracts 2,400 m³ of water per day in order to provide cooling to the company's data centre. Unwanted heat is discharged safely to the canal. GlaxoSmithKline estimates that up to 1,400 MWh of energy is saved each year, displacing approximately 276 tonnes of CO₂ and generating cost savings of around £180,000 per year. Please see the Attachment I at the end of this note for further details.

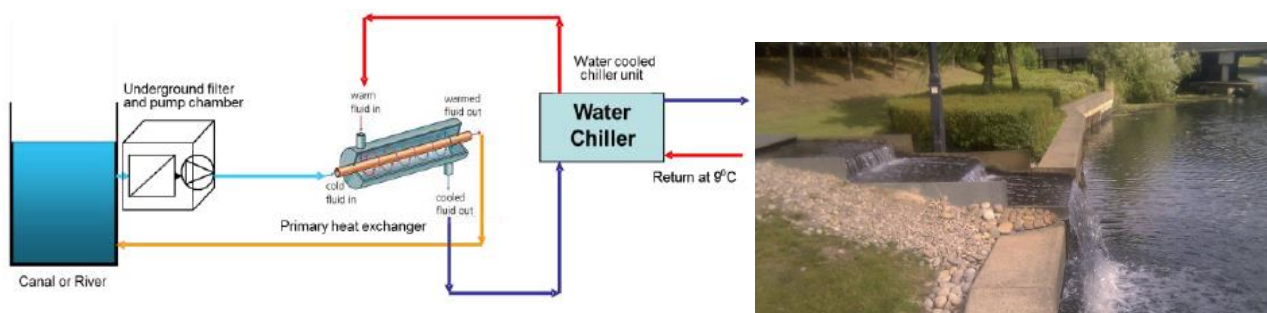


Figure A.3.2. Schematic Diagram of GSK System (left) and Return Water Discharge to Canal (right)

(Source: GSK)

The Department for Business, Energy and Industrial Strategy (BEIS), which provides a high-level assessment of available water heat sources via the National Heat Map⁶, indicates that the River Brent can provide approximately 650 kW of heat capacity, while the Grand Union Canal in the area can provide 1.6 MW of heat capacity. Discussion with the CRT has confirmed that the canal in this area could provide between 1 – 3 MW of heat (but the exact figure would need to be determined by hydraulic modelling). It is likely that there will however be limitations on the total amount of heat that can be extracted over a given time period (either on a seasonal or annual basis). The potential for increasing the amount of extractable heat from the canal, by using it as a source of cooling in summer months is possible, although this would need to be confirmed through additional investigations and detailed modelling.

Given the proximity of the canal to major heat loads in the proposed development, compared to the River Brent (which runs to the west of the Park Royal industrial estate), the Grand Union Canal is considered the more viable heat source. Correspondence with the CRT has confirmed that the use of the Grand Union Canal in particular as a source of heat would be welcomed. In general the EA has greater concerns about warming London's water bodies rather than cooling them, although they can be used for cooling provided temperature limits are observed.

An open-loop system for extracting heat from the river or canal would require specialist equipment, including an abstraction facility for taking water from the canal known as a leat; a chamber for pumping, screening and filtration; pipework to take the filtered canal water to a plant room; and a heat exchanger to transfer heat to a second closed-loop circuit. It may be possible and desirable to locate the filtration chamber and/or heat exchanger in a plant room adjacent to the canal, in order to limit the pumping of canal water large distances to the heat exchanger. Further pipework would then be required from this initial heat exchanger to pump the closed-loop circuit to another plant room, where a heat pump would elevate temperatures in a third circuit to that required for the primary DH network. CRT has indicated that it may be possible to route pipework along or beneath the towpath beside the canal. Heat loss is likely to be limited by the relatively small temperature difference between the canal water and ground temperature, although reducing the distance between heat source and demand will reduce pumping energy requirements.

Surface water sources could be used to provide both heating in winter months, and cooling in summer months. However, careful design considerations would be needed to ensure the extraction and/or rejection of heat from these water sources does not breach limits on the amount of energy that can be sourced from them, and does not degrade their potential to offer a long-term and sustainable source of energy.

A.3.1.2 Borehole Water Abstraction for Heat Pumps

Sub-surface bodies of water that could potentially be used as a heat source include the London Aquifer. The bedrock geology in the London area, and in particular the area around Old Oak, is dominated by the London Clay Formation. Beneath this clay layer are further layers of rock, which include permeable formations known as the Chalk Basal Sands that comprise White Chalk, Thanet Sand and Lambeth Group Upnor Formation. These strata contain what is known as the London lower aquifer, a permanent body of water. Boreholes in the Old Oak area indicate that the depth to the top of the Chalk is between 80 – 95 metres below ground level (mbgl).

The Chalk is a low storage, high transmissivity aquifer, with flow and storage occurring in both fractures and in the rock matrix. Most flow occurs in the fractures, with storage in the matrix released to the fractures when groundwater levels fall. For open-loop ground source heat extraction, boreholes would usually be used to abstract and recharge from the Chalk. Transmissivity in the Chalk varies according to the fractured nature of the stratum; a more fractured zone often leads to greater transmissivity, and therefore the potential for greater extraction rates. The extraction rate cannot be guaranteed and will not be known with certainty until the borehole is sunk and pumping tests carried out, to obtain site-specific transmissivity values for the Chalk. Typically it can range from 15m³/day to zones where hundreds of m³/day are possible; Fry 2009⁷ confirms that, of the sites that are active or undergoing investigations, the most common system design is a pair of wells where a non-consumptive abstraction of 10 – 20 l/s (864 – 1,728 m³/day) is operated for combined heating and cooling. The EA confirms that in 2016 groundwater levels in Old Oak had risen in the preceding 5 – 6 years⁸.

⁶ <http://tools.decc.gov.uk/nationalheatmap/>

⁷ Lessons from London: Regulation of open-loop ground source heat pumps in central London, V.A. Fry, May 2009

⁸ Management of the London Basin Chalk Aquifer, Status Report 2016, Environment Agency

The London Aquifer could be used for heat extraction using the same broad principles as those used for canal/river heat sources, abstraction from the canal being replaced by pumped abstraction from a borehole sunk into the chalk. While there are examples of abstraction-only boreholes serving development in London (e.g. Portcullis House, Westminster and Sadlers Wells Theatre), it is likely that if multiple boreholes were being proposed the EA would require the abstracted water to be returned to the aquifer via a return borehole to maintain ground water levels; this is known as a doublet system. The rate and volume of water that can be utilised will be limited to the lowest value of the abstraction rate and the volume at which the water can be recharged back into the aquifer from the return borehole. When discharging heated or cooled water to the aquifer, the water is considered a pollutant and the groundwater temperature would require assessment to ensure that the heat is within guideline values. The EA recommend a maximum change in temperature of 10°C between abstraction and discharge. Risk assessment is required to demonstrate that there are no adverse environmental impacts associated with the discharge of heated waters.

In order to ensure thermal stability in the aquifer, the EA's preference is for a balance between heat reinjection to (in building cooling mode) and heat abstraction from (in building heating mode) groundwater doublet schemes. These doublet schemes however require boreholes to be sufficiently spaced in order to avoid thermal breakthrough (or 'thermal short circuiting') within the aquifer. Thermal short-circuiting occurs in instances where the cooler water discharge back into the aquifer (in heating mode) reduces the temperature of the warmer water within the aquifer. This thermal short-circuiting would result in lower efficiencies of the overall heating system. When providing new boreholes, the applicant will be required to demonstrate that they have not derogated the water extraction rate for existing boreholes in the area before a formal abstraction license is granted. Although a general rule for aquifers in the London area is that borehole doublet pairs should be spaced approximately 500m from each other, it is recommended that site-specific investigations, ground modelling and risk assessments are undertaken, as it is strongly influenced by the hydraulic gradient and the local fracturing and fracture connectivity within the Chalk layer. For reference, schemes in Central London are typically spaced between 250-500 m from adjacent systems⁷.

In addition to the licences and permits required for using canals and rivers in this way, the use of the London aquifer would require a groundwater investigation consent to be obtained from the EA. Abstraction and discharge licenses would also be time dependent and subject to renewal.

The London Aquifer could be used to provide both heating in winter months, and cooling in summer months, or potentially simultaneous heating and cooling. However, careful design would be needed to ensure the extraction and/or rejection of heat from these water sources does not breach limits on the temperature and abstraction rates and volumes which EA will require to be monitored and which will limit the energy available.

The use of the London aquifer as a source of heat to serve the proposed development at Old Oak is considered technically challenging. A number of boreholes would need to be drilled, to a depth of c.100m in order to enable the abstraction of aquifer water and the discharge of water back into the aquifer. Submersible pumps are typically used to raise the water and these require clearance above the well head to enable pumps to be lifted for maintenance or replacement. Further equipment would be required, including a heat exchanger to transfer heat to a second closed-loop circuit, which may then need to be pumped to another plant room, where a heat pump would elevate temperatures on a third circuit (the primary DH circuit).

It is estimated that, with ideal spacing arrangements, approximately 12 pairs of doublet boreholes could be accommodated within the Old Oak area. However, given the potential constraints over the siting of boreholes and their proximity to energy centres, it is assumed that, for the purposes of this study, a maximum of 5 are likely to be able to be accommodated next to energy centres. It may be possible to accommodate additional boreholes in order to directly serve individual development plots; this should be assessed on an individual basis. Although testing would need to be done to ascertain the achievable flow rates from the initial borehole, 20 litre/sec for the achievable extraction rate (based on typical systems in the London area) would indicate that each doublet pair could provide approximately up to 1.2 MW of heating/cooling (accounting for the efficiency of the system). With a total of 5 doublets, aquifer heating could provide up to 6 MW of heating (25,000 MWh p.a.) to a heat network. It must be noted that the extraction rate will be highly dependent on the local properties of the chalk and extraction rates will not be known until the borehole is sunk.

An example of the use of the London Aquifer for this purpose includes the installation at St George Wharf development in Vauxhall. The residential building is currently the tallest building in the Vauxhall/Nine Elms area, and uses the London aquifer as the lead source of heating the building in the winter and cooling in the summer⁹. Other schemes in London include Portcuillis House, and the Royal Festival Hall¹⁰.

A.3.2 Taylor's Lane Power Station

Taylor's Lane is a gas-fired power generating facility located approximately 2km to the north of the OPDC site boundary in Willesden. The site was commissioned in 1979, and is now operated by E-ON. The plant was originally designed for 132 MW electrical capacity; however, correspondence with E-ON confirms that the plant has since been downrated to 99 MW electrical power generation.

E-ON has also confirmed that the plant is only licensed to operate for a maximum of 100 hours per year and that the engines used are relatively old and have relatively poor characteristics in terms of their air quality impacts. E-ON has no immediate plans to upgrade the site and do not see the Taylor's Lane site providing an opportunity for heat or power provision for Old Oak. Had a heat source been available a major hurdle would have been routing this via the many infrastructure barriers between Taylors Lane and Old Oak.

This heat source has therefore been ruled out.

A.3.3 Powerday

Powerday operates the largest Materials Recycling Facilities (MRFs) in Southern England. Its main facility in London is located at Old Oak, approximately 300m south of Willesden Junction Tube and Overground station, and immediately to the north of the Grand Union Canal. The facility opened in 2006, leasing the land from Network Rail. It is understood that a significant length of time still remains on the current lease.

The facility at Old Oak is licenced to process approximately 1.6 million tonnes of construction and demolition waste, municipal waste, and commercial and industrial waste a year from across London and beyond¹¹. Were the facility to process the maximum allowable under this licence, it would be able to process c.10% of all of London's waste generated every year (c.15 million tonnes¹²). The current site however, has the capacity to process approximately 50% of the licenced maximum (up to 800,000 tonnes p.a.).

The site operates 24 hours a day, 7 days a week, separating materials of value that can be resold to recycling facilities (e.g. wood products, hard plastics, metals and cardboard). Residual materials (which include soft plastics, small wood chips and unrecoverable paper and cardboard) are processed into Refuse Derived Fuels (RDF) or Solid Recovered Fuel (SRF) products. These products are currently transported off site by road for use in EfW plants throughout the UK and Europe. Powerday estimates that approximately 31% of the waste that arrives on site is eventually processed into RFDs or SRFs. The RDF and SRF typically have a biomass content of between 50-60% and are therefore considered relatively low carbon fuels. The specific energy content (MJ/kg) can be varied to suite the requirements of the end user. Powerday has indicated that it plans to further expand their customer markets.

Almost all of the material arriving and leaving the site is transported by road. However, road access to the site and the surrounding industrial area is problematic, with only two main access roads connecting the site to the main arterial roads (A40 and Harrow Road). Access to the Harrow Road is further restricted by a bridge on Scrubs Lane, over railway lines serving the Bakerloo Line, which is subject to an 18 tonne weight limit. A canal wharf has been built on site. However, it is understood this is not currently used for transporting material on and off site in a significant way. The site is also served by a railhead, which can be used for moving material on and off site. The licence for processing the maximum of 1.6 million tonnes requires a third to be delivered each by rail, road and water (i.e. the canal) and hence the mass that could be delivered by road would be limited to 533,000 tonnes.

⁹ <http://stgeorgewharfapartments.net/the-tower>

¹⁰ Open-loop ground source heat pumps and the groundwater systems: A literature review of current applications, regulations and problems, C. Abesser, British Geological Survey (Natural Environment Research Council), 2010

¹¹ <http://www.powerday.co.uk/facilities/old-oak-sidings-materials-recycling-facility/100/>

¹² London Plan 2015 (see para 5.68 of Policy 5.16 for 2012 figure)



Figure A.3.3. Powerday Commercial Waste Sorting and Recycling Centre.

(Note the fog mist in the image is water vapour used to suppress dust.)

The Powerday site currently only processes incoming waste into RDFs and SRF, which is subsequently exported off site. Powerday does not currently operate an EfW plant on the site or nearby. In order for the site to be a viable and consistent source of heat for a DH network, an EfW plant would need to be operational. With the current Powerday facility providing significant quantities of RDFs and SRFs, the potential for the low carbon and renewable generation of heat and power is significant.

Powerday confirmed that they intend to install EfW equipment on site, with a number of capacity options under consideration (3 MWe, 5 MWe or 5.7 MWe). This would be subject to a successful planning application and the acquisition of necessary permits and licences. Planning applications for EfW sites often experience strong public opposition. GLA waste policy would not support direct incineration technologies, and approval is likely to be dependent on utilising advanced thermal processes to improve efficiency and limit emissions. Potential impacts on air quality and consideration of flue heights and topple distances to surrounding rail lines are some of the issues that would need to be considered if proposals come forward.

Powerday confirmed that their expectation would be for a grid connection to be installed in order to support the export of power generated directly to the electricity grid. However, not all the electricity generated will be exported, as the parasitic power of the Powerday site (i.e. the power requirements to support the site's operations) is approximately 2.2 MWe. Any excess power generated by a future EfW plant is expected to be exported to the grid but should a local electrical consumer be identified, whose demands are large enough to make the direct sale of electricity to them commercially viable, it is expected that Powerday would welcome a Private Purchase Agreement (PPA) with the 3rd party consumer. Network Rail or Transport for London (TfL) could potentially have substantial power demands. This could potentially be done via a Licence Lite mechanism.

Although the 'grades' of heat (i.e. temperature) from different technology options (generation via a steam turbine or reciprocating engine) would vary, it is expected that both technologies could support a well-designed and best practice heat network. For reference, steam turbine technology generates high-grade (i.e. high temperature) heat, in the form of steam, which can be used to generate hot water for a heat network. The heat recoverable from reciprocating engines however, is both high-grade (heat recovered from the high-temperature (c.450°C) flue/exhaust gases) and low-grade (c.90°C heat recovered from the 'engine jacket' used for cooling the engine). However, since a well-designed and best practice network should operate flow conditions below these temperatures, both technology choices are expected to be able to provide heat to any potential future heat network.

A 5.7 MWe EfW plant could require approximately 50,000 tonnes of RDF/SRF p.a. to operate. AECOM estimates that, based on the expected calorific value of the fuels (~13 MJ/kg¹³) and expected operating hours of c.8,000 p.a., the electrical efficiency of the EfW plant would be c.24%.

¹³

http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.showFile&rep=file&fil=ENERGY_WASTE_CERTH_2012_pres.pdf

The 50,000 tonnes of RDF/SRF p.a. fuel input (required to operate a 5.7 MWe EfW plant) would represent approximately 20% of the site's current total c.250,000 tonnes p.a. of RDF/SRF production capacity (produced from a current sorting capacity of 800,000 tonnes p.a. of received waste). At present, Powerday produce around 100,000 tonnes p.a. of RDF/SRF a year, which exceeds the minimum required to power the largest EfW plant that is currently being considered.



Figure A.3.4. Proposed Location for Powerday EfW Facility, with Railway Lines and Car Giant Site beyond

Were the Powerday site to operate at its full current operating capacity of 800,000 tonnes p.a. of waste received, the facility could produce approximately 250,000 tonnes of RDF/SRF p.a.

Heat pipework would need to be carefully routed to enable any export of heat generated on the Powerday site. Given the site location between the canal and a number of railway lines, options for routing the pipework off the site could include thrust boring beneath these infrastructure barriers. The current proposed location for the EfW plant is to the south east of their main warehouse and to the north west of the railway lines. There is potential to thrust bore under the railway to reach the large Car Giant site to the east of the site. The feasibility of this and acceptability to Network Rail would require further assessment.

Overall, the potential for Powerday to provide heat is considered significant. An EfW plant onsite could be a significant source of low-carbon heat for early phases of development, should Powerday be able to submit a successful planning application. A successful use of this heat source will rely on heat customers with a sufficient demand being identified, an operator being able to invest in the infrastructure required to connect supply with demand, and commercial terms and timing risks being acceptable to all parties. The capacity of the heat available could depend on the EfW technology adopted.

Local planning policy could be used to create a supportive environment for this technology by protecting the site for future waste use and by requiring that any EfW facilities are required to provide heat off-take to achieve planning approval.

Further investigations will need to address the potential air quality concerns associated with any new EfW facility.

A.3.4 Sewage Network

Sewage infrastructure carries warm material from which heat could potentially be recovered for use in a DH network. Systems such as this are gaining interest in both the UK and internationally.

Suez (of France) has experience of 15 case study installations of sewer heat recovery in France, and is seeking opportunities in the UK. In the UK, Thames Water and Suez are working on a pilot project in the London Borough of Haringey to trial heat recovery from sewers to supplement the heat provided by two existing gas-fired boilers serving a communal heating system for two tower blocks on an existing estate. As this project is currently under development, and would be the first of its kind in the UK, it will be a test bed for trialling the technology, and the potential commercial and contractual arrangements.

The technology consists of curved metal heat exchangers approximately 1m in length, which are designed to fit the profile of the sewer (see Figure A.3.5).

The units are designed to be small enough to be taken down through existing access chambers and then connected together in series along the bottom of the sewer to form a single length of heat exchanger. The maximum length that can currently be installed is 200m (maximum length is limited by pumping and hydraulic considerations). The panels are designed to have a thin profile so as not to obstruct the flow in the sewer, but are strong enough to ensure they allow maintenance engineers to walk over the top of them. Installation requires the sewer flow to be diverted for the few days the panels take to install. Water flows through the heat exchanger panels to provide heat to a heat network via heat pumps, which lift the temperature up to the desired flow temperature of the network. Works will be required to create a connection between the heat exchangers in the sewer and the network at the surface.



Figure A.3.5. Sewer Heat Recovery Plates Prior to Installation (left), and In Situ (right)

(Source: SUEZ, UK)

The largest Suez scheme in France, at the Sainte-Geneviève in Nanterre, was opened in October 2011. It operates 2 no. 400 kW heat pumps over a length of 200 m of heat recovery units, serving 800 homes, a school and retail units. The flow in the sewer is typically in a temperature range of 15-21°C. Approximately 1,337 MWh of heat is recovered from waste water each year.¹⁴

Suez's installations typically achieve heat outputs of 2 – 5 kW/m² of heat exchanger (or c.1 – 2 kW/m of installation), with annual heat output of c.6 – 20 MWh/m p.a. (delivered to network). In the current absence of details on flow temperatures and flow rates for the sewers that cross Old Oak, these case study figures are used for analysis for the Old Oak area.

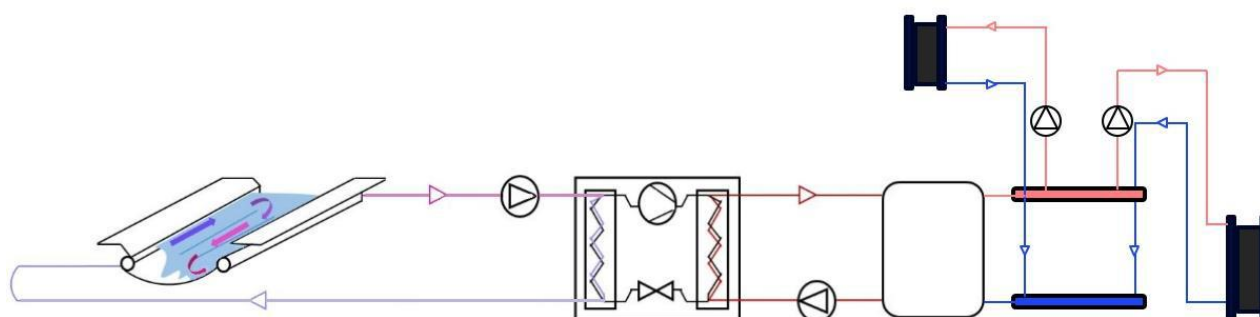


Figure A.3.6: Typical Sewer Heat Recovery Schematic of Suez System

¹⁴ Recovery of sewer heat: 2 case studies on a district heating and a swimming pool application, Suez, October 2016

Another example of heat recovery from sewers is in Vancouver, Canada, where the facility at Southeast False Creek Neighbourhood Energy Utility serves 395,000 m² of residential, commercial and institutional accommodation (including 4,389 residential units) via a 4.7 km DH network¹⁵. The facility, which combines a sewage pumping station and heat recovery units, began operations in 2010 after a C\$30m investment. It supplies approximately 70% of the annual energy demand of its customers, with the remaining 30% being provided by top-up gas-fired boiler units. In 2015, the facility generated 30,172 MWh, and reduced CO₂ emissions by 2,436 tonnes (or 60% of the emissions associated with space heating and hot water provision in the buildings it serves). Further examples of heat recovery from sewers in North America include installations at Whistler, British Columbia and one currently being designed for the city of Denver, Colorado. Lessons learnt from these systems include the benefits that arise from using separate sewers for waste streams and surface run-off flows. Separating these systems allows heat recovery from the warm waste sewer at higher and more stable temperatures (i.e. not impacted by rain events), which increases operational efficiencies.

Thames Water believes that sewer heat recovery could offer significant potential at Old Oak, in addition to Thames Water's wider network. Thames Water¹⁶ has indicated that they would potentially be interested in piloting the technology at Old Oak.

Opportunities at Old Oak could include the installation of heat recovery in existing sewers, or in the new sewer networks that would likely need to be installed to enable development at Old Oak. These could serve individual buildings, or a wider DH network.

There are a number of potential constraints that need to be considered however. These include physical constraints such as the sewer being large enough for installers to work within and install the panels, and access points large enough to get panels down and into place. The minimum diameter that is considered possible for people to work within a sewer is 900mm. Given the restrictions on the maximum length of heat exchangers that can be installed in series, should sewer heat recovery be extensively used it would require a number of heat substation plots. These could be co-located in individual development plots, or on available plots of land that are not planned for development. However, they would need to be located adjacent to the mains sewers that would be used for heat recovery. For the purposes of this study, it is estimated that a maximum of c.6 no. sewers could host 200 m length heat recovery systems in suitable locations for the heat to be usefully accessed.

The capacity of the heat that can be extracted is dependent both on the volume flow of the sewerage, but also the velocity at which it passes over the heat exchanger. As the temperature of the sewer material will fluctuate with rain events, it is likely that Thames Water would restrict the maximum temperature drop in the flow to no more than 5°C (detailed parameters would need to be developed for a specific project), in order to prevent the temperature in the sewer dropping to a point where it impacts the necessary microbial process at the treatment works further downstream. Thames Water has in previous discussions with AECOM indicated they would need to avoid the inflow temperature at the water treatment works dropping below 10°C.

Initial calculations indicate that between 1 – 3 MW of heat could be delivered to a local heat network from 6 number of heat recovery systems installed on the Old Oak estate¹⁷. Annual heat recovery could be between 8,000 – 12,000 MWh p.a.¹⁸

Were the potential for heat recovery from sewers to be taken forward, further technical analysis would need to be conducted to ascertain the capacity of the system, including consideration of the sewer dimensions, flow rates, routes and current access points for existing sewers that cross the Old Oak site, and the potential temperature of the flow in the sewer under typical conditions. AECOM has asked Thames Water to provide data they have on temperatures and flows in the local network; however, it appears unlikely Thames Water currently collect this data but they have indicated it would be relatively easy for them to install a simple monitoring device.

Contractual agreements between OPDC and Thames Water would likely need to cover the cost of heat (which could be informed by the pilot scheme, currently being undertaken in Haringey), that would take

¹⁵ <http://vancouver.ca/home-property-development/southeast-false-creek-neighbourhood-energy-utility.aspx>

¹⁶ Nick Mills, head of Waste Water Innovation at meeting on 7th November

¹⁷ Based on 6 number of 200 m length sewer heat recovery installations, recovering between 1.1 – 2.8 kW/m heat from sewer. This is raised to network operating temperatures via a heat pump (CoP 2.9). Assumed deltaT of sewerage of 5°C.

¹⁸ Based on 6 number of 200 m length sewer heat recovery installations, recovering between 7 – 10 MWh/m of heat from sewer. This is raised to network operating temperatures via a heat pump (CoP 2.9). Assumed deltaT of sewerage of 5°C.

account of installation costs, operational cost implications, and the costs for reaching contractual agreements. Agreements would need to address future access arrangements for maintenance, protections around restrictions to flow, any limitations on the capacity of heat that can be extracted, the impact on sewerage flow temperature, the responsibility for maintenance or repair costs for the sewer, and compensation agreements.

Subject to the considerations identified above and being able to develop an acceptable commercial position for Thames Water and the heat provider/customer, there appears to be no obvious technical barriers that would prevent this technology being deployed in sewers of a suitable dimension. The fact that schemes have been delivered successfully in other countries suggests that it may be possible to agree acceptable commercial arrangements and this technology is considered to be worth pursuing further.

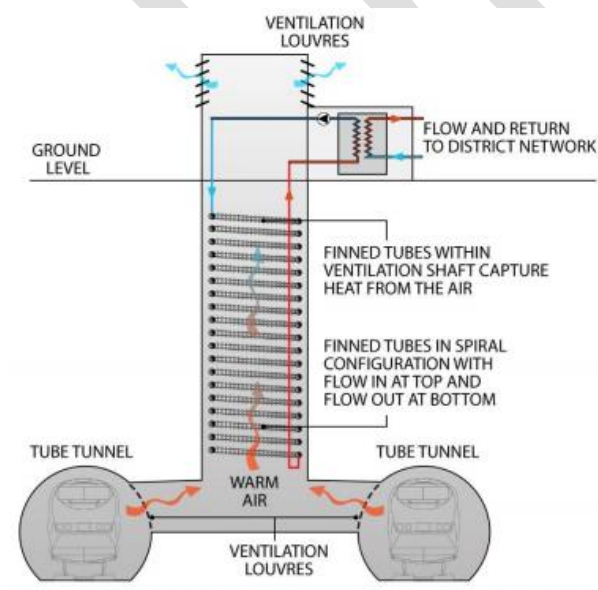
A.3.5 Transport Tunnels

With subterranean railway tunnels experiencing elevated temperatures throughout the year (due to the heat generated by platform activities and the acceleration and breaking of trains), there is the potential to recover significant amounts of heat. Heat recovery from subterranean transport infrastructure can be achieved through the deployment of a number of technologies (including air-source, ground-source and water-source heat pumps). These include the recovery of heat from warm tunnel ventilation air, from the tunnel wall lining materials, or from pumped drainage water.

The recovery of heat from subterranean tunnels or transport infrastructure is potentially an option for enabling low-carbon heat infrastructure on the OPDC site. This is particularly so given the significant railway infrastructure that will be installed in or nearby to the Old Oak area.

A.3.5.1 Ventilation Heat Recovery

The recovery of heat from warm ventilation air can be achieved by placing heat recovery units (modified air source heat pumps) in the warm air currents rising through ventilation shafts. The first system of this kind will be installed to serve the Bunhill Heat and Power scheme in the London Borough of Islington. Correspondence with the Decentralised Energy Project Officer at Islington Council has confirmed that the system operates in a ventilation shaft which discharges approximately 70 m³/s of air from the tunnels serving the Northern Line. As the Northern Line is a deep-set line on the London Underground network, the temperature of the discharged air varies between 14-30°C, depending on the time of day and the season. Whilst these temperatures are too low to serve a DH network directly (the Bunhill scheme operates heat pumps to provide water at 80°C), the temperatures are significantly higher than ambient. This results in significant efficiency gains for the heat pump compared to conventional heat pumps operating in ambient air¹⁹.



¹⁹ Net gain in efficiency would vary, and be dependent on the elevation in temperature from ambient conditions and the temperature at which the heat pump provide heat to the heat network

Figure A.3.7. Heat recovery from metro tunnels

(c/o Secondary Heat: London's Zero Carbon Energy Resource, GLA²⁰)

The conditions within the Bunhill ventilation shaft enable significant quantities of low-grade heat to be recovered; the Project Officer has indicated that a 1 MWth heat pump will be installed (at the time of writing, the system is under construction, with the ventilation shaft currently being rebuilt by London Underground). However, the heat pumps and heat exchangers require specific design characteristics to enable their effective operation. This is due to the high particulate content of the ventilation air, which is expected to result in challenging and potentially corrosive operating environments. Other technical challenges include the high pressure loadings (due to tube train movements) on the fans used to ensure air flow rates are maintained. Correspondence with the Project Officer for the Bunhill scheme has indicated that there are potentially other technologies (such as those outlined below) that may be less challenging from a technical/maintenance perspective. The Decentralised Energy Project Officer has indicated that the system is expected to meet a large proportion of the load for the full network for most of the year, and all the load in summer.

The new transport infrastructure planned for the Old Oak area will require ventilation facilities to enable effective and safe operation. However, the Crossrail route will be a surface line when it reaches the Old Oak area²¹. Although there are likely to be some subsurface activities for any potential future Old Oak Crossrail station, the potential for significant ventilation needs for subsurface Crossrail activities will be minimal.

²⁰ http://www.bre.co.uk/filelibrary/events/BRE%20Events/Developing%20heat%20networks/Peter_north.pdf

²¹ <http://www.networkrail.co.uk/improvements/crossrail/>

The proposed High Speed 2 (HS2) line is expected to operate in bored tunnels throughout its route in the Old Oak area²². These tunnels will require ventilation shafts to operate along the route to enable effective air dispersion within the tunnels as the trains operate. According to a recent paper on journey times and frequencies²³, HS2 will operate up to 18 trains per hour, with each train carrying up to 1,100 passengers. (For reference, typical Northern Line trains at the Bunhill ventilation heat recovery facility can carry up to 665 passengers²⁴.) It is therefore expected that the recoverable heat from any potential future HS2 tunnel ventilation shaft could be roughly comparable to the heat recovery expected at the Bunhill facility (peak output of 1 MWth, with total annual heat provided to a local heat network approximately 3,000 – 4,000 MWh p.a.).

However, discussions with HS2 Ltd have confirmed that the main tunnel ventilation shafts are expected to be located outside the Old Oak area. The exceptions to this include the ventilation shafts serving the new HS2 station. It is expected that, were HS2 to be supportive of heat recovery from warm ventilation air, it would be best utilised to serve the operations of the HS2 station itself, rather than a larger area-wide network subject to further assessment of station demands.

It has been concluded that tunnel ventilation heat recovery is unlikely to provide a major heat source for heat networks at Old Oak, however, the opportunity for heat recovery from the HS2 Station ventilation shaft should be considered by those bringing forward the station design and this could be addressed through future planning discussions with HS2.

A.3.5.2 Tunnel Lining Heat Recovery

Heat recovery from tunnel wall linings was considered for a demonstration tunnel between Tottenham Court Road and Fisher Street shaft on the Crossrail line. The technology, known as Tunnel Energy Segments (TES), was designed to use embedded pipework within the tunnel lining concrete segments, through which water would be pumped in a closed loop heat pump system. This is effectively a ground source system, utilising a source medium which is warmer than normal ground conditions at the same depth.

Nicholson et al²⁵ estimated that, for a 500m stretch of tunnel, TES could provide approximately 1,200 MWh of heat annually. Heat extraction could peak at approximately 30 W/m² of tunnel surface area (approximately 600 W/m tunnel length), with an average heat extraction of 13 W/m² (250 W/m). The same source also estimates that the manufacture and installation of the TES system would cost between £400 and £530 per metre run of tunnel. It is understood that this technology was not proposed for inclusion in the Crossrail construction.

It is understood that the use of TES technology was also considered in a submission to the London Underground Board for inclusion in the Northern Line Extension (NLE), currently under construction. While the concepts and principles were considered to be well formed, hurdles such as the approval of materials and the Operation and Maintenance (O&M) impacts of the scheme (whole life impact and those related to warranty) were considered significant. As a result, it is understood that the use of this technology was not proposed for the NLE.

²² <http://interactive-map.hs2.org.uk/>

²³ Journey Times and Frequencies, HS2: Engine for growth, July 2013

²⁴ http://assets.hs2.org.uk/sites/default/files/consultation_library/pdf/P2C37_Journey%20times%20and%20frequencies%20LOW.pdf

²⁵ <https://tfl.gov.uk/corporate/about-tfl/what-we-do/london-underground/rolling-stock>

²⁶ The Design of Thermal Tunnel Energy Segments for Crossrail, UK, Nicholson et al, Institute of Civil Engineers, Engineering Sustainability Volume 167 Issue E53

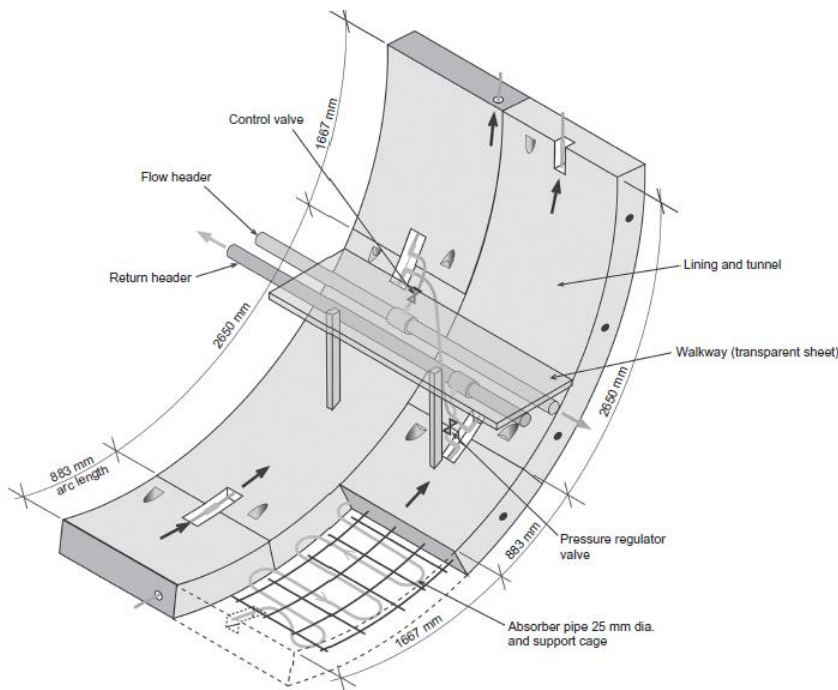


Figure A.3.8. Schematic Diagram of TES Design

(Source: Institute of Civil Engineers²⁶)

Efficiency gains on the heat pumps used to supply a heat network which sources heat from TES technology are achieved through the relatively high temperatures of the heat source (relative to ground temperatures in areas not affected by tunnel heat build-up). While the technology represents a significant source of heat, its recovery through this technology is considered technically and logistically challenging, given the need to install the TES system during the construction of the tunnels, the pressure testing required for each segment as it is installed, and the potential access problems associated with maintenance.

The Old Oak site is surrounded by many key railway lines, some of which also dissect the site. Although many of these lines are surface lines in this area (including Crossrail), the proposed High Speed 2 (HS2) line is expected to be tunnelled in the Old Oak area. As a conservative estimate, approximately 2.5 km of HS2 tunnels crossing the central Old Oak site (between Scrubs Lane and Old Oak Lane, including both east and west tunnels) could be fitted with the TES technology that was examined for Crossrail and considered for the NLE. Calculations indicate that the potential recoverable heat from the tunnels in the immediate area around Old Oak could amount to approximately 5,000 MWh p.a., with a peak output of between 1 – 2 MW. Given that additional lengths of tunnels could be fitted with TES technology, extending outwards from the core Old Oak area bounded by Scrubs Lane and Old Oak Lane, there may be potential for larger quantities of heat to be recovered. However, the baseline figures used for this analysis assumed the same heat output predicted for Crossrail would also apply to the HS2 tunnels. This may not be achievable, given the likely less frequent services of HS2 compared to Crossrail.

Further potential challenges in relation to this technology being deployed successfully at Old Oak include the required dependence on successful cooperation with HS2 in the design, construction and operation of TESs in the tunnels. Discussions with HS2 Ltd have confirmed that TES technology was considered for use on HS2 but will not be taken forward.

It has been concluded that TES will not provide a source of heat for heat networks at Old Oak.

A.3.5.3 Tunnel Drainage Heat Recovery

Tunnel drainage water could also potentially be used as a source of heat. This drainage water collects in tunnels as it leaches out of the surrounding earth. In order to stop flooding of the track, pipes are laid below the ground alongside and beneath tracks to redirect surface water away from the railway and back into the

²⁶ The design of thermal tunnel energy segments for Crossrail, UK, Nicholson et al, Institute of Civil Engineers, Volume 167, Issue ES3

water table. This constant maintenance ensures the safe operation of the railway, while also ensuring the rails and the sleepers that support the rails are kept in good working order. (Transport for London (TfL) estimates that this maintenance extends the life of the track from 20 years to between 45-60 years.²⁷)

This option would effectively utilise water source heat pumps to extract low grade heat from drainage water. Efficiency gains on the heat pump are achieved through the same principles as those described above; the temperature of the water relative to other sources of heat at the surface means increases the efficiency of the heat pump.

Discussions with HS2 indicate that tunnel drainage will be designed to direct tunnel water to sumps at the bottom of the tunnel vent shafts which are outside the Old Oak area where it will be pumped out. The tunnel gradient falls away in both directions from the station which is elevated to assist with braking and acceleration of stopping trains; the vent shafts are located at a low point on the line. As the extraction points are outside the Old Oak area, it is unlikely tunnel drainage water would provide a viable source of heat. While initial discussions with HS2 did not determine the likely volume of water, the expectation is that volumes would be relatively small and unlikely to offer a major heat source.

It has been concluded that tunnel water extraction is unlikely to provide a significant heat source for Old Oak.

A.3.6 Heat Recovery from Data Centres

Data centres are used extensively to host data servers. The Powergate data centre is an example of a data centre in the Park Royal estate, located approximately 600 m west of the Powerday site (see Figure A.3.9), it is a large data centre that provides approximately 15,000 m² of data centre space and 29 MW of customer data capacity.



Figure A.3.9. Location of Powergate Datacentre (in red), with Powerday (in blue) for Reference

Owing to their very high data rack power densities (up to 20 kW per rack, or 2 kW/m²), data centres typically have very high year-round cooling requirements. While some of this cooling can be undertaken using free cooling during the winter months, for most of the year, active mechanical cooling is required. Publicly available data suggests the facility is fitted with a maximum of 36 MW of cooling capacity (plus redundancy), provided via chilled water systems. Chilled water systems circulate water in flow/return pipework to provide cooling (flow temperatures are typically c.6°C, return c.12°C), with the temperature difference serving the cooling load. Chillers and heat rejection units (cooling towers) are used to reduce the temperature of the return chilled water back down to supply temperatures.

²⁷ <https://tfl.gov.uk/campaign/tube-improvements/behind-the-scenes/track-renewal?intcmp=21272>

This is a significant source of low-grade heat, with an expected peak heat rejection of c.40 MW, which could potentially be recovered. An illustration of how this could be done is shown in Figure A.3.10. There are however, a number of key constraints on the amount and temperature of the heat that could be recovered.

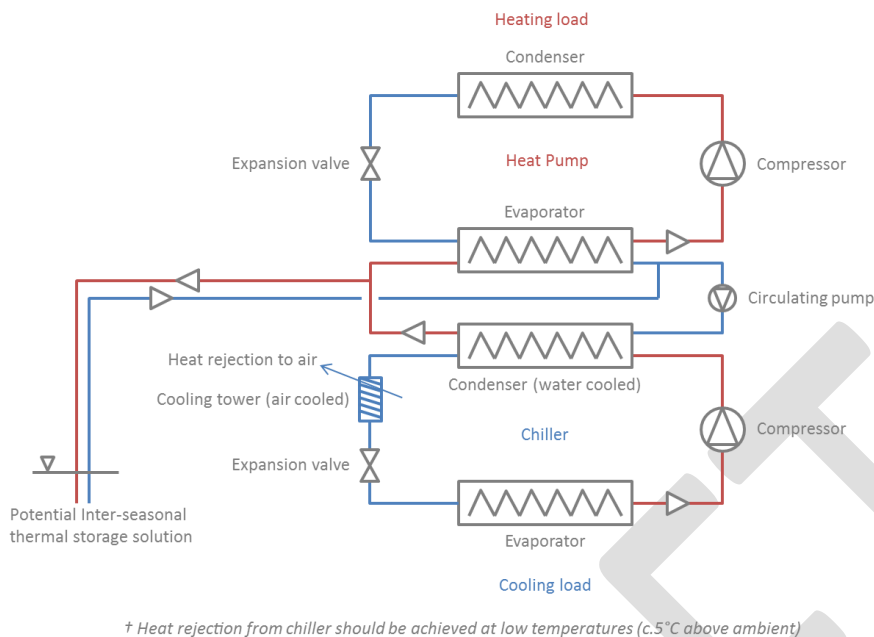


Figure A.3.10. Schematic of Potential Heat Recovery from Data Centre Cooling Equipment

It is understood that the facility makes use of free cooling at certain times of the year, thereby significantly reducing the potential for recovering heat during winter and shoulder seasons for use in an area-wide heat network. The 40 MW heat rejection through mechanical chiller work that is seen in peak summer conditions, is therefore significantly reduced in non-peak seasons, perhaps to c.10 MW.

Additionally, the sensitivity of operating temperatures on the efficiency at which the data centre's chiller plant operates significantly limits the temperature at which heat can be recovered from the cooling system. In order not to negatively impact the efficiency of the data centre's cooling plant, the temperature on to the heat pump evaporator (which serves to cool the condenser on the chiller unit) should not be more than c.5°C above ambient²⁸. This means that, during summer, when ambient temperatures are high (c.25 – 30°C), heat could potentially be recovered at c.30 – 35°C. However, during winter, when ambient temperatures are low (c.5°C), heat recovery could only be undertaken at c.10°C.

These low-temperatures of heat rejection from the cooling plant will therefore not be able to serve as a direct heat source for use in an area-wide district heating system. However, it could act as an indirect heat source, whereby heat pumps use the rejected heat as a source to supply heat at the temperature used in the supply route of the local heat network. However, since the heat source is likely to be only c.5°C higher than ambient, the benefit, compared to ambient-air sourced heat pumps, could be limited.

Although the temperatures at which heat is recovered could be increased (thereby increasing the efficiency of the heat pump operation), the resulting reduction of the chiller unit operation would likely mean that a compensatory regime, that facilitates additional payments from the heat network to the data centre, would need to be put in place. This additional payment would need to offset the reduced efficiencies, and therefore increased energy consumption, at the data centre. A further point to note is that the net effect, of increasing the temperature at which heat is recovered, on the carbon efficiency of energy use (in both the data centre cooling system and the heat recovered for use in a heat network) would remain the same (i.e. the decreased carbon intensity of the heat output from a heat pump sourced by rejected heat at the data centre, would be counterbalanced by the increased carbon intensity of the cooling output from the data centre chillers).

²⁸ c.5°C allows for the increased specific heat capacity of water, compared to air, and therefore the effectiveness of water to act as a cooling medium, compared to air. This is important, since the absence of heat exchange through water onto a heat pump circuit would mean that heat rejection from the data centre's chillers would need to occur via an air-cooled cooling tower.

These constraints and considerations mean that the optimum use of data centres as a heat source is during summer periods, when the mechanical cooling load at the data centre is highest, and when ambient conditions mean that heat can be recovered at a temperature that would allow efficient operation of a heating-load oriented heat pump. However, an area-wide heat network at Old Oak will experience low heat loads during summer, due to the absence of a space heating demand (DHW loads will likely be the main load during summer months). This non-coincident alignment of load and maximum opportunity means the effective use of data centre heat recovery is limited, unless it is coupled with inter-seasonal thermal storage.

Potential inter-seasonal thermal storage solutions could potentially include injection of heat into the London Aquifer, or other sub-surface ground-based storage systems during warm summer months, for extraction later in the year during colder winter months when the demand for heat is high.

A further barrier to use of heat from an existing data centre will be the priority of the data centre operator to maintain maximum operational resilience. Ensuring resilience of data storage will far outweigh any consideration of energy cost or carbon emissions and hence there is no guarantee that an operator would be willing to explore the retrofitting of technology that may be perceived to add risk to their operation. Further detailed discussions would be required with any data centre operator to explore their attitude to this risk, these have not been held to date.

Furthermore, the data centre is located some distance from the Old Oak site, which would involve significant costs to run primary pipework to the data centre and obtain the necessary consents for doing so. It is noted that the proposed HS2 logistics tunnel, that is being considered to carry excavated material (EM) from the tunnel boring activities to the rail head for disposal, would pass relatively close to the data centre. In future, this tunnel could potentially provide a route for heat network pipes subject to no other use being identified by HS2. There would be challenges making connections from the tunnel to energy centres or points of load at the surface and the likely ongoing maintenance requirements for the tunnel would need to be considered. It is also not guaranteed that the appointed tunnel contractor would pursue the construction of a logistics tunnel as their preferred method of disposing of EM.

It has been concluded that while heat could potentially be recovered from the data centre, there are some significant challenges to the deliverability of this option, but it should not be ruled out at this stage.

A.4 Summary

A.4.1 Heat source capacity

The approximate capacity of each of the heat sources is indicated in Table A.4.1, for both peak capacity output (MW) and total annual energy output (MWh p.a.).

Heat source	Heat delivered to network (MWth)	Heat delivered to network (MWh p.a.)	Comment
Grand Union Canal heat pump	1 – 3	5,000 – 13,000	Hydraulic modelling will be needed to confirm outputs once specific demand profiles and proposed operating temperatures are known.
London aquifer heat pump	<1.2 (per borehole)	<25,000 (5 no. boreholes)	Ground hydraulic modelling will be required to determine minimum distances between boreholes. Outputs will be unknown until boreholes have been sunk and pumping tests carried out. Balanced heat extraction & injection likely to be favoured by the EA.
Taylor's Lane Power Station heat recovery	-	-	Communications with E-ON have confirmed that E-ON do not consider the use of current facilities as a viable source of waste heat.
Energy from Waste	3 – 10 (potentially more)	24,000 – 80,000	Capacity based on planned EfW facility.
Sewage network heat pump	200 – 500 kW (per installation)	8,000 – 12,000 (6 no. installations)	Based on 6 no. 200 m length heat recovery installations in existing sewers with diameter >900 mm (considered accessible).
Ventilation shaft heat pump	<1	3,000 – 4,000	Based on 1 no. ventilation shaft
Tunnel Energy Segment heat pump	1 – 2	>5,000	Based on estimated 13 W/m ² heat extraction for 6.2 m diameter tunnel between Scrubs Lane and Old Oak Lane. ²⁹
Tunnel drainage heat pump	Negligible	Negligible	Outputs expected to be small and likely drainage points outside Old Oak area.
Data centre heat recovery	TBC	TBC	Capacity will vary seasonally and would be subject to more detailed technical assessment and detailed design considerations.
Gas-fired CHP comparison	Any capacity	Any capacity	Would ideally be sized to meet the base load, and to operate c.6,000 hours p.a. CHP could operate as a part of a multi-energy source Energy Centre.

Table A.4.1. Approximate Heat Capacity of Heat Source

A.4.2 Heat Source Carbon Content

Table A.4.2 provides an indication of the expected carbon intensity of the heat generated from the various sources discussed in this Technical Note. The SAP 2012 figures are based on the current fuel type emission factors that support calculations in Part L of Building Regulations and which would be used by developers submitting applications today. The second column (SAP 2016) uses the emission factors that BEIS have recently proposed as part of a consultation on updated emission factors for a proposed revised SAP 2016. These include the assumption that average emission factors for grid electricity drop from 0.519 kgCO₂/kWh to 0.398 kgCO₂/kWh. The SAP 2016 figures are intended to indicate the substantial impact that even these

²⁹ The design of thermal tunnel energy segments for Crossrail, UK, Nicholson et al, Institute of Civil Engineers, Engineering Sustainability, Volume 167, Issue ES3, June 2014

early changes to electricity grid emission factors would have on relative emissions of heat pump based technologies compared with gas CHP.

The carbon intensities associated with the use of heat pumps are dependent on both the temperature of the source medium (e.g. water temperature) and the supply temperature to the network. The figures for heat pumps assume a low temperature heat network would be deployed with a supply temperature of 70°C. A good practice heat network serving Old Oak should ideally be designed to operate at a low temperature as this will improve system efficiency. The figures for conventional CHP comparator assumed an 80°C supply temperature.

It should be noted that the emissions factors shown are for the generator with allowance for the losses in the distribution network. They do not however take account of the combination of technologies that would likely be needed to run a network from a practical perspective. For example a gas CHP engine cannot meet 100% of the heat load for technical and economic reasons, and typically if gas CHP is the main heat source serving a network, gas boilers will be providing 20 to 40% of the heat on an annual basis depending on how well the system is designed and operated.

It is likely that a best practice network would have primary network losses (losses from the generator to the heat substation serving an individual development plot) of between 5 to 10% (higher in the early years while loads build up) and secondary network losses (the losses from the individual plot heat substation to point of use in the dwelling) of 10-15%. Total losses of 20 – 25% would not be unreasonable; losses for recently delivered networks in London have been shown in some cases to be far higher. The figures shown include an allowance for the electrical power for pumping based on the SAP assumption that pumping energy is 1% of the heat energy delivered.

The relative carbon performance of each thermal generator technology option is shown here in Table A.4.2. For more details and analysis of carbon trajectories please see Appendix F of the main report, Appendix G provides analysis of the carbon emissions for different technical scenarios.

Carbon Intensity of Heat (kgCO ₂ /kWh)	Carbon content based on SAP 2012	Proposed SAP 2016 emission factors	Energy driver ³⁰	Comment
Grand Union Canal heat pump	0.251	0.192	Electricity	Average water temperature assumed to be 5.5°C ³¹ .
London aquifer heat pump	0.227	0.174	Electricity	Chalk aquifer average temperature of 14°C assumed ⁸ .
Taylor's Lane Power Station heat recovery	0.083	0.063	Waste heat from power station	Table 12 SAP: Waste heat from power station. Communications with E-ON have confirmed that E-ON do not consider the use of current facilities as a viable source of waste heat.
Energy from Waste	0.069	0.103	Refuse Derived Fuel	Table 12 SAP: Heat from boilers – waste combustion.
Sewage network heat pump	0.214	0.164	Electricity	Average sewage temperature of 18°C assumed ¹⁴ .
Ventilation shaft heat pump	0.242	0.186	Electricity	Assumed average ventilation air temperature of 22°C, based on maximum and minimum temperatures experienced at Bunhill Energy Centre in Islington (14 - 30°C).
Tunnel Energy Segment heat pump	0.241	0.185	Electricity	Assumes 17.5°C average temperature, based on expected 13W/m ² heat extraction ²⁹ .

³⁰ Table 12, Standard Assessment Procedure (SAP) for Energy Rating of Dwellings, 2012 edition, version 9.92 (October 2013)

³¹ National Heat Map (<http://tools.decc.gov.uk/nationalheatmap/>)

Carbon Intensity of Heat (kgCO ₂ /kWh)	Carbon content based on SAP 2012	Proposed SAP 2016 emission factors	Energy driver ³⁰	Comment
Tunnel drainage heat pump	0.265	0.203	Electricity	Average drainage temperature of 10°C assumed.
Data centre heat recovery	0.200 (summer) 0.265 (winter)	0.154 (summer) 0.203 (winter)	Electricity	Assumes heat recovered at temperatures no greater than ambient plus 5°C. Therefore significant seasonal variation.
Gas-fired CHP comparison	0.054	0.216	Gas	As with all cases above this is for the engine only and ignores network heat losses and pumping energy. It illustrates the dramatic impact that proposed changes to electricity emission factors will have on the carbon savings from gas CHP.

Table A.4.2. Carbon Content of Heat Source Delivered to Customer via Heat Network

Note that, for those technologies that use electricity as the main driver will benefit in the longer term, due to the expected reduction in grid electricity carbon intensity.

A.4.3 Heat Source Cost Context

For a detailed discussion of cost analysis, please see Appendix G of the main report. A high level comparative assessment of the cost context is provided here for information. Please see Table A.4.3. The assessment is made on a 'per kWh of heat' basis.

Note that this analysis is qualitative in nature. A detailed assessment of all costs, income stream and available grants and tax reliefs will need to be undertaken at a later date. It is assumed that all energy centres would require a gas supply for backup gas boilers so would be common to all cases. Assumed all would require an energy centre and distribution network to serve the building demands so this is ignored for this qualitative comparison.

	CAPEX	OPEX	Capex Comments	Opex Comments
Grand Union Canal heat pump	Medium	Medium	Canal water extraction infrastructure and associated land costs, pipe networks to access canal. EIA and licensing application costs, potential CRT costs.	Maintenance and cleaning of river water filters, general maintenance of heat pumps, river water quality, fish and temperature monitoring associated with license approval.
London aquifer heat pump	High	Medium	Twin 100m+ borehole costs, submersible pumps, plant room costs, license application costs.	General maintenance of submersible pumps and heat pumps, water quality and temperature monitoring associated with license approval.
Taylor's Lane Power Station heat recovery	High	Low	Significant cost of connection route.	Cost of heat purchase from power station.
Energy from Waste	Low	Low	Technology costs low if planned in as part of Powerday delivery. Relatively short primary pipe route to Energy Centre in Old Oak North, possibly significant cost for negotiations with network rail for undertrack crossing.	Relatively limited maintenance cost as maintenance of heat generation plant falls to EfW operator.

	CAPEX	OPEX	Capex Comments	Opex Comments
Sewage network heat pump	Medium	Medium	Costs for heat exchanger installation in sewer, creating connection to surface, pipe runs from sewer to energy centre or plant room.	Potential maintenance payments to Thames Water for heat exchangers. Maintenance for heat pumps.
Ventilation shaft heat pump	Medium	High	Substantial costs for planning and implementation of heat recovery technology in tunnel shaft. Associated costs for heat pumps and pipe runs to tunnel vent.	Substantial maintenance for cleaning of heat exchanges to remove particulate build up. Likely rigorous safety testing related to train operator safety regime. Maintenance for heat pumps.
Tunnel Energy Segment heat pump	High	Medium	Substantial cost for technology development testing and additional cost of tunnel delivery. Cost for tunnel to surface connection, associated pipe runs to energy centres.	Potential for substantial maintenance cost if systems leak or fail but limited maintenance cost in tunnels if implemented successfully. Assumed on-going costs for maintenance and inspection but possibly borne or shared by tunnel operator as serves to extract heat. Maintenance for heat pumps.
Tunnel drainage heat pump	High	High	Assume water pumped to surface by HS2 anyway. Additional cost for pipework to energy centre and cost of heat pumps.	Maintenance and inspection costs for pumps possible borne/shared by train operators. Heat pump maintenance.
Data centre heat recovery	Medium	Medium	Significant cost for pipe run (c.600m) to nearest development/energy centre. Design and retrofit of heat offtake and potential back-up systems. Contractual agreements and negotiations with data centre.	Rigorous operational maintenance and testing at data centre to maintain resilience. Potential additional costs to compensate any loss of performance of the data centre's chiller plant.
Gas-fired CHP comparison	Medium	Low	Gas engine cost.	Gas engine maintenance contract.

Table A.4.3. Cost Context of Heat Source

Attachment I

Please see overleaf for Case Study information on GlaxoSmithKline canal-based cooling installation.

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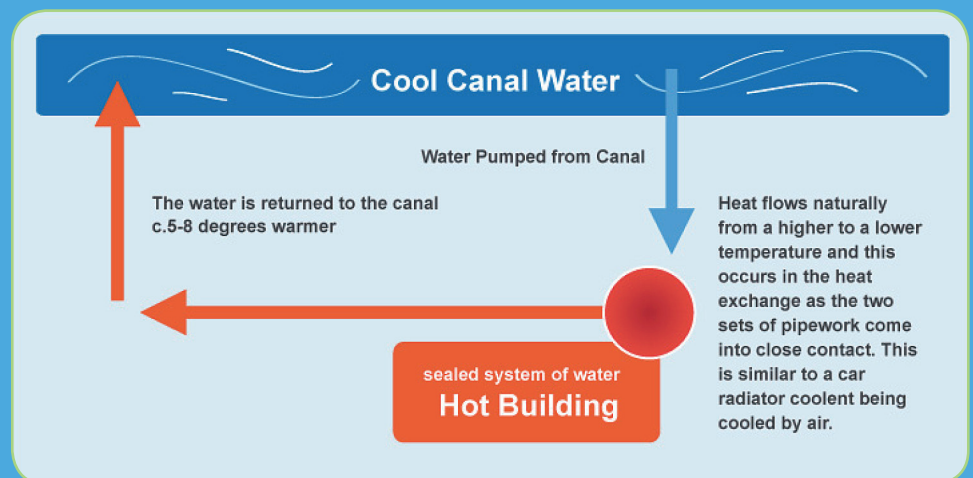
Linden Environmental is a consultancy working to help organisations dramatically reduce their energy bills by using canal and river water to cool buildings. We are part of the Linden Organisation, a group of companies that has been trading for over twenty years.

Linden Environmental offers systems that use river and canal water to cool large buildings, dramatically reducing air conditioning costs and providing better working conditions for staff. This is a tried and tested technology that has been working in some locations for almost thirty years, with organisations such as University of Huddersfield and GlaxoSmithKline in their global headquarters building in London.

How does it work?

It is heat exchange technology, similar to that used in everyone's fridge or radiator in a car. To put it simply, we take water from a waterway, bring it to a heat exchanger and draw out the heat from the building into the canal or river water.

The two fluids do not come into contact but exchange heat across a fine barrier. The coolant is then pumped around the building helping to keep the temperature at a pre-determined level and the water is returned to the waterway downstream of where it was extracted, slightly warmer than it was drawn in. The system is sealed so unlike other air-conditioners there is no need to treat the water, it never mixes with any other fluid used in the building thereby eliminating the risks of legionella.



Linden Environmental works with a range of partners to deliver our services to clients, including being the exclusive reseller of British Waterways' water for cooling schemes. We also work with organisations such as the Environmental Association for Universities and Colleges to raise awareness of water cooling for buildings as an option to reduce costs and carbon.



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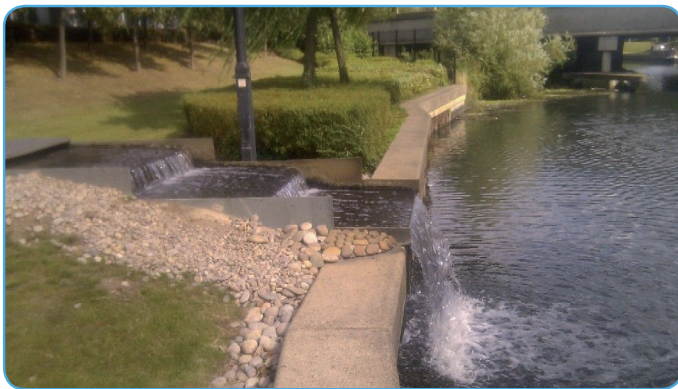
Case Study



GlaxoSmithKline had an increased demand for cooling capacity in the global data centre, located at GSK House. Meeting this 1MgW cooling need had a high cost in electricity consumption and carbon. GSK, Johnson controls and British Waterways devised a project to reduce energy consumption by utilising canal water. The Environment Agency (EA) set strict parameters so as not to affect the wildlife or the biodiversity surrounding the canal and the project managers worked hard to ensure that the heat dissipation is considerably less than the limits set by the EA, and aim to improve the water quality of the canal. The non-consumptive system reduced their electricity bill by over 50% and saved 276 tonnes of carbon each year. The scheme won the British Institute of Facilities Management 2010 Sustainability and Environmental Impact Award.



At its simplest it is a system that dissipates unwanted heat generated in the data centre by discharging it safely to a local waterway, in this case, the Grand Union Canal. Through two heat exchangers, waste heat from the data centre is transferred through 1km of newly installed piping to the chiller located in a newly constructed plant room in the basement. It is here the waste heat is passed out to be discharged over a waterfall which dissipates some of the heat before flowing back into the canal.



GSK significantly reduced the amount of power/ electricity it used compared to traditional air cooling. Initial figures estimated the amount of power used each year would be 1,794,816KW but after the first year of actual operation the amount was reduced further to 1,212,898KW per annum versus traditional air cooling which would consume 2,589,281KW. By using water rather than air cooling for the data centre saves 1,376,383 KWh p.a. and it estimated that a further

500,000 KWh p.a. can be saved with the spare capacity within the system. This amounts to a total carbon saving of 276 tonnes each year. The financial savings from the scheme were originally £131k a year but with some other improvements have increased to almost £200k a year.

Far from damaging the canal environment the heat exchanger system has made an improvement to the locality. The canal does suffer with one regular difficulty, on hot summer days when the flow of water is minimal, the oxygen levels in the canal reduce which severely stresses all of its fish and in very severe conditions they die. By returning the water from the heat exchanger via the cascade and waterfall, additional air is introduced in to the canal water and, locally to the cooling system, the levels of oxygen are improved. The elegantly designed cascade and waterfall and the comprehensive information board on the west bank of the canal has also raised interest in the canal.

Appendix B Summary of Energy Strategies for Existing Planning Applications in the OPDC Area

B.1 Executive Summary

This short briefing note was prepared in November 2016. It provides a high level summary of the energy strategies being proposed by the developers of sites in the OPDC area at the time the review was undertaken. AECOM reviewed the OPDC planning portal for submitted applications and downloaded the Energy Statement for all sites where they were available. AECOM reviewed the summary section of each statement to obtain a high level overview of current plans.

The aim of this exercise was to help inform which landowners AECOM and OPDC should be seeking to engage with regarding their energy strategies and in particular to identify which sites were currently proposing gas CHP fuelled communal heating networks.

Section B.2 provides a map showing the approximate location of the sites reviewed and a table providing a high level summary of the energy strategy proposed for each of the developments and whether or not they are proposing an on-site communal heating system served by CHP and whether they make reference to a connection to a wider network.

We were not able to locate energy statements for Gypsy Corner, the Power House or Hilltop Works. The latter two proposed developments are very small which may explain why no separate energy statement was available.

B.2 Summary of Sites Reviewed

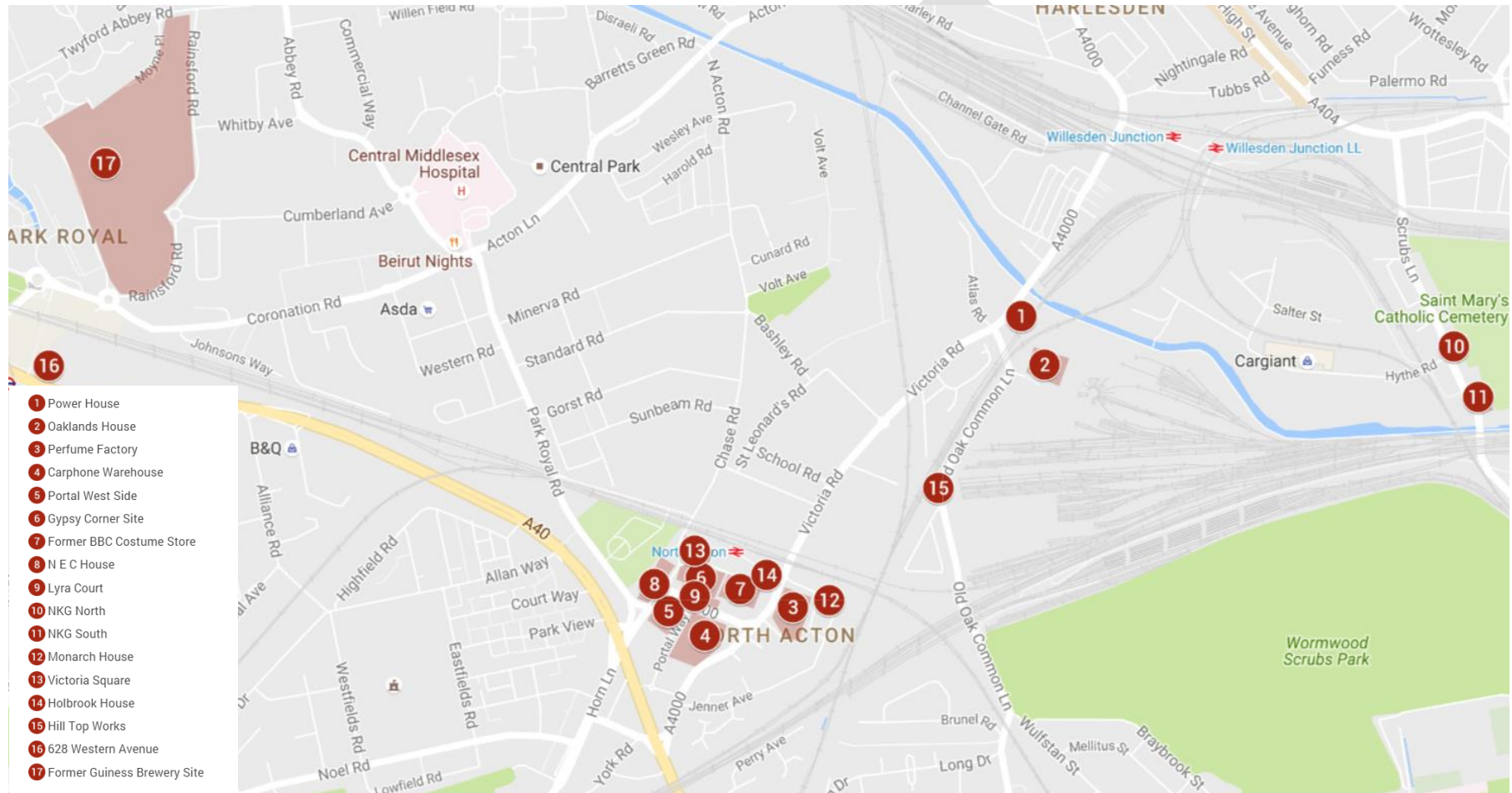


Figure B.2.1. Approximate Location of Sites Reviewed

Reference	Development	No. of Residential units	Floor area of commercial elements	CHP Provision	Connection to DH network	Renewable technologies in place
1	Power House	21 self-contained flats		unknown	unknown	unknown
2	Oaklands House	605 residential units	3,500 m ²	Gas-fire CHP engine (398 kWth) to serve residential elements	Future proofed design to allow for connection to a wider district heating scheme as part of the overall Old Oak Decentralised Energy Strategy	-
3	The Perfume Factory	534 residential units	6,147 m² Class B1/live work 2,175 m² Class B1; 1,381 m² Class A1/Class A3 548 m² Class A1/Class A3 564 m² Class D1 nursery	Either gas-fire CHP (207 kWth) on-site or connection to One Portal Way's Energy Centre	Discussion for connection to One Portal Way's Energy Centre for creation of a district system	300 m ² of Photovoltaic panels
4	Carphone warehouse / One Portal Way	764 residential flats	5,134 m ² (A1, A2, A3, A4, A5 Use Classes, D1, D2 use classes and A1-A5, B1a, D1, D2, C3 Use Class).	Gas-fire CHP engine (400-600kW _e)	Possibility of expanding the energy centre to serve adjacent developments. Future proofed design to allow for connection to a site-wide network.	Biomass boilers to supply 25% of the heat demand 300 m ² of Photovoltaic panels
5	6 Portal Way/ Portal West	578 residential flats	3079.2 m ² (use class A1 and/or A2 and/or A3 and/or A4 and/or B1 and/or D1 and/or D2)	Gas-fire CHP engine (200 kWth) to serve residential elements	Connection to nearby sites has been investigated. Future proofed design to allow for connection to a site-wide network.	ASHPs for commercial units
6	Gypsy Corner Site (Ebbett, Trentham and Poulton Courts)	Building 1 : 61 residential units Building 2 : 120 residential units	Building 1 : 125 m² A1, A2, A3, A4 & A5 use classes 576 m² B1a use class Building 2 : 343 m² A1, A2, A3, A4 & A5 use classes 805 m² B1a use class	unknown	unknown	unknown

Reference	Development	No. of Residential units	Floor area of commercial elements	CHP Provision	Connection to DH network	Renewable technologies in place
7	Former BBC Costume Store	718 bedrooms of student accommodation 4 studios for academic staff	286 m ² (A1/A2/A3/A5 Use Classes)	If biomass plant installation is not approved, a combination of CHP/ground source heat pumps will be considered.	-	Biomass plant (200-250 kW) serving DHW/space heating.
8	N E C House	592 study rooms 66 students studios - one rector studio	1,675 m² (Use Class B1) 930 m² (use classes A1/A2/A3) 130 m² (use class D1)	Gas-fire CHP engine (203 kWth) to serve student accommodation tower	-	2 no. roof mounted arrays of 50 m ² of Photovoltaics.
9	Lyra Court/Portal Way	184 student units	382 m ² (Use Class A1, A2,A3,A5,B1,D1)	Gas-fire CHP engine (25 kW _e) to serve circa 40% of the DHW demand.	-	-
10	North Kensington Gate North	48 residential units	165 m ² (Use class A1/A2/A3)	No (communal boilers are proposed)	Future proofed design to allow for connection to OOPOA District Heat Network	Photovoltaic panels (32 no. of 9.9 kWp)
11	North Kensington Gate South	170 residential units	600 m ² ((Use class A1/A2/A3/B1a)	Gas-fire CHP engine (110 kWth) to provide space heating and DHW to all residential elements and DHW to non-residential elements	Future proofed design to allow for Connection to OOPOA District Heat Network	Photovoltaic panels (24 no. of 7.7 kWp)
12	Monarch House	-	133 bed hotel	CHP system to preheat the domestic hot water service	-	ASHP to provide the heating and cooling requirements of the bedrooms, café and back of house area
13	Victoria Square	151 residential units	673 m ² (Use Class A1, A2,A3,A5,B1,D1)	Gas-fire CHP engine (61 kWth)	-	-

Reference	Development	No. of Residential units	Floor area of commercial elements	CHP Provision	Connection to DH network	Renewable technologies in place
14	Holbrook House	424 bed spaces	Ground floor ancillary student accommodation and a commercial unit for flexible Use Classes A1, A2, A3, A5, B1 or D1 uses.	CHP (201kW _e .) providing DHW and up to 40% of the space heating requirements of the student residences.	Future proofed design to allow for connection to a site-wide network, should such a connection be legally, technically and economically feasible.	20kW ASHP to provide approximately 10% of the space heating requirements and 100% of the cooling requirements A 35kWp solar photovoltaic (PV) array
15	Hill Top Works	nine self-contained flats	-	unknown	unknown	unknown
16	628 Western Avenue/Park Plaza	-	158 bedroom hotel (6850 square metres) 1870 square metres comprising of an indicative office (B1 use class) and associated landscaping, public realm improvements, car and cycle parking,	2no. CHPs (15kW _e) to provide space heating and DHW.	Future proofed design to allow for connection to a site-wide network	183 m ² of Photovoltaic panels
17	Former Guinness Brewery Site		49,797m ² of B1(c), B2 and B8 floor space, café and gatehouse			- Solar thermal panels 760 m² of Photovoltaic panels

Table B.2.1. Summary of Sites Reviewed

Appendix C Heat Networks & Energy Centres

C.1 Executive Summary

This technical note summarises the issues and considerations around the development and siting of district heating networks and supporting energy centre facilities that could potentially serve the planned development at Old Oak. It is intended to help inform future masterplanning work.

Development in the Old Oak area is expected to provide approximately 26,000 new homes alongside significant non-residential facilities to support the effective development of a new district in West London. The expected high density of development is anticipated to be favourable to the successful deployment of a district heating network in the area. However, there are significant challenges, particular to the Old Oak site, that will need to be addressed in order to ensure district heating is viable at Old Oak. These include the location of low carbon heat sources relative to heat demand; the availability of plots for siting energy centres; and the significant physical barriers present on site (e.g. railways and the Grand Union canal).

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

C.1.1 Low Carbon Heat Opportunities

A number of low carbon heat sources have been identified in the Old Oak area. These include:

- The potential to connect to an EfW facility;
- Heat extraction from the London Aquifer;
- Heat recovery from the sewer system; and
- Heat extraction from the Grand Union canal.

The geographic location of these heat sources will impact significantly the design of any proposed energy systems.

C.1.2 Energy Centres

A number of land plots have been identified that could host a dedicated energy centre. These include plots which are not currently planned for development, such as the large triangular plot between North Acton and Wormwood Scrubs Park, and the smaller triangular plot immediately to the south of the Powerday site. Additional sites are also potentially available, including on plots currently planned for development or amenity provision. See Figure C.1.1 for potential energy centre locations.



Figure C.1.1 Potential Energy Centre Locations in Old Oak

The triangular plot between North Acton and Wormwood Scrubs Park (see plot A in Figure C.1.1) is not expected to be developed on, and has therefore been identified as a key potential opportunity for siting a significant energy centre. The available area is significant (consisting of c.20,000 m² of land) and is split over two plots by a key surface railway line (the Underground Central line). A large key substation currently occupies part of the smaller site, although it is anticipated that the plot could also accommodate an energy centre of a significant size (up to c.2,000 m² for a double height energy centre).

The larger of the two plots in the area between North Acton and Wormwood Scrubs Park currently hosts a disused building that could be replaced with an energy centre of significant size (potentially up to 3-5,000 m² or a double height arrangement). However, both this site and the adjacent smaller plot are characterised by challenges regarding access. Both sites are surrounded by railway lines that represent significant barriers and obstacles for access, both for the construction of any energy centre, and for future operation and maintenance procedures. Old Oak Common Lane however does provide some access to the eastern edge of the smaller plot, although any use of this route for accessing a potential energy centre in this plot will need to accommodate the needs of the substation that currently occupies part of this plot.

The railway lines also represent obstacles for providing utility access routes and for routing District Heating (DH) pipework into and out of these plots. However, pipework/utilities could be routed out of the sites alongside the Central Line (and beneath the railway lines running along the western and southern edges of the plot) towards the North Acton developments to the west and south of this plot. For the smaller plot, potential routes to/from the smaller plot could be achieved via the adjacent Old Oak Common Lane. Alternatively, thrust boring techniques could be used to direct services/utilities/pipework underneath railway lines; however consent from Network Rail would be needed to do this.

Other potential plots for locating an energy centre are also identified, including a small triangular plot adjacent to the canal and immediately to the south of the Powerday site (see plot B in Figure C.1.1). Due to the irregular shape of this plot, it is unlikely to be able to accommodate an energy centre with a footprint larger than 800 m². This plot will also represent challenges in terms of access, particularly for construction and operation/maintenance, as the plot is bounded by surface railway lines on two sides, and the canal on

the other. There are however potential routes in and out of the plot for utilities and DH pipework, along the canal towpath leading east from the site adjacent to the canal.

Other potential energy centre plots include the proposed EfW facility at Powerday (see C in Figure C.1.1), the energy centre proposed by Car Giant (see D in Figure C.1.1), and the proposed landscaped amenity space on the south bank of the canal (see E in Figure C.1.1).

Additionally, there is the potential to locate energy centres in plots identified for development. These could be used to complement the above options, and be co-located alongside development, potentially at ground or basement level. However, a number of factors should be considered when determining appropriate locations, including the phase in which the plot is expected to be developed; the proximity of the plot to other development sites that could be dependent on heat services; and the proximity of the plot to the low carbon heat source that the energy centre will target for exploiting. Low carbon heat sources that could be utilised in a plot-based energy centre include sewer heat recovery systems, and open-loop heat pump systems extracting heat from the London Aquifer.

C.1.3 Network Challenges and Opportunities

DH network routes around the Old Oak site are expected to encounter a number of key challenges. These include a number of railway lines (including the planned HS2 line and the Crossrail line currently under construction), the Grand Union canal, and a lack of available crossing points over these obstacles. The grouping of development into geographical clusters, separated by the numerous railway lines in particular does represent significant challenges (see Figure C.1.2).

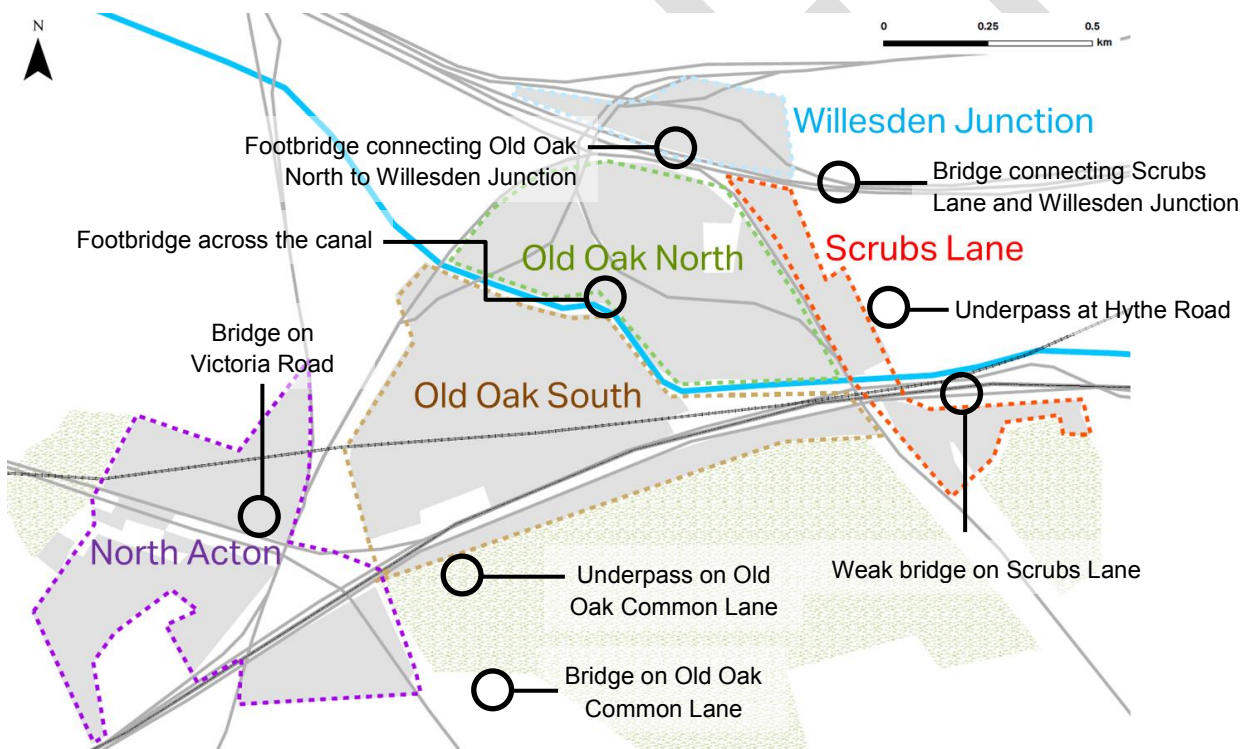


Figure C.1.2 Clustering of Development at Old Oak

The Willesden Junction cluster is geographically isolated from the rest of the site by major railway lines running east-west. With only a footbridge currently linking Willesden Junction to the development plots in Old Oak North, a new road bridge is expected to be provided (see Figure C.1.3). This new link will likely provide a key route for utility and potentially DH network routes; coordination at the Masterplanning stage of works will be required to safeguard the potential to use this link for DH routing of pipework to the Willesden Junction cluster.

The Scrubs Lane cluster is also isolated from neighbouring clusters. Although there is a bridge connecting the Scrubs Lane cluster to Willesden Junction in the north, this bridge is likely to carry key existing utility

routes. Furthermore, the southern-most part of the Scrubs Lane cluster is currently only connected to the rest of the cluster by a bridge which spans the canal and the railway lines which will in future be used for Crossrail services. This bridge is weak however, and is subject to loading restrictions. Connections to the Old Oak North development are currently provided via a single underpass road beneath the railway line at Hythe Road. See Figure C.1.2. However, many of these crossings are expected to undergo improvements as part of the wider works to enable development in the Old Oak area (see Figure C.1.3). Coordination at the Masterplanning level will be required in order to establish and safeguard the potential for utilising these roads and bridges as conduits for routing DH pipework.

North Acton is in the south-western most part of the Old Oak site, and is separated from the main Old Oak development by key railway lines. Key routes to North Acton include Old Oak Common Lane and Victoria Road. These roads provide crossings over the various railway lines in the area, via both bridges and underpasses (see Figure C.1.2). However, many of these routes and crossings are expected to undergo significant upgrades as part of the enabling works for the wider Old Oak development, including a significant realignment of Victoria Road due to HS2 requirements (see Figure C.1.3). Engagement during the Masterplanning works will be needed in order to establish the potential of these roads for routing DH networks.

Old Oak North and Old Oak South are separated by the Grand Union canal, which dissects the site. Although only one pedestrian footbridge currently connects the two sites (see Figure C.1.2), significant new road and pedestrian infrastructure is expected to be provided as part of the Masterplan (see Figure C.1.3). Within Old Oak North, the existing railway line running through the site towards the southeast is expected to be raised to provide an elevated section of the line. This will open up the potential of laying DH network pipework along the new road network planned for the area.

In Old Oak South, development will mostly occur on podiums, raised above the new railway infrastructure planned for the area (Crossrail sidings and HS2); design of the podium system will need to accommodate heat network pipework requirements assuming development of these plots occurs prior to substantial decarbonisation of the electricity grid, and DH services are required for these developments. The expected improvements to Old Oak Common Lane are also likely to provide opportunities for network routing to the southern-most areas of Old Oak South which are separated from the rest of the site by Crossrail and HS2 infrastructure. An alternative route to the southern-most parts of Old Oak South could also be reached via new footbridges that may be provided in the Masterplan (see Figure C.1.3); coordination at the Masterplanning phase of works will be needed in order to safeguard these routes and establish the potential incorporating DH pipework.

Figure C.1.3 shows the expected new infrastructure provision for the Old Oak area, including new road bridges, pedestrian bridges, new road networks and potential junction improvements.

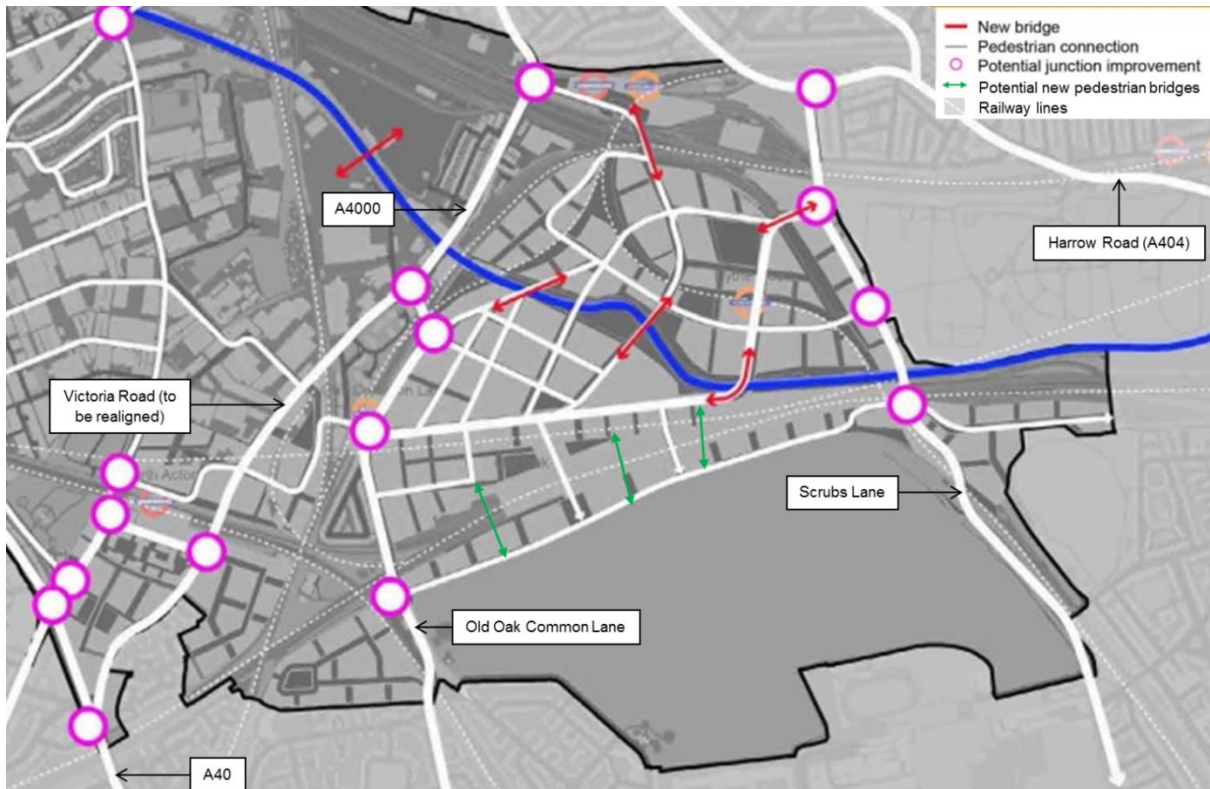


Figure C.1.3 Expected new infrastructure provision

C.1.4 Indicative routes

Indicative options for energy centre locations and routes for the main DH transmission network are illustrated in Figure C.1.4. Routes for the primary distribution routes (connecting individual development plots to cluster-based energy centres) should be established during the Masterplanning works, and will need to consider the challenges and opportunities identified in this Technical Note.

Secondary pipework (from the boundary of plot development sites to the interface with individual dwellings) and tertiary pipework (within dwellings) should be designed to the standards set out in Section C.5 of this Technical Note during the detailed design stages of individual plots.

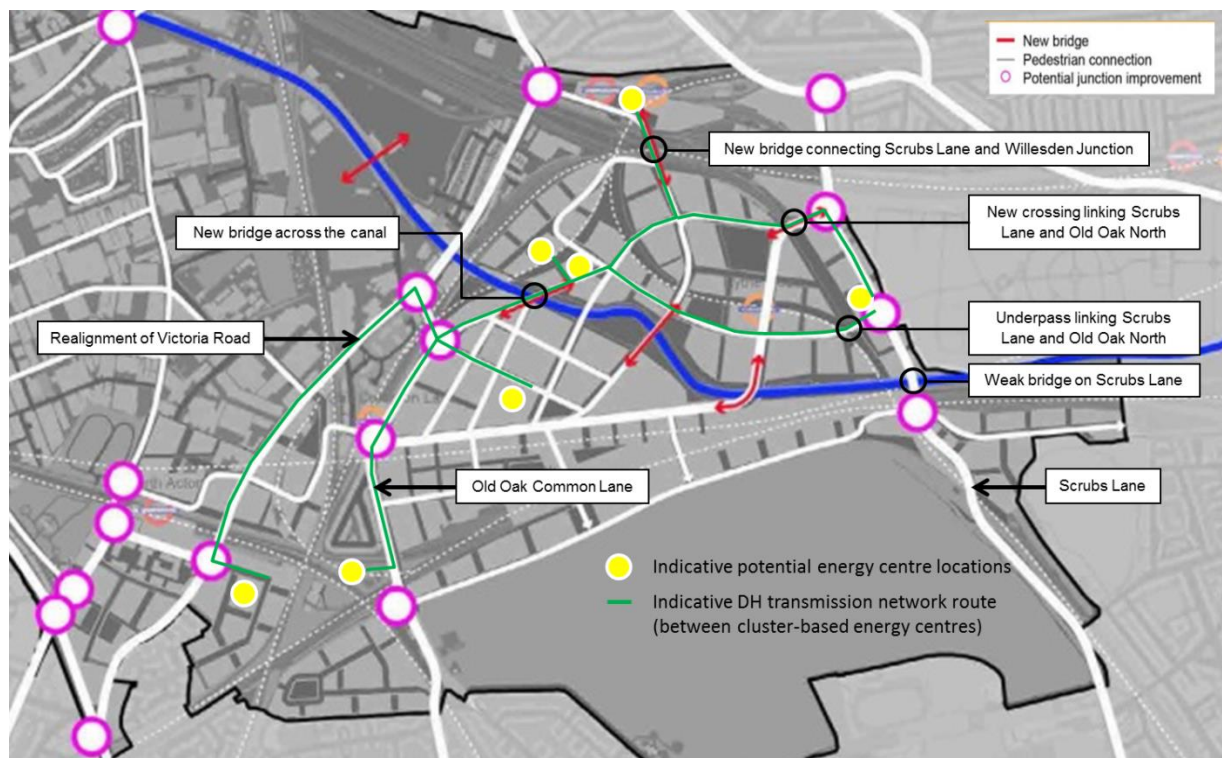


Figure C.1.4 Indicative route for DH transmission network and energy centre locations

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

Determining appropriate network routes will need to consider the viability of linking North Acton to the wider network; the two main options for this include via Victoria road or via Old Oak Common Lane. Both of these roads are expected to undergo improvement works as part of the wider works to enable development in the area (in the case of Victoria Road, realignment of this route is expected as part of HS2 works).

New bridge and road crossings are also expected as part of the improvement works to enable development in the area. While the primary purpose of these new crossings are expected to be to ensure a more coherent and accommodating townscape, they are likely to provide a secondary purpose to enable utility and services routes to cross the site. It is recommended that the design of the Masterplanning works is coordinated with discussions regarding DH pipework, in order to safeguard potential route options.

Key crossings and routes that should be considered for incorporating DH pipework are outlined in the following sub-section.

C.1.5 Key considerations for Masterplan

Key considerations for the Masterplanning works that relate to determining appropriate locations for energy centres, and for the routing of DH pipework (transmission and primary distribution pipework), include the following:

- Identifying key crossing points across the canal;
- Identifying key road crossings across railway lines to reach the Scrubs Lane and Willesden Junction clusters;
- Safeguarding these key crossings to ensure that their design can accommodate DH network pipework;
- Identifying when key crossing points would need to be delivered in order to enable expansion of the network to key demand clusters;

- Identifying energy centre locations and safeguarding access to them for construction, maintenance and network route access; and
- Identifying opportunities for coordination with the installation of other utility infrastructure, and either construction of new civil infrastructure or the upgrading of existing civil infrastructure.

DRAFT

C.2 Introduction

C.2.1 Context

The development projected to occur at Old Oak will require significant new energy infrastructure, including services for both space heating and for domestic hot water generation.

The viability of low carbon heat sources has been investigated by AECOM with findings presented in a separate Technical Note¹. The heat sources found potentially viable include the utilisation of water sources such as the London Aquifer and the Grand Union Canal; in addition to a potential EfW facility; and local sewage networks.

If these low carbon heat sources can be viably utilised as sustainable sources of heat in addition to conventional heat sources such as gas Combined Heat and Power (CHP), a network system to distribute the heat to different development parcels and customer buildings will likely be required to maximise the benefits associated with their use.

District Heating (DH) networks are simply a means of distributing heat that is generated in one location (typically an energy centre, containing heat generators such as boiler units), and delivering it to a customer in another location. This is done on a 'district' level, covering large areas of development. While conventional utilities provide electricity and gas infrastructure to the customer's door, DH services provide thermal energy (heat) for use by the customer. Although an interface between the DH service and the customer is required (typically through the use of Heat Interface Units (HIUs) at the plot or building boundary), the use of DH facilities does however negate the need for gas-fired combustion plant in customer buildings. Additionally, mains gas infrastructure may also not need to be provided to each building, unless required for catering or other uses.

DH networks typically distribute water in a dual circuit of insulated pipework. A typical network circulates warm water in "flow" pipework at a temperature greater than the parallel "return" pipework. Extraction of heat from the network by customer systems results in the return pipework being at a lower temperature than the supply pipework. The extracted heat is replenished through the use of heat generators in the energy centre.

DH networks can operate at a variety of temperature settings. Commonly used temperature regimes operate flow temperatures of c.70-90°C, with return temperatures of c.40-60°C (providing a temperature difference between flow and a return, or dT of c.30°C). However, older networks typically operate at higher temperatures and pressures (Medium Temperature Hot Water) and a smaller dT (20) but with very little commonality of design.

There is a concerted move however to ensure new networks operate with lower temperatures and/or with as large a dT as possible, since this both improves the efficiency of heat generation and reduces significantly the flow rate of circuited water required (and therefore the power required to pump the water around the circuit). There is no common standard for DH design in the UK. Industry guidance is available², which identifies best practice but it is not a requirement nor suitable if the heat customer systems are inappropriately designed.

Pipe sizes can also be significantly reduced for networks with high dTs, thereby significantly reducing the installation costs for the pipework. There is also a move to reduce overall circuit temperatures, as this can also improve the efficiency of heat generation, while also reducing the heat losses experienced in the distribution pipework (by reducing the temperature gradient between the pipework and the surrounding medium, e.g. earth).

Heat networks typically consist of:

- Transmission network – transmission network connecting different energy centres in each geographic cluster (transmission networks are not always employed in DH systems in the UK, although they are commonly used in Scandinavian countries for large, interlinked networks);

¹ Technical Note 1: Heat Sources, AECOM, 2016

² CIBSE CP1: Heat Networks: Code of Practice for the UK: Raising standards for heat supply, CIBSE /ADE, July 2015

- Primary network – main distribution pipework from an energy centre(s) to the boundary of a development parcel or plot;
- Secondary network – pipework from the boundary of a development parcel to the building and in the case of residential buildings to the heat interface unit (HIU) of the dwelling units (including ‘risers’ and ‘laterals’ within the building); and
- Tertiary network – pipework within dwellings, from the HIU to the point of service (e.g. hot water taps or central heating radiators).

The heat networks under consideration in this Technical Note are the transmission network and the primary distribution route. The secondary and tertiary networks are the subject of building- or plot-level design. However, guidance on appropriate design principles for secondary and tertiary networks is provided. Please see Section C.5 for more details.

Further considerations for this Note include the potential locations for energy centre(s), as these will have direct impacts on the network and route. Energy centres would likely host any HIUs required for incoming low carbon heat supplies, conventional heat generation plant such as gas CHP engines, heat pumps, and standby or peak load gas boilers. Additional plant that would likely need to be located within an energy centre include water treatment plant and pressure stations for the network; thermal storage units for maximising the utilisation of low-carbon heat sources; pumping equipment; and any electrical switchgear needed. Energy centres housing gas boilers or gas CHP also normally require a medium pressure gas supply. All combustion plant including CHP engines and gas boilers will need to be designed to meet air pollution emission limits set out in the Mayor’s Supplementary Planning Guidance on Sustainable Design and construction and this may also require flue treatment units (e.g. Selective Catalytic Reduction (SCR) units).

Energy centres also typically require large plots of land; if designed with flexibility for multiple future energy sources this may impact on space requirements. Suitable locations for energy centres in the Old Oak area are discussed in this Technical Note.

C.2.2 Key Considerations

Should DH be considered a viable and preferable site-wide energy strategy for the development at Old Oak, key considerations for the early phases of development will be to ensure that:

- Developments are designed to be compatible with, and easily connected to, a local DH network;
- The potential for first-phase connection to local heat sources is explored, in order to initiate and encourage the phased expansion of the network;
- Potential routes for DH networks are safeguarded on and around the plots being developed;
- The utilisation of available heat sources in the area is not compromised (e.g. locations for, and access to and from, local heat sources and distribution facilities are safeguarded); and
- Consideration is given to undertaking construction of enabling nearby infrastructure, during construction of the first plots, in order to make future connections of customer plots to the network easier. The potential for coordinating the installation of this infrastructure alongside other utilities should also be investigated to establish potential cost savings.

C.3 Energy Centres

Energy centres are dedicated facilities for generating energy for use in a DH system. Energy centres typically consist of:

- Heat generating plant (e.g. Combined Heat and Power (CHP), gas boilers);
- Thermal storage vessels (used to shift the demand for and generation of heat, in order to more fully utilise low-carbon or economically valuable heat resources);
- Pumps (to pressurise the circulating water in the distribution network);
- Pressure vessels (to control and equalise the pressure in the distribution network);
- Water treatment equipment (to maintain the water quality in the distribution pipework);
- Flue emissions control equipment, if applicable (e.g. SCR for NO_x emissions controls);
- Ancillary equipment (including ventilation equipment for ensuring the energy centre building and plant is adequately ventilated; electrical switchgears; heat rejection units for rejecting waste heat; pipework; valves; insulation; and noise attenuation); and
- Building Management System (BMS) and control platform.

Appropriate locations for energy centres are discussed below.

C.3.1 Energy Centre Locations

There are a small number of plots around the masterplan site that have not been identified for development. These include the triangular site in North Acton immediately to the northwest of Wormwood Scrubs Park, and the smaller triangular site in Old Oak South immediately opposite the Powerday site on the south bank of the Grand Union canal. Additional opportunities adjacent to the canal could be utilised for accessing the canal for water source heating and/or cooling. These are labelled in Figure C.1.1 alongside the planned energy centre on the Car Giant site, and the energy from waste facility planned at Powerday. These opportunities are discussed in turn as follows.

C.3.1.1 Plot near North Acton

The total land area is approximately 22,000 m². However, the site is bounded by railway lines, with the Central Line also running through the centre of the site, dissecting the site into a larger parcel approximately 12,000 m² in land area, and a smaller parcel of approximately 8,000 m². See Figure C.3.1.

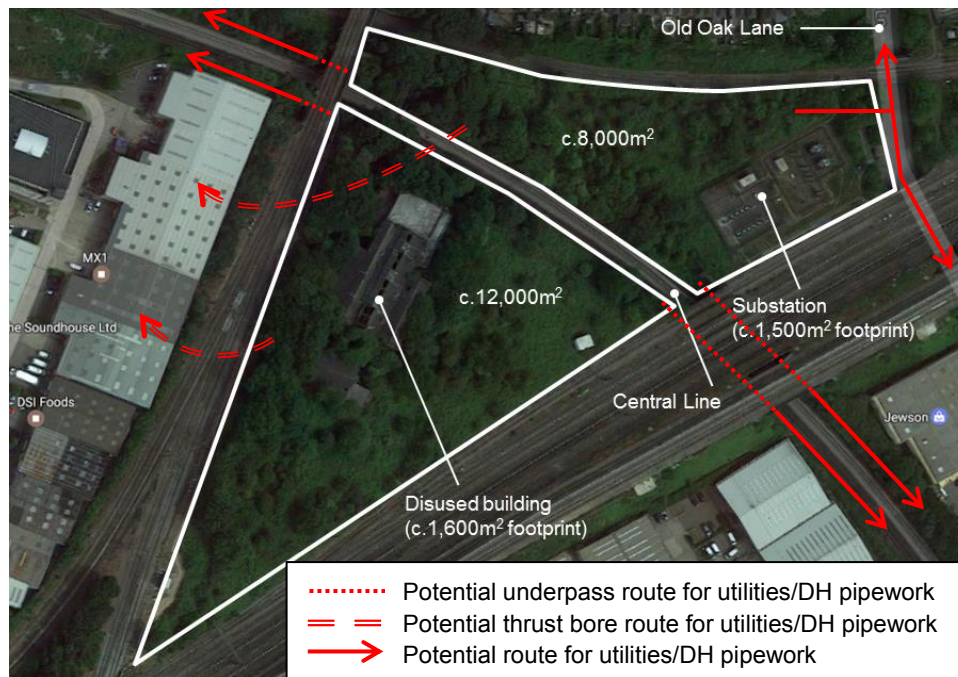


Figure C.3.1 Plot adjacent to North Acton

The larger of the two plots currently hosts a disused building which has a footprint of approximately 1,600m², indicating that an energy centre of around 3-5,000 m² floor area could be accommodated. Routing out of the site for pipework or utility services is potentially possible under the railway lines, via a thrust bore operation, or alongside the Central Line running west to the North Acton development area (and beneath the railway line running along the western edge of the triangular plot). However, access for construction, operation and maintenance is likely to be a key challenge for this site, with the land bounded on all sides by railway lines, which may render this site unusable.

The smaller of the two plots currently hosts a large substation with a footprint of c.1,500 m². Given the criticality of a substation like this, it is likely that any additional development on this plot would need to accommodate the substation and any access required for it. However, it is expected that the plot could still host an energy centre with a footprint c.1,000 m² (providing total floor area of up to 2,000 m² if a double height energy centre is developed). Access could potentially be achieved via Old Oak Common Lane, although a steep gradient between the road and the plot would need to be overcome. Routing could also utilise Old Oak Common Lane towards the later-phase developments in North Acton to the south of this plot. Routing of utilities or district heating pipework could be directed to the main North Acton development site potentially under the railway line using thrust boring. Any routing of pipework under or adjacent to railway or Underground lines is likely to require extensive engagement with Network Rail and or Transport for London (TfL) for necessary approval of works.

3.1.2 Plots adjacent to the Canal

There is an available plot of land adjacent to the canal and opposite the Powerday site on the north-western edge of the Old Oak South site. See Figure C.3.2. The total land area is approximately 3,400 m²; however the unusual shape of the plot is likely to limit significantly the footprint that could be used for an energy centre. It is estimated that an energy centre of c.800 m² footprint could be accommodated; should double height construction be used, a larger facility could potentially be accommodated. It is expected that this plot would be large enough to accommodate the necessary plant and equipment required for a canal-sourced heat pump system. Alternatively, it could also be used as a location for boreholes to enable an aquifer sourced heat pump system.

However, this triangular site is very challenging in terms of access, with the site bounded on two sides by railway lines, and the canal on the third side. Access for construction, operation and maintenance may need to be provided via the canal. However, routing of utilities or district heating pipework could potentially be

provided along or beneath the canal towpath towards the main Old Oak South site, and across new footbridges towards the Old Oak North site.

A further opportunity to consider in relation to this site is that it sits above the planned route for HS2's planned logistics tunnel that would take excavated material from the HS2 tunnelling works for disposal via the rail network. If constructed, the tunnel might in future provide an opportunity for routing utility infrastructure.

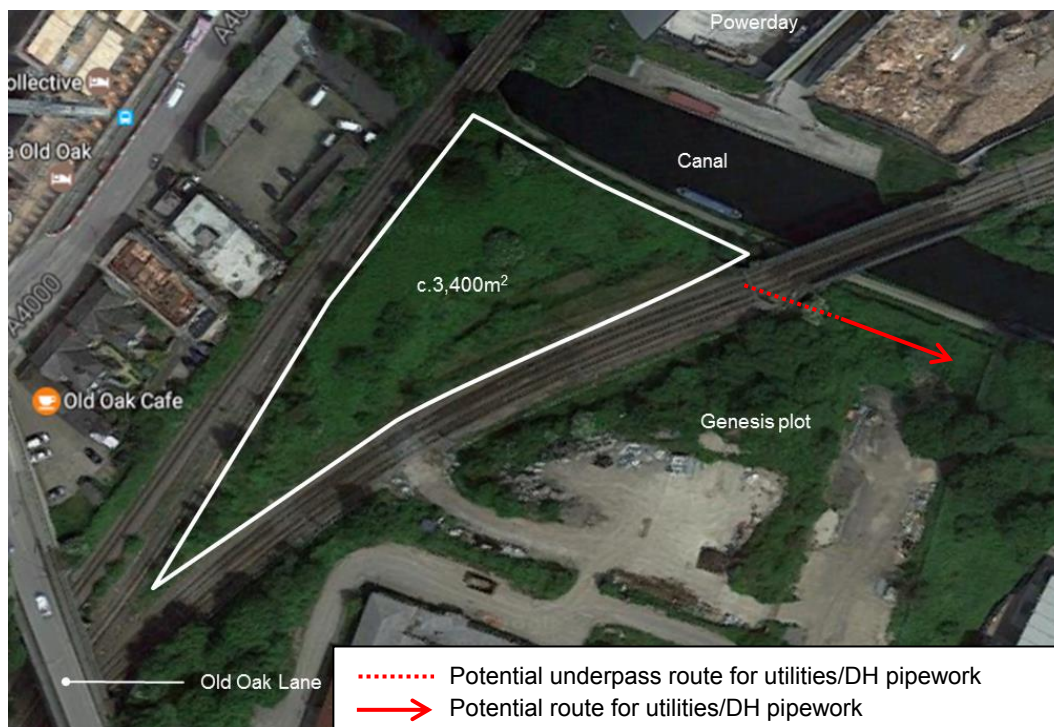


Figure C.3.2 Plot adjacent to Genesis & Canal

There is additional land available adjacent to the canal in Old Oak South. See Figure C.3.3. This land is anticipated to be landscaped, in order to maximise the opportunities for creating an attractive townscape for the area.

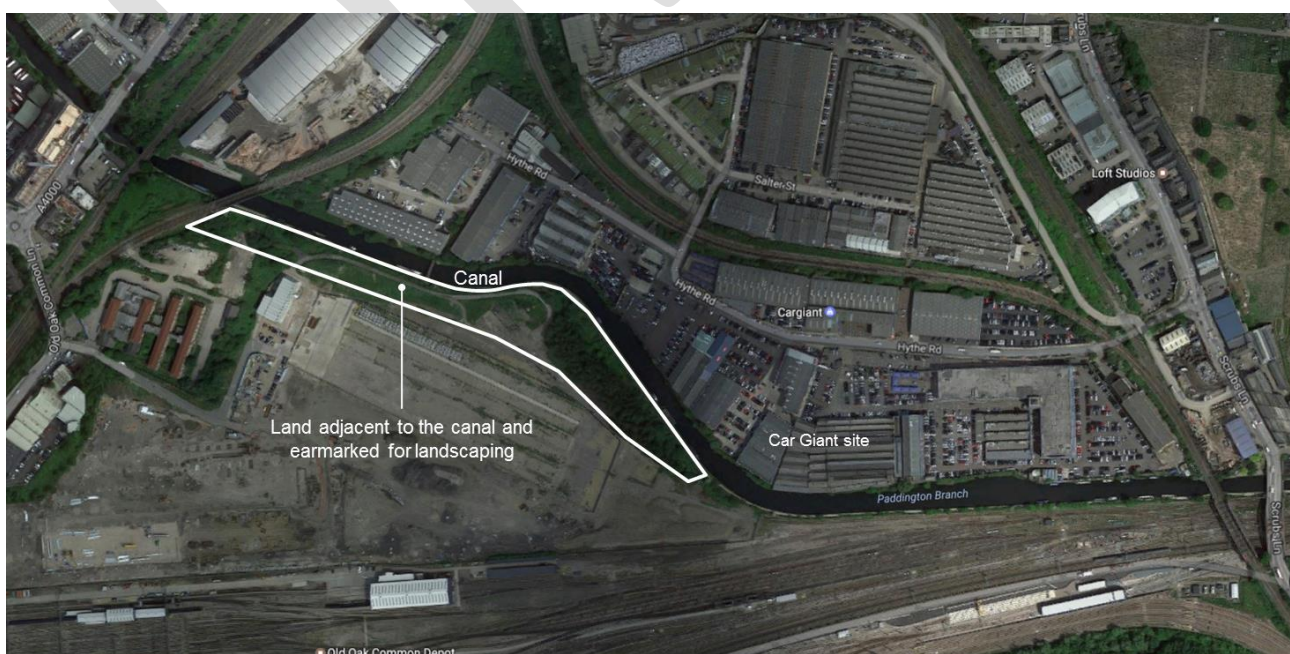


Figure C.3.3 Land adjacent to the canal scheduled to be landscaped

Although this land will unlikely be suitable for locating a traditional energy centre (owing to its prime canal-side location), it may be possible to house a canal-based water source heat pump system. An example of creating a system that could complement an attractive canal-side amenity space has been demonstrated at the GlaxoSmithKline facility in Brentford that utilises the River Brent for cooling purposes. See Figure C.3.4. A similar system, designed to be sympathetic to the expected landscaping of this area could potentially be a solution for exploiting a canal-based water-sourced heat pump system at Old Oak.



Figure C.3.4 GlaxoSmithKline Water-Sourced Heat Pump System at the River Brent

3.1.3 Powerday

Powerday operates a large commercial waste management business in a large plot in the northwest of the Old Oak North site. The facility processes and sorts waste into constituent categories for resale, including metals, wood products and hard plastics. The majority of the residual materials (including soft plastics, small wood chips and unrecoverable paper and cardboard) are processed into Refuse Derived Fuels (RDFs) for sale to EfW plants across the UK and Europe.

Powerday is developing proposals for an EfW plant (expected size 3 – 5.7 MWe) on their site at Old Oak, to be fuelled entirely by the RDFs produced onsite. The EfW plant could offer the potential to export significant amounts of heat to neighbouring development sites in the Old Oak area. Powerday has indicated that it intends to locate the EfW facility on their own site. For more information, please see Appendix A of the main report.

Enabling connection of the EfW facility to the wider Old Oak site will be challenging, since the site is surrounded on all sides by railway lines or the canal. The site is currently accessed via a small access road leading under railway lines to the northeast of the site. See Figure C.3.5.

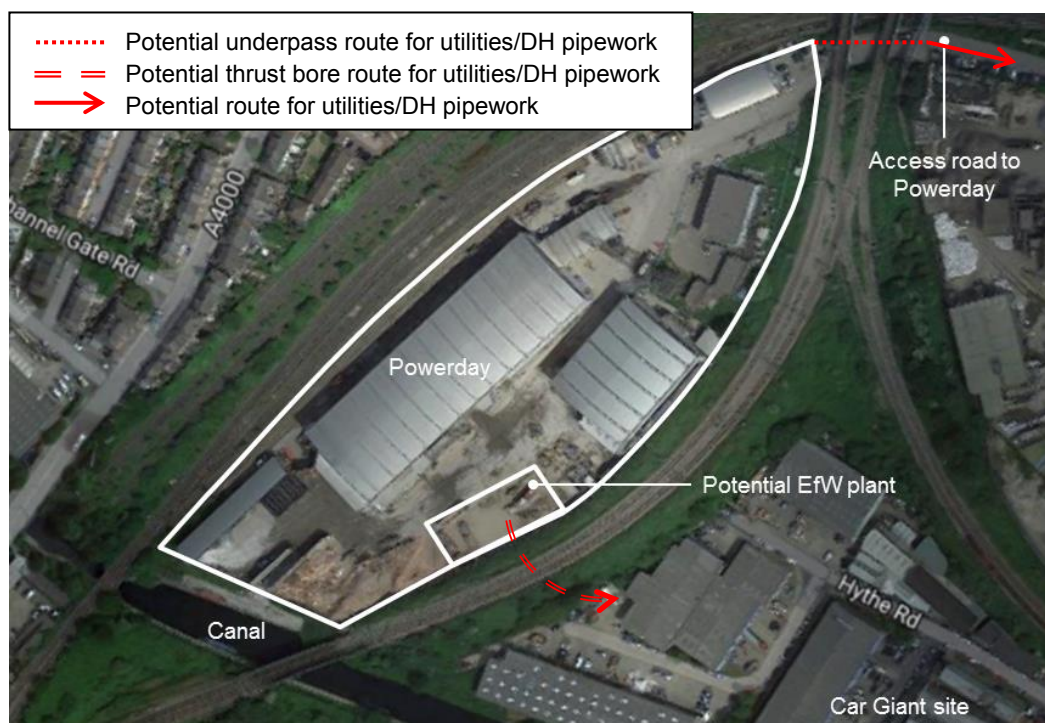


Figure C.3.5 Powerday

A potential option for reaching the Car Giant site would be thrust boring beneath the railway to the east of the Powerday site. This option could feed heat generated by an EfW facility into an energy centre located on the western edge of the Car Giant site. Initial discussions with Car Giant suggest this would be their favoured location for an energy centre. The feasibility of thrust boring beneath the railway would need to be explored further with Network Rail.

If the facility is to serve other developments around the Old Oak area, the potential for routing pipework through the Powerday site and along (beneath) the access road to Powerday should be investigated, as this could be a more economical solution compared to thrust boring beneath the railway line. However, the impact of such works on the operation of Powerday, both during construction and operationally should be considered. There may also be existing utilities present beneath the access road, which could restrict the viability of this route. Further investigation of these potential limitations should be undertaken during the masterplanning works.

3.1.4 Development Site Energy Centres

Development plots could potentially be used to complement the above options for accommodating energy centres. These could be located in any of the anticipated development plots, although a number of factors should be considered when determining appropriate locations. These include the phase in which the plot is expected to be developed; the proximity of the plot to other development sites that could be dependent on any heat services provided by the energy centre; and the proximity of the plot to the low carbon heat sources targeted for exploiting. Low carbon heat sources that could be utilised in a plot-based energy centre include sewer heat recovery systems, and open-loop heat pump systems extracting heat from the London Aquifer. Energy centres incorporated into the development could also be sited to enable heat extract from the canal, for example an energy centre at the West of Car Giant's site could be located close to the canal and with the boundary of Powerday's site.

Existing and expected new large sewers (>1m diameter minimum required for maintenance access) in the area are expected to offer the potential for 200 – 500 kWth of heat output per installation, generating c. 1-2,000 MWh of annual heat output (per installation). Suez Plc has confirmed that the installations they operate in France are subject to a number of design limitations. These include a maximum length of

continuous heat exchangers of 200 m (due to hydraulic limitations), and a maximum distance between the heat exchanger and a heat pump of 300 m³.

The London Aquifer offers a potential source for delivering heat to a local or area-wide network. The use of aquifer-sourced heating will need to consider the space requirements of borehole equipment, heat pumps and heat interface units within the basement of a development plot. Space will need to be retained above the boreholes for the equipment needed to lift the submersible pumps for maintenance. Consideration should also be given to appropriate locations for maximising the potential of borehole heat extraction. Analysis of existing borehole records in the area suggest the potential for water extraction (and therefore heat extraction) varies considerably depending on location. Whilst extraction rates cannot be guaranteed, and investigatory boreholes will be required to determine achievable extraction rates, areas to the south and east of the Old Oak site (particularly at Hammersmith Hospital) are expected to offer the greatest opportunities for significant rates of water extraction. An abstraction and return borehole are likely to be required and these will need to be positioned a substantial distance apart to avoid thermal breakthrough between the abstraction and return water temperatures. Ground modelling will be required to explore this but separation distances of greater than 100m may be required.

For more information on these technologies, please see Appendix A of the main report.

C.3.2 Utility Requirements

In addition to the technology required to generate heat from the local low carbon heat sources, energy centres will also likely utilise gas boiler systems. These will operate as peaking plant, in order to meet loads during times of peak heating demand (e.g. during cold winter mornings, when the demand for space heating is high, and the demand for hot water services is also high). Back up plant will also be required when the main duty plant is taken out of service for planned or unplanned maintenance. Mains gas supply networks, serving the gas requirements of energy centres that host gas systems will therefore be required.

While peak and back up plant is likely to be gas boilers in the early phases, the strategy could potentially transition to electric boilers in later phases as the electricity grid decarbonises. This would be subject to the relative future cost and carbon content of gas and electricity. At present, gas has a lower cost per unit of heat output than direct-use electricity. However, in future, a greater focus on demand management could lead to more dynamic tariff arrangements, with prices being adjusted according to daily demand patterns.

A small mains water supply will also be required to serve each energy centre, in order to refill or top-up a boiler. Boilers are routinely drained for maintenance purposes, resulting in the need to refill. Typically a 15 MW energy centre would require a c.54 mm water mains.

³ Recovery of sewer heat: 2 case studies on a district heating and a swimming pool application, Suez, October 2016

C.4 Network Routing

Appropriate network routing design for DH pipework will need to consider a range of factors in order to maximise the potential benefits of the available low carbon heat sources. These include appraising the significant physical barriers on the site (e.g. railway lines); the effect of development phasing on heat demand (which will see loads starting from a low level and coming on line progressively as development continues); the effect of phasing on the potential development of enabling routing infrastructure (e.g. bridges over significant physical barriers such as the canal); and the coordination of routing design and installation alongside other utilities. Each of these factors are considered in turn below.

C.4.1 Physical barriers & opportunities

There are significant onsite constraints that need to be considered in developing a potential DH network on the Old Oak site. These include existing and planned infrastructure, in particular major roads and railway lines, in addition to the Grand Union canal.

Figure C.4.1 shows key existing and proposed new infrastructure on the Old Oak site, as per the OPDC Local Plan⁴.

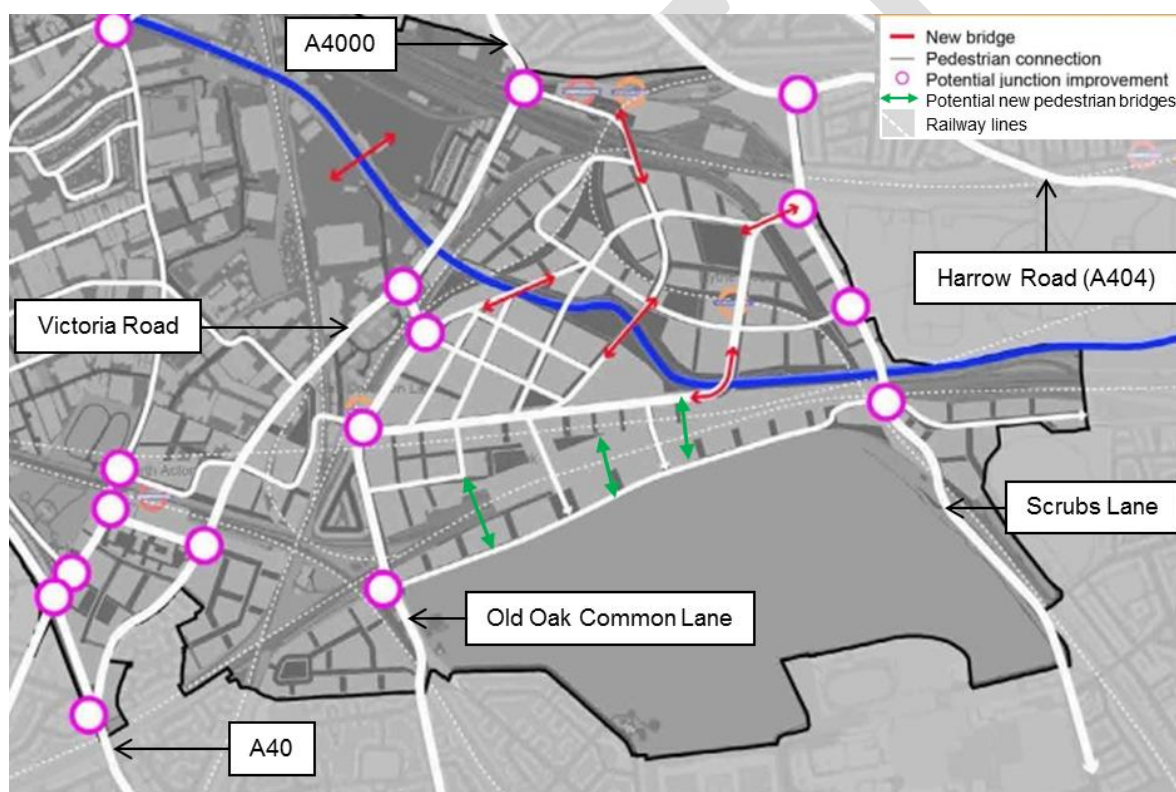


Figure C.4.1 Major Infrastructure (Existing and Planned) in Old Oak

C.4.1.1 Roads

The North Acton area is bordered to the southwest by the A40, a major 6-lane trunk road serving West London and providing direct access to Central London and the M40 motorway. To the north, the Willesden Junction area is bordered by Harrow Road (A404), another significant road linking Central London and northwest suburbs including Wembley. To the east, Scrubs Lane provides key north-south access between the A40 and Harrow Road, while in the west, the A4000, Victoria Road and Old Oak Common Lane also provide key links. See Figure C.4.1 for key road infrastructure around the Old Oak site, and expected junction improvements.

⁴ Extract from OPDC Local Plan, received from OPDC 18th October 2016

While DH pipework can be routed beneath and along roads, some of these roads are such vital routes in and out of the city (particularly the A40) that obtaining permission to be able to route along or across these roads is likely to be very challenging. However, the roads likely to be key for routing DH pipework around the site are less significant, and are also likely to be upgraded, especially in order to enable the scale of development being planned for the area.

It is also understood that some of the existing bridges in the area (e.g. the bridge over the canal on Scrubs Lane) are weak and have maximum load restrictions on them.

Existing roads that are likely to be key for routing DH pipework include Victoria Road, Old Oak Common Lane and Scrubs Lane. Victoria Road in particular will be rebuilt to accommodate HS2 works and this may present an opportunity to coordinate any DH pipework installation into the proposed roadwork programme which could offer cost savings and sharing, subject to HS2 programme requirements. Other key roads that will be needed for routing the network around the site will be developed as the build out of the scheme takes place.

Since the masterplan will likely require the provision of new, rerouted or re-surfaced roads within the development area (as indicated in Figure C.4.1), there will likely be opportunities to incorporate DH networks within these new/improved roads.

C.4.1.2 Rail

Numerous railway lines (see dotted white lines in Figure C.4.1) dissect and border the site, including the main intercity lines out from Paddington towards Reading and Bristol, the Central Line, the Bakerloo Line and the Overground network. Freight lines also cross the site, while new railway infrastructure is either being constructed for Crossrail, or planned for HS2. Future stations are also planned for the area, including a future Crossrail station and Crossrail/HS2 interchange station at Old Oak.

These railway lines and stations represent significant obstacles for utilities, since crossing them or routing utilities alongside them is technically challenging and can also lead to difficulties when coordinating with Network Rail.

Options for crossing railway lines include burying pipework in roads that either bridge over or pass under the lines. Using existing bridges as a conduit to cross railway lines would likely mean that problems associated with coordinating with existing utilities, that would likely already be located in the bridge, would be encountered. There is also the potential that existing bridges are not able to carry the additional structural load, and/or are not deep enough to ensure DH pipework can be sunken within the existing surface.

Thrust boring beneath lines is also a potential option where the lines being traversed are surface lines. However, extensive consultation and design coordination with Network Rail would need to be undertaken to ensure that the works do not impact on the required railway safety standards.

The potential for using railway bridges to traverse other obstacles (e.g. the canal) may be limited by a number of factors. In addition to the ownership, access and structural concerns for existing bridges, these include the level changes between rail bridges and ground level beneath the bridge. This could be problematic, should DH pipework be directed from bridge level down to the level of the development plots below. This would likely result in exposed critical pipework infrastructure, additional heat energy losses and risk factors related to degradation of the infrastructure, although technical solutions may be available to address these issues (i.e. anti-vandalism measures and additional insulation).

Where new rail or station works are being programmed ahead of development delivery, designs should seek to facilitate any likely future provision of district energy pipework and other utilities, for example by building undertrack crossing points into the design as part of the station or rail works. This will help to avoid subsequent more challenging approvals for work around or under operational networks.

C.4.1.3 Grand Union Canal

The canal runs through the centre of the Old Oak area, and represents a significant barrier to routing a site-wide network. Apart from a footbridge and railway crossings, there are currently no significant crossing points across the canal in the central part of the Old Oak site; however, several new bridges are identified for construction, primarily to allow better access between plots either side of the canal and improve the community connectivity in the area. See Figure C.4.1.

The canal could be traversed using thrust boring techniques similar to those discussed in relation to crossing rail infrastructure. However, this undertaking will likely need consent from the Canals and Rivers Trust (CRT).

The canal presents an opportunity for routing DH network pipework along its length, potentially buried beneath the towpath. This will require discussion with and consent from the CRT. Discussions with Car Giant's advisors Arup suggest that Car Giant may need to undertake works to the northern edge of the canal to improve amenity provisions, to re-route services and to maintain the canal wall.

C.4.1.4 New Bridge Opportunities

Given the extensive development that is planned for Old Oak, there are expected to be a number of new bridge crossings made available. The primary purpose of these bridges will be to ensure community connectivity throughout the site. However, a secondary purpose will also be to enable multiple utilities and services to reach into and around the site. See the extensive redesign of the road network around the site in Figure C.4.1.

Figure C.4.1 also shows three options for new pedestrian bridges over the new HS2 infrastructure⁵. These offer the most viable means of enabling any potential DH network to cross many of the railway lines in the area. However, effective coordination with the planning and design teams responsible for locating and designing these new bridges will be essential in order to ensure that provisions are made that enable any potential DH network to use these bridges as conduits if necessary. This need would be particularly acute were pedestrian bridges be used for this purpose, as usually these are not designed to carry structural loadings consistent with large-scale utilities. The Local Plan could respond to this likely need, by including within policy statements a requirement that any planned crossing needs to consider and be designed to accommodate utilities infrastructure. LLDC's Local Plan includes a policy of this nature.

A number of new bridges will be used to cross the Grand Union canal that dissects the site east to west. The canal creates a natural barrier that will present challenges to ensuring public access around the site, as well as to the routing of DH pipework. The planned new bridges across the canal therefore present opportunities to safeguard network route options, through early engagement with planning and design teams responsible for locating and designing the bridges, and by ensuring that provisions are made that enable any potential DH network to use these bridges as conduits for routing pipework if necessary.

C.4.2 Effect of Phasing on Routing

Phasing will have a significant effect on the options and opportunities for routing a potential DH network across the site. The optimal development and routing of the network will likely be dependent on the size and density of development in different areas of the site. For example, the detailed network plan will need to consider where development occurs at different phases of the trajectory, in addition to the type and scale of development that will be provided (e.g. residential or commercial). There may be opportunities to provide DH network services to certain plots and areas of the site in advance or on completion of the planned development; in others areas of the site, an optimal network development plan could see the planned development coming forward on the basis of local and temporary provisions of conventional heating services during an initial period prior to the extension/development of a wider DH network.

Additionally, where enabling infrastructure is being provided for those plots being developed early, consideration will need to be given to the infrastructure requirements of those plots being developed in the latter phases of programme.

⁵ Old Oak Common – Footbridge Feasibility Study, Pell Frischmann, February 2016

C.4.3 Coordination with Other Utilities

Effective coordination with existing and planned future utilities will be essential. Much of the site will likely see significant new utility provisions, including new gas networks (medium pressure and low pressure routes), mains water supplies, foul and drainage sewers, high-voltage (HV) electrical infrastructure, and telecommunications. Whilst coordination will be necessary in order to ensure that there is space provision along all required routes, there may also be a potential for cost sharing, for example through their coordinated design, installation and procurement.

An illustration of a potential coordinated design principle is shown in Figure C.4.2. A multi-utility combined trench like this is expected to be used in parts of the Vauxhall Nine Elms Battersea opportunity area; its coordinated design is likely to offer significant cost savings overall, since the cost of installation will be reduced and shared among each utility.

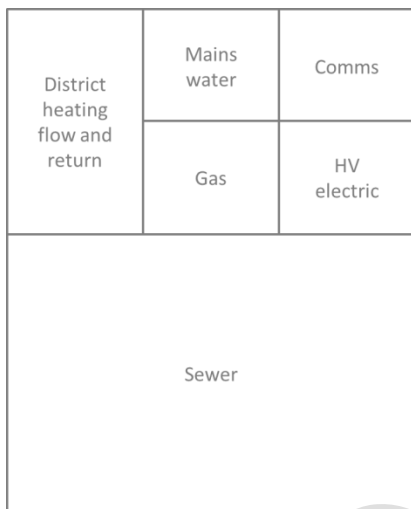


Figure C.4.2 Example of a Combined Multi-utility Trench

C.4.4 Indicative Routes

Indicative routes for the main transmission network (linking cluster-based energy centres together or major sources of heat to energy centres serving major clusters of demand) are illustrated in Figure C.4.3 and Figure C.4.4. These examples should be treated only as illustrative options. However, they have been developed through considering the factors and issues discussed above.

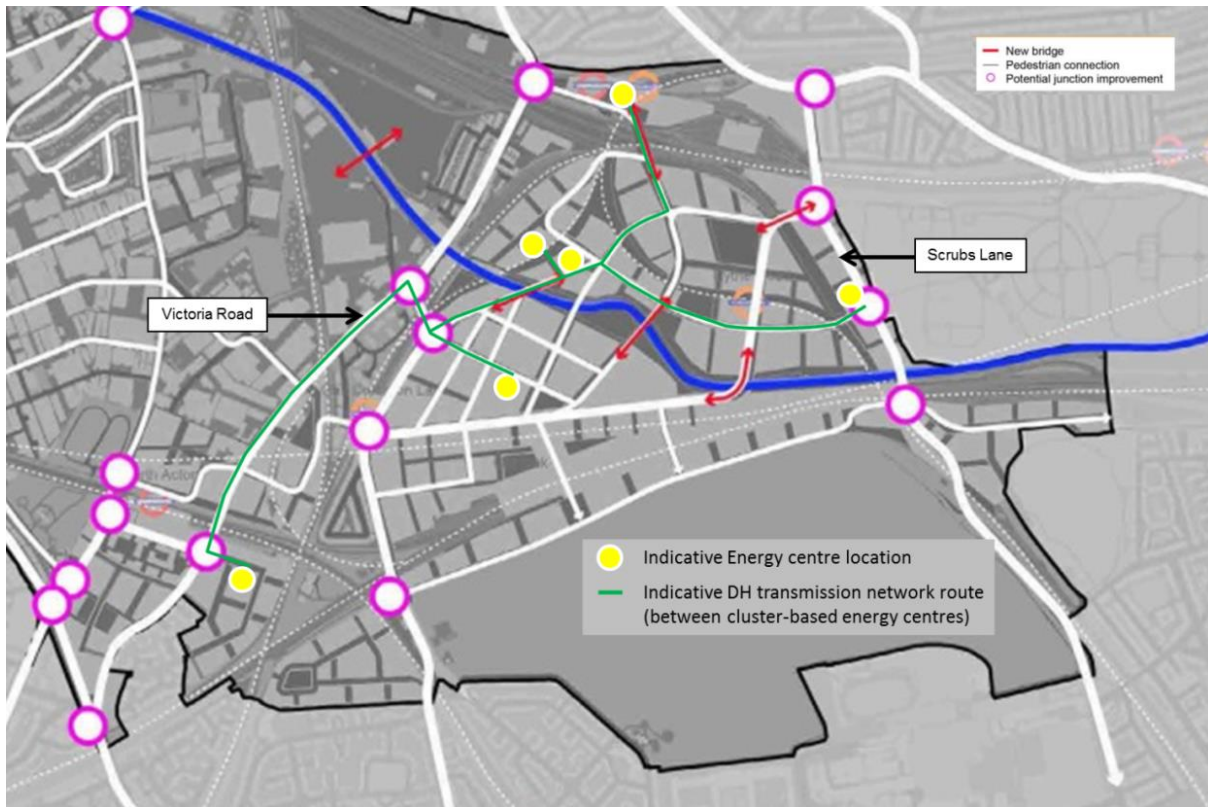


Figure C.4.3 Indicative Route for Transmission Network (Example A)

Example A in Figure C.4.3 shows the DH transmission network centred on the Powerday site and the adjacent energy centre on the western edge of the Car Giant site. The network extends northwards across the planned new bridge crossing over the railway line to the Willesden Junction cluster, and eastwards to the Scrubs Lane cluster via an improved road junction with Hythe Road.

The network extends over the canal, via a planned new road bridge over the canal immediately to the southeast of the Powerday site. Further connections to a future energy centre located in Old Oak South could be provided via new roads planned for the development on the Crossrail or HS2 sites. Routing to North Acton is indicated here to follow Victoria Road, which is expected to be reconstructed as part of the HS2 works.

The example shown in Figure C.4.4 shows an alternative route for the DH transmission network. This shows an alternative option for connecting the main areas of the site to the North Acton area and the land parcel identified as a potential location for an energy centre (see Figure C.3.1), via Old Oak Common Lane. This option could offer potential advantages compared to extending the transmission network via Victoria Road, by offering routes for connecting to plots in the southern part of the Old Oak South cluster (in particular those to the south of Crossrail).

An alternative route for connecting to the Scrubs Lane cluster is also shown, via the potential junction improvement at the northern end of Scrubs Lane.

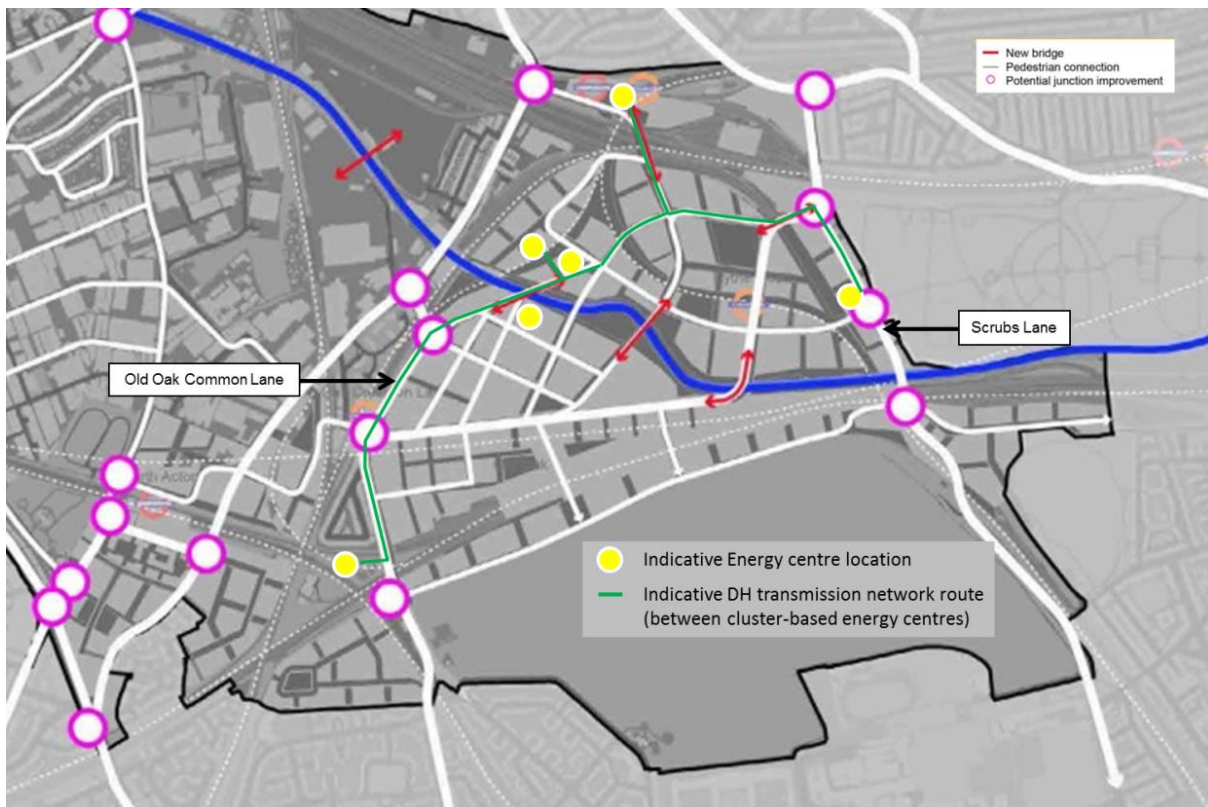


Figure C.4.4 Indicative Route for DH Transmission Network (Example B)

Note that the routes and energy centre locations shown above in Figure C.4.3 and Figure C.4.4 are indicative only, and further analysis (of the best routing options and energy centre locations) should be undertaken as part of the masterplanning stage of works. Note also that additional routes will need to be allowed for primary distribution pipework. This pipework will distribute heat from the cluster-based energy centres to individual development plot boundaries.

Key considerations for determining appropriate routes for all transmission and primary distribution networks include:

- Identifying key crossing points across the canal;
- Identifying key road crossings across railway lines to reach the Scrubs Lane and Willesden Junction clusters;
- Safeguarding these key crossings to ensure that their design can accommodate DH network pipework;
- Identifying when key crossing points would need to be delivered in order to enable expansion of the network to key demand clusters;
- Identifying energy centre locations and safeguarding access to them for construction, maintenance and network route access; and
- Identifying opportunities for coordination with the installation of other utility infrastructure, and either construction of new civil infrastructure or the upgrading of existing civil infrastructure.

C.5 Design Standards

Other considerations include ensuring that any potential DH network is designed in accordance with industry best practice guidelines as set out in the Heat Network Code of Practice CP1 (HNCOP)². The HNCOP is a joint project between the Chartered Institute of Building Services Engineers (CIBSE) and the Association for Decentralised Energy (ADE), and represents the industry's coordinated approach to ensure that heat networks are designed, built and operated to a high quality that delivers customer satisfaction. Minimum and best practices standards are specified in order to provide greater confidence for specifiers and developers.

Figure C.5.1 illustrates some of the typical features needed for an efficient heat network.

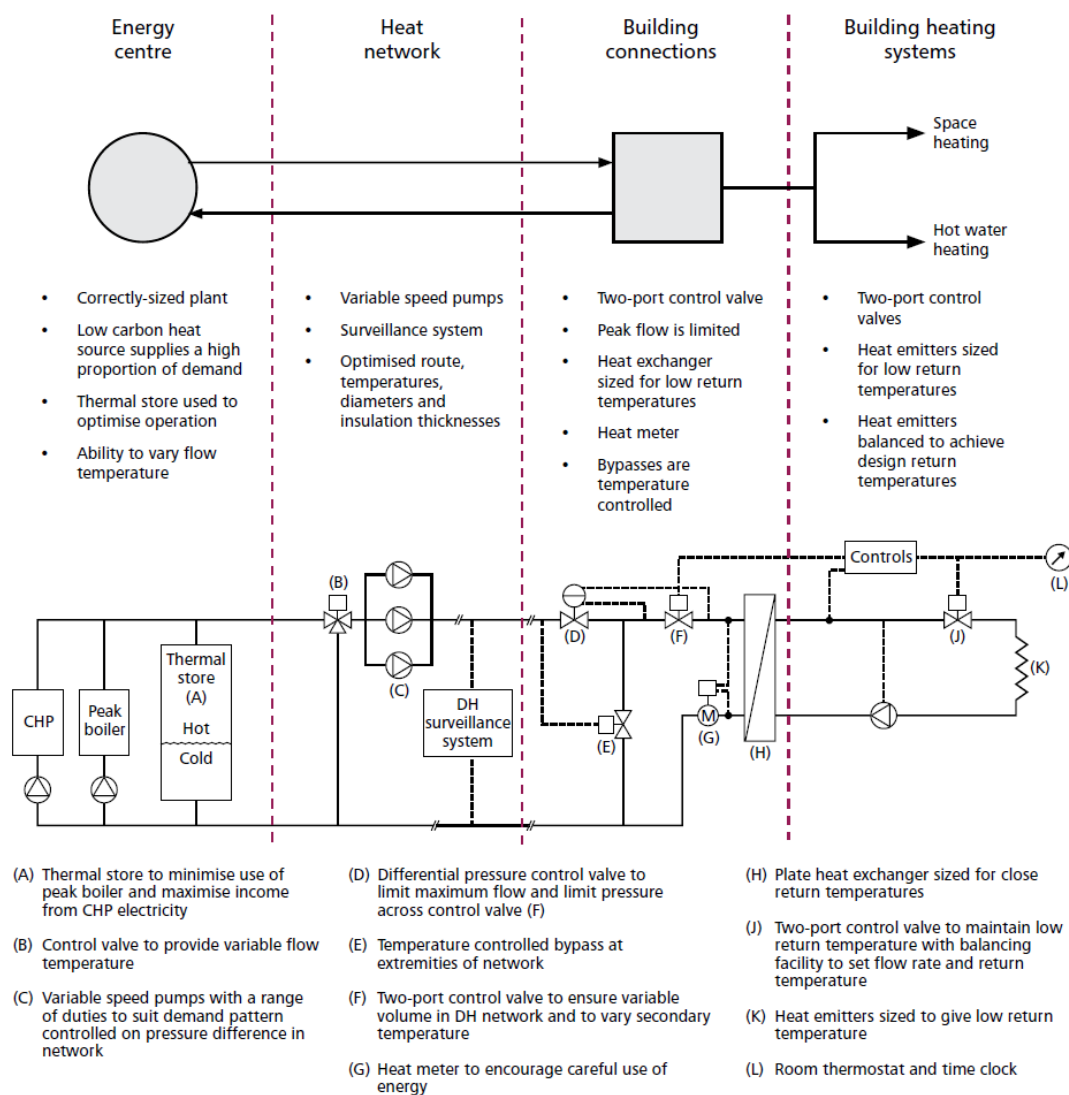


Figure C.5.1 Illustration of some Typical Features of an Efficient Heat Network with an Example Schematic Diagram (source: HNCOP²)

Heat loss from heat networks is a key consideration that should be addressed early in the design. HNCOP recommends best practice that, for most schemes, the heat losses in a heat distribution network (up to the point of connection to each building when built out) should not exceed 10% of the sum of the estimated annual heat consumption of all connected buildings. A heat loss of 15% or more would indicate either a low density development or the need for a re-evaluation of the design and insulation specification. Since development at Old Oak is expected to be of high density (between 300 – 600 dwellings per hectare depending on location), losses from the network should be expected not to exceed 10% of the total. This means the design of the network should minimise unnecessary lengths of pipework.

Factors that will need to be considered at the design stages include ensuring pipe diameters are minimised where possible (without reducing the peak heat output and while ensuring future expansion requirements have been considered); the use of pipework insulation is maximised; and that network temperatures are optimised. For new buildings, the HNCoP recommends that flow temperatures are minimised (and do not exceed 95°C) and that return temperatures do not exceed 50°C.

Further guidance on the design of heat networks is provided in other key references, including:

- Technical Guide to Heat Networks (BRE⁶, 2014)
- AM12: Combined heat and power for buildings (CIBSE, 2013)
- District Heating Manual for London (GLA⁷, 2013)

The installation of heat networks is also a key cost consideration. Since many heat networks are planned for existing buildings, the cost of installation can be significant, particularly in high density urban areas. These costs can be as high as £2,000 /m in Central London, making the installation of even modestly-sized district heat networks potentially very expensive. The majority of these costs are associated with the civil component of the installation (i.e. site protection, buried services coordination and diversions and trench formation and re-instatement). Costs could be minimised for the development at Old Oak by ensuring coordination of the network design with other utilities and masterplan services such as road designs. It should also be recognised that while there is a cost for the provision of heat network infrastructure, this reduces the potential size of plant that needs to be accommodated within the buildings themselves, with costs being balanced against the costs of energy centre plant, plant space and flues within buildings. This is particularly true if the energy centres can be accommodated in locations with lower potential land values.

⁶ Building Research Establishment

⁷ Greater London Authority

C.6 Summary

The high density of the planned development at Old Oak is expected to favour the utilisation of district heating; however there are a number of key challenges specific to the Old Oak area, particularly around the potential for energy centres on the site, and the physical barriers associated with major roads, railway lines and waterways in the area. The viability of DH systems to support the anticipated development at Old Oak therefore depends significantly on the feasibility of providing network infrastructure.

C.6.1 Energy Centres

A number of potential land plots have been identified for hosting energy centres in the Old Oak area. These include plots that are not being planned for development, for example the triangular plot between North Acton and Wormwood Scrubs Park, and the plot immediately south of and opposite to the Powerday site on the south bank of canal. Other potential plots include within development plots and under landscaped amenity areas to the south of the canal.

The key considerations for assessing the potential locations for energy centres include:

- Scale of energy centre proposed and the targeted low carbon energy resource;
- Proximity of the site to nearby low carbon energy resources;
- Access arrangements to the energy centre for construction, maintenance and operations;
- Viability of routing utilities (e.g. gas, water) and DH pipework to and from the site; and
- Potential flue requirements and the required flue heights relative to neighbouring buildings.

Selected plots for energy centre locations should be safeguarded in the masterplan for their construction. Additionally, the heat resources targeted for exploitation should be safeguarded in the masterplan, in order to not compromise their use.

C.6.2 Network Routing

Routing of DH networks around the Old Oak site will be subject to a number of challenges specific to the Old Oak area. Foremost amongst these are the numerous railway lines that dissect the site, including the Crossrail line currently under construction, and the HS2 line that is planned to run east-west through the site. In addition, the Grand Union canal also dissects the site, representing a further barrier to network route options.

With few options currently available for crossing these major barriers, there is, as part of the masterplan, expected to be significant investment provisions for new infrastructure that will provide a more accommodating and attractive townscape for the area (e.g. new bridges). Further investment is expected for upgrading the existing infrastructure (in particular road junctions), in order to ensure they are able to better serve the increased capacity and demand expected to result from the planned development.

These new crossings and road improvements are likely to provide opportunities for network routing. Key considerations for assessing network routing design in the masterplan include:

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

Selected network routes and required enabling crossings should be safeguarded in the masterplan.

Appendix D Review of Existing Delivery Models for Low Carbon Decentralised Energy Infrastructure

D.1 Executive Summary

This technical note was prepared in December 2016 as an interim deliverable of the stage 2 work to inform OPDC on the available models and options for district energy delivery and to inform the development of the preferred decentralised energy strategy.

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

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

Possible delivery vehicles cover a spectrum in terms of ownership from: **wholly public** (internal department or wholly owned municipal companies), through **hybrid**, to **fully private** sector companies (invariably '**Special Purpose Vehicles**' (SPVs), likely to be subsidiaries of specialist energy companies and often afforded exclusive rights to supply heat, e.g. through a concession). Examples of a hybrid company include: a **public sector-led SPV** (which could be: a **public + private joint venture**, or a wholly owned, arms-length **municipal limited company**); and a community-owned **mutual limited company** or **cooperative** (although community ownership is initially unlikely to suit the setting up of a large scheme serving new development).

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

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

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

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

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

Table D.1.1. Outline of Common Delivery Models for Large Heat Network Schemes

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

D.1.1 Lessons from Previous Schemes

OPDC and AECOM held three meetings with a total of six invitees with experience of five existing district heating-based decentralised energy schemes in the UK. The following stand out as lessons from those schemes with implications for the establishment of a delivery model in the Old Oak area:

1. The context of every scheme is unique and the objectives of the sponsors are different in each case leading to the adoption of a range of delivery models, all of which have been proven to work with varying strengths and weaknesses. A sustainable financial case is essential for every scheme and each model may offer opportunities to achieve viability. Schemes led by the public sector have more opportunities to access cheaper finance and grant funding to support the financial case, but the private sector can also leverage 'patient' private investment, organisational experience, multi-utility solutions and economies of scale.
2. Enabling contextual factors can be critical to the business case and should be a focus for development of the contractual structure of the scheme, e.g. for OPDC: access to surplus heat (Powerday); potentially lucrative private wire electricity sales (to HS2 and commercial sites); a supportive planning environment that contributes to reducing scheme risks (planning policy on connections (reducing demand risk), SPD including draft technical standards (reducing technical risk), designated land use for (energy from) waste site (supporting long term heat supply resilience), etc.).
3. There are emerging risks for gas-fired CHP (an inevitable long-term fall-off in carbon savings due to grid decarbonisation, with no savings projected by the early 2030s; and potential short- to medium-term headwinds in planning and Building Regulations compliance contexts when grid electricity emission factors in the National Calculation Methodologies used for Part L change). However, gas-fired CHP was essential to the technical feasibility, business case, and operational resilience of all the major heat network schemes reviewed, and invitees at the lessons learned sessions felt strongly that this will remain the case for new schemes in the near term.
4. A Multi Utility model appears to offer opportunities for high value utilities (e.g. data networks) to cross-subsidise investment in other utilities, such as heat, that offer lower returns. As such, a

decentralised energy delivery model would ideally retain the option to work as part of a multi utility solution.

5. Taking on the role of the ESCo requires a large amount of knowledge to be developed within the sponsor organisation (which needs to be retained) and setting up the contractual arrangements involves significant effort and costs.
6. Technical standards and in particular performance of the secondary network are frequently a problem in early phases of new networks and the delivery model should address this by bringing the eventual network operator on board early with a remit to control network design and construction quality.

DRAFT

D.1.2 Next Steps

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

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

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

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

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

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

D.2 Introduction

D.2.1 Purpose

This note explores the range of delivery models available for the development of low carbon decentralised energy (DE) infrastructure in the Old Oak area.

D.2.2 Basis, Scope, Assumptions and Terminology

The note is based on a review of published information and guidance from authoritative sources about heat network delivery. The reference material reflects the experience of the maturing DE sector in planning and delivering heat network infrastructure.

It is assumed in the note that OPDC:

- Is in the role of scheme ‘originator’ or ‘sponsor’ and would either take a direct role in the delivery of the scheme or at least ensure that a supportive planning context will be in place and facilitate development of a scheme;
- Is a ‘public authority’, with powers and constraints similar to Local Authorities, which have often been the sponsors of existing heat networks; and
- Has or could develop the capacity to opt for any of the range of potential delivery models.

The term ‘delivery models’ covers:

- The identity, corporate nature, and boundaries between key parties involved in overseeing, sponsoring, designing, building and operating the energy infrastructure in question;
- The sources and types of funding available to the parties; and
- Outline of the roles of the parties and contractual relationships between them.

The review focuses on delivery models for heat networks because the decision on whether to develop an area-wide heat network, will fundamentally shape the overall long-term energy strategy for the Old Oak area. The implications for non-network DE options should be considered further in parallel.

The term ‘scheme’ is used to refer to the potential heat network project developed in the Old Oak area, or in general for a network realised by a sponsor.

D.2.3 Structure and Content of the Note

The remainder of this note is structured as follows:

- Section D.3 Heat networks and the role of public authorities in delivery
- Section D.4 Common scheme delivery models
- Section D.5 Factors influencing choice of delivery models
- Section D.6 Lessons learned from case studies
- Section D.7 References

D.3 Heat Networks & the Role of Public Authorities in Delivery

D.3.1 Heat Networks

In this paper, the term 'heat network' is taken to cover the elements illustrated in Figure D.3.1:

- Heat sources (potentially including waste heat from a power station, industry, or energy from waste plant, for example) and the energy centre(s) in which scheme heat generators and accumulators are housed;
- Primary heat transmission and distribution pipework, i.e. the larger diameter pipe network which transfers heat from the scheme energy centre(s) (and potentially also from third party heat generators supplying the scheme) to property or development site boundaries; and
- Secondary heat supply pipework up to and including the heat interface units in homes, and heat exchangers in non-domestic buildings.

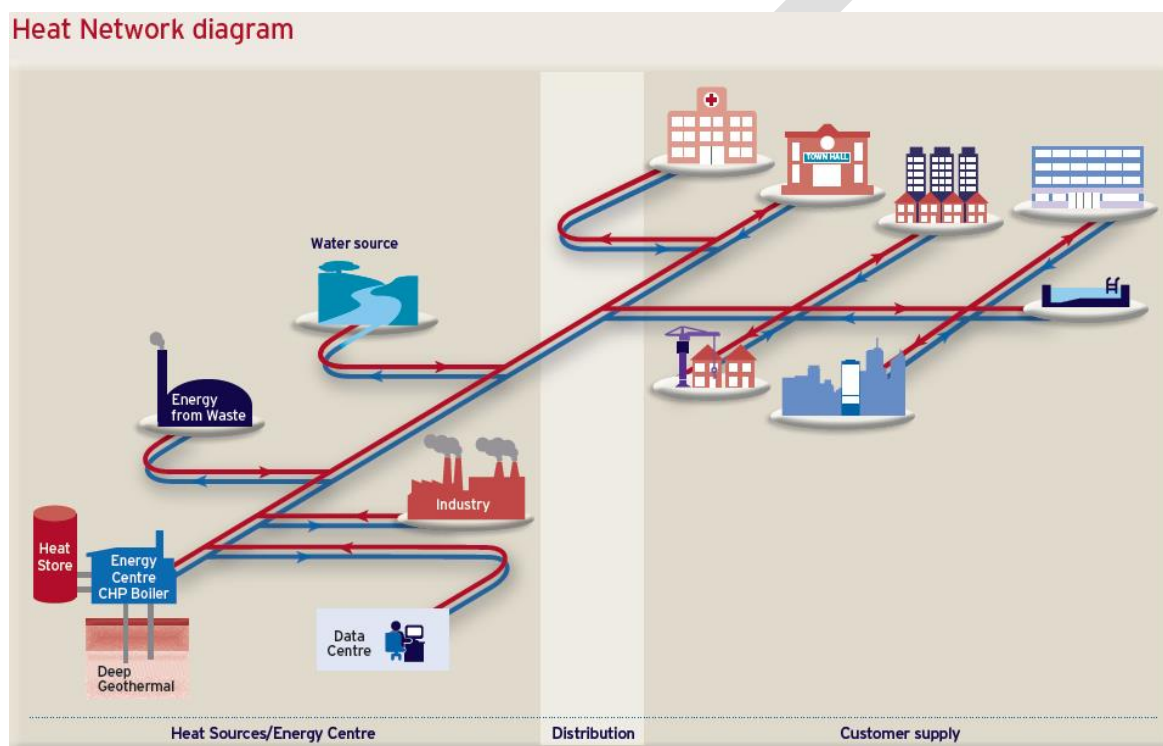


Figure D.3.1. Elements of a Heat Network Scheme

[Source: (DECC, 2015)]

Delivering such a network typically involves the 'works' and 'services' elements and property-related agreements listed in Table D.3.1.

Works elements	Services elements	Property agreements
• Design • Construction of energy centre and heat network • Connection of premises	• Energy (fuel, heat) purchase • Generation of heat and electricity • Operation and maintenance • Metering and billing • Connection of new customers • Supply of heat or heat and electricity to connected customers • Customer services	• Sale or lease of operational land and buildings • Easements, rights of way and access arrangements on private land and buildings • Street works licence

Table D.3.1. Works and Services Elements and Property Related Agreements for Scheme Delivery

Source: (GLA, 2014)

D.3.2 Stages of Development for a New Heat Network

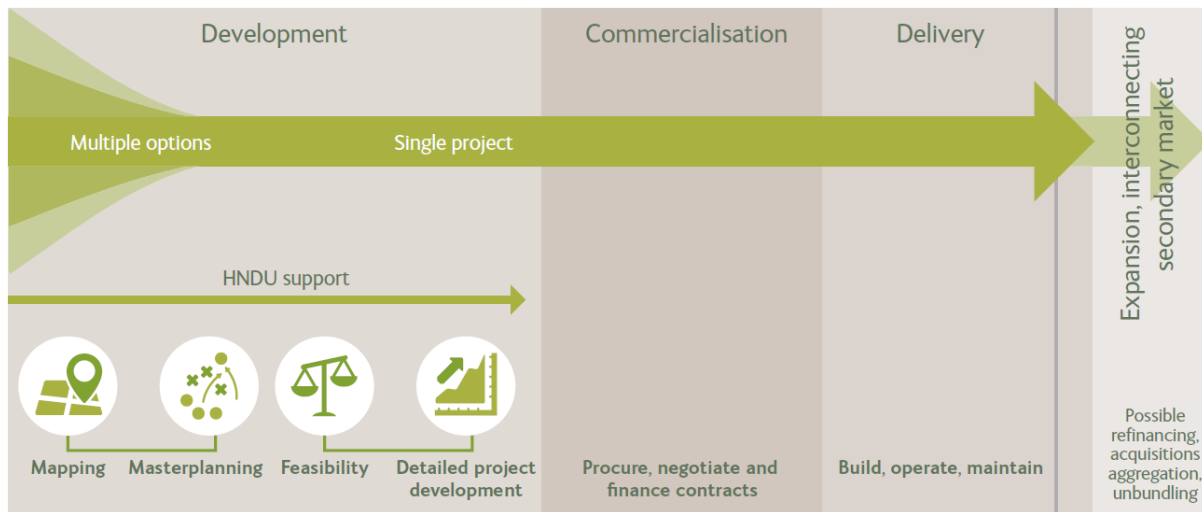


Figure D.3.2. Stages of Development for a New Heat Network

[Various sources, e.g. (Green Investment Bank)]

The creation of new heat networks generally follows an established pattern consisting of the following stages (see Figure D.3.2):

- Development – Mapping & masterplanning (to determine where heat will be generated and used and network routing options), and feasibility and detailed project development (where options are developed and iteratively tested to arrive at a deliverable project – i.e. technically feasible and economically viable).
- Commercialisation – Establishment (e.g. public SPV or JV, if not already in place) or procurement (e.g. private SPV) of the primary delivery vehicle, negotiation of top tier contracts and agreements, procurement of subsidiary works and services contracts, and securing of finance by relevant parties.
- Delivery – Building of energy centres, connection to heat sources and / or purchase and connection of heat generators; customer connections and network operation, maintenance, metering and billing. And (potentially),
- Further network development – Expansion of the network, interconnection with other existing and developing networks, and potentially: aggregation of network ownership (i.e. through acquisitions) and / or unbundling – i.e. functional separation, potentially down to separate generating companies, a PipeCo (see D.5.7), and heat supply and services companies.

D.3.3 Common Roles of Public Authorities

Public authorities generally play an important part in the development of heat networks. Figure D.3.3 illustrates the roles that they may play through the full development stages of a scheme. A public sector sponsor is more likely to fulfil the development stage roles than to take on funding and delivery of a scheme, although there are examples of local authorities taking a direct role in delivery (e.g. Woking and London Borough of Islington).



Figure D.3.3. Potential Role of Public Authorities in Heat Network Schemes

[Source: (Green Investment Bank)]

At the ‘development’ stage, public authorities invariably act as scheme sponsors. In practice, this means taking a lead on the following issues, using the authority’s planning powers where appropriate:

- Mapping heat demands, including projecting demands for new development;
- Energy masterplanning, including identifying, facilitating and where possible securing / safeguarding locations for heat network infrastructure such as energy centre(s), and primary heat transmission and distribution pipework – with particular attention to overcoming existing infrastructure constraints, i.e. crossing road, rail, waterway and buried services routes;
- Planning policy support, which often involves a mix of directly supportive policies – e.g. expecting new developments in specified areas to connect to an existing network or to provide for future connection to planned networks – and indirectly supportive policies;
- Acting as scheme originator and developer, i.e. developing a scheme to the point that ongoing development and commercialisation is taken over by a delivery vehicle set up by the authority or procured from the private sector (or a joint venture);
- Acting as a champion for the scheme, particularly facilitating communications with stakeholders such as by brokering connections with developers and other potential customers;

At the next stages – of ‘commercialisation’, ‘delivery’ and beyond – the role of a public authority will depend on the delivery model for the scheme and context-specific things, such as whether the authority controls assets like existing property or development land. An authority with a major stake in the scheme, directly as a future heat customer, or indirectly as the owner of land for commercial and residential development, may have sufficient incentive to provide assets (e.g. land), funding, financial guarantees, and ultimately to take full or part ownership of the network delivery vehicle. The authority’s decision on whether to take on funding and delivery roles will then depend on an assessment of a range of factors, discussed further in section 0.

D.3.4 OPDC role

In terms of a heat network scheme in the area, OPDC will want to think about which of the potential roles of public authorities it would consider taking on, and subsequently how to fulfil them. The potential roles for OPDC (i.e. those listed in Figure D.3.3) are reviewed in Table D.3.2 with commentary on context-specific considerations for the Old Oak area. The roles have been reorganised to better reflect the chronology of the planning context and likely OPDC decision-making.

Potential role	OPDC capacity / appetite	Considerations
1. Positive policy and planning	High	Draft (Regulation 18) OPDC Local Plan policies (consulted on in February – March 2016) includes the following that particularly support development of heat networks: EU1: Strategic policy for the environment and utilities – Preferred Policy Option: OPDC will support proposals that: f) Support delivery of coordinated and area-wide utilities infrastructure. EU6: Decentralised energy – Preferred Policy Option: OPDC will support and facilitate: b) the provision of infrastructure to deliver a decentralised energy network; c) proposals which contribute to the delivery of a decentralised energy network subject to [conditions]; The next Draft (Regulation 19) OPDC Local Plan is scheduled for March 2017. The OPDC Community Infrastructure Levy Preliminary Draft Charging Schedule was published in October 2016. The Regulation 123 list does not include decentralised energy infrastructure. However, the document notes that “[T]he list... excludes infrastructure projects that are required to make a development acceptable in planning terms in accordance with the planning policies set out in the OPDC Local Plan... Such infrastructure will therefore be secured as part of the development through the use of planning conditions or Section 106 planning obligations... ..[A] Supplementary Planning Document on Planning Obligations will be published...”
2. Energy masterplanning	High	OPDC has produced a draft Old Oak Decentralised Energy Strategy. Further energy masterplanning work is planned.
3. Heat mapping	High	Mapping and projection of demands from new development forms part of energy masterplanning, above. AECOM has submitted a proposal for additional work which includes early mapping of expected heat demands.
4. Service and asset provider / landowner	TBC	OPDC's stake as a development landowner and future scheme customer may influence its preferred scheme delivery model.
5. Scheme customer / off-taker	TBC	
6. Initial scheme originator / developer	TBC	
7. Underwriter of some project risk	TBC	Whether OPDCs' role is limited to scheme sponsor, or extends into delivery depends on the delivery model chosen.
8. Funder / investor	TBC	
9. Operator / retailer	TBC	
10. Champion / advocate / facilitator	High	The extent of OPDC's involvement in these roles depends on the preferred scheme delivery mode which in turn will be influenced by OPDC long term remit and the funding it can access. Important roles for OPDC regardless of the delivery model. Responsibility may need to be separate from any OPDC role in delivery, and this separation should be planned for.

Table D.3.2. Considerations Regarding OPDC's Role in Scheme Development and Delivery

D.3.5 Role of London Boroughs of Brent, Ealing and Hammersmith & Fulham

The Old Oak area covers land within the London Boroughs of Brent, Ealing and Hammersmith & Fulham¹. Of immediate relevance to this paper is the potential influence of these neighbouring Boroughs on the consideration of scheme delivery models.

The plans of the neighbouring Boroughs with respect to the development of heat networks were not reviewed, nor were the Boroughs consulted on delivery models when preparing this paper. Synergies between the Borough heat plans and development of a heat network serving the Old Oak area should be considered as part of planning, heat mapping and energy masterplanning activities.

In the absence of specific information about the interests of the Boroughs, the following general points are raised for consideration:

- The Boroughs may be potential partners in a joint venture delivery vehicle, or have an interest in acquiring scheme ownership in future;
- The Boroughs may have stakes in existing or planned heat networks outside the Old Oak area and an interest in future interconnection to an Old Oak area scheme; and
- Potential anchor heat loads both within and outside the Old Oak area may already have been identified as part of Borough heat mapping activities and may be relevant to planning and delivery of a scheme.

The Old Oak Decentralised Energy study prepared by GLA's decentralised energy delivery unit (February 2016) that is part of the evidence base for the local plan recommends that opportunities to connect to nearby decentralised energy developments proposed at White City and Wembley should be considered.

The interests of the neighbouring Boroughs should be considered further as part of the study of potential delivery models and the Boroughs would ideally be consulted as part of developing a preferred model alongside future masterplanning work.

¹ Referred to for convenience as the 'neighbouring' Boroughs.

D.4 Common Scheme Delivery Models

The delivery model for a heat network scheme broadly consist of the delivery vehicle – the corporate entity that will develop and enjoy ownership of scheme assets – and the contractual structure, i.e.: how the individual ‘works’ and ‘services’ elements of the scheme are bundled and procured, what property-related agreements are needed, and any other necessary legal agreements between parties.

D.4.1 Delivery vehicles

Possible delivery vehicles cover a spectrum in terms of ownership:

- Wholly public, e.g. internal department or wholly owned municipal companies;
- Hybrid, examples include:
 - a public sector-led SPV (which could be: a public + private joint venture, or a wholly owned, arms-length municipal limited company); and
 - a community-owned mutual limited company or cooperative (although the latter are unlikely to suit a large scheme serving new development);
- Fully private sector companies (invariably ‘Special Purpose Vehicles’ (SPVs), likely to be subsidiaries of specialist energy companies and often afforded exclusive rights to supply heat, e.g. through a concession).

In practice, only a handful of delivery models are common (to date) or likely to work well for large schemes and these are illustrated in Table D.4.1 (also Table D.1.1), which outlines the relationships between the scheme sponsor (outlined in green), public authority (OPDC in this case), delivery vehicle (black outline), customers, and the works and services delivery, and provides an indication of the roles typically fulfilled by (or open to) the public and private sectors (orange and blue shading respectively).

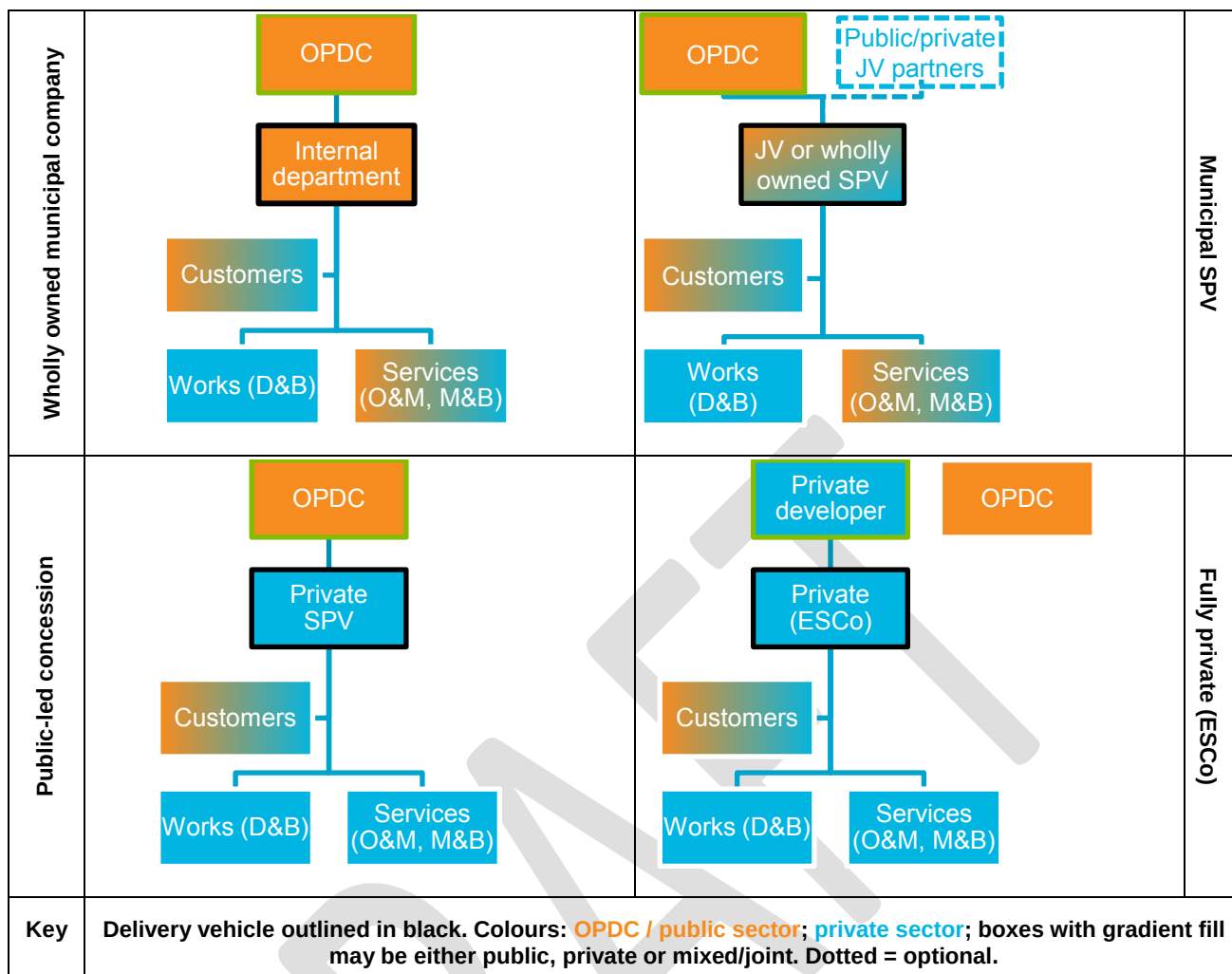


Table D.4.1. Common Delivery Vehicles, Sponsors, and Public/Private Roles

[Based on (Scottish Futures Trust, 2016)]

The choice of delivery vehicle will strongly influence the sources of finance available for scheme development and delivery. Wholly and partly public owned entities have access to public debt facilities, at lower rates of interest than will be available from commercial debt providers, and are eligible for public scheme development support (currently offered by the Heat Networks Development Unit) and grants (Heat Networks Investment Project funding to support scheme delivery is currently being piloted).

D.4.2 Contractual Structures

The choice of delivery vehicle does not necessarily constrain the approach to the contractual structure for building and operating a scheme. There are many ways that the individual 'works' and 'services' elements of a scheme could be bundled and procured, and this needs to be considered case by case.

Various options for grouping the functions involved in heat generation and supply are illustrated in Figure D.4.1, each of which would require a different set of contractual relationships between the corresponding parties. Missing from this picture are insights into asset financing and ownership, the role of the scheme sponsor, and other types of relationships and obligations – especially property-related issues.

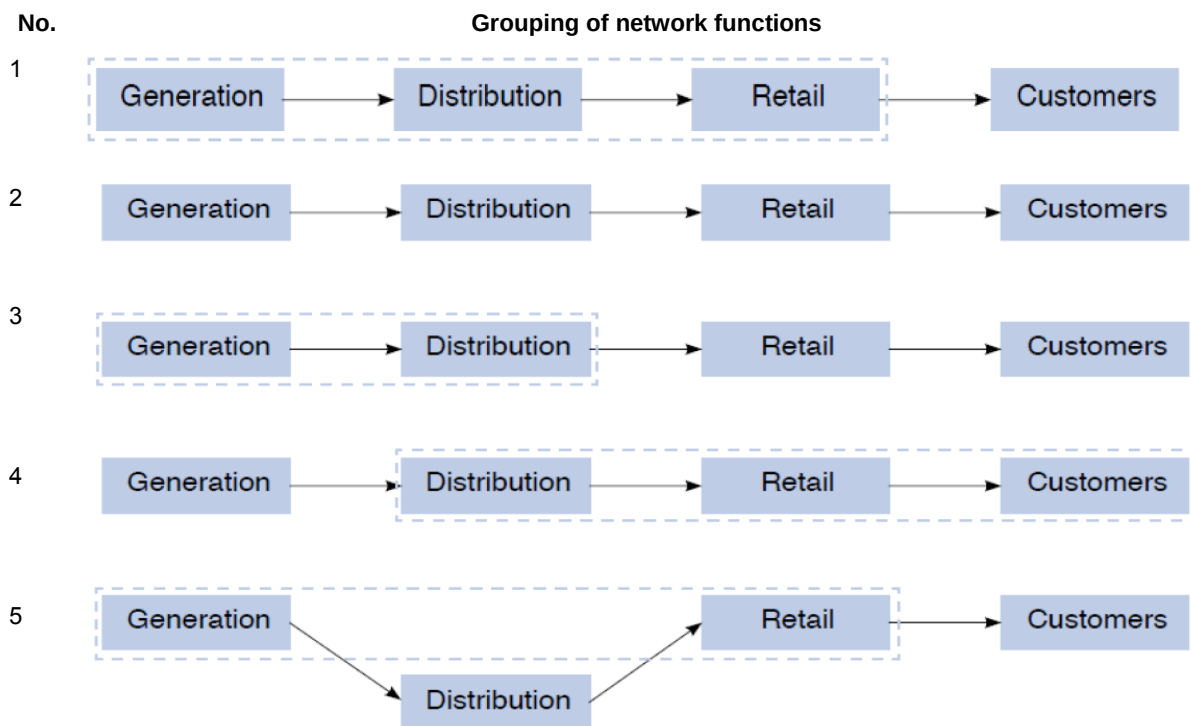


Figure D.4.1. Options for Functional Separation of Heat Network Operation

[Source: (King, 2014)]

The London Heat Manual identifies four common types of contractual approaches used for heat network schemes, as described in Table D.4.2. This perspective begins to link up the 'type' of delivery vehicle, its relationship with the scheme sponsor, and the specific types of contracts required between parties, including property leases – which would address issues such as obligations to connect, access for maintenance, wayleaves, etc. The last ('Network operation') approach in Table D.4.2 could apply, for example, to a case where a municipal company or SPV had separately procured construction of the network.

Type	Description	Contracts required
Energy supply (ESCo)	An energy services company (ESCo) undertakes to supply heat to the customers, and for that purpose to build and operate the heat network. This could be set up with a defined set of consumer buildings to be connected, or to provide the service to developments within a defined area.	- Master agreement - Connection contract - Heat supply contract - Service level agreement (SLA) - Property leases
Wholesale supply of energy	A sponsor appoints a single contractor to design, build, own, operate and supply wholesale heat and electricity. The sponsor sells the energy retail to consumers, and may be a consumer itself. ESCos often prefer wholesale supply to multi-occupant commercial buildings.	- Master agreement or design, build, operate (DBO) Contract - Wholesale heat supply contract with SLA - Connection contract - Property leases
Network delivery and operation (DBO)	A sponsor (such as an owner of tenanted properties) appoints one or more contractors to design, build, operate and maintain a heat network but the sponsor remains the asset owner and contracts to supply heat and electricity to consumers. The sponsor may also purchase the fuel required	- DBO contract or a combination of D&B contract and O&M contract with SLA (Metering and billing contract) (Connection contract)
Network operation (O&M)	An operator is contracted to run a heat network that has already been constructed, for example under a main building contract. The operator may also be contracted to undertake metering and billing and customers services, if the landlord wishes to outsource these activities.	- O&M contract with SLA (Metering and billing contract)

Table D.4.2. Commonly Used Types of Contracts for Heat Network Schemes

[Source: (GLA, 2014)]

One way to get a fuller picture of the contractual structure that might apply to an Old Oak area scheme is to draw on specific cases. Figure D.4.2 shows an example of the contractual relationships and agreement types for a 'fully private (ESCo)' arrangement (indicative of E.ON's arrangements for its Cranbrook and Skypark scheme in Exeter). This illustrates the majority of works- and services-related relationships and contracts required to build and operate a scheme.

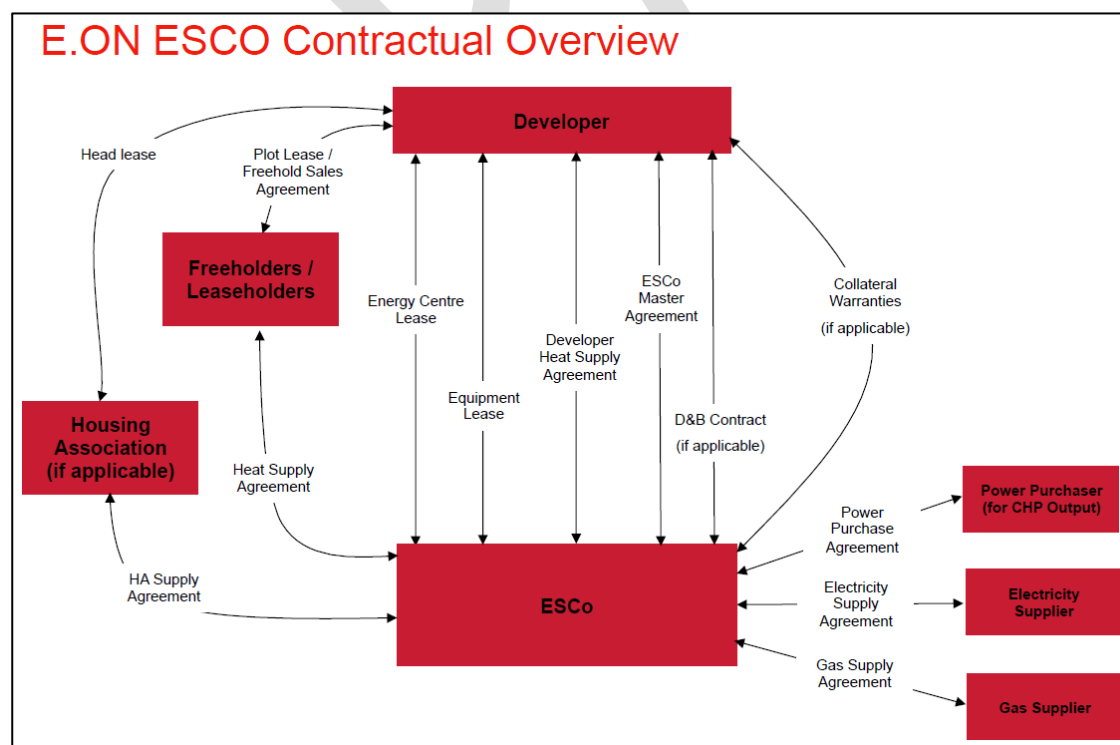


Figure D.4.2. Contractual Relationships for a 'Fully Private ESCo'

[Source: (E.ON, 2014)]

In the case of a Concession, the 'Developer' and 'ESCO' in Figure D.4.2 would be replaced by 'Public authority (OPDC)' and 'Private SPV' respectively, with the agreements needed remaining largely similar. For a municipal SPV, a third party design & build contractor would be procured to construct the infrastructure, and operation & management and metering & billing services might also be outsourced or could be delivered in-house (see Figure D.4.3). And for a wholly owned municipal company, the parties labelled 'OPDC' and 'SPV' in Figure D.4.3 would be different arms of OPDC with a degree of flexibility about how to define and regulate the internal roles and relationships.

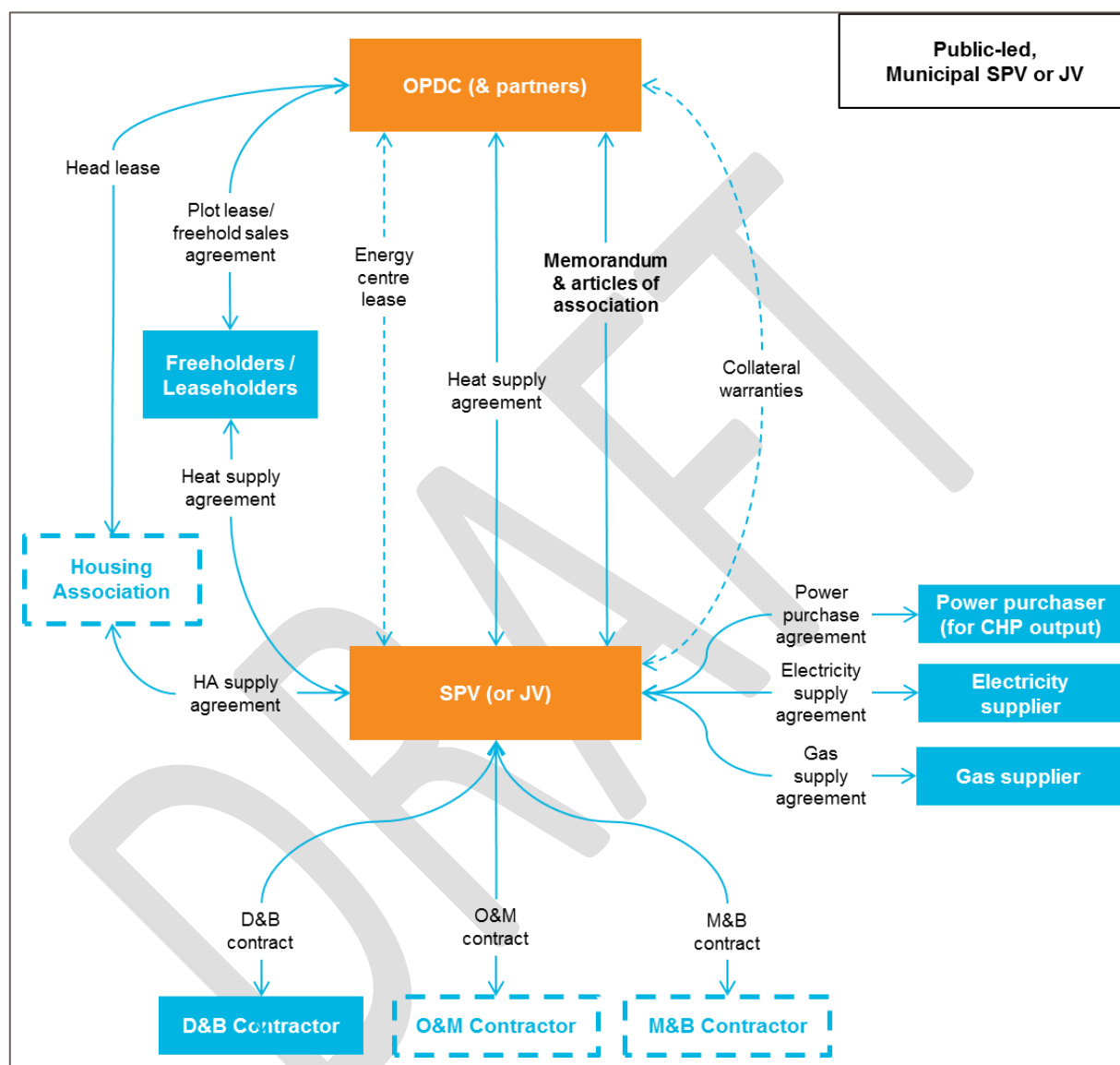


Figure D.4.3. Contractual Relationships for a 'Fully Private ESCo'

D.5 Factors Influencing Choice of Delivery Model

Given the variety of available delivery models, OPDC needs a framework for considering its preferred model. The first priority will be deciding on the type of corporate entity, i.e. the delivery vehicle, to take forward a scheme, after which the detailed contractual structure can be progressively put in place.

OPDC's choices about how to deliver a heat network to serve the Old Oak area will depend on what it wants to achieve by developing a scheme; the financial, technical and commercial capabilities it can contribute to scheme development and the constraints it faces. The ways in which these factors may influence OPDC's choice of delivery model are discussed below under the following headings:

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

The 'PipeCo' has been conceived as a mechanism that could improve investment efficiency and unlock funding for heat network rollout in the UK. The concept is presented and its cross-cutting effects are discussed under a separate heading:

- The PipeCo concept.

D.5.1 Strategic Objectives

Heat networks provide a range of potential benefits. The strategic objectives of a scheme sponsor will primarily relate to the achievement of these benefits, and the criticality or relative priority of delivering each one.

The London Heat Network Manual (Arup 2014) provides a summary in which the potential benefits are grouped in terms of the beneficiaries, which are listed as: consumers, developers, and the environment. Summarising the suggested benefits for each group²:

Beneficiary	Potential benefits of heat networks
Consumers	More affordable* low or zero carbon energy supply than micro renewables (*assuming price control to this end) (With multiple heat sources:) Resilient Space efficient Low user maintenance
Developers	Lower cost of meeting planning carbon targets than micro renewables (With an attractive ESCo:) Reduced up-front capital costs and no need to engage in long term infrastructure management Reduces labour and maintenance costs as compared to individual systems. May reduce the developer's cost of compliance with Building Regulations.
Environment (and systemic)	Lower carbon emissions Durable energy centre(s) and extensible pipe network enable: use of surplus recovered heat, efficient low carbon CHP (during transition to decarbonised grid), diverse fuels and other heat sources Interconnection for greater efficiency and increased volume of low carbon heat Grows low carbon economy

Table D.5.1. Beneficiaries and Potential Benefits of Heat Networks

[Based on (GLA, 2014)]

² The table has been heavily summarised. The original row heading 'London and the Environment' has been replaced here by 'Environment (and systemic)'; some of the benefits listed are clearly synergistic effects or systemic benefits with the effect of increasing or extending the primary environmental benefit of reduced carbon emissions.

A scheme sponsor needs a clear understanding of its objectives if it is to take effective decisions about its preferred delivery model. Delivery models where the sponsor owns and controls the delivery vehicle (fully or in part) and operates the scheme would make it inherently easier to align long term outcomes with strategic priorities. Consistent achievement of the objectives in other cases would rely on the inclusion of effective provisions in contracts governing design & build, operational services, etc. of the scheme. A sponsor then needs to negotiate contracts that aim to foresee and address predictable issues, or make contractual provisions that afford greater ongoing control and governance.

D.5.2 Appetite for Control and Governance

As noted above, OPDC's appetite for ongoing control and governance of a scheme is likely to relate to ensuring that key benefits of the network are realised. Particular areas of interest related to ongoing operation of the network are likely to be:

- Consumer prices – Price control mechanisms will be a key part of contracts under most delivery models. The balance between connection, capacity (standing), and unit charges, and the effect of network heat losses on standing charges, will influence affordability and customer perceptions of the network.
- Carbon emissions rates – determined by: fuel / heat source mix, generator efficiencies, primary and secondary heat losses; demand profile. Affects: net carbon emissions and savings relative to baseline, developers' costs and ability to meet planning and Building Regulations Part L targets and hence desirability of connecting to the network.
- Connection of new (non-gas CHP) heat generation capacity to the network in future – This will be essential to maintaining a low carbon heat supply in the medium to long term (new capacity connected from the mid-2020s onwards). There is no guarantee that lower carbon heat generation options will be cheaper by that time. The risk profile of these options, may also make them less attractive to a scheme operator making purely economic decisions.

Greater inherent control and governance can be achieved by opting for delivery models where OPDC owns and controls the delivery vehicle (fully or in part) and – for maximum control – operates the network. In other words, ranking the delivery vehicle options by inherent degree of sponsor control, the order would be as in Table D.1.1, i.e.:

1. Public led, municipal department or wholly owned company
2. Public led, municipal SPV (limited company) or JV
3. Public led, private SPV
4. Private led, private SPV

D.5.3 Allocating Scheme Risks

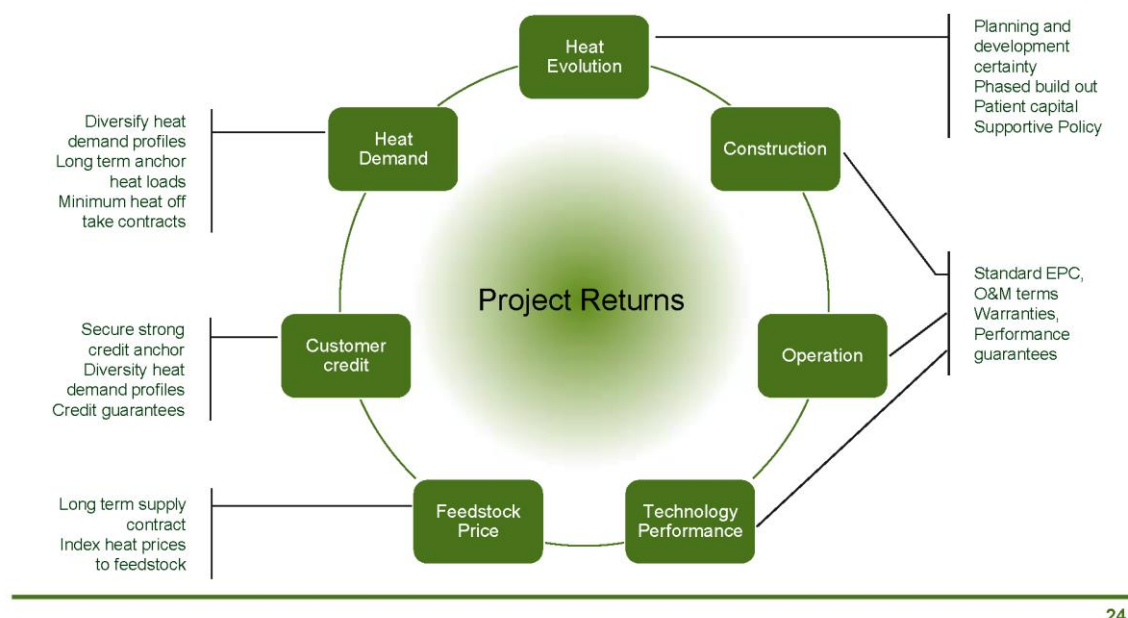
A heat network scheme in the Old Oak area will face a specific set of risks that will need to be identified, assessed, controlled, and reduced or eliminated where possible. A subset of these risks are common to most schemes, e.g.:

- Uncertainty about heat evolution (timing and scale of heat demands from new development and network extension);
- Construction-related risks (programme, cost and quality);
- Operation (including technology)-related risks (reliability; overall cost-effectiveness; generator efficiencies, network heat losses and fuel mix achieved and hence carbon emission rate);
- Feedstock fuel (including third-party heat) purchase prices;
- Customer credit; and
- Heat (and electricity) demand and sale prices.

These risks are presented in Figure D.5.1 along with indications of how they are commonly controlled.

DISTRICT HEATING PROJECT RISKS

The development and design of an investable district heating project must effectively allocate project risk to achieve an efficient cost of finance



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Figure D.5.1. District Heating Project Risks – Types and Controls

[Source: (Green Investment Bank)]

A key consideration will be the efficient allocation of the project risks identified for an Old Oak area scheme given the technical and organisational capability, types of finance available, and the risk appetite of OPDC as project sponsor, and of potential funders and contractors. Counterparties will expect financial compensation for the risks they take on, which will be higher for less controlled risks. Costs of finance will tend to be higher for parties taking on less controlled risks. And risk transfers to the private sector will tend to feed back in higher scheme costs due to a risk premium on the price of contracts. So overall there is a strong incentive for OPDC to understand and control project risks where it can, for example by:

- Producing and maintaining the best possible heat demand projections for new development;
- Adopting a strongly supportive planning policy framework for a heat network;
- Aggregating and guaranteeing some anchor / base heat demand (e.g. for public buildings);
- Providing (for public) or brokering (for private) customer credit guarantees.

The first step would be to assemble a risk register, which may then influence the consideration and choice of delivery model.

D.5.4 Acceptable Rates of Return

Each potential investor in a scheme will have a minimum threshold of financial return they expect from any investment, often expressed as an 'internal rate of return' and referred to as a 'hurdle rate'. Private sector hurdle rates for heat network schemes at the development and commercialisation stages are likely to be in the order of 12+%. This may come down slightly if some of the risks described above are carried by the public sector, and also as scheme delivery progresses and risks have been well controlled, providing opportunities for refinancing at lower rates of interest. The hurdle rate set by public bodies for projects with

societal benefits can be lower, at around 6+%, reflecting the effective underwriting of some internalised risk, a lower cost of borrowing, and less inherent need to generate a financial surplus due to the value assigned to social and environmental benefits.

D.5.5 Sources and Costs of Finance

The range of funding for the development of large scale heat networks is fairly well-defined, with the sources available to a particular scheme depending on its ownership – public, private, or joint – as summarised in Table D.5.2.

Funding sources available to...	
Private and public sectors	Uniquely public sector
• Equity – value of shares in the asset company held by its owner(s) • Debt – commercial loans from banks, including specialist Green Investment Bank as project finance (senior project debt) to the project delivery vehicle / SPV • Capital contributions – direct contributions from developers; indirect developer contributions via community infrastructure levy or Section 106 payments; grants from public authority local carbon offset funds	• Heat Networks Development Unit – grant funding for scheme development • Public Works Loan Board – public debt via Debt Management Office • Heat Networks Investment Project – grant funding for scheme delivery via Salix³

Table D.5.2. Funding Available to Public and Private Sectors for Scheme Development and Delivery

The costs of finance vary across these funding sources. It is beyond the scope of a paper at this stage to make more than general points of comparison, for example: public debt tends to be cheaper than private debt (Figure D.5.2), the administrative costs of accessing public grant funding are unlikely to impact the balance sheet but the funding itself cannot be guaranteed; and capital contributions (from developers or public authorities via CIL, S.106 or local carbon offset funds) are likely to be small relative to the total investment required.

³ <https://hnp.salixfinance.co.uk/>

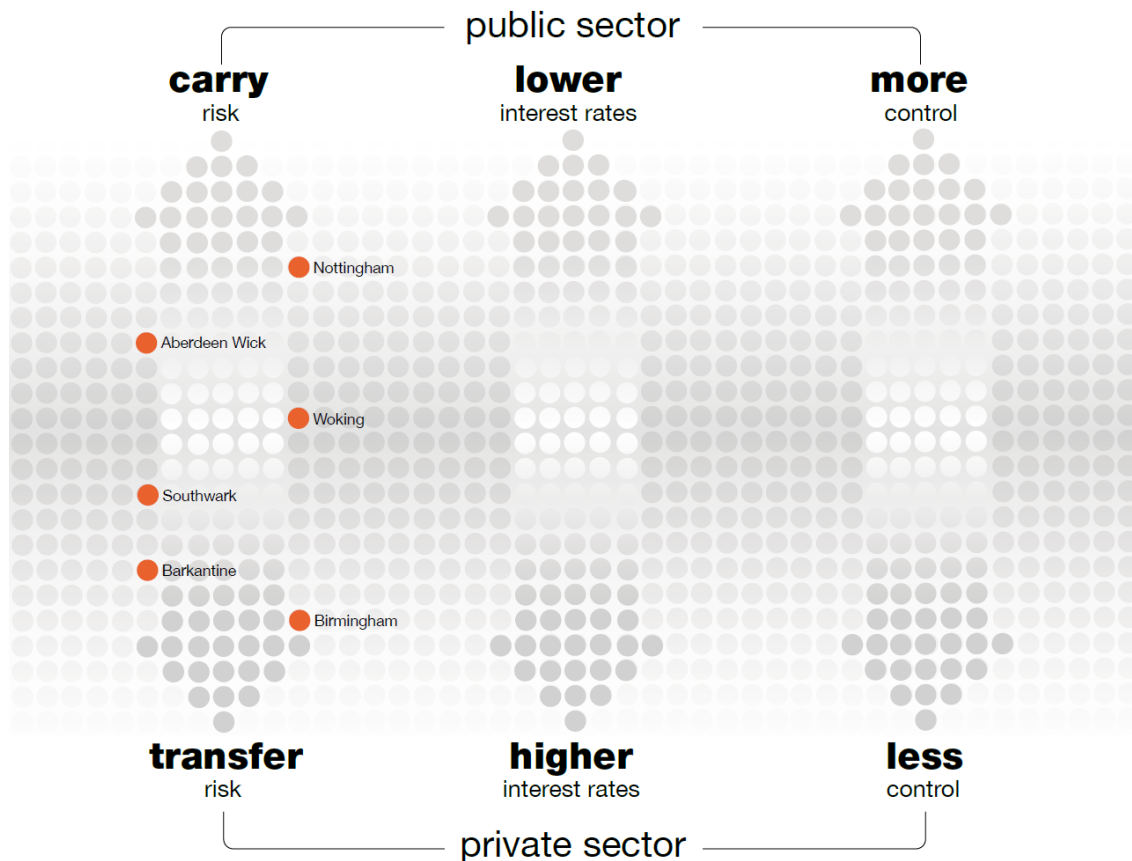


Figure D.5.2. Relationship between Risk, Control and Cost of Capital for Public and Private Sector Projects
[Source: (ADE, TCPA & LDA Design, 2010)]

It is worth noting the current status of planning mechanisms for the Old Oak area that could potentially provide funding for a scheme:

- CIL – funding for heat network infrastructure is NOT included in the Regulation 123 list in the Draft CIL charging schedule;
- Section 106 – a Supplementary Planning Document is proposed that “will provide further advice and clarity on how CIL and s106 will interact and operate within the Old Oak area”.
- Local carbon offset fund(s) – in the draft OPDC Local Plan and supporting documents, no references were found to OPDC’s approach to carbon offsetting; a review of local carbon offsetting approaches in London (National Energy Foundation, 2016) indicates that Brent, Ealing and Hammersmith & Fulham are collecting offset payments related to new development;
- Developer contributions – There may be other conceivable mechanisms by which developers could be induced to contribute to the delivery of a scheme.

D.5.6 In House Technical and Commercial Capacity

With the exception of a fully privately led and delivered scheme, all of the delivery models would require OPDC to develop and maintain some in-house commercial capacity to agree and manage scheme contracts. In the case of a municipal company or SPV, an OPDC owned or controlled company could choose to develop and maintain technical staff to deliver some network services, rather than outsourcing them to the private sector.

OPDC would need to establish its inherent appetite to develop extensive technical and commercial heat network capabilities in house as well as considering the related risk and financial trade-offs.

D.5.7 The PipeCo Concept

Of potential relevance to the choice of delivery model is the idea of the 'PipeCo'. Conceptually, once a heat network scheme is constructed and customers are connected and providing income, a PipeCo would buy the distribution pipe network. The company that made the original investment in the pipe network would immediately recoup a large part of its investment, improving cash flow and potentially freeing capital for new investment. The PipeCo is financed by institutional funds seeking low-risk investments. It levies a regular 'use of system charge' on those distributing heat through the network and is content to accept returns which, while relatively low, are reliable for the 50-60 year life of the network. The concept is analogous to the refinancing of infrastructure loans following the design and build phase; investors expect higher returns up to that point to compensate for the relatively high risk.

The PipeCo concept is new. There are only a few references to the approach in the literature and the main source used for this paper (Manders & Groth, 2016) acknowledges there may be only one existing example of a PipeCo in the context of property development (likely to be outside the UK) and "one major player in the UK district heating market is seriously considering setting [one] up". However, the theoretical benefits of the approach, particularly in a context like the Old Oak area of dense development that will be brought forward over a long time scale, make it worthy of consideration.

To facilitate a PipeCo, thought would need to be applied to the contractual and financial implications of the transfer of the heat distribution pipework assets. Given the novelty of the approach, it would potentially be valuable to seek input from those promoting the concept in the UK and likely to have insights from the limited experience that is available.

Assuming initial technical options appraisal demonstrates that a district heating scheme will offer value compared with alternative dwelling or block based solutions, this input could be sought when developing a preferred district heating solution as part of the forthcoming masterplanning phase.

D.6 Case Studies & Lessons Learned

OPDC and AECOM held three meetings with individuals representing or knowledgeable about five existing heat networks in the UK, as summarised in Table D.6.1.

Meeting	Date	Invitee & company*	Heat networks discussed
1	15/11/2016	Ian Guest – Lee Valley Heat Network Ltd Andy Kotowicz – London Legacy Development Corporation	Lee Valley HN, Enfield and Queen Elizabeth Olympic Park HN
2	17/11/2016	Paul Woods – ENGIE Michael King – Aberdeen Heat & Power Co Lucy Padfield – London Borough of Islington (apologies)	Aberdeen HN, Bunhill HN, and Queen Elizabeth Olympic Park HN
3	23/11/2016	Anthony Peter – Argent Andrew White – Metropolitan	King's Cross Heat Network
* Peter O'Dowd, Mo Williams, Dan Epstein and Alaina Tolhurst of OPDC, and Miles Attenborough and Zac Grant of AECOM also attended each of the meetings and minutes were circulated to OPDC attendees and relevant AECOM project staff.			

Table D.6.1. 'Lessons Learned' Meeting Dates, Invitees and Heat Networks Discussed

D.6.1 Case Studies

D.6.1.1 Lee Valley Heat Network

Drivers	Strategic: Regeneration in the Upper Lee Valley Opportunity Area provided a strategic focus for decentralised energy studies from which the potential to recover heat from waste management activity at Edmonton Ecopark emerged as a key opportunity. A Lee Valley Heat Network linked to the Edmonton Eco Park is one of eight planning framework objectives for the area. Local: Secure economic (inward investment, jobs, training, and energy security), social (low cost heat and community energy), and environmental (carbon reduction) benefits.
Objectives	Enfield Borough Council: Provide affordable heat to new homes, reduce fuel poverty, and cut carbon emissions. Strategic stakeholders: Same as the council, plus a long term ambition to interconnect Lee Valley, Queen Elizabeth Olympic Park and London Thames Gateway strategic heat networks.
Delivery structure	Lee Valley Heat Network Limited and subsidiary Lee Valley Heat Network Operating Company Limited established as the asset holding and operating companies respectively, wholly owned (two-tier) by Enfield.
Governance	Enfield Council controls the holding and operating companies through their Articles of Association, financing subject to approval of business plans, and appointments of directors.
Initial scheme	'Strategic network' consisting of a District Heating Energy Centre and the heat network to receive heat from a planned new energy from waste facility at North London Waste Authority's Edmonton Ecopark and supply it to 5000 new homes in the Meridian Water development. LVHN Limited is also to adopt a heat network 'Satellite scheme' serving 513 new homes, a hotel and commercial buildings completed in 2015 at Ladderswood.

Finance	Grant funding from the London Energy Efficiency Fund, private debt in the form of commercial bank loans from the European Investment Bank, and public debt from the Public Works Loans Board, all provided via Enfield Council.
Procurement	Currently in the process of procuring: design, build and operation services for the District Heating Energy Centre for the strategic network to serve Meridian Water; a framework for the operation of Satellite Schemes, and an initial contract to operate the Ladderswood scheme; and a customer services provider for the company's heat customers.
Subsequent / planned expansion	Potential increase from 5000 to 8000 homes at Meridian Water; additional Satellite schemes at Alma Estate and New Avenue; further Satellite schemes potentially including some in neighbouring Boroughs; and interconnection of Satellite schemes to the strategic network, subject to connection of sufficient local demand.

D.6.1.2 Queen Elizabeth Olympic Park Heat Network

Drivers	Sustainability agenda for 2012 London Olympics.
Objectives	Enable the Games and Legacy Communities Scheme development to meet carbon targets.
Delivery structure	ENGIE was appointed as concessionaire to finance, construct and operate the scheme under a 40 year concession agreement.
Governance	London Legacy Development Corporation and Stratford City Development Limited are the joint employers. A concession agreement establishes expected levels of service, price controls for consumers, contractual templates for future connection agreements between ENGIE and heat and cooling customers, and controls on the cost of those connections. It also makes contractual arrangements for appointing a new concessionaire to ensure continued operation after the initial 40 year concession period.
Initial scheme	Two separate but interlinked heat networks served by Energy Centres at Kings Yard on the Olympic Park and in the Stratford City development. The heat networks are served by a combination of biomass boilers, gas CHP engines and gas boilers and the cooling networks are served by a combination of vapour compression and absorption chillers.
Finance	ENGIE invested in the construction of the heating and cooling networks and energy centres that serve them. In return for this investment ENGIE was granted exclusive 40 year rights to provide heating to developments including the Olympic Venues, the Westfield shopping centre, East Village, and all legacy development on the Olympic Park within the concession area.
Procurement	Procured by the Olympic Delivery Authority (which transferred its share of governance of the scheme to the London Legacy Development Corporation) and Stratford City Development Limited as part of the regeneration of the Olympic Park for the 2012 Olympic Games.
Subsequent / planned expansion	The heat network has been or is being extended to serve the majority of the Legacy Communities Scheme on Queen Elizabeth Olympic Park, sites at Stratford, and in some neighbouring areas subject to feasibility, including developments at Chobham Manor, East Wick and Sweetwater, the Cultural and Education District (including Stratford Waterfront), the International Quarter, and Angel Lane.

D.6.1.3 Bunhill Heat Network

Drivers	Primary driver was to reduce fuel poverty
Objectives	Reduce fuel poverty and cut carbon emissions
Delivery structure	Project development; procurement of expert consultancy, design, build, operation and maintenance services; billing and customer services; and related legal and other services undertaken in-house by the Energy Services team and relevant departments within Islington Borough Council.
Governance	The network is run as part of the wider delivery of Council services, with the corresponding mechanisms for control and accountability. The activities and performance of third party service providers are governed by contract.
Initial scheme	Bunhill Energy Centre housing a 1.9 MWe gas CHP engine and 115 m ³ thermal store, one kilometre of trenching containing two kilometres of insulated district heating pipework serving 850 homes and two leisure centres.
Finance	£3.8 million energy centre and heat network were funded by grants secured from the Greater London Authority and the Homes and Community Agency with the remainder from Islington's own budget.
Procurement	Design and build and a 10-year operation and maintenance service were procured from the private sector.
Subsequent / planned expansion	An extension, Bunhill phase II, will serve a further 454 homes at the King's Square estate, a school, sheltered housing block, a community centre and a nursery utilising heat from a vent shaft on the Northern Line.

D.6.1.4 Aberdeen Heat Network

Drivers	Aberdeen City Council's strategic need to improve its housing stock and provide affordable, sustainable energy.
Objectives	A major improvement in the National Home Energy Rating of multi-storey flats; affordable warmth for tenants; reduction in CO ₂ emissions; sustainable and affordable energy for Aberdeen City Council; improved economic returns to the Council from its housing stock; affordability to council in terms of capital outlay (Hawkey & Webb, 2014).
Delivery structure	Aberdeen Heat & Power Ltd set up by Aberdeen City Council as a 'not for profit' company in 2002 to develop and operate district heating and CHP schemes to serve multi-storey council housing.
Governance	Aberdeen Heat & Power Ltd is an independent company limited by guarantee. Board of volunteer directors consists of Council and tenant representatives and up to 6 independents with relevant expertise.
Initial scheme	Based round the Stockethill Energy Centre, with 268 homes in four blocks of flats served by a gas-fired 210 kWe / 300 kWth CHP engine and two boilers for peak loads.
Finance	The initial Stockethill scheme was financed through a mix of grant funding from the Government's Community Energy Programme (~40% of capital costs) and energy utilities via the Energy Efficiency Commitment (now superseded by ECO; ~7%), and private debt in the form of commercial bank loans (the remaining ~53%) enabled by a loan guarantee from the Council, which committed £215,000/year from the housing capital budget.

Procurement	The company used the services of a consulting engineer to design and procure a build contract. Aberdeen Heat & Power operates and maintains the systems.
Subsequent / planned expansion	Schemes were subsequently added based round energy centres at Hazlehead, Seaton, and Tillydrone serving predominantly multi-storey housing and some commercial buildings.

D.6.1.5 King's Cross Heat Network

Drivers	Planning policy, particularly the London Plan and the energy hierarchy
Objectives	Enable the King's Cross development to meet carbon targets.
Delivery structure	Metropolitan King's Cross (MKC) set up as a private, single purpose company operated by developer Argent King's Cross (90% share) and specialist utilities infrastructure provider Metropolitan (10% share).
Governance	MKC's role is to supply heat; ensure that pricing is competitive; ensure network performance; enter into all heat contracts; and collect monies from customers. The company is signed up to the Heat Trust Scheme that sets customer service standards and customer protection requirements and provides customers free access to the Energy Ombudsman.
Initial scheme	2000 new homes, 800 student apartments, 3 million ft ² office space, 0.5 million ft ² retail space; served by: 1 energy centre (3x 2 MWe gas-fired CHP engines, thermal store, 3 top-up gas boilers with a total capacity of 36 MWth), a cooling pod.
Finance	Argent invested from the capital raised for the development, which includes 'patient' investment finance from the BT Pension Scheme.
Procurement	Metropolitan (part of Brookfield) was brought in as the Multi Utility Services Company providing power, gas, water and drainage, and data infrastructure, in addition to heat and cooling.
Subsequent / planned expansion	Development work on the site is ongoing and a 250 kWe to 1.4 MWe fuel cell will be added to the energy centre.

D.6.2 Lessons Learned

AECOM prepared a summary of key lessons learned as part of the minutes for each meeting. Synthesising the information from the individual sessions, the following emerge as lessons for the development of a heat network scheme in the Old Oak area:

1. The context of every scheme is unique and the objectives of the sponsors are different in each case leading to the adoption of a range of delivery models, all of which have been proven to work with varying strengths and weaknesses. A sustainable financial case is essential for every scheme and each model may offer opportunities to achieve viability. Schemes led by the public sector have more opportunities to access cheaper finance and grant funding to support the financial case, but the private sector can also leverage 'patient' private investment, organisational experience, multi-utility solutions and economies of scale.
2. Enabling contextual factors can be critical to the business case and should be a focus for development of the contractual structure of the scheme, e.g. for OPDC: access to surplus heat (Powerday); potentially lucrative private wire electricity sales (to HS2 and commercial sites); a supportive planning environment that contributes to reducing scheme risks (planning policy on connections (reducing demand risk), SPD including draft technical standards (reducing technical

risk), designated land use for (energy from) waste site (supporting long term heat supply resilience), etc.).

3. There are emerging risks for gas-fired CHP (an inevitable long-term fall-off in carbon savings due to grid decarbonisation, with no savings projected by the early 2030s; and potential short- to medium-term headwinds in planning and Building Regulations compliance contexts when grid electricity emission factors in the National Calculation Methodologies used for Part L change). However, gas-fired CHP was essential to the technical feasibility, business case, and operational resilience of all the major heat network schemes reviewed, and invitees at the lessons learned sessions felt strongly that this will remain the case for new schemes in the near term.
4. A Multi Utility model appears to offer opportunities for high value utilities (e.g. data networks) to cross-subsidise investment in other utilities, such as heat, that offer lower returns. As such, a decentralised energy delivery model would ideally retain the option to work as part of a multi utility solution.
5. Taking on the role of the ESCo requires a large amount of knowledge to be developed within the sponsor organisation (which needs to be retained) and setting up the contractual arrangements involves significant effort and costs.
6. Technical standards and in particular performance of the secondary network are frequently a problem in early phases of new networks and the delivery model should address this by bringing the eventual network operator on board early with a remit to control network design and construction quality.

D.7 Conclusion

The selection of a delivery model for a heat network depends on context and not least the strategic objectives of public authorities that often play a critical role as scheme sponsors. OPDC must decide the extent to which it expects to lead the development of a scheme in the area. Its role could be limited to facilitation – creating the right environment for a fully private sector solution to emerge – or extend to a part or full ownership stake in the delivery vehicle and direct involvement in scheme development, delivery and ongoing operation and governance. Work to develop and consider technical scheme options is underway. Alongside the technical studies, OPDC should take steps to define its strategic aims and objectives for a scheme and hence – alongside consideration of other key factors – its preferred delivery vehicle for a scheme.

The key points in this paper and next steps for OPDC are set out in the Summary at the start of this paper.

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Appendix E Review of Smart Energy Technology

E.1 Executive Summary

This technical note was prepared in December 2016 as an interim Stage 2 deliverable to provide a high level review of the potential for Smart Technology to influence energy demands at Old Oak.

Smart technology has the potential to reduce the energy demand and energy infrastructure required to service buildings within the Old Oak area. A desk-based review has been undertaken of possible smart technologies that could be implemented within the development for both heating and power loads and their potential impact on energy demand and their ability to help Old Oak and Park Royal Development Corporation (OPDC) to meet both carbon reduction objectives and reduce energy infrastructure costs.

Smart technologies have the potential to reduce energy consumption in buildings through more sophisticated control systems and data analytics as well as encouraging changes to occupant behaviour. In particular, research suggests that domestic smart meters and in-home displays could achieve energy savings of 3 per cent. Research is on-going as to whether smart domestic heating controls generally save energy and, if so, by how much. It may not be possible to count the benefits of smart technologies towards meeting the Part L and London Plan targets as the associated calculation procedures do not currently allow for such technologies.

Smarter solutions are being developed to reduce peak demand on heat networks and thus reduce the size and use of more carbon intensive peak gas boiler plants. As an example, hot water priority controls are being incorporated into Heat Interface Units (HIUs) which shut off the space heating for the short period of time when domestic hot water is being drawn off and, as a result, there is no need to add the hot water demand to the space heating demand when sizing for peak loads. Another solution being trialled is looking to flatten the heat demand profile through monitoring the space heating and hot water loads for each building, forecasting demand 24-hr in advance, and adjusting heat supply as appropriate including pre-heating buildings to shift demand and using the thermal mass of the building as a thermal store. As an estimate, smarter technologies could together reduce peak heating demand by 10-20%. A potential barrier in implementing these (and other) smart solutions is resistance from engineers to adopt new design practices. Engineers are legally required to deliver to published professional standards which may not yet capture state-of-the-art innovations.

There is also significant opportunity for a more intelligent local electricity network to potentially reduce the peak capacity requirements and associated costs. This is through both: (i) demand-Side Response (DSR) which involves dynamically managing demand and any embedded generation capacity on the local network to reduce the peak load on the network, and (ii) the storage of excess renewable energy generated either from excess generation nationally or embedded generation within the local network.

- **Local Generation:** There is the potential of integrating any CHP engine from the district heating network with the local electricity distribution network. However, previous analysis suggests that this approach may be constrained to provide demand response primarily in the spring and autumn months. Furthermore, whilst there is the potential to use back-up generators installed in local buildings it depends on the building owners' willingness to participate and such generators tend to be diesel-powered and have relatively high carbon intensity.
- **Flexible Domestic Demand:** Domestic smart meters can encourage consumers to shift electricity consumption away from periods when it is most expensive to generate energy through the use of time-of-use tariffs. Trials have demonstrated this can alter patterns of energy usage during the day by up to 10%. There may be greater opportunities for DSR in the domestic sector in the future with increases in electricity use on the grid (e.g. from electric cars and heat pumps) and some flexibility around their time of use. A key challenge is likely to be the commercial arrangements to derive these benefits: (i) the electricity supplier has the relationship with the consumer and the distribution network operator (DNO) is not able to influence the tariff structure to reflect its needs, and (ii) this approach is dependent on consumers voluntarily altering their behaviour in response to financial signals (albeit this can be automated to a degree).

- **Flexible Commercial Demand:** It is likely that the main opportunity for DSR in commercial buildings is from shifting the Heating, Ventilation and Air Conditioning (HVAC) demand. It is both a significant contributor to the electricity load in the buildings and such loads can be interrupted temporarily with no significant impact on comfort. Again, the analysis suggests that the challenges are likely to be more of commercial viability than technical – in this case signing up sufficient commercial building owners at terms of payment that make this commercially viable for the DNO.
- **Electricity Storage:** An analysis has been undertaken of the opportunity for solar photovoltaics and battery storage at Old Oak. An initial high-level estimate suggests a maximum available potential of 9MWh per day in winter to 88MWh per day in summer. Furthermore, there are current trials of grid-level electrical energy storage e.g. UK Power Networks' on-going Smarter Network Storage project which is trialling the deployment of 6MW / 10MWh of lithium-ion storage. These numbers are potentially significant; the total electricity capacity requirements are around 120MVA and battery storage could potentially be used to supplement the main electricity supply. Further analysis would be needed to more accurately determine the potential supply from battery storage as well as its viability.

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E.2 Introduction

E.2.1 Purpose

Smart technology has the potential to reduce the energy demand and energy infrastructure required to service buildings within the Old Oak area. This review has been undertaken of possible smart technologies that could be implemented within the development for both heating and power loads and their potential impact on energy demand and thus ability to help OPDC to meet both carbon reduction objectives and to reduce the costs of energy infrastructure.

The Old Oak and Park Royal Development Infrastructure Funding Study ¹ has already identified that there are potential benefits of a smarter local electricity grid. Indeed, it questions whether a smarter electricity network undermines the rationale for investment in a heat network highlighting factors including: (i) the reduced heat load requirements for new highly insulation buildings which can be met by electric panel heaters supplied by low-carbon electricity from a decarbonised grid and (ii) the reduced infrastructure costs for a smarter electricity distribution network through measures to reduce peak demand and thus peak capacity requirements.

The OPDC Smart Strategy Interim Report: Local Plan Supporting Study ² was developed to inform the draft OPDC Local Plan. It highlights the need to consider: (i) smarter building management, (ii) flexible energy demand, and (iii) the potential for local energy production and storage, and its accommodation within the design of buildings and spaces.

E.2.2 Basis, Scope, Assumptions and Terminology

The note is based on a review of published information and some stakeholder engagement around smart technology. For the purpose of this review, smart technology has been defined broadly as ICT-enabled infrastructure/energy distribution and ICT enabled buildings. The focus has been on smart technology that reduces energy infrastructure, hence the review does not consider smart technology that may, for example, solely improve the customer experience.

This review assumes the development of a low carbon decentralised energy (DE) infrastructure in the Old Oak area. In particular, it has been assumed that heating for buildings will be provided through a district heat network.

The review has particularly focussed on residential development with some consideration given to non-residential buildings.

E.2.3 Structure and Content of the Note

The remainder of this note is structured as follows:

- Section E.3 Improving energy efficiency through building-level smart technology;
- Section E.4 Smarter district heat networks;
- Section E.5 Smarter local electricity networks.

¹ https://www.london.gov.uk/sites/default/files/final_old_oak_difs_141015_new_cover.pdf

² https://www.london.gov.uk/sites/default/files/smart_strategy_interim_report_opdc_hypercat_final_jan_2016_new_cover.pdf

E.3 Improving Energy Efficiency through Building-level Smart Technology

E.3.1 Introduction

In recent years, both Part L of the Building Regulations and the Mayor's London Plan have been increasingly tightening the level of energy efficiency and carbon emissions in new building designs. London Plan policy 5.2B sets carbon reduction targets for new development which go beyond Building Regulations. Current policy is that new residential buildings should now be 'zero carbon' and new non-residential buildings should be 'zero carbon' from 2019.

Smart technologies have the potential to reduce energy consumption as described below. These benefits are principally delivered through more sophisticated control systems and data analytics as well as encouraging changes to occupants' behaviour in relation to energy consumption.

However it is important to recognise that it may not be possible to count the benefits of smart technologies towards meeting the Part L and London Plan targets. In both of these policies, the building's energy performance is determined using a standardised calculation methodology. In particular for residential buildings, the SAP methodology is used to assess the energy performance of buildings³. The SAP methodology currently does not incorporate smart technologies. Hence, it may not be possible to account for any energy efficiency benefits from smart technologies towards meeting the London Plan's targets.

E.3.2 Domestic Smart Meters and In-home Displays

The Government is committed to ensuring that every home and business in the country is offered a smart meter by the end of 2020⁴. Domestic customers will be offered an In-Home Display (IHD) which will be connected to the smart meter through a Home Area Network (HAN) enabling them to see in real-time their energy use and cost. This system will give consumers the opportunity to engage with their energy use and make savings on the basis of better information about their consumption. Government-funded research suggests that it is reasonable to expect durable energy savings of 3 per cent (for gas and electricity) provided consumer engagement is effective, and larger savings are feasible in the future as innovation in products and services using smart meter data are developed⁵. As the efficiency gains are driven by changes in occupancy behaviour, the level of saving will vary between different households.

Heat meters are required for district heating schemes but there is currently no requirement for them to be smart – in particular, no requirement for an In-Home Display providing real-time information on energy use and cost to encourage behaviour change and demand reduction. Some manufacturers do offer In-Home Displays^{6, 7}. There is little evidence of how much impact they will have on energy reduction but it seems reasonable to assume that they would achieve a similar reduction to that of smart gas meters as above. In order to enable better demand management OPDC and developers will need to mandate that Smart remotely addressable heat meters are installed to all heat network customers - this can be addressed in the local plan policy.

As highlighted in the introduction, the SAP methodology does not currently provide any benefit from the adoption of smart meters. Hence, benefits from smart meters would not go towards developers demonstrating that they have met the London Plan's CO₂ reduction targets.

³ <http://www.bre.co.uk/sap2012/page.jsp?id=2759>

⁴ http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/science-and-technology-committee/smart-meters/written/32093.html#_ftn3

⁵ <https://www.gov.uk/government/publications/smart-metering-early-learning-project-and-small-scale-behaviour-trials>

⁶ http://www.ccrmagazine.com/index.php?option=com_content&task=view&id=16266&Itemid=33

⁷ http://www.gurusystems.com/guru-hub/#guru_hub

E.3.3 Smart Domestic Heating Controls

There are increasing numbers of smart heating control products being offered for domestic customers. These can utilise temperature sensors in different zones, external temperature sensors, planned occupancy periods, required set point temperatures and learned heat profiles to optimise the point at which space heating and hot water systems are switched on and the flow of heat to different zones of the home⁸. There is the suggestion that automatic heating controls could save energy by, for example, turning down heating in non-occupied rooms or when the property is empty⁹. However, a literature review in 2014 suggests that few UK studies have rigorously evaluated the overall effect of providing households with technologically improved heating controls in terms of energy saved¹⁰. A key dependency is how the user interacts with the system which could lead to energy savings or, indeed, energy increases (e.g. if the result of the interaction with the smart controller is to increase the set point temperature). The Government is currently undertaking research to evaluate the impact of smart domestic heating controls.

SAP does account for the benefits of some heating controls which, for example, allow the occupant to manually programme the temperature at different times in different parts of the home. However, SAP does not currently account for these more sophisticated heat control systems which incorporate, for example, advanced heating algorithms that can learn occupant habits and sensors that can detect occupancy. The Government is currently undertaking a SAP consultation which includes a request for evidence on the benefits of smart heating controls on the energy performance in homes, for their potential inclusion in the SAP methodology in the future¹¹.

E.3.4 Non-residential Buildings

New non-residential buildings already incorporate significantly more advanced metering and control systems than residential buildings.

- Part L recommends that all buildings should have sub-metering of energy use in buildings. Sub-metering is likely to include a combination of both location-based and energy load specific measurements thus enabling assessment of the consumption of the various energy uses (e.g. lighting, power, heating and cooling energy) as well as, say, how the consumption varies by floor/commercial occupier in the building.
- Non-residential buildings already incorporate a number of control features, the benefits of which are recognised in the National Calculation Methodology (NCM) – the equivalent of the SAP methodology for non-residential buildings. These include controls for the HVAC and lighting systems in the building. Larger non-residential buildings incorporate a Building Management System, which is a computer-based control system that monitors and controls the building's mechanical and electrical equipment to run in an energy-efficient manner. The NCM includes benefits for the incorporation of specific building management features such as automatic Monitoring and Targeting (aM&T) where data from the building's energy sub-meters can be analysed to help ensure energy efficient operation and identify energy reduction opportunities.

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https://www.london.gov.uk/sites/default/files/gla_migrate_files_destination/Smart%20City%20Intelligent%20Energy%20Opportunities_0.pdf

⁹ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/254877/smarter_heating_controls_research_programme_overview.pdf

¹⁰ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/277552/FINALHow_heating_controls_affect_domestic_energy_demand_-_A_Rapid_Evidence_Assessment.pdf

¹¹ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/566049/SAP_consultation_document__with_links_.pdf (see Proposed Amendment 19)

E.4 Smarter District Heating Networks

At present heat networks in London are typically served from centralised energy centres comprising gas engine CHP units, gas boilers providing peak capacity and standby loads and thermal stores. Heat is circulated through a flow and return heat network to supply heat demands in homes and non-residential buildings, typically via a heat interface unit (HIU) at the building. Based on early review of heat sources within the Old Oak area it may be that the network will incorporate more distributed low-carbon heat generation including, for example, Energy from Waste from the Powerday site and/or using heat pumps to extract heat from the Grand Union Canal, sewers or bore-holes.

Currently the primary control of the heat network is to maintain constant flow and return temperatures sufficient to meet consumer demands and modulate flow volume (variable volume design). More sophisticated systems also allow the flow and return temperatures to adjust, in addition to flow, to reflect the changing seasonal needs of the customers. However, there is typically no link between the consumer's heating system controls and the controls in the energy centre.

Increasingly, consumer demand is being managed in a more intelligent manner through more sophisticated control systems which can reduce consumer energy demand as well as better manage peak load on the network, the latter allowing the greater and more efficient use of baseload heat generation and peak generation capacity requirements to be reduced. This is particularly relevant for OPDC to achieve its low-carbon objectives as there appears to be a number of opportunities for low-carbon heat sources to be used for baseload heat generation and by reducing peak demand it reduces the size and use of more carbon intensive peak gas boiler plants.

A key enabler of this improvement is the development of digitally controlled HIUs. This allows better control of the time and volumes at which heat is drawn from the network for use within buildings. A particular example is the integration of hot water priority into HIUs. Currently, in determining the heat demand requirement for a network, the domestic hot water (DHW) demand is typically calculated and added to the space heating demand. A diversity factor is applied to allow for the fact that domestic hot water is typically not required at the same time in all buildings, and an allowance of c2-3kW per new dwelling is typical. By contrast, a hot water priority system, shuts off the space heating when the hot water is being drawn off. As this occurs for a relatively short time in any one dwelling the internal temperature will not noticeably reduce, especially for well-insulated dwellings. As a result there is no need to add the hot water demand to the space heating demand. This reduces the peak demand depending on assumptions made on diversity, the relative demand of space and hot water heating and the location in the network. As an illustration, for the purposes of this work, a peak demand reduction was estimated of around 6% for a development of 1000 dwellings. It is assumed in this example that the energy saving reduces the peak demand and that additional space heating energy will be required subsequently to those homes where the space heating had temporarily been turned off.

More innovative solutions are currently being trialled and it would be reasonable to assume that peak generation capacity could be reduced by a further 5-10%. These solutions take further advantage of the connectedness offered by digital-controlled HIUs. As an example, PassivSystems is looking to flatten the heat demand profile through monitoring the space heating and hot water loads for each building, forecasting demand 24-hr in advance, and adjusting heat supply as appropriate including, where necessary, pre-heating buildings to shift demand and using the thermal mass of the building as a thermal store. Based on initial field research, they suggest that they achieve a 15% reduction in peak demand through this approach (including benefits of hot water priority)¹². Other solution providers are looking to better integrate HIUs across a network to flatten the head demand. For example, Thermal Integration is currently patenting an approach for hot water priority across the heat network as a whole¹³. Hence, space heating and hot water loads are balanced across the whole network rather than on an individual building basis.

¹² Based on personal communications with Ian Rose of PassivSystems

¹³ http://www.heatweb.co.uk/w/index.php?title=The_HIU_Revolution

There may be some benefit in delivering these more sophisticated control systems to distribute thermal storage through the network or in the buildings themselves. It will depend on whether both suitable locations can be identified and that the impacts on costs and space of this storage are not too high. In general, designing the building itself to be used as a thermal store, through taking advantage of its thermal mass, may be considered as an alternative solution rather than including a separate heat store. However, additional thermal storage may provide additional capacity depending on the scheme design.

There is the potential also of additional revenue streams from integration with the electricity network. Where the market conditions are favourable, the CHP engine could generate additional electricity with excessive heat stored. This is discussed further in the next section.

It is important to highlight potential barriers in implementing these (and other) smart solutions. In particular, there may be resistance from engineers to adopt new design practices. Engineers are legally required to deliver to published standards, the best currently for district heating schemes being the Heat Networks Code of Practice¹⁴. Such standards are typically designed to help achieve a good standard of practice across the industry but may not capture state-of-the-art innovations. This may be something to be reviewed in further detail if more innovative solutions are to be implemented in the Old Oak area.

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¹⁴ <http://www.cibse.org/Knowledge/knowledge-items/detail?id=a0q200000090MYHAA2>

E.5 Smarter Local Electricity Networks

E.5.1 Introduction

The local electricity distribution networks carry electricity from the high voltage transmission grid via transformers (sub-stations) to domestic, commercial and industrial users. Currently, the primary purpose of the local electricity network is to maintain adequate supply to the various electrical demands. The Distribution Network Operator (DNO), such as UKPN, manages the local electricity distribution network.

A significant opportunity is for a more intelligent local electricity network.

- Demand-Side Response (DSR) involves dynamically managing demand and any embedded generation capacity on the local network to reduce the peak load on the network and thus the peak capacity requirements and associated costs. An important principle of DSR is that any generation and/or demand capacity need to be available and sufficiently flexible to change the electrical load on the system at points in time.
- The storage of excess renewable energy generated. This could include excess generation on the national network from, for example, intermittent wind turbines. It could also include embedded generation on the local network e.g. electricity generated from PV in the middle of the day may be more valuably used during the evening where networks principally serving residential developments tend to have peak demands.

To manage this system, greater intelligence, communications and controls needs to be integrated into the network. This is so that the system as a whole can be managed, ideally automatically, in real-time.

As part of the Low Carbon Network Fund field trials, a number of Distribution Network Operators (DNOs) undertook trials of more intelligent local networks including DSR and/or local storage such as UKPN's Low Carbon London programme¹⁵, WPD's Falcon programme¹⁶, and SSE's DSR programme¹⁷. Some DNOs are commercially deploying such solutions.

Within the rest of this section, we discuss the various opportunities for DSR and local storage.

E.5.2 Local Flexible Generation

There is the potential of integrating any CHP engine from the district heating network with the local electricity distribution network. This approach was previously evaluated by AECOM for the GLA¹⁸. Where the market conditions are favourable, the CHP engine could generate additional electricity with additional thermal storage likely located at the energy centre, although it could be located at building level with more limited use. In practice, CHP is likely to provide demand response primarily in spring and autumn where assets are not fully utilised but there are still significant heat loads. Only a limited response could be provided in summer, because then the thermal load is so small that if the engine is to be used it would need to use thermal storage and the heat from this would need to be discharged before the CHP could be used again to offer a demand response.. Extra electricity generation could not be provided in winter as the CHP engine could already be expected to be operating at full load 100% of the time to meet heat demands, although the electricity generation could be turned off as a demand response subject to market conditions.

¹⁵ [http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-\(LCL\)](http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL))

¹⁶ [https://www.westernpowerinnovation.co.uk/Projects/Falcon.aspx#FAQLink49;javascript:void\(0\);](https://www.westernpowerinnovation.co.uk/Projects/Falcon.aspx#FAQLink49;javascript:void(0);)

¹⁷ http://www.smarternetworks.org/Files/Honeywell_I&C_ADR_-_Demand_Response_130130162149.pdf

¹⁸

https://www.london.gov.uk/sites/default/files/gla_migrate_files_destination/Smart%20City%20Intelligent%20Energy%20Opportunities_0.pdf

Another option is to take advantage of any significant back-up generators installed in local buildings. These are particularly likely to be installed for electricity-critical organisations, such as hospitals or data-centres. For example, in the Low Carbon London LCNF study, they used local generators, each with capacity between 1000kW and 3000kW¹⁹. In principal, as the generators are used rarely, there should be significant availability during the year for use with DSR. However, the Low Carbon London study suggests that only 20% of potential operators of back-up generators may be willing to participate. Furthermore, back-up generators tend to be diesel-powered and inefficient, and the resultant relatively high carbon intensity needs to be considered against OPDC's objectives for a low-carbon energy system.

E.5.3 Local Flexible Domestic Demand

An additional benefit of domestic smart meters is that they will be able to record consumption and set separate prices for each half hourly period. This will make it possible for energy suppliers to offer time-of-use tariffs with different price periods throughout the day. Such tariffs can incentivise demand-side response, which can encourage consumers to shift electricity consumption away from periods when it is most expensive to generate energy. Research suggests that the evening peak demand is more than three times higher than the baseload. Cooking, lighting and audio-visual appliances use the largest share of peak power – however washing appliances and cold appliances also account for a significant share of the peak load, and probably offer more potential for changing the times of use²⁰. Trials have demonstrated that time of use tariffs can be expected to alter patterns of energy usage during the day by up to 10%^{21, 22, 23}.

There may be greater opportunities for DSR in the domestic sector in the future.

- Smarter appliances such as washing machines or driers and fridge freezers may be incorporated with smart controllers which, based on tariff signals from the smart meters, will automatically take advantage of times of day with lowest energy prices e.g. operating the washing cycle overnight.
- The number of households with air conditioning may significantly increase due to rising temperatures as a result of climate change. This will significantly increase load on the electricity network and potentially some of this load can be shifted through, for example, pre-cooling homes.
- There is an expected significant increase in usage of electric vehicles. Battery storage gives some flexibility of charging time (see Section 5.5).
- If heat pumps are used as part of the heat network solution, which currently appears a possibility, thermal storage could enable electricity use to be separated from heat production (alternatively, gas could possibly be substituted for electricity at specific times).

The main challenge is likely to be the commercial arrangements to derive these benefits. Some key challenges have been identified, for example, as part of UKPN's Low Carbon London programme.

- The approach described above relies on consumers voluntarily responding to price signals which may limit the level of participation. A more formal commercial arrangement could be implemented, but there is the challenge of upfront cost of agreeing contracts with many individually small consumers outweighing the benefits.
- The commercial relationship is currently between the electricity supplier and consumer. The electricity supplier would set any time-of-use tariffs to reflect wholesale electricity prices which may not be coincident with the times of peak load on the local network. An alternative commercial arrangement is likely to be needed to better meet the needs of the DNO.

¹⁹ [http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-\(LCL\)/Project-Documents/LCL%20Learning%20Report%20-%20A7%20-%20Distributed%20Generation%20and%20Demand%20Side%20Response%20services%20for%20smart%20Distribution%20Networks.pdf](http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL)/Project-Documents/LCL%20Learning%20Report%20-%20A7%20-%20Distributed%20Generation%20and%20Demand%20Side%20Response%20services%20for%20smart%20Distribution%20Networks.pdf)

²⁰ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/275483/early_findings_revised.pdf

²¹ https://www.ofgem.gov.uk/sites/default/files/docs/2011/06/energy-demand-research-project-final-analysis_0.pdf

²² <http://www.networkrevolution.co.uk/project-library/insight-report-domestic-time-use-tariffs/>

²³ [http://www.cer.ie/docs/000340/cer11080\(a\)\(i\).pdf](http://www.cer.ie/docs/000340/cer11080(a)(i).pdf)

E.5.4 Local Flexible Commercial Demand

It is likely that the main opportunity for DSR in commercial buildings is from shifting the Heating, Ventilation and Air Conditioning (HVAC) demand. It is both a significant contributor to the electricity load in the buildings and it is possible to rapidly reduce the demand when required. Space heating, cooling and ventilation loads can be interrupted with no significant impact on comfort with the degree of turn-down dependant on factors such as the thermal mass and insulation of the building. For example, UKPN's Low Carbon London DSR trials included both hotels and offices and ran demand turn-down events in each building for an hour with an average demand reduction for hotels and offices of 230kW and 380kW respectively (note that the size of the demand reduction is dependent on the size of the buildings and the initial energy demand which is likely to be higher in older, less-efficient buildings). In practice, a longer DSR period can be achieved by turning down different buildings in sequence and pre-heating or pre-cooling the building prior to the demand-reduction event. The demand reduction potential is likely to be more significant in summer as the electrical load is likely to increase from greater use of air conditioning.

Again, the challenges are likely to be more of commercial viability than technical and would require further exploration if DSR is to be implemented. For example, DSR is currently applied nationally to help balance national grid demands and an aggregator (a company acting as an intermediary between the network operator and end-use customers to deliver demand response capacity) may sign-up commercial end-users which have a portfolio of buildings, such as a supermarket chain. Hence for a single contractual arrangement (which will take time and cost), the aggregator is able to sign-up a considerable demand reduction capacity – the combined demand reduction potential across the portfolio of buildings. In the case of a local network, it is more likely that contractual arrangement will need to be agreed one-by-one for individual buildings owners as they may well be all separate commercial entities – hence significant resources will still need to be expended on contractual arrangements but the benefits are less as only gaining demand reduction capacities from one building per contract. Another challenge is whether the payments to the commercial building owners are sufficiently attractive for their participation in DSR; it may be that it is cheaper to add additional peak capacity to a new local distribution network, as well as gain the advantage of the reliability of this installed capacity rather than reliance on the commercial organisation to deliver the DSR in practice, than meet the level of fees that the commercial organisations would wish to participate in DSR.

E.5.5 Local Storage

Reducing costs for PV and previous Government incentive schemes have rapidly increased the total PV generation capacity feeding into networks. Previous national grid studies have concluded that battery storage potentially offers one of the best routes to help manage the intermittency of PV generation in relation to changing levels of sunshine and daylight. Battery storage can also help to shift the pattern of generation against demand allowing a greater proportion of the energy to be utilised within the home providing greater economic benefit to users e.g. storing solar energy during the day and used to help meet the electrical load in the home during the evening at peak prices.

Domestic electrical energy storage is a developing technology. As an example of current products available, Tesla is marketing the Powerwall²⁴ which provides a capacity of 14kWh, with a power output of 7kW peak / 5kW continuous, for £5400 (excluding insulation and software). PowerVault is another example of a battery storage technology being promoted to better utilise and manage PV generation.

In the context of OPDC, the opportunity for solar photovoltaics and battery storage is restricted due to the limited roof space per dwelling/apartment unit. However, it is expected that there would still be extensive application of PV. Early estimates by Atkins have suggested that 131,000m² of PV panel could potentially be accommodated at Old Oak with an annual energy generation of 17000MWh/yr. To estimate the maximum potential, assuming that all of the energy generated is stored by batteries with no losses and no electricity consumed within the buildings themselves, this results in around 47MWh per day being available. In practice, solar irradiance changes across the year and allowing for this, it is estimated that the total capacity per day would range from 9MWh per day in December to 88MWh per day in June. This potentially could help to reduce evening peaks which occur with residential developments, albeit there is less capacity available during winter months when the peak electrical load will be higher.

²⁴ https://www.tesla.com/en_GB/powerwall

It is useful to put this into context. The total electricity capacity requirements are estimated at around 120MVA. Of this 30MVA are each spread across the SSE and UKPN patches and single client loads of around 30MVA each for HS2 Over Site Development (OSD) and Crossrail OSD. Based on the above calculations, the PV generated electricity is relatively large and could potentially be used to supplement the main electricity supply e.g. to provide additional generation during times of peak demand (i.e. 'peak lopping' or 'peak shaving'). Further analysis would be needed to more accurately determine the potential supply from battery storage as well as its viability.

The potential provision of PV at Park Royal is considerably greater. However, it would be expected to be focussed on commercial uses where there will be greater potential to utilise the power directly at the time of generation.

This technology can be taken a step further with PV generation and battery storage being linked to electric vehicle charging. Tesla has been one of the innovators in this area. Development densities, resulting lack of public space and need to promote more healthy sustainable modes of travel are likely to mean that parking provision and individual car ownership at Old Oak will need to be restricted. However, it is expected that some pooled provision of cars through car sharing operators will need to be provided. With current pressures on air quality, it is expected that this will need to be focussed around electric vehicles. While unlikely to make a substantial impact on overall energy demand, where significant numbers of electric vehicle charging points are provided, control mechanisms can be implemented to schedule charging so that peaks on the local distribution system are minimised. Furthermore, it is possible that the PV generated electricity can help manage further these reduced peaks.

Another option is the use of grid-level electrical energy storage which is connected to the distribution network. There have been a number of demonstrations projects, particularly as part of the Low Carbon Network Fund, such as UK Power Networks' on-going Smarter Network Storage project which is trialling the deployment of 6MW / 10MWh of lithium-ion storage on the distribution network. One particular benefit of grid-level storage is as an alternative more cost-effective solution to reinforcement of the grid due to increased loading. However, in the case of a new distribution network, the benefits of battery storage may be less attractive and it may be useful to discuss this with UKPN. There are other benefits of grid-level storage including helping balancing the supply and demand across the network, particularly with increased amounts of intermittent renewable generation.

Battery storage has benefits in offering near instantaneous supply in fault situations and can help with frequency response and voltage response.

E.5.6 Virtual Power Plants

A Virtual Power Plant (VPP) is a collection of distributed generated assets collectively operated via a central control mechanism. Hence, in the context of the discussion above, as an example this could include clusters of PV, CHP units, local and grid-level storage (and fuel cells if, for example, used to provide any energy production for buildings or electric vehicles).

VPPs allow for the delivery of peak load generation, as well as the ability to match generation with load. VPPs also help to smooth the intermittent nature of smaller scale renewable generation. They effectively aggregate all the generation together so that the assets behave like a centralised plant and enable the impact on the system to be managed. As local contributing generators grow, VPPs will provide a means for these assets to be integrated into the grid without disruptions, becoming part of a local power plant that is not necessarily located within the same geographical area. To enable this generation assets need to be enabled for remote monitoring and control, and an entity is required with access to multiple generation assets. The closest model to this at present is demand aggregation companies trading into grid balancing services.

Appendix F Carbon Emission Factor Projections

F.1 Background

To understand the carbon emissions over time from development in the Old Oak area, assumptions need to be made about:

1. The carbon emissions arising from the use of each kWh of electricity supplied from the national grid – referred to as the ‘grid supplied electricity emission factor’; and
2. The carbon emissions avoided (carbon savings) for each kWh of electricity supplied by decentralised energy systems integrated into new development and therefore not supplied from the national grid – referred to as the ‘grid displaced electricity emission factor’.

The following are outlined in this note:

1. The main types of emission factors that are used to understand the impact of grid electricity demand and savings from new development:
 - a. The average emission factor for grid electricity;
 - b. The marginal emission factor for grid electricity; and
 - c. Technology-specific marginal emission factors for grid displaced electricity.
2. Relevant projections that are available for electricity emission factors and the key contexts in which the use of particular electricity emission factors is mandated by regulation or policy guidance, namely:
 - a. Building Regulations and carbon reporting / footprinting; and
 - b. Impact Assessment of Government policies and projects.

The note concludes with a recommendation on the carbon emission factors for grid supplied and grid displaced electricity to be used for OPDC scenario modelling. (The introduction of the different types of emission factors and contexts in which they are used touches on debates about the ‘correct’ way to account for changes in electricity use in new developments.)

F.2 Types of Grid Electricity Emission Factors

F.2.1 Average Emission Factor (for Carbon Reporting / Footprinting)

The average emission factor for grid electricity is the total amount of carbon emissions arising from all power stations divided by the total quantity of electricity supplied to customers, typically expressed in units of kgCO₂e/kWh or gCO₂/kWh. This factor will clearly change over time, as the mix of power stations supplying electricity changes from year to year. The factors used are generally based on time series of calculated historic and projected future annual averages.

The carbon emissions associated with grid electricity supplied to existing buildings for carbon reporting purposes (aka footprinting) are calculated by multiplying the average grid emission factor by the quantity of electricity demand, and this is uncontroversial in that context.

F.2.2 Marginal Emission Factors

New buildings give rise to sustained changes in the demand on the electricity grid. The change in demand from any particular new development, and even all new development in any given year, is small relative to the total demand. A general principle when considering systems is that the effects of small changes should be considered 'at the margin'. In simple, immediate terms, this means that the emission factor of an extra kWh of demand from a new development is equal to the carbon intensity of the generator that increases its output by one kWh to meet the demand. A basic application of the principle involves calculating the emissions associated with increases and savings in demand from new development based on the aggregate annual carbon intensity of just the mix of generators that serve the aggregate additional annual demand.

The concept and methodology underpinning the use of 'Long-run marginal emission factors' for electricity are described in background guidance to the Treasury Green Book supplementary appraisal guidance on energy and GHG appraisal and evaluation as follows:

The marginal electricity emissions factor is intended to reflect the change in emissions that would result from a small but sustained change in electricity consumption. The change in electricity consumption is assumed to be constant throughout the day and year (i.e. no differentiation is made between peak and non-peak. Figures are an average for each year).

The marginal plant(s) refers to what energy source(s) we expect to increase or decrease when there are marginal but sustained changes to energy demand or supply. The marginal emissions factor allows us to conduct policy analysis relative to a baseline that includes implemented, adopted and planned policies and in which sufficient plant is built to meet projected demand...

The calculations are based on the assumption that until very recently a Combined Cycle Gas Turbine (CCGT) plant was the long-run marginal electricity generation plant on the basis that it was both relatively cheap and quick to build. Therefore, the marginal emissions factor in 2010 reflects that of a typical CCGT plant (0.349 kgCO₂e/kWh before taking into account distribution and transmission losses). However, going forward there are reasons to think that this may not remain the case, particularly given the policies in place to incentivise low carbon electricity generation.

Illustrative demand reduction scenarios have been modelled in DECC using the Dynamic Dispatch Model (DDM)(6) to examine the impact of a change in electricity consumption on capital build and generation. The model predicts that CCGT plant will form a significant part of the marginal impacts, but that going forward in time, there are impacts on other plant, including low carbon technologies.

In order not to draw overly precise conclusions from the modelling of an inherently uncertain future, the results of the demand reduction modelling have been used to inform a profile of emissions factors between the CCGT plant in 2010, and the marginal emissions factor modelled in 2030. A moving average of the results suggests broadly an increasing rate of decline in the emissions factors over this period.

In the longer run, uncertainties increase even further. Given that it is very difficult to identify what the marginal impacts would be, a pragmatic approach of using the projected average grid emissions factor from 2040 onwards is taken.

(6) Further information on the DECC dynamic dispatch model may be found here: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48383/5425-decc-dynamic-dispatch-model-ddm.pdf

(Department of Energy & Climate Change, 2015)

A more detailed explanation of the marginal emission factor concept and methodologies for calculating such factors is beyond the scope of this paper. The essential point to understand is that marginal emission factors tend to be a blended average of the carbon intensity of two groups of electricity generators:

1. The generator type with highly controllable variable output that for most of the year sits at the 'top' of the stack of power generating capacity (in the UK this has tended to be combined cycle gas turbine power stations with a carbon intensity of around 0.349 kgCO₂/kWh, before transmission and distribution losses), and
2. New generators added to the electricity system, which in the future are projected to be largely renewable, nuclear and other low carbon generators.

The marginal emission factor is currently significantly lower than the average emission factor as both CCGTs and new generating capacity have carbon intensities below the current grid average. The marginal and average factors converge over time, to parity from 2040 onwards.

F.2.3 Technology-specific Marginal Emission Factors

Specific technologies such as CHP, heat pumps and PV have (on aggregate) distinct daily and seasonal electricity supply or demand profiles. The carbon intensity of the grid changes greatly depending on the time of year and the time of day. As such, we would expect the carbon savings from displaced electricity associated with heat-led CHP (generating more electricity in winter, and morning and evenings when development heat demand and national electricity demand is high) to be different from the savings from PV (generating more electricity in summer and in the middle of the day when national electricity demand is lower). The basic marginal emission factor approach ignores these technology-specific demand profile effects. CHP advocates in particular argue that it is critical to consider the demand profile when calculating the grid displaced emission factor because a disproportionately large amount of CHP electricity is generated at times when the carbon intensity of the grid is high.

As a result of the ongoing policy agenda in support of heat networks, work for DECC (Department of Energy & Climate Change, 2015) established bespoke projections of the electricity emission factor for CHP based on modelling the effect on the electricity system of adding predetermined amounts of new CHP capacity over time. Unfortunately (to our knowledge) there has been no study to establish equivalent technology-specific factors for other important comparative technologies, notably heat pumps.

F.3 Emission Factor Projections and Contexts in which they are Used

There are three main sources of emission factors that are relevant to the OPDC scenario modelling exercise:

1. SAP 'Table 12: Fuel prices, emission factors and primary energy factors'
2. 'Table 1: Electricity emissions factors to 2100, kgCO₂e/kWh' supporting the DECC/HM Treasury Green Book supplementary appraisal guidance on valuing energy use and greenhouse gas (GHG) emissions.
3. 'Emissions Factors for Electricity Displaced by Gas CHP' from DECC Bespoke natural gas CHP analysis.

F.3.1 SAP

SAP Table 12 emission factors are used for calculations in the context of Building Regulations compliance. Most planning policy targets are also based on the use of SAP emission factors. BRE¹ and DBEIS published a consultation on SAP 2016 in November 2016 (BRE, 2016). The consultation sets out revised emission factors for the period 2016 – 2018, and for future 3-year periods up to 2027. The revised emission factors, and the equivalent factors projected in the analogous SAP 2012 consultation (BRE, 2011) are set out in Table F.3.1.

(kgCO ₂ /kWh)	2013-2015	2016-2018	2019-2021	2022-2024	2025-2027
SAP 2016	0.558 (TBC*)	0.399	0.302	0.229	0.183
SAP 2012	0.522 (0.519*)	0.463	0.397	0.338	0.286
SAP 2016 values from: BRE Consultation Paper: CONSP:07 - CO ₂ AND PRIMARY ENERGY FACTORS FOR SAP 2016: https://www.bre.co.uk/filelibrary/SAP/2016/CONSP-07---CO₂-and-PE-factors---V1_0.pdf					
SAP 2012 values from: BRE Proposed Carbon Emission and Primary Energy Factors for SAP 2012: https://www.bre.co.uk/filelibrary/SAP/2012/STP11-CO₂04_emission_factors.pdf					
* Final emission factors used in SAP Table 12 for Building Regulations Part L					

Table F.3.1. Proposed Electricity Carbon Emission Factors for SAP 2016 & 2012

The SAP 2016 consultation makes no change to the methodology for electricity emission factors, which is summarised in the following excerpts from the consultation documentation:

"2.5 Energy and emission factors are based on average values for energy sources supplied in the UK over the proposed three year compliance period.

...

2.6 Energy and Emissions for grid supply electricity are system average values (as against marginal values)

System average values reflect the primary energy and emissions associated with grid supply electricity in the UK and are appropriate for measuring and reporting energy and carbon impacts. In contrast marginal emission factors are appropriate for measuring the effect of changes in demand compared to a normal or baseline situation.

2.7 The system average value for grid supply electricity is applied to electricity exports and electricity generated using CHP

System average values are also applied to electricity generated by the building (generally from renewable sources) which is exported to the grid. This reflects the fact that each kWh of electricity generated by a building displaces a kWh of electricity which would have otherwise had to be generated by the grid.

¹ BRE manages SAP for government departments and other stakeholders

For CHP the SAP calculation uses the power station displacement method to allocate emissions between electricity and heat outputs(7) so it is appropriate to apply the system average grid value.

(7) The convention assumes that the electricity generation by CHP displaces electricity generated by the grid taking into account transmission and distribution losses."

There is no additional discussion to support either of the assertions that average emission factors are more appropriate than marginal factors in general, nor that they are appropriate for electricity generation by CHP that displaces electricity generated by the grid. A stronger justification might be expected given that there were different emission factors for grid supplied and grid displaced electricity in versions of SAP used for Building Regulations between 2006 and 2010, implying that the basis for emission factors is open to argument.

Note that average emission factors are also used for mandatory greenhouse gas reporting in the context of the 'Companies Act 2006 (Strategic Report and Directors' Report) Regulations 2013' and similar voluntary carbon reporting and footprinting. In those contexts, DBEIS provides historic emission factors for UK electricity (Department for Business, Energy & Industrial Strategy, 2016). The historic factors for 2013 to 2015 published by DBEIS for company reporting do not agree very well with the 3-year average factors used in SAP. SAP emission factors are based on Updated Emissions Projections data, also produced by DBEIS. However, BRE publishes limited information on the methodology by which emission factors for SAP are derived from the UEP data. Nor is there a detailed justification of the methodology used and the results by comparison with the other main projection of average emission factors (see Treasury Green Book supplementary appraisal guidance discussed in the next section) used for policy assessment.

F.3.2 Treasury Green Book Supplementary Appraisal Guidance

Treasury Green Book supplementary appraisal guidance on energy and GHG appraisal and evaluation are used for impact assessment of policies and projects across government. This guidance mandates the use of the 'long-run marginal emission factor' for electricity when appraising the effect of small but sustained changes in electricity consumption. It provides a projection of these marginal factors, which are set out in Table F.3.2.

The TGB supplementary guidance also includes projections of average electricity emission factors. For 2010 to 2014, these agree well with the historic factors published by DBEIS for company reporting.

F.3.3 Bespoke Gas CHP Displaced Electricity Emission Factors

After the Government's heat policy publication "The Future of Heating: Meeting the challenge" identified the potential for additional natural gas fired Combined Heat & Power (CHP) plant to reduce whole system carbon emissions, DECC commissioned research to examine a range of different financial support options for CHP, which reported in December 2014. Part of the work involved electricity system modelling to establish the emission factor for electricity displaced by gas CHP up to 2044. The reporting provides a projection of these marginal factors for electricity exported to the grid and used on site, which are set out in Table F.3.2.

F.3.4 Summary of Relevant Electricity Emission Factors

The electricity emission factors from the three sources judged to be most relevant to deciding the factors to use for OPDC scenario modelling are summarised in Figure F.3.1 and Table F.3.2.

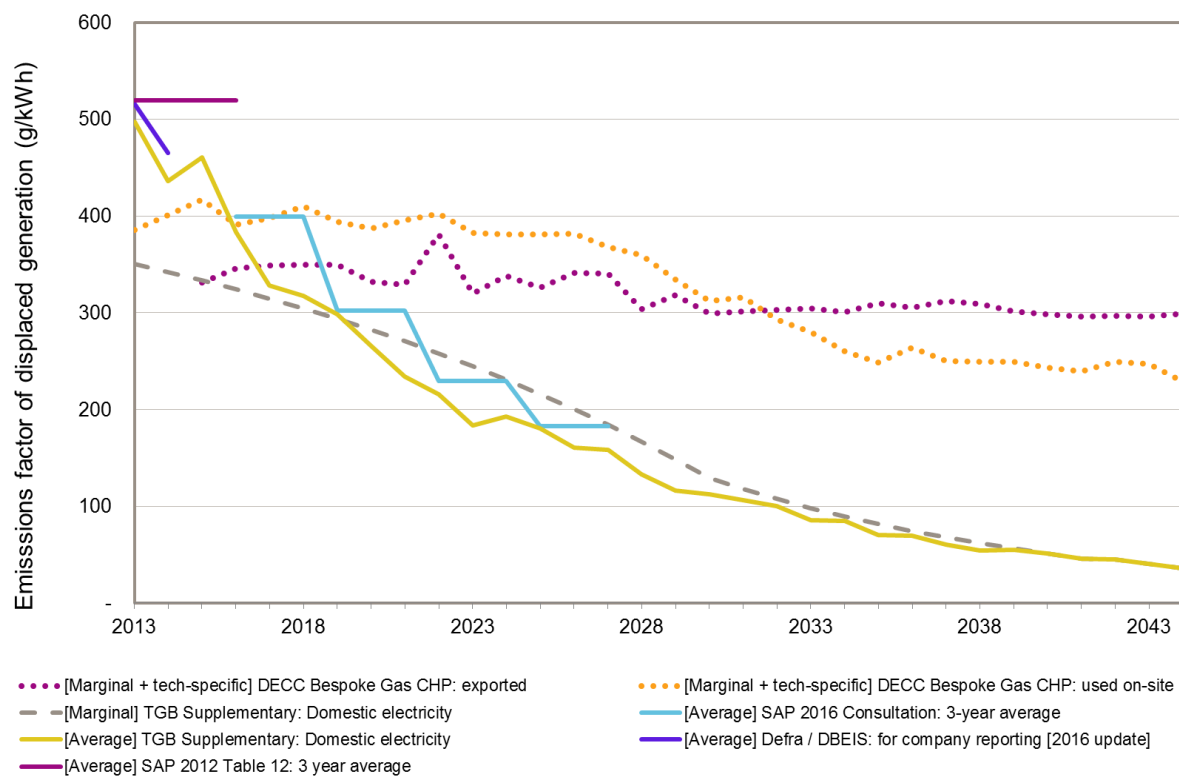


Figure F.3.1. Emissions Factors

Notable features of the emission factor comparison are:

1. SAP 3-year average emission factors are notably higher by the end of the 3-year period than the outturn factors published by DBEIS and the average emission factor projection published in the TGB supplementary guidance.
2. In the TGB projections, marginal factors start well below the average factors, cross over in 2020, before converging by 2040, so the choice between average and marginal factors (for these projections) is not equivalent to choosing higher or lower factors.
3. DECC bespoke CHP emission factors (applicable only to displaced grid electricity) are well above all general system-wide average and marginal factors by 2020 and remain above 300 gCO₂/kWh until the 2030s.
4. The DECC bespoke CHP emission factor for electricity used on site falls below the factor for exported electricity in ~2030 (as it replaces an increasing amount of electricity from renewable generators).

Year	DECC Bespoke Gas CHP: exported	DECC Bespoke Gas CHP: used on-site	TGB Supplementary: Domestic electricity - Marginal	TGB Supplementary: Domestic electricity - Average	SAP 2016 Consultation: 3-year average
2013		385	350	497	[519*] 558
2014		401	342	436	[519*] 558
2015	331	417	333	461	[519*] 558
2016	345	391	324	383	399
2017	349	398	314	328	399
2018	349	410	304	317	399

Year	DECC Bespoke Gas CHP: exported	DECC Bespoke Gas CHP: used on-site	TGB Supplementary: Domestic electricity - Marginal	TGB Supplementary: Domestic electricity - Average	SAP 2016 Consultation: 3-year average
2019	349	394	294	298	302
2020	332	387	282	265	302
2021	329	395	270	234	302
2022	381	402	258	215	229
2023	319	383	245	183	229
2024	338	381	231	192	229
2025	326	381	216	180	183
2026	341	382	200	160	183
2027	341	368	184	159	183
2028	304	359	167	133	
2029	318	334	148	116	
2030	299	312	129	112	
2031	301	316	118	106	
2032	303	293	107	100	
2033	305	280	98	86	
2034	300	260	89	85	
2035	309	248	81	71	
2036	305	264	74	69	
2037	312	250	68	60	
2038	309	249	62	54	
2039	301	249	56	55	
2040	298	243	51	51	
2041	296	239	46	46	
2042	297	249	45	45	
2043	296	247	40	40	
2044	299	229	35	35	
			36	36	
			33	33	
			30	30	
			31	31	
			28	28	
			28	28	
* 519 is the factor used in SAP 2012 for the period 2013 – 2016, and is the value plotted in Figure F.3.1. The retrospective factor calculated in SAP 2016 for the period 2013 – 2016 is 558.					

Table F.3.2. Emission Factors

F.4 Recommended Electricity Emission Factors for OPDC Scenario Modelling

F.4.1 Recommended Emission Factors

Recommended scenario modelling periods and corresponding emission factors for grid electricity for OPDC modelling scenarios are set out in the 'Scenario projections' columns to the right of Table F.4.1.

Emission factors for grid electricity						gCO ₂ /kWh			
Source projections						Scenario projections			
Phase	Year	[Average]		[Marginal]	[Marginal + tech-specific]	Period	Decarbonisation		Sensitivity
		TGB Supplementary: Domestic electricity	SAP 2012 + SAP 2016 Consultation: 3-year average	TGB Supplementary: Domestic electricity	DECC Bespoke: 50% export, 50% on site		Slower	Faster	Gas CHP
							All electricity	Displaced electricity	
1	2016	383	519	324	368	Current	519	-	-
	2017	328	399	314	374	2017 - 20	351	302	367
	2018	317	399	304	380				
	2019	298	302*	294	372				
	2020	265	302	282	359				
2	2021	234	302	270	362	2021 - 25	234	201	339
	2022	215	229*	258	391				
	2023	183	229	245	351				
	2024	192	229	231	359				
	2025	180	183*	216	354				
3	2026	160	183	200	361	2026 - 30	153	136	320
	2027	159	183	184	354				
	2028	133	133**	167	331				
	2029	116	133**	148	326				
	2030	112	133**	129	305				
	2031	106		118	309	2031 - 35	89	304	
	2032	100		107	298				
	2033	86		98	292				
	2034	85		89	280				
	2035	71		81	279				
4	2036	69		74	284	2036 - 50	43	270	
	2037	60		68	281				
	2038	54		62	279				
	2039	55		56	275				
	2040	51		51	271				
	2041	46		46	267				
	2042	45		45	273				
	2043	40		40	271				
	2044	35		35	264				
	2045	36		36	264***				
	2046	33		33	264***				
	2047	30		30	264***				
	2048	31		31	264***				
	2049	28		28	264***				
	2050	28		28	264***				
* Note for SAP projections that the projected SAP and TGB emission factors agree closely at the start of each SAP 3-year period ** SAP projection extended to complete period based on TGB factor at the start of the SAP 3-year period *** factor assumed to remain at the 2044 value up to 2050									

Table F.4.1. Recommended Emission Factors for Grid Electricity for OPDC Modelling Scenarios

F.4.2 Rationale

The recommended emission factors for grid electricity for OPDC modelling scenarios were selected based on the following reasoning:

1. Starting in 2021, projected emission factors for scenario modelling were averaged over 5 year periods up to 2035, broadly tying in with the projected development phasing schedule, although Phase 3 (2026 – 35) was split into two emission factor periods. Rapid decarbonisation of the grid is expected over the period 2020 – 30 so a single average factor for 2026 – 35 would be a poor fit. A single factor is then proposed for the remaining 15 year period to 2050. (Little development is projected during the period from now to 2020 and it is unclear when any emission factor revisions to Part L would be introduced. If emissions for Phase 1 are modelled, average projected SAP factors for 2017 – 20 could be used.)
2. Factors were broadly based on SAP methodology – i.e. the use of average emissions factors is proposed and the same factors should generally be used for electricity supplied and displaced from the grid – and on the SAP 2016 projections as far as they are available, i.e. up to 2027. SAP emission factors are the ones commonly used in planning because it makes sense for planning targets to be set and assessed on the same calculations as eventual Building Regulations compliance. On this pragmatic basis, the debate about whether average or marginal factors are preferable was ignored. Available SAP projections end mid-way through the proposed 2026 – 30 period. Noting that for SAP projections the projected SAP and TGB emission factors agree closely at the start of each SAP 3-year period, the SAP 3-year average factor for the period 2028 – 30 is taken to be the TGB value projected in 2028 (133 gCO₂/kWh). In the absence of SAP projections beyond 2027, proposed factors for scenario modelling are based on the TGB projections from 2036 – 2050.
3. Both SAP and TGB projections are available for the period 2021 – 2035. 5-year average factors based on the TGB projections reflect faster decarbonisation to 2030 than those based on the SAP projection
4. Under the emission factor methodology used in current SAP 2012 and retained in the SAP 2016 consultation (i.e. identical factors for grid supplied and displaced electricity), the carbon savings from electricity generated by gas CHP – and therefore from the use of gas CHP overall – will reduce rapidly as the grid decarbonises. This represents a divergence in policy drivers from the DBEIS continuing support for heat networks, under which gas CHP is assumed to continue to save carbon up to the early 2030s, based on the use of gas CHP-specific emission factors for grid displaced electricity developed through the 'Bespoke natural gas CHP analysis' research (Department of Energy & Climate Change, 2015). Continued use of SAP average emission factors would constitute a significant disincentive for gas CHP in relation to GLA planning targets. Policymakers will presumably want to resolve this divergence and continue to support gas CHP, which is likely to remain key to heat network development in many cases until grid decarbonisation makes heat pumps clearly preferable. The divergence could be resolved either through changes to grid displaced emission factors in SAP / Part L or solely for planning purpose, e.g. through GLA energy assessment guidance. As such, it seems reasonable to check the sensitivity of scenario modelling results to the grid displaced emission factor assumed for gas CHP, taking the specific marginal factors projected by DECC as alternatives to the SAP average factor. The same reasoning would apply if specific marginal factors became available for heat pumps and other technologies such as PV and fuel cells, if these are expected to be widely installed.
5. TGB marginal emission factors, averaged over the proposed scenario modelling periods, lie between the SAP and TGB average factors. So using these factors offers no further insights to the scenario modelling exercise.

F.5 Bibliography

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