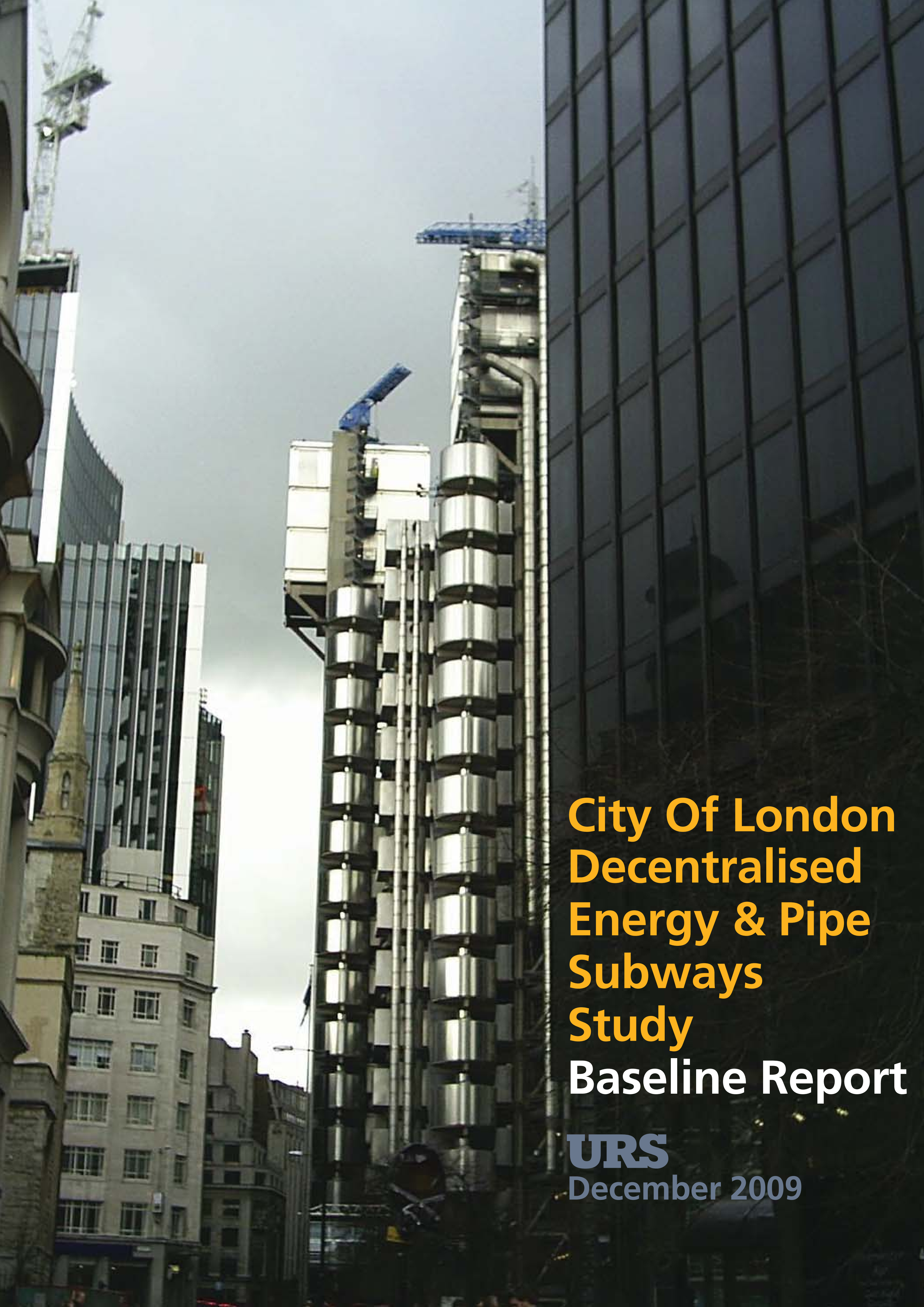

City Of London Decentralised Energy & Pipe Subways Study

Baseline Report

URS

December 2009

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Client Contact Name:	Steven Bage
Client Company Name:	City of London
Issued By:	URS Corporation Ltd. St Georges House 5 St Georges Road Wimbledon London SW19 4DR United Kingdom Tel: + 44 (0) 20 8944 3300 Fax: + 44 (0) 20 8944 3301 www.urscorp.eu

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Issue No:	**Name**	**Date**	**Position**
Prepared by	Darshini Ravindranath	December 2009	Assistant Project Manager
Prepared by	Alan Davis	December 2009	Sustainability Principal
Prepared and checked by	Brendan Tapley	December 2009	Project Manager
Reviewed and approved by	Rory Brooke	December 2009	Project Director

LIMITATION

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CONTENTS

Abbreviations

Abbreviation	***Full***
BREEAM	Building Research Establishment Environmental Assessment Method
CCHP	Combined Cooling, Heat and Power
CERT	Carbon Emission Reduction Target
CHP	Combined Heat and Power
CoL	City of London
CDM	Construction (Design & Management)
CRC	Carbon Reduction Commitment
CSA	Cross sectional areas
CTP	Cooling the Tube Project
DE	Decentralised Energy
DECC	Department of Energy and Climate Change
DED Unit	Decentralised Energy Delivery Unit
DEMaP	Decentralised Energy and Energy Masterplanning Programme
DEN	Decentralised Energy Network
DNO	Distribution Network Operator
DTI	Department of Trade and Industry
ECJ	European Court of Justice
ESCo	Energy Services Company
EU	European Union
ETS	Energy Trading Scheme
F&R	Flow and Return
FIT	Feed in Tariff
GLA	Greater London Authority
GW	Gigawatt (=1,000MW)
H&S	Health and safety
JESSICA	Joint European Support for Sustainable Investment in City Areas
kVA	Kilovolt Ampere
kW	Kilowatt (=1,000W)
LB	London Borough
LDA	London Development Agency
LDF	Local Development Framework
LDO	Local Development Order
LTGDC	London Thames Gateway Development Corporation
LU	London Underground
MUSCo	Multi-Utility Services Company
MW	Megawatt (=1,000kW)
MWe	Megawatt of electricity
MWh	Megawatt hour
NJUG	National Joint Utilities Group
Ofgem	Office of Gas and Electricity Markets
OfWAT	Office of Water (The Water Services Regulation Authority)
PFI	Private Finance Initiative
POT	Post Office Tunnel
PPP	Public Private Partnership
PPS	Planning Policy Statement
PRO	Public Record Office
RHI	Renewable Heat Incentive
RO	Renewables Obligation
ROC	Renewable Obligation Certificate
SBEG	South Bank Employers Group
SCL	Sprayed Concrete Lining
SI	Statutory Instrument
SOAS	School of Oriental and African Studies
TBM	Tunnel Boring Machine
TfL	Transport for London
UPS	Uninterrupted Power Supply
UCL	University College London

1 INTRODUCTION

This report is the first of two reports covering the second stage of work for the City of London Decentralised Energy and Pipe Subway Networks study. The overall study is to evaluate the feasibility of a comprehensive decentralised energy and pipe subways network to serve the future needs of the City and surrounding areas. The first stage was a high level analysis to confirm whether a technical and financial case exists to warrant subsequent investigation.

This report provides a comprehensive analysis of the baseline information needed to inform and appraisal options. The work covers: utilising and extending pipe subways; the supply and distribution of decentralised energy; and combinations of these systems.

The work is conducted for: the City of London; London Development Agency (LDA); EDF Energy; National Grid; Eon; and the Better Building Partnership by URS Corporation and its partners: KPMG; Nabarro; Turner and Townsend; Dr G Sauer Corporation; Integrated Service Utilities (ISU) and GVA Grimley.

1.1 Objectives

The overall aims of the study are to evaluate:

- The opportunity to extend the existing pipe subway network so as to enable the effective distribution of utility networks to City buildings to serve the future needs of the City and nearby surrounding areas.
- The feasibility of an energy services company (ESCO) entering into a public/private partnership to deliver a decentralised energy network to buildings in the City and any possible outlying residential areas.
- Opportunities to marry the aspirations to deliver a comprehensive scheme that would combine the two components outlined above.

1.2 Background and Context

The work is designed to help the City and its partners in supporting the future growth, competitiveness and prosperity of the City of London.

The context is that there are a number of significant issues and constraints around the provision of new underground utilities infrastructure needed to accommodate future growth. The City is facing increasingly onerous challenges in providing the utilities connections needed to accommodate continued growth and service requirements. Continual road excavations are causing ongoing disruption to businesses, pedestrians and transport flows, and with administrative burdens placed on the City of London Corporation.

Carbon costs via a growing range of regulatory frameworks represent an increasingly significant cost item for businesses and another driver for this study. The London Plan and Central Government plans to tighten carbon emissions from new development suggest that there will be increasing incentives to find local low carbon sources of energy[1]. The presence of an extended decentralised energy network could be a cost-effective way to achieve this requirement. A transit to a low carbon economy is also important to maintaining London's ongoing competitiveness as a global financial centre, leading the way for the broader UK economy.

1.3 Approach

The overall approach to the study is divided into three critical stages, each culminating in a report:

- Stage 1: High level scenarios and recommendations
- Stage 2: Baseline review
- Stage 3: Options development and appraisal and recommended next steps.

The baseline report builds on the high level scenarios report, examining in more detail the key technical, legal and financial considerations that will inform the options for achieving the objectives of the study. The analysis focuses on three technical infrastructure areas:

- Tunnels infrastructure and technologies
- Decentralised heating infrastructure and technologies
- Utilities infrastructure.

As the high level scenarios report documented a number of findings from the baseline review,

[1] Another example is that the City of London's commercial carbon footprint equates to a cost of £19.9 million using the Carbon Reduction Commitment (CRC)'s starting carbon price of £12/tonne of carbon (tCO2). Within three years, when the cap on emissions is applied the price (and costs to businesses) is likely to increase significantly.

these findings are also documented in this baseline report.

The integrated baseline assessment is based on desktop analysis, consultations with the client group, other key utility providers and ESCOs. The integrated baseline assessment is further tested through a legal and financial analysis.

1.4 Structure

The report is structured as follows:

- Section 2 presents a review of key policy and contextual drivers relevant to the study
- Section 3 reviews the condition and suitability of the City's existing tunnel network based on available information, along with a review of other vacant tunnels in the City
- Section 4 reviews the existing utilities network and total utilities demand
- Section 5 reviews the condition and suitability of existing decentralised energy infrastructure, and identifies the benefits of expansion, interconnection, connectivity and viability in and around the City
- Section 6 reviews the physical constraints to the expansion of the tunnels network and/or decentralised energy systems
- Section 7 identifies technologies relevant to the design and construction of tunnels and decentralised energy
- Section 8 identifies potential sites for energy centres
- Section 9 sets out the various costs associated with the integrated baseline assessment
- Section 10 covers the legislation and powers for pipe subways and district heating
- Section 11 summarises the financial model framework and delivery model options
- Section 12 summarises the way forward.

2 POLICY AND CONTEXTUAL DRIVERS

2.1 Introduction

A high level review of key strategies and policies relevant to the study is presented below. Policies reviewed focus on the low carbon agenda and the regulatory framework relevant to utilities, particularly electricity. In addition, there are a number of incentives backing up the policy instruments.

2.2 Low Carbon Policy and Context

EU Policy and Incentives

The European Commission announced the new Climate Action and Renewable Energy Package on 23rd January 2008. The proposals, which are likely to come into operation in 2010, set targets for the reduction of CO_2 and the supply of renewable energy across Europe. The headline targets are:

- Overall target of 20% cut in EU emissions by 2020 (UK target for cutting emissions to be set at 16% by 2020); and
- Overall increase of 20% in EU renewable energy by 2020 (UK target for increasing renewable energy is 15% - from a 2005 UK base of under 2% by 2020)[2].

EU ETS

The EU ETS is currently the main mechanism in the EU to achieve carbon reduction, targeting large CO_2 emitters. The current range of savings assumes that, post 2012; the UK will have the same amount of CO_2 allowances as during Phase II of the EU ETS. However, it is very likely that the number of allowances will be tightened in each country, in order to meet EU CO_2 reduction objectives.

JESSICA

The Joint European Support for Sustainable Investment in City Areas (JESSICA) is an initiative led by the European Commission and European Investment Bank (EIB) which gives Member States the option of using some of their EU grant funding to make repayable investments in projects to regenerate urban areas, creating a revolving investment fund.

The £100 million JESSICA Holding Fund, launched in 2009, is made up of £50 million from the European Regional Development Fund (ERDF) and £50 million match funding. Two 'Urban Development Funds' (UDFs) will then be procured and launched in 2010 – allocating £64 million to decentralised energy and £36 million to waste infrastructure improvements, and inviting potential projects to bid for funds.

Funds will be invested in projects in the form of equity, loan or guarantee, and returns arising from successful investments will be returned to the fund.

National Policy and Incentives

The government has identified the following relevant national targets:

- 80% reduction in greenhouse gases by 2050
- All dwellings to be zero carbon by 2016 and non-domestic buildings to be zero carbon by 2019 through Building Regulations Part L (and the Code for Sustainable Homes and BREEAM).

This is particularly relevant to the City because developers will be looking for sources of renewable energy so they can be classed as zero carbon.

A selection of relevant government programmes and policies are reviewed below.

Carbon Reduction Commitment (CRC)

The CRC is an emissions trading scheme that applies to non-energy intensive organisations such as larger corporations, banks, government departments, and large local authorities to provide incentives for them to improve their energy efficiency and reduce their carbon emissions. The CRC will do this by placing a cost on emissions and by providing financial and reputational incentives for those businesses that are most successful in lowering their emissions over the course of the scheme. Those falling under the CRC will thus have to account for the emissions associated with their use of electricity, gas and certain other fuels. Those who burn gas to generate their space heating and/or hot water may be able to benefit from a temporary CRC 'windfall' through connection to a district heating network. Where a customer imports heat (whether to provide heating or cooling) from a third party, this will be zero rated for emissions under the CRC in the hands of the customer. This is so whatever means was used to generate the heat (although the third party

[2] BERR (2007) Energy White Paper

heat supplier may fall under the CRC or other climate change regulation). Consequently, this effective "outsourcing" of emissions provides an incentive to CRC participants. However, the windfall effect will last for a maximum of one CRC phase (from 2013, each phase lasting 5 years). This will limit the value of the potential carbon incentive from an investment perspective. Thereafter, a consumer's focus will be primarily on a cost comparison between conventionally delivered heat/hot water and heat delivered through a district heating scheme.

The scheme starts in April 2010. It will tackle CO_2 emissions not already covered by Climate Change Agreements and the EU ETS.

The CRC is relevant to the City because it provides incentives (in terms of both money and reputation) for City businesses to tap in to low carbon energy supplies. It is expected that the publicity and reputational consequences of being at the top (or bottom) of the publicly disclosed performance league will prove to be more significant than the recycled payment itself.

Feed-in-Tariffs (FITs)

The Energy Act 2008 provides broad enabling powers for the introduction of feed-in tariffs (FITs) for small-scale low-carbon electricity generation, up to a maximum limit of 5 megawatts (MW) capacity or 50 kilowatts (KW) in the case of fossil fuelled CHP. The FITs will be introduced through changes to electricity distribution and supply licences.

These provisions are intended to encourage the uptake of small-scale low-carbon energy technologies while the Renewables Obligation (RO) continues to be the main support mechanism for large scale renewables deployment.

As of April 2010 FITs are proposed to be applied to wind, solar PV, anaerobic digestion, biomass and biomass combined heat and power (CHP), and non-renewable micro CHP.

Tariffs for 2010-2011 have been preset by the Department for Energy and Climate Change (DECC), as published in its Consultation on Renewable Electricity Financial Incentives 2009. Proposed tariff levels included in the Feed-in Tariffs framework are shown in **Table 2.1** below.

Table 2.1 Proposed FIT Tariffs

Technology	*2010-2011 Tariff (pence/kWh)*
Anaerobic Digestion CHP, < 5MW electricity	11.5
Biomass CHP, < 5MW electricity	9.0
Bonus for Export	5.0

Renewables Obligation (RO)

The RO works by placing an obligation on UK suppliers of electricity to source an increasing proportion of their electricity from renewable sources. A green certificate called the Renewables Obligation Certificate (ROC) is issued to all accredited generators of eligible renewable electricity generated within the UK and supplied to customers within the UK by a licensed electricity supplier. The RO is relevant to the City to the extent that new energy centres qualify for ROCs.

Renewables Heat Incentive

The Energy Act 2008 (Section 100) allows for the setting up of a Renewable Heat Incentive (RHI), which would provide financial assistance to generators of renewable heat and to some producers of renewable heat, such as producers of bio-methane. The RHI will:

- Apply to generation of renewable heat at all scales, whether it is in households, communities or at industrial scale.
- Cover a wide range of technologies including biomass, solar hot water, air and ground source heat pumps, biomass CHP, bio-gas produced from anaerobic digestion and injection of bio-methane into the gas grid.
- Be banded so different rates of support may apply to different technologies or scales i.e. some (e.g. larger scale biomass heat) may require less support per MWh than others.

The RHI provides added (financial) incentive to the use of CHP. There is some overlap between FITs, RO and RHI which DECC are currently assessing the best way to address. However, once the RHI is implemented the heat output of CHP will be rewarded under the RHI. As an interim measure initial FITs for CHP generators include an uplift comparable to that which applies under the RO.

Zero Carbon Homes

National government policy provides a commitment that all new homes will be zero carbon from 2016. Although this is more relevant to new than to existing buildings, it is important to note that the Government is interested in the potential for heat infrastructure developed as part of Zero Carbon Homes to support multiple developments, including existing residential and commercial properties. These "allowable solutions" may encourage community scale low and zero carbon energy, such as district heating networks. Although there is limited residential accommodation within the Square Mile, zero carbon homes policy could, potentially incentivise connections from surrounding Boroughs.

New Development Carbon Targets

The Government has identified decentralised and renewable or low carbon energy as one of the principle means of meeting the UK's carbon emissions reduction targets. As a result, both national planning policy[3] and regional planning policy[4] states that local authorities can expect new development to connect to an existing decentralised energy network or be designed to enable connection to such a network in the future (see section 2.3).

2.3 Planning Policy

Overall planning policy at the national, regional and local level places increasing emphasis on including renewable energy in schemes to obtain planning permission. In addition policy highlights the importance of low carbon energy schemes in achieving national, regional and local targets for reduced carbon emissions.

At the national level relevant planning policy includes PPS1 ‘Delivering Sustainable Communities’, PPS22 ‘Renewable Energy’ and the companion guide to PPS22. These are intended to encourage the appropriate development of renewable energy schemes throughout the UK. This includes schemes in urban as well as rural locations, ranging in size from the domestic to the commercial scale. The documents highlight that if the targets are to be met a positive and innovative approach will be required.

[3] The Planning and Climate Change supplement to Planning Policy Statement 1

[4] The London Plan

Regional Policy and Incentives

The Mayor of London’s Climate Change Action Plan aims to stabilise London’s emissions at 60% below 1990 levels by 2025. The Climate Change Action Plan also sets a target of 25% of London’s heat and electricity coming from decentralised energy sources by 2025. The Mayor of London has recently published a report supporting the targets titled ‘Powering Ahead – Delivering Low Carbon Energy for London’.

The London Plan aims to achieve 20% of the energy requirements for new development from onsite renewable energy and states that boroughs should develop energy master plans for specific decentralised energy opportunities and new developments should incorporate site-wide combined heat and power plant where feasible.

The London Plan also requires boroughs to identify and safeguard existing heating and cooling networks and maximise the opportunities for providing new networks that are supplied by decentralised energy[5].

The London Development Agency has allocated up to £16 million for decentralised energy projects over the next four years (from 2009/10) and is working on 14 projects currently across the capital. The LDA is also actively involved in providing incentives for providers and consumers of decentralised energy, such as the London Green Fund.

The London Green Fund is a revolving fund that will make investments in initiatives, including decentralised energy that tackles climate change.

The fund structure is expected to allow the creation of commercial templates, spurring markets in new financial asset classes, once the cash flows from investments begin to stabilise. It will do so by investing equity in projects at an early stage of their development, making financing more viable and cost effective. The fund will take a long term and realistic view on both the scale and timing of financial returns on investment than would normally be taken by markets in the current credit environment.

[5] The ‘London Plan’ published in February 2008 will have legal status until the replacement plan, the ‘Consultation Draft Replacement London Plan’ of October 2009 is formally published, though the replacement plan does already constitute a material consideration.

Once projects under a specific initiative have demonstrated a track record and return, the fund will be able to sell down its original investments in part or in full, releasing equity back into the London Green Fund.

Initial seed funding of £4 million from the LDA and GLA will be supplemented by the private sector as the fund becomes more established. The aim is to create a fund size of over £100 million with investment from central government, development banks, and sovereign and infrastructure funds. It will be managed by a reputable external fund manager to introduce the required discipline, allowing projects to be fully analysed as to financial and environmental impact prior to commencement. At the same time, it will allow the LDA and the GLA to determine and set the high level objectives for the fund and each initiative, whilst retaining focus on delivery.

Local Policy and Incentives

The City of London aims to maintain its position of being 'a world class City that protects, promotes and enhances the environment, is competitive and promotes opportunity, and supports our communities'[6]. To support this, the City of London has developed a Climate Change Adaptation Strategy and is currently developing a Climate Change Mitigation Strategy.

The City is currently working to set up its Local Development Framework (LDF), with the 'Delivering a World Class City' Draft Core Strategy currently out for consultation. This includes the following draft policies:

- Policy CS4 'Crossrail and the North of the City', Point 5, states that 'Safeguarding the Citigen combined cooling heating and power (CCHP) network and ensuring that, where feasible, all new development in the Eco Design area is designed to enable connection to the CCHP network.'
- Policy CS13 'Sustainable Development and Climate Change', Point 2, includes 'Requiring development to minimise carbon emissions and contribute to a City wide reduction in emissions, using decentralised energy networks, CHP ready designs, renewable energy or other 'allowable solutions' as appropriate.'

Planning conditions or planning obligations are likely to be used to ensure compliance with planning policies.

2.4 Energy Regulation Policy

Ofgem regulates the 14 monopoly regional distribution network operators (DNOs) to protect the interests of present and future consumers. It sets a price framework every five years that gives the maximum revenues that each DNO can collect from customers at a level that allows an efficient business to finance its activities. It also places incentives on DNOs to innovate and find more efficient ways to provide an appropriate level of network capacity, security, reliability and quality of service.

The current price control expires on 31st March 2010. As part of the current Distribution Price Control Review 5 (DPCR5), Ofgem has set out final proposals for the revenues the companies should be allowed to earn from 2010 to 2015.

It also sets out the new obligations and incentives that will be introduced, outlining decisions on the base cost of capital and the range of equity returns that an efficient network business can earn based on their performance and consistent with the overall balance of risk and reward in the settlement.

Ofgem has set a 4.7 per cent rate of return (4.0 per cent post tax) to allow DNOs to fund the cost of debt and equity. The baseline return on equity is 6.7 per cent (post tax).

To mimic the incentives that unregulated companies have, Ofgem have given DNOs an opportunity to enhance returns by improving network efficiency, reliability and customer service. DNOs that significantly improve performance in all of these areas could earn shareholder returns of up to 13 per cent. Mismanaged, inefficient companies performing poorly could earn as low as 3 per cent.

Ofgem are also introducing a £500m new fund - the Low Carbon Networks fund – to stimulate culture change, innovation and trialling of the new technologies, commercial and operating arrangements the DNOs will need to deliver a low or zero carbon electricity sector. DNOs are also being encouraged to do more to tackle climate change for example by reporting on their business carbon footprint, giving due

[6] City of London (2008), The City Together Strategy - The Heart of a World Class City 2008-2014

consideration to using demand side management to address network constraints and by requiring them to provide simpler information to local generators who are looking to connect to their networks.

3 TUNNELS NETWORK BASELINE

3.1 Introduction

The following section provides an analysis of the condition and suitability of the existing pipe subway tunnels network in the City of London including those with available space. The section also analyses other vacant tunnels to determine whether they could be used in combination with the City's tunnels to carry utility pipes including for decentralised energy.

3.2 City Tunnels Network

The City of London owns a number of existing pipe subways that could be of interest for connecting to a pipe subway network. These are shown in **Figure 3.1** and summarised in **Table 3.1**.

Table 3.1 Pipe Subways in the City of London

Location of pipe subway	***Status***	***Area of City***	***Available Space[7]***
London Wall	Capacity	Eastern cluster	60%
St. Martin's le Grand	Capacity	Central Connection Cluster	70%
Holborn Viaduct	Capacity	Citigen Cluster	50%
Shoe Lane	Capacity	Citigen Cluster	95%
Paul's Walk'	Capacity	Central Connection Cluster	90%
Basinghall Avenue	Capacity	Eastern cluster	60%
Bush Lane/Suffolk Lane	Capacity	Central Connection Cluster	60%
Peter's Hill	Capacity	Central Connection Cluster	60%
London Bridge	Capacity	Eastern cluster	60%
Barbican	Capacity	Citigen Cluster	5%
Monument Street	Capacity	Eastern cluster	50%
Fenchurch Avenue'	Capacity	Eastern cluster	40%
Houndsditch	Capacity	Eastern cluster	30%
Snow Hill	Capacity	Citigen Cluster	40%
Middlesex Street	Capacity	Eastern cluster	50%
Queen Victoria Street[8]	No capacity	Western cluster	5%

[7] Approximate estimates based on observation and discussion with the City Pipe Subway Manager.

Remaining Spatial Allocation

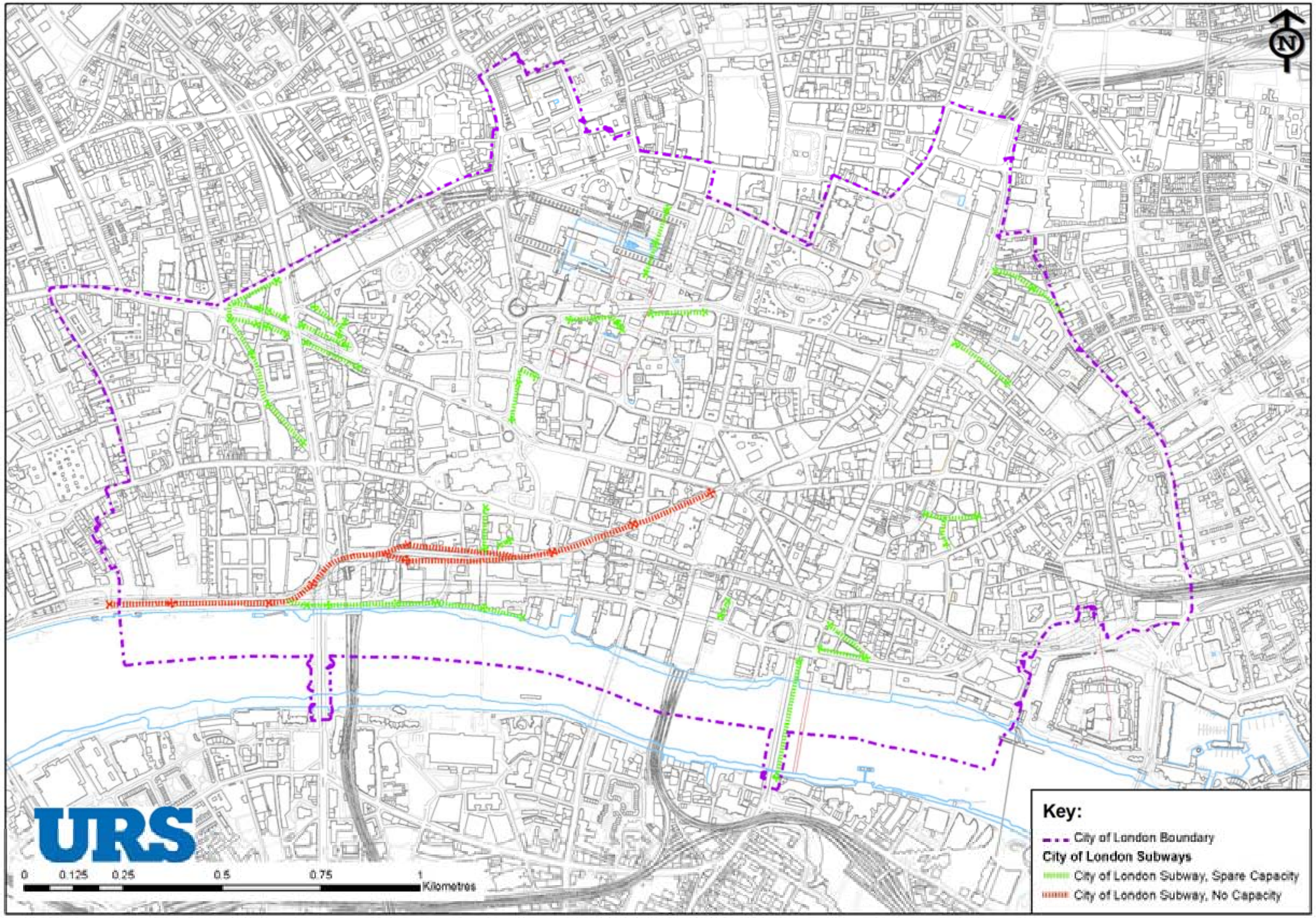
The table above indicates the amount of available space in each of the pipe subways in the City of London. A majority of the city tunnels appear to have available space, with those at Shoe Lane (Citigen cluster) and Paul's Walk (Central Connection Cluster) indicating 90% or more spare capacity. Assets that have no spare capacity are less relevant to this project unless existing capacity in be released. **Figure 3.1** illlustrates pipe subways with available space.

There are though a range of factors that influence the availability of space. The packing density of services, the degree of redundancy, the location of services, the location and frequency of services entry and egress points together with any opportunities to establish and then remove redundant services all need to be taken into account when installation of additional services is being considered. A detailed survey can confirm the situation.

As regards the minimum access space, this is expressed in terms of cross sectional areas. Specifications given in British Standard 8313 apply to passageways and adequate space also needs to be provided to enable maintenance, removals, installation of new services as well as good housekeeping, which tend to require more space around individual services.

[8] The Queen Victoria Street subway is generally very congested, although different segments vary in capacity. In particular, the Distaff Lane segment of the subway which has around 70% of its space available.

Figure 3.1 Pipe Subways with Available Space



3.3 Other Tunnels in the City

As well as the CoL Corporation's own tunnels we have carried out a review of other existing tunnels in the City to consider their potential suitability for use as part of a utilities tunnel network. This includes the following structures:

- Post Office Tunnel (POT) also referred to as the 'Mail Rail Tunnel' or 'Royal Mail Tunnel'*
- BT Tunnel (Kingsway Trunk Exchange)
- Ministry of Defence Tunnels
- London Underground (LU) Shallow Tunnels
- LU Deep Tunnels
- LU Disused Tunnels*
- Pedestrian Subways
- Crossrail*
- Liverpool Street proposed pipe subway*
- Thameslink Tunnel – Moorgate-Farringdon Branch*
- London Sewers
- EDF Subway under Farringdon Street*

We have mapped these tunnels where we have been able to obtain information and these items are denoted with an asterisk (*) in the above list and shown in **Figure 3.2.**

Post Office Tunnel (POT) also referred to as the 'Mail Rail Tunnel' or 'Royal Mail Tunnel'

This was designed for the movement of letters and parcels. The tunnel is 37km long, around 20m below surface level and was built in 1853 (early beginnings) and then from 1915 to 1927 (main line between Paddington and Whitechapel). The structure consists of two 2.7m (9ft) diameter cast iron segment tunnels merging at step plate junctions at a total of nine stations (two of which are located within the CoL boundaries). Delivery operations ceased in May 2003.

Given the central location of the POT, its structural integrity and size there appears to be potential to use the tunnels, particularly for strategic infrastructure.

Several scenarios for a meaningful purpose have been looked into over past years. At least one of them was for LU who looked at using the tunnel for the 'Cooling the Tube Project' (CTP). EDF also put forward their Project Orpheus proposals in 2003 and entered in to negotiations with Royal Mail. They subsequently withdrew from these discussions in 2003. Our recent discussions with EDF confirmed their potential re-kindled interest in the POT.

A drawback is its depth at approximately 20m which will require vertical connection structures feeding into it and for branching out of the POT as a possible part of the pipe subway. The tunnel is dry and spacious, similar in look to a tube tunnel. However it is apparent that the tunnel requires continual maintenance, with hundreds of pumps and a full time operations team currently being employed.

BT Tunnel (Kingsway Trunk Exchange)

Built in 1940 this tunnel was initially 1.6km long and later extended to a 19km system of tunnels some 30m underneath the Central Line between Chancery Lane and Holborn Stations. Originally built to house military staff, it was later converted to storage facilities for the Public Record Office (PRO) and in 1954 again converted and rebuilt as the BT Tunnel referred to as Kingsway Trunk Exchange, 'A city under the city', dealing with 15% of all of London's telephone traffic at the time.

Because of the depth of these tunnels and thus the large effort required to connect to them they appear potentially more attractive for strategic infrastructure rather than a network serving the City.

Ministry of Defence Tunnels

A number of tunnels are still in secret locations, which according to some sources are mostly below or adjacent to LU station tunnels on the Central Line.

These tunnels are limited in length and at great depth (deeper than 30m), with large cross sections and given, amongst other matters the difficulty of gaining information on and access to these tunnels, they are unlikely to be of any value for the pipe subway.

London Underground (LU) Shallow Tunnels

These include the Circle and District Lines running parallel (west to east) to the river from Temple to Tower Hill where they turn north toward Liverpool Street Station. The shallow tunnels lie between 0.5m and 3m below surface.

Assuming LU grants access and right of way to these assets an incorporation into a pipe subway network could be feasible. There are however, a number of operational and maintenance issues associated with using the still in use LU tunnels.

LU Deep Tunnels

These include:

- Northern Line
- Central Line
- Waterloo & City Line, and
- DLR.

Given the position and depth (all deeper than 20m with the Northern Line the deepest at 35m) of these assets their incorporation into a pipe subway network seems unlikely.

LU Disused Tunnels

There is a stretch of disused LU tunnels near Temple Gardens running north from the embankment along Temple Avenue.

Pedestrian Subways

These include:

- A total of 18 within CoL
- The Tower Subway

Further work would be needed to show if access, right of way and space within these assets will allow incorporation into a pipe subway network.

Crossrail

The current Crossrail alignment follows a similar route to the POT through the CoL stretching west to east between Farringdon and Liverpool Street and going towards Whitechapel. The running tunnels will be a twin bored segmental concrete lined TBM tunnel approximately 35m deep. There is a long construction programme and the line is due to be operational around 2017.

Because of the depth of these tunnels and the large effort required to connect to them, especially outside any station limits, they are unlikely to be of any value to the pipe subway.

Liverpool Street proposed pipe subway

As part of the Crossrail project Liverpool Street station is going to have a new ticket hall constructed. To accommodate this expansion a box culvert pipe subway beneath Liverpool Street has been proposed to take existing services. If spare capacity was incorporated into this new subway it could be utilised by CoL for their decentralised energy network.

Thameslink Tunnel – Moorgate-Farringdon Branch

The Farringdon to Moorgate branch (via the Barbican station) opened in 1868 and permanently closed to passenger traffic on 20 March 2009. The route includes two tunnels owned by London Underground (LU). The first goes beneath Charterhouse Street in an easterly direction from Farringdon before surfacing prior to entering the Barbican Station. The second continues from the Barbican Station to Moorgate in a south easterly direction. The branch into Moorgate is closed to allow the platforms at Farringdon Station to be extended over the junction as part of the Thameslink project. The rails for the branch line are expected to be removed in December 2009.

The Moorgate Farringdon Branch had to close in order for Network Rail to extend the Farringdon station platforms. The platforms at Farringdon cannot be lengthened northwards because the track drops down in gradient. The only option is to extend southwards taking the platforms across the junction for Moorgate. This option requires permanently cutting off the branch line from the mainline.

The tunnels are close to the surface and would be of sufficient size to accommodate energy utilities. A connection from Moorgate Station to the POT would be possible using inclined pipe jacking. Service and maintenance of the tunnels would also be straightforward. For any incorporation of the tunnels into a decentralised energy network. Network Rail and LU would need to be consulted in order to grant access.

London Sewers

The London sewage system was initiated after 'The Great Stink' in 1858[9]. It includes a 2,000km network of Victorian brick sewer tunnels and large structures.

Due to their structural nature (brittle red brick), their utilisation and the large effort required to connect to them, they are unlikely to be of any value for the pipe subway.

In individual cases abandoned branches could be utilised for street crossings and other options. More detailed, project specific research on the structural integrity of these tunnels would need to be performed.

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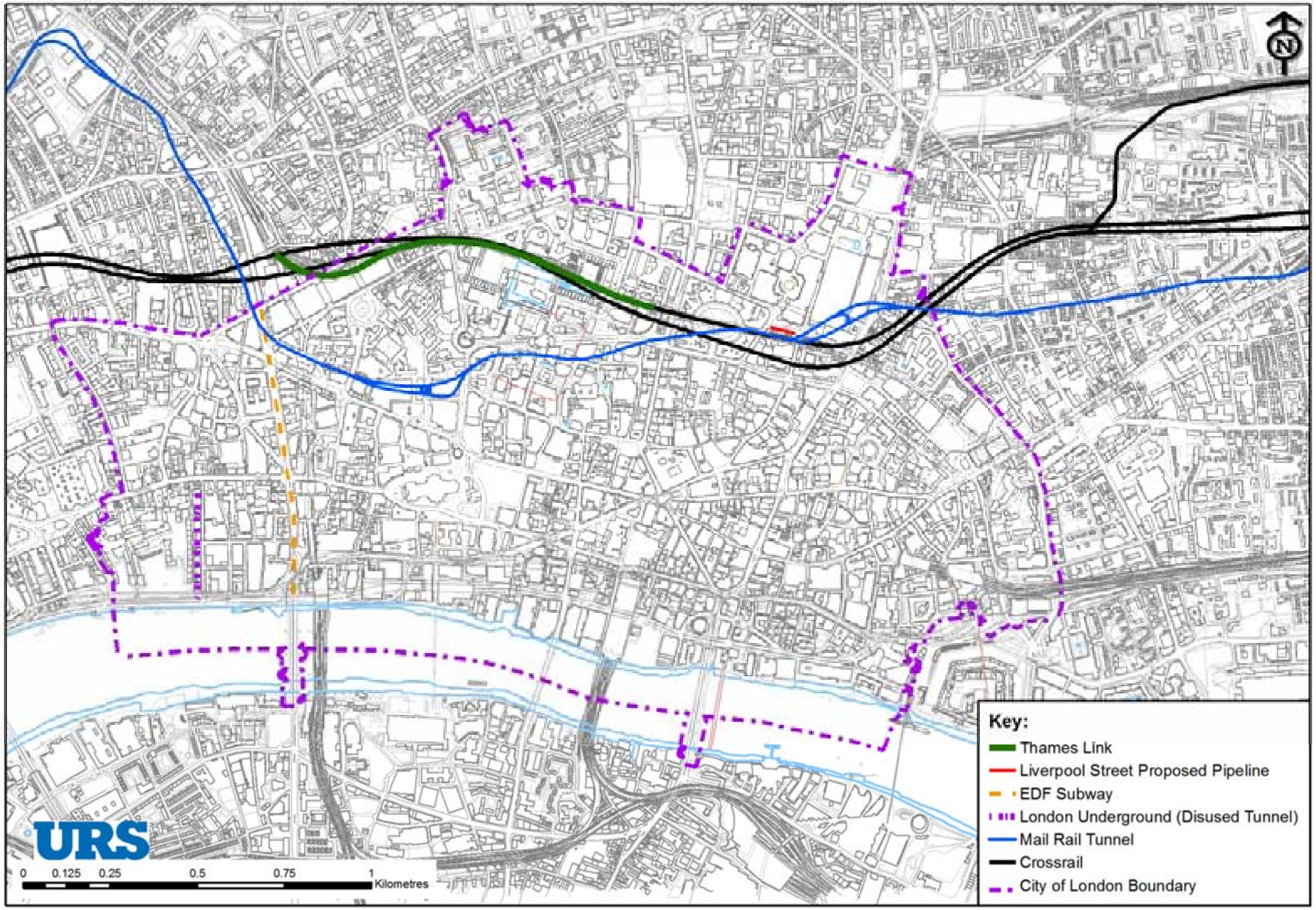
[9] Founded by Sir Thomas Bazalgette.

EDF Subway under Farringdon Street

Initial discussions with EDF indicate that most of the tunnel space is being used for EDF utility infrastructure and that use of the subway by another party would be difficult to negotiate given the legal implications of sharing a pipe subway and security of supply issues.

Figure 3.2 Other Tunnels in the City



3.4 Condition of CoL Tunnels

We review below information on the requirements for use of the tunnels and how this compares with condition and suitability of the City's existing tunnel network.

Access to Tunnels

Access for personnel appear to be at street level and are relatively limited in size. Future use may require other access points. Ease of access is liable to be a potential problem wherever new access/egress is required for services, or personnel, or both.

Layout of Existing Services

Existing services appear to be organised, but it appears to become very disorganised and chaotic where take-offs occur. It appears that, in some cases, little thought has been given to either other services and their needs and future requirements.

Cabling installations appear to vary from neat, tidy and well-ordered to the extreme opposite and some installers have not taken due account of other services.

Apparent chaos at take-off points

A further take off point. The triplex red sheathed cables running left to right are high voltage, probably 11kV.

Pipework often appears to have signs of external corrosion and in some cases apparent leakage at flanges and valves. Space for safe operation of valves and for 360 degree access of pipework appears to be very limited.

In the tunnel having Citigen flow and return pipes, these appear to be in good condition.

Where services enter or leave tunnels, crossovers are inevitable and these appear to take up space that would put a limit on the linear space available making the tunnels less usable for the installation of further services.

Organised pipe and cable runs: large pipes

Well organised pipe and cable runs. HV cables and LV cables to the left, uninsulated pipes at low level and comms cables to right

Support Systems

Support systems in the tunnels generally appear to be adequate, notwithstanding apparent overloading noted. Where cables leave the tunnel, they appear to be largely unsupported until they reach their egress ducts.

Ventilation

Ventilation such as it is, would appear to be by means of grilles set in the underside of the tunnel structures to pavements above. This may not be sufficiently effective either in terms of vitiating stale or foul air or in assisting in stabilising environmental temperature. The requisite quantity of air to enable personnel to carry out their work safely together with air quality could be an issue and may drive the need for mechanical ventilation.

Cable supports: HV cables at top, comms middle, LV lowest. No labels apparent.

Lighting

Subways appear to have mains voltage power and lighting supplies available for the general use of persons working within the subway, as per the Code Of Practice For Access & Safe Working In Local Authority Service Subways.

Overall, the lighting observed in the tunnel is of a level that would require torches or other additional forms of illumination for personnel working in the tunnels.

Illustration of current lighting. Vertical pipe would appear to be a gas service. Untidy cabling to the right.

Water Ingress

There are issues relating to the ingress of water. From a services perspective, water ingress may not necessarily be problematic for electric cables because they are normally capable of direct burial, but the presence of water could complicate maintenance when, for example, new joint(s) are to be installed. Likewise for water or gas pipework where this is of Polyethylene (PE) or similar. However, deterioration could occur, and appears to have occurred where the pipework is ferrous, making future maintenance and replacement of sections of pipe or seized valves and the like very difficult, if not impossible. Water ingress could be a problem for insulated pipework leading to the deterioration and nullification of the insulation, and to the ferrous pipework beneath, which could deteriorate in a hidden – and dangerous - manner.

3.5 Extended Network Requirements

Legislation

Legislation that relates to the operation, design, management and construction is covered by the Health & Safety at Work Act 1974 and in particular the following Statutory Instruments (SI)s.

The Confined Spaces Regulations 1997 will apply where the tunnels may be defined as confined spaces, and, supplemental to these, The Code of Practice for Access & Safe Working in Local Authority Service Subways.

The Construction, Design and Management Regulations must be adhered to when demolition works or construction works are undertaken.

The Code of Practice covers the following:

- Entering subways
- Safety - access and safe working, supplementary to the SI for confined spaces
- Naked flame devices
- Power And lighting
- Leaving subways
- Emergencies.

It does not deal with spatial requirements, what may or may not be installed, how services are to be laid out, or with any technical parameters concerned with the design of tunnels and their services.

We assume that all personnel and their employers adhere to the Code of Practice and that if services and subways do not meet current H&S legislation, then relaxation is requested by employers and granted by the appropriate authority. Normal anthropomorphic requirements may need to be relaxed within existing tunnels owing to space constraints, and in any new tunnels to put a reasonable limit on their size, but this would need to be done with the agreement of each utility stakeholders.

Under the Code of Practice a permit to work system is in use, and we should expect this to continue, particularly given that the tunnels are confined spaces subject to the Code of Practice and the Statutory Instrument.

Human Access to Tunnels

Access for personnel is required on unimpeded 24/7 basis to tunnels and plant to meet emergency requirements. This could involve the creation of less constrained access than currently exists. However there is a need for security to ensure the resilience of systems is not compromised.

Service Access to Tunnels

Access points for services can be made quite simple by the inclusion of appropriate ducts that run off to the footway for connection to plant (substation) or buildings as required, but, strategically, these could be allowed for at regular intervals within the design of any new tunnels.

Careful consideration during pre-design should be given to services egress and access points in order to avoid congestion of the sort witnessed in the existing tunnels. Future access to existing tunnels will be more problematical owing to the arrangement of services already installed, as they will need to be avoided during construction works and with continued access after. The utility companies always require unrestricted 24/7 access for their staff in order to maintain their services or to re-start as soon as possible following a break in supply.

Space Allocation

For future tunnel installations, it will be of importance to ensure that appropriate allocation of space and that coordination of the multifarious services is carried out and that discipline is adhered to by users and their contracted installers.

Labelling of Services

It should become a key part of agreement between tunnel owner/operator and utilities that labelling shall be carried out, and maintained, and subject to regular inspection and overhaul against schematic drawings. Also, record drawings should be produced detailing layouts and allocations of space.

Support Systems

For new support systems, each utility will doubtless have its own requirements and standards to which design would need to be carried out. A uniform design approach is desirable to ensure modularity, easy extendibility, and to facilitate modification where necessary.

Ventilation

A design process would need to be undertaken to predict temperature rise both with, and without, ventilation, and the need for means of central mechanical ventilation considered. Such a system would require to have a standby. Its power consumption could reduce sustainability benefits.

Summary

The following elements should be considered for inclusion within the design of new tunnels or the reconfiguration of existing tunnels:

1. The co-ordination of the various cable and piped services within their allotted spaces to ensure that minimum distances necessary for safe, efficient, interference-free operation and maintenance can be carried out.
2. The spatial allocation of services in a uniform manner with agreed principles (e.g. pipe work always low, water to one side, gas the other, power cables middle and high one side and all communications cables installed middle and high the other side)
3. Clearance issues: ensuring that the service providers obtain clearance necessary to properly and adequately maintain and replace their service, to safely operate valves, and the like
4. Adequate permanent lighting and emergency lighting systems
5. The interfacing of services between the through runs and where they access/egress the tunnels
6. Constraints; that is, the presence of existing services in tunnels, their continued safe operation both during construction and new installations work and after; other constraints could include air quality, and obstructions in the path of planned tunnels routes. These could be addressed on a tunnel-by-tunnel basis.
7. Support philosophy, the design, approval, ownership and maintenance of support systems and the responsibility for ongoing adequacy
8. Access for personnel on unimpeded 24/7 basis, taking into account emergency requirements
9. Similarly, access for plant on unimpeded 24/7 basis, taking into account emergency requirements
10. The need to obviate any hot working: by design by the utilities of their services (for example, use of HV cables not requiring lead sheaths)
11. Local general purpose power (110V CTE (centre tapped to earth)
12. Provision of adequate ventilation, preferably natural, but mechanical as necessary
13. Provision of alarm systems for personnel including: fire, gas (ground) gas (leaked) flooding, water leakage, air quality monitoring
14. Provision of anti vermin measures
15. Provision of CCTV
16. Thermometers
17. Means of communications.

3.6 Redundant Infrastructure in City Tunnels

There are redundant pipes in the City's tunnels. Any redundant infrastructure is not likely to be admitted or removed by utility companies as things currently operate as:

- They will want to have the flexibility to potentially re-use the pipes/space.
- The existing rental charge for City pipe subways does not currently provide much of an economic incentive for utility companies to make optimal use of the space granted to them[10].

The following provides more detail of the potential issues and opportunities associated with redundant infrastructure.

Redundancy of Services

Only utility companies or the operators of the services are able to identify redundant services. This may be more complicated by the lack of

[10] The April to June 2009 average rental charge for each metre of the City's pipe subways came to a nominal amount of £3.75 per metre; equating to £15 per metre per annum (reflecting maintenance, repairs, inspection and energy costs). However, this figure does not include the occasionally large costs to refurbish pipe subways – which were not incurred over the quarterly time period.

labelling and may, therefore, involve testing each service. Subsequently they could be removed and the space re-used. This would be subject to agreements or negotiations as, presumably, there is an easement or form of legal agreement in place. Additionally, it is doubtful that redundant infrastructure would be removed owing to cost and complications (qv) and more likely abandoned by the stakeholder, unless specifically being replaced by new infrastructure.

Ease of Removal of Redundant Services

It is relatively easy to remove cabling. Pipework is more difficult and depends upon how it was installed. Should it consist of bolted sections, then they could be unbolted but may still require cutting to facilitate their manoeuvring and removal from the tunnels. Cutting is liable to be an arduous and dangerous operation when carried out within the confines of such limited space.

Large Power Cables

The owner may wish to remove and recover since he can regain the cost of the metal (mostly copper) The actual method may be more difficult than envisaged as the cable or cables to be removed could well be under many other live cables, which will raise the cost and may negate the equation recovery cost less than metal recovery cost, in which case they may 'donate' it to City of London, subject to agreement of the easement rights.

Pipework

The owner may wish to remove and recover since he can regain the cost of the metal. The same equation (recovery cost less than metal recovery cost) may pertain, but in this case removal costs may be much higher, depending on the method of construction (e.g. if a pipe is of welded construction, it will need to be cut up in situ) subject to agreement of the easement rights.

Communications Cables

Redundant copper communications cables potentially have recovery value. Redundant fibre optic cables, however, probably have little value in recovery terms. The owners of redundant fibre optic cables may prefer to abandon them rather than bear the cost of removal as this may be less than cost of recovered materials. An option here could be to donate the redundant infrastructure to the City for disposal, subject to agreement of the easement rights.

Funding Services Removals

The mechanism for funding the services removal could be that the value of the recovered metals may pay or at least contribute to the costs of recovery. Alternatively a condition could be placed upon any new installer of infrastructure to remove the existing redundant service before installation of new infrastructure.

Easements

Normally utilities require easements, that is, legal agreement that allows them to install their services in or across the easements for a fixed – but very long period – at a peppercorn rent. If this kind of agreement applies within the tunnels it will be difficult to obtain agreement for the relinquishment of space allocated to the utility.

Power to remove redundant infrastructure from pipe subways

To the extent that current infrastructure 'clutter' in the existing City pipe subways relates to statutory utility infrastructure, statutory rights to remove infrastructure, even when redundant, are, at best, limited. In other contexts, contractual rights and rights under property law are usually relied on. These are summarised below and in Table 3.2.

Statutory utilities generally have a statutory right to lay infrastructure necessary for their licensed activity and statutory rights protecting that infrastructure once laid. These operate for so long as the infrastructure remains part of their regulated networks. In this sense, however, regulation generally protects the utility, not the landowner or customer. There are generally no statutory rights for a landowner or customer to require the removal of utility infrastructure - although this may be inferred from the statutory right to require modification.

Contractual entitlement to require removal or relocation in various scenarios may exist. Access and occupation rights are usually granted under a lease and easements (eg. for a substation and associated wires) or wayleaves (eg. for pipe or wire routes). These can, but commonly do not, include specific provisions allowing the landowner to require the removal or relocation of utility infrastructure as and when it becomes redundant or if the landowner wants to redevelop.

If the infrastructure is redundant and the statutory or contractual right to occupy has come to an end, it may be possible for the City to remove the infrastructure itself but, again, this depends on the nature of the infrastructure. There are statutory restrictions as to who can perform certain types of works to certain types of utility infrastructure. If the redundant infrastructure does not belong to a statutory utility, then the City will generally have the right to remove the infrastructure – but the City would need to take precautions to avoid committing breach of any agreement it may have entered into or damage to property in carrying out the removal.

Whether or not the City bears the cost of removal will, therefore, depend on the terms of any agreement entered into in relation to the relevant infrastructure and, if none, the City is most likely to have to negotiate the price of removal with the infrastructure owner or simply bear the full cost itself. However, we assume that all such infrastructure laid within the City's pipe subway will be governed by a common set of terms of use.

Consequently, before any removal process is commenced the following should be established:

(I) Any contractual rights to require removal or allocation of costs of removal;

(ii) The type and ownership of infrastructure and whether it is 'operational' or 'redundant';

(iii) Whether 'redundant' infrastructure is connected to operational infrastructure and, if so, where (physical inspection);

(iv) Any statutory rights to require removal of the redundant infrastructure;

(v) The type of works needed to disconnect and/or remove it and who can perform them; and

(vi) Who bears the cost of relevant works (review subway agreements, statutory provisions)

Table 3.2 Rights to Require or Undertake Removal Of Redundant Utility Infrastructure

UTILITY	*Statutory right to require utility to remove infrastructure?*	*If rights available, requires payment?*	*Statutory right to remove redundant infrastructure by self?*	*Statutory restrictions on removal or disconnection 'works' on infrastructure?*	*Need to check contractual arrange-ments?*
ELECTRICITY					
	x (BUT can request as part of a modification of an existing line)	√	x	√	√
GAS					
	x (BUT can request as part of a request for modification of an existing line)	√	x	√	√
WATER					
	√ (unless installed under a street)	√	x	√	√
TELECOMS					
	√	√	√ (notice procedure)	√	√

3.7 Summary

The section summarises information on CoL tunnels and the degree to which they may have spare capacity. It also identifies other vacant tunnels that could potentially be of use to the pipe subway network. These included tunnels such as the POT, LU disused tunnels and cross rail tunnels. It was found that utilisation of these tunnels would be less likely as proposals would be subject to further intensive enquiry and are likely to involve complex negotiations between a number of parties.

This section reviews a number of issues regarding the condition and suitability of the existing CoL pipe subway networks. The tunnels were observed to be in some parts poorly lit with inadequate labelling and arrangement. Areas where utilities services enter and leave the tunnels were seen to be particularly chaotic.

The removal of existing redundant services is important for new utility installations as spatially there is little space for new and additional services. The issues and opportunities for applying a mechanism to remove redundant infrastructure were reviewed, and a suggested process for identifying and removing redundant infrastructure was set out.

4 UTILITIES BASELINE AND DEMAND ASSESSMENT

4.1 Introduction

This section presents a baseline assessment of utilities infrastructure. It presents an analysis of the potential scale of demand for new utilities connections and decentralised energy supply, a discussion of key issues for delivering utility infrastructure in the City, and a closer look at demand for heat networks and CHP.

This draws on utility companies' views on the potential attractiveness of connections between tunnels and decentralised energy networks. The demand analysis is conducted both for developments within the City and in the fringes of the City. This section highlights the inter-relationship between decentralised energy networks and utilities demand.

4.2 Development In and Around the City

The demand and take-up of utilities and heat network infrastructure will depend upon the scale and location of existing and new development.

In 2007 the City of London had over 5.1 million square metres (sqm) of office space, 240,000 sqm of retail space and just over 5,700 dwellings[11].

Current development pipeline projections up to 2015 show approximately 1.3 million sqm of planned additional office floorspace[12]. Our analysis also indicates the City is set to provide an additional 1,800 dwellings by 2026 with an increase in the population of more than 4,000 residents. Forecasts also indicate an increase in leisure and comparison good retail by approximately 6,000 and 67,000 sqm respectively up to 2026.

The table below show the projected growth in commercial floorspace and residential dwellings in the City of London. These numbers are used as an input in our estimates of changes in demand for utilities services discussed below.

Table 4.1 Baseline and Projected Commercial and Residential Growth in City of London

	Existing	*Growth by 2026*	*Growth as % of existing*
Business/office floorspace 2007 (m2)	5,136,000	1,090,880	21%
Population	8,000	4,227	53%
Dwellings	5,720	1,800	31%

Note: Floorspace includes all bulk classes – mostly consisting of office space and to a lesser extent retail space. Source: URS calculations based on historical growth rates as included in the Central London Infrastructure Study 2009. Informed by the GLA London Office Policy Review 2007 and further GLA 2008 research.

4.3 Utilities Infrastructure Context

The physical system that each network is based upon differs but, principally, the operational aspects do not. The major issues that generally face the utility industry now are:

- Typical infrastructure life is around 40 years and much of it is near the end of its operational life.
- Any spare capacity in existing utilities infrastructure has been or is being taken up.
- Demand in most cases is expected to continue to grow, both from existing users and new users.

The issue of asset life is one that each utility company is dealing with in their own way. Thames Water, for example, has Victorian mains that leak excessively and do not generally meet the requirements of the 21st Century. There is an extensive 'asset replacement' programme underway for most services based upon regulatory requirements.

The growth demands of each network is also a challenge. This is split into two facets: firstly, the strategic requirements for each company are onerous. Secondly, the physical space available beneath the highways in built up areas is often no longer present to install more apparatus and the cost to remove existing assets is high.

Companies are using technologies to help achieve a minimum disruption approach. For

[11] Source: URS calculations based on historical growth rates as included in the Central London Infrastructure Study 2009. Informed by the GLA London Office Policy Review 2007 and further GLA 2008 research.
[12] Based on the City's currently available development pipeline 2008-2012+. Actual development will vary depending on economic conditions, and being lower than *planned* development.

example the water and gas industries utilise slip lining where new plastic mains (PE or polyethylene) are inserted into older cast iron mains leaving just the service connections into each building to be transferred via an open cut process.

Whilst the main four providers (EDF Energy, National Grid, Thames Water and BT) have the most complex and voluminous networks, they are not the only users of space beneath highways. The telecommunications industry for example has generated many new companies who have installed apparatus in recent years.

4.4 Utilities Infrastructure in the City

Utility networks broadly fit into three categories: UK strategic, regional strategic and local, using terminology such as 'transmission', for strategic networks, and 'distribution' networks for more local systems.

The transmission networks operate at different, and usually greater, pressures to the distribution networks, with implications associated with physical security and far stricter management criteria. This ties in with the general level of response from the utility owners whom are guarded about shared tunnels when it comes to strategic infrastructure.

The focus for using a pipe subway network has therefore leaned towards the distribution networks.

To provide contextual understanding, transmission networks would include: intermediate or high pressure gas mains; 132kV (132,000 volts), 275kV and/or 400kV electricity mains; high pressure water mains.

Distribution networks therefore would include 33kV (new voltage level of distribution for the City) electricity, 11kV and low voltage electricity mains; low and medium pressure gas mains; water mains typically up to say 180mm in diameter.

Whilst the distribution networks are the target market, there are sub elements to consider. The mains that provide local strategic support (the 'motorway' networks or 'A to B' functionality) and the more local mains (street connections).

Within each utility field there are also various requirements to manage. Broadly, this falls into two categories: asset replacement; and new connections. The two functions are mostly managed by different teams within each company given that one is more a market lead (new development) and one is more a regulatory lead (asset replacement).

The function of each is only important in the context of understanding likely interest. For example the asset replacement team may be interested in the project whilst the new connections team remain ambivalent.

New connections will relate directly to requirements that incoming end-users will have. For example a new headquarters for a bank will have specific requirements, such as multiple utility connections, especially for electricity and telecommunications.. The regulatory process provides a more reactive platform for this element.

Asset replacement is more investment driven and linked to monies secured from the Regulator (OfGEM and OfWAT) for renewal of mains and services that are coming to the end of their useful life.

Typically, utility networks operate to a 40 year cycle. However the water mains are substantially older than this. Given this criteria, any equipment installed during the 1960s may require renewal within the next 10 years or so.

Regardless of network, each operator is tasked with providing consistent quality of supply and security of supply to end-users.

Electricity Infrastructure

EDF Energy own and operate the electricity distribution network in, and around, the City.

The networks that are being considered for inclusion into the tunnels project relate to 33kV (33,000 volts) and 11kV cables. Low voltage networks are not likely to present viable options given that the City has buildings that consume substantial amounts of energy – almost certainly in excess of the capability of individual low voltage cables.

EDF currently operate systems that interconnect so that security, or resilience, is achieved in line with regulatory obligations. The 11kV system, for example, operates on a ring main design, providing security of supply from a one from two scenario – i.e. if one cable fails the alternative cable can take over.

The system for the City is based on decreasing voltage levels until a connection into a building is made. Given the requirements of many of the individual buildings, this is generally at 11kV.

The 11kV system extends from two main substations located at Back Hill and Osborne Street (Brick Lane area). The strategic pressure into these stations is 132kV where two 120MVA capacity transformers reduce the voltage to 11kV.

Numerous cables then exit these strategic points and traverse the City, via a mixture of ‘direct lay’ routes (i.e. in highway) and tunnels (EDF own their tunnels albeit these are limited in number and location) giving connections to individual buildings. Each cable has a unique capacity with the largest cross sectional cable being able to take up to around 8MVA.

The existing 11kV system is at capacity and this presents many difficulties for EDF when considering the growth that the City is predicting. The number of additional cables required, the connection points available and physical highway space required being some of the immediate issues.

As building design increases (height and specification for example), the number of cables required to provide supplies to individual buildings are also increasing.

Gas Infrastructure

National Grid own and operate the gas distribution network in, and around, the City.

The networks that are being considered for inclusion into the tunnels project relate to low and medium pressure as it is these that will provide suitable infrastructure for the growth proposals.

National Grid consider that strategic capacity is available although local upgrading works for specific spot loads may be required.

Building design, particularly in, say, a new office complex, generally specifies air conditioning to heat or cool the work space. This has effectively stalled the expansion of the gas network with a predicted reduction in gas use in the short term.

(One option for decentralised energy is the use of gas to fuel systems but even the gas demand from a hypothetical new 50MWe combined cooling heat and power energy centre is considered to be manageable).

National Grid has a significant asset replacement programme, following an enforcement notice issued by the Health and Safety Executive, in which all cast iron mains within 30m of a building are to be replaced by 2031.

Works on strategic, large diameter mains in the City and adjacent areas including Westminster, require detailed planning. At this stage, current thinking is that no works in and around the City will commence until 2020.

National Grid have a limited system of tunnels already in use in London but the mains are of considerable size and available space is minimal.

Where mains are laid under the highway, National Grid have developed a technique to insert a new length of PE (polyethylene) main into the existing cast iron main. This means that only local excavation is required to transfer individual services, and avoids the disruption that would be caused by an open cut process.

There is a requirement to replace large diameter mains that run east to west (Aldgate East to Parliament Square) and one that runs north to south (Blackfriars to St Pancras). The option to slip-line these two main feeds is not feasible and therefore new routes are required. An extended pipe subway network could offer a role in a deliverable solution for National Grid.

Water Infrastructure

The City’s water supply is provided by Thames Water as part of the London Water Resource Zone. This is sourced from several water catchments including the River Thames and the River Lea. This is then subsequently stored in reservoirs at Crossness, near Bexley, and Walthamstow Marshes. There are also minor boreholes that are used as well as a new de-salination plant at Beckton due to be brought into service to support the overall strategic requirements.

The mains that extend from the water treatment plant to the City are generally Victorian with relatively high leakage rates. Thames Water have embarked upon an asset replacement programme that uses, as with National Grid, a mixture of slip lining and direct laying. This is an ongoing programme that will take many years to complete.

To date Thames Water have not provided us with details of their network routes or limitations in the City.

Sewers

The sewers in Central London (including the City of London) are owned and operated by Thames Water. London's sewers were originally designed in the 19th century as a combined surface and foul water system based on a much smaller population. In Central London Thames Water own and operate 68,000 km of sewers, 800,000 manholes, 2,530 pumping stations and 349 sewage treatment works receiving 4.3 million cubic meters of sewage per day. The three main treatment plants for the Central London area are Beckton and Crossness in East London and Mogden in West London.

There is an extensive sewers network serving the City, with close to 90% of the local sewers typically located around 4-6m below street level.

To lay many of the City's existing pipe subways is likely to require diverting or changing sewer pipes. Existing sewer pipes therefore represent a constraint to the development of an extended pipe subway network. (Chapter 6 discusses physical constraints in more detail).

We have requested sewer network records from Thames Water.

Telecommunications Infrastructure

Telecommunication providers, as yet, have not commented specifically about their individual networks. As such, generic information is provided to afford a degree of understanding.

BT operate a large network in the City given their historical background as the GPO. However, since privatisation in the 1980s numerous other providers, such as COLT (City of London Telecommunications), Virgin Media and Cable & Wireless have emerged to compete with BT, particularly in the provision of business services.

In addition, new technology, such as broadband and fibre optic cables, has meant that the telecommunications networks have been subject to upgrading.

Whilst BT do have their own tunnels they also use a system of ducts and boxes which means that excavation is not always necessary.

Newer providers have either had to share existing duct runs or install their own via open cut excavation.

The telcommunications network is intricate with main exchanges and cabinets located at strategic positions so as to provide high speed, high quality telecommunications.

The telecommunications operators generally take a reactive rather than planned approach to new demand.

COLT (City of London Telecomminucations) and BT have been consulted, with both providing a limited degree of response.

4.5 Potential Interest in Pipe Subways

Context to Analysis

Demand for utilities services is predicted to grow substantially in the City of London. In assessing demand, the degree of current consumption is used as a benchmark. We then consider what new development, refurbishment and minor works may occur.

The City is likely to continue to attract high profile end users, and therefore any methodology employed needs to be robust so that the current standard of utility provision continues to be enjoyed. This includes security of supply and quality of supply.

A substantial new decentralised energy network could alter or reduce the nature and impact of the predicted growth in demand for electricity and gas significantly. At least in early phases it is likely though that the scale of any such decentralised energy network will be modest compared to the overall demand for existing electricity/gas and so no account is taken of this impact in this section.

Utilities Demand and Potential Interest

Demand for energy in the City during the course of 2007 reflected some 2,555GWh of electricity and 963GWh of gas. This is recorded against some 13,500 users of electricity and 3,700 users of gas.

Based upon the City of London's floorspace growth forecasts, the predicted increase in demand, of each utility network, with the exception of National Grid, is substantial.

The additional predicted water consumption of some 6.7M litres per day and up to 140MVA of electrical demand reflects growth beyond organic expansion. This means that strategic reserves, in addition to the local infrastructure, need to be considered, bearing in mind that this is only one of area of London.

Utility network operators, particularly EDF Energy, may ultimately require support in securing land for new assets to facilitate growth in a timely manner.

EDF recognise the City's growth projections, albeit they are currently completing their own demand computations. Thames Water also have projected additional consumption figures for the City but do not specifically confirm the values.

National Grid and BT do not anticipate issues with regard to strategic capacity.

The installation of new tunnels offers all network operators an opportunity to gain access to end-users in a reasonably efficient and timely manner, particularly once built.

This is considered important to the City as timeframes currently employed can prove prohibitive to potential incoming clients.

Electricity Demand and Potential Interest

The estimated impact of new growth in the City alone, without the implications of refurbishment of existing building stock, will see circa 100MVA of energy required, with computed predictions ranging from 81MVA to 140MVA[13]. The level of infrastructure required to support this is significant.

To put these figures in context, this equates to 3% of the overall level of consumption for the whole of Greater London.

Given the known capacity limitations of the 11kV network, EDF's current thinking, subject to regulatory approval, is to create a second tier distribution network. This is to be based on 33kV noting that this voltage level is considered regionally strategic (hence the extra regulatory approval process).

This proposed 33kV distribution network is based on a system of a group of five cables that would run between the two main substations serving the City. A third main substation located south of the river could also be used to link into the system as this would afford an increased level of security of supply as well as splitting the increase in energy demand amongst several sources. This is shown in **Figure 4.1**.

There are likely to be several groups of 33kV cables required with routes yet to be defined, although resilience of supply, and the likely growth points in the City, will help determine the principles that EDF follow.

For larger end users, the 33kV system would divert into the building using the one from two security of supply convention. Once in the building, a substation will transform the voltage to low voltage which can then be circulated to end users.

Compared to 11kV, the 33kV system also provides different, and potentially better, options for the connection of export electricity that is likely to be derived from low carbon generating installations such as CHP.

Current network configuration limits the ability to connect to CHP as fault levels, and general network availability, are proving significant obstacles that ultimately present unsustainable financial exposure for a development.

EDF are reviewing the options to deliver the growth required in the City and the tunnels offer a potential solution given that routing and space availability afford the required operational criteria.

Included in the wider EDF appraisal is the Royal Mail tunnel as this existing structure could serve to offer immediate options to the City. Discussions are at an early stage and financial implications are yet to be fully understood.

EDF could enter a 33kv cable into the tunnel at Back Hill near the corner of of Clerkenwell Road and Farringdon Road; and then exit at Osborn Street near Brick Lane. This spans nearly the entire length of the DEPS study area.

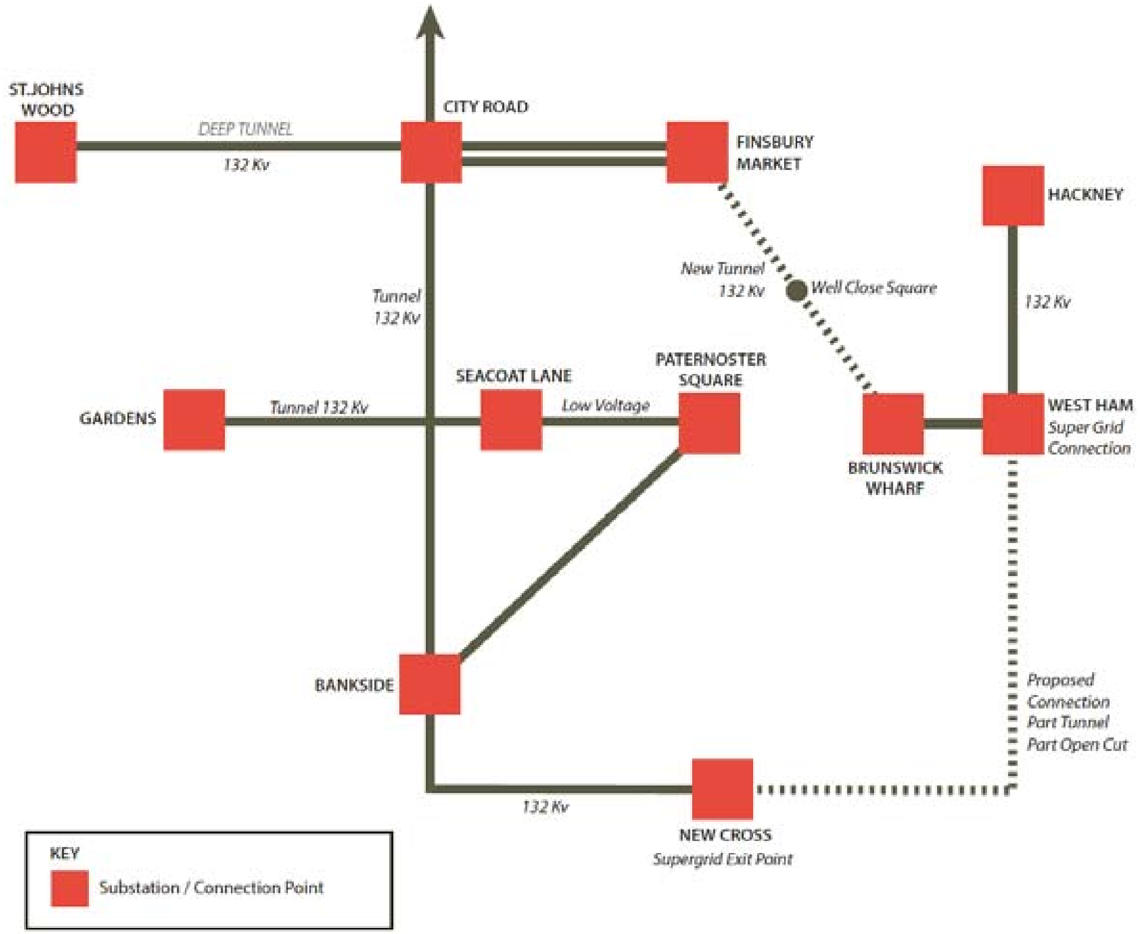
Assuming that the 33kV network proposals, and the Royal Mail tunnel options, meet with regulatory approval, the financing of the future networks will subsequently prove challenging.

EDF are currently concluding their next five yearly plan which determines investment, via a regulatory approval process, for the electricity network. Current rules mean that sums for the phasing of the 33kV network construction could be included in the next regulatory period (2015 to 2020) given that the option to include any sums in the forthcoming 2010 to 2015 'Distribution Price Control Review' is not now an option.

[13]The Computations completed have been derived from the Central London Forward study and use conventional rules for office, residential and retail space.

Possible options beyond this, again subject to approval by the regulator, would be to make specific charges against developments. In this scenario, Londoners would not be expected to pay for this substantial development growth via their electricity bills. An example of this is the Anglian Water Wing reservoir upgrade where, in effect, a roof tax has been applied to all new connections.

Figure 4.1 Schematic Diagram of EDF's 33Kv twork Proposals



Gas Demand and Potential Interest

National Grid have assessed the likely impact of developmental growth in the City, noting emergingr building regulations for non-residential purposes, and computed that current strategic capacity remains in excess of likely consumption.

Existing gas demand in the City is predicted to remain static, or reduce, in the longer term as influences such as increased energy efficiency, and supplementary energy sources such as non-gas decentralised/renewable energy act to reduce the demand for gas. In particular the use of air condjtioning technology – being wholly reliant upon the electricity network – has contributed to the predicted negative growth of the gas system.

In the shorter term gas consumption may increase in the City as decentralised energy is required as part of the wider political agenda and the use of biomass, or other renewable sources, are less readily usable options.

With regard to using gas to furnish fuel for CHP plants, the implications of applying a bio-gas generated remotely from the City is also under consideration noting that this is not proven technology as this moment in time.

If this does prove feasible, then bio-gas would aid the green credentials of the City. Theoretically, the gas, produced via a biomass scheme would occur where access to waste product, transport and land is more feasible than the City of London. Whilst this is not necessarily ideal, an exemption from planning norms, along with regulatory approval, would help the ethos of the City.

Technically, National Grid would need to secure a mixture of gas that worked in conjunction with natural gas so as not to affect end users. Of course, the idea is that the City does not necessarily use the gas produced remotely as this would require dedicated mains that would then defeat the purpose of the proposal.

In relation to this study, National Grid have a greater need to consider asset replacement as opposed to new development, noting that some local reinforcement may be necessary for specific spot load requirements.

This asset replacement programme includes two major mains that cross the City east-west and north-south. Were the route to follow main thoroughfares, particularly those with mains requiring replacement, the use of the tunnels could mitigate spatial issues that National Grid have in their own tunnels and / or public highway.

Water Demand and Potential Interest

Our predicted growth in water demand for new development is 6.2 million litres/day for non–residential development, and 0.5 million litres/day for residential development, giving a total of 6.7 million litres/day.

Current predictions for the London area by Thames Water are based upon a 160l/person/day usage for residential purposes and using a direct apportionment 80l/person/day for non-residential. With the Code for Sustainable Homes, and the greater pressures from Building Codes, the target is 120l/person/day using technologies such as grey water harvesting.

Thames Water however do not believe this to be achievable at the moment and use a figure of 150l/person/day with a figure of 135l/person/day being the best they perceive as being possible.

To conform with national policy requirements Thames Water submits a water management plan (including consideration of growth management) to the Secretary of State for Environment, Food and Rural Affairs (DEFRA) and OfWAT. The regulator and the Environment Agency then review proposals. Thames Water have recently submitted their proposals, known as AMP5, for approval and a decision has recently been made in preparation for the 2010 to 2015 period. Initial announcements by Thames Water suggest that expenditure associated with leakage management will be limited and this may impact upon asset replacement programmes.

Strategically, Thames Water recognises that they have significant shortfalls in their system and have been planning a new reservoir in Oxfordshire but this has recently been delayed as forecasting processes have enabled Thames Water to defer investment. Added to this is a planned and approved de-salination plant that will help to fill shortfall in capacity.

Thames Water has not published a specific mains replacement programme for the City. A request has been made to furnish basic details but no information has been provided.

Broadly, current assessment of the situation is that the asset replacement programme and the likely connections to new development would benefit from an extended pipe subway network although there are physical issues that would need to be addressed. This is predominantly because standard sized mains are produced in 6m lengths. These need to be installed into the tunnel and then pushed along – in reality, this is a difficult process to achieve.

Sewers Demand and Potential Interest

Discussions with Thames Water and our analysis of the compatibility of different infrastructures in pipe subways suggest that it is unlikely to be appropriate to include sewers within any extensions to the City's pipe subway network. Consequently demand for sewers is not considered further.

Telecoms Demand and Potential Interest

The telecommunications networks tend to be more reactive to growth although they too will require consideration at some juncture.

Noting that BT have tunnels already in existence, it is likely that strategic provision is already catered for. The tunnels, if they were to take into account new development locations, may then prove of interest to BT.

BT are in contact with the project team and information is being sought.

With regard to COLT, and other third party providers, the routes would be of interest, particularly if they could subsequently offer services to end users.

4.6 Conclusion

The potential tunnel network is of interest to the distribution elements of the utility industry, subject to the final findings of this study and the quantirication of tangible benefits. Factors to take in to account in working up design include:

- operational security to each system
- routes that take into account asset replacement requirements, and
- routes that take into account new development and, where possible, known refurbishment locations.

The benefits to each operator will differ but broadly the ability to offer access to utility capacity and connection will afford the City significant opportunity to engage with new clients.

So far, EDF have expressed the most tangible degree of interest in the possibility of developing an extended pipe subway network – resulting in them looking further into the use of the Mail Rail tunnel.

National Grid have indicated possible uses for new pipe subways – particularly where they require large diameter mains to run east to west (Aldgate East to Parliament Square) and north to south (Blackfriars to St Pancras).

The other consulted utility companies have expressed initial interest

5 DECENTRALISED ENERGY BASELINE AND DEMAND ASSESSMENT

5.1 Introduction

The City's high density of development is potentially well suited to decentralised energy systems. In assessing the potential of a decentralised energy network this analysis is structured around the following steps:

- Identify existing infrastructure
- Estimate current and future energy demand, and
- Estimate optimal decentralised energy network capacity.

The first two sections of this chapter identify existing and planned decentralised energy schemes and their condition and suitability for connection in an expanded decentralised energy network. This helps identify the opportunities within and outside the City to establish a wider decentralised energy network.

The remainder of this chapter assesses the potential scale of demand for decentralised energy supply from existing and forecast development in the City and City fringe areas, and how different demand/land uses may offer opportunities to balance supply and demand.

Since higher heat load densities offer better returns, as investment costs are lower, the development of a heat network should be based on an analysis of the heat loads in the City and City fringe Areas, an analysis known as energy demand mapping.

As indicated in the Decentralised Energy and Energy Masterplanning Programme (DEMaP) website, there is currently a lack of information and certainty surrounding London's heat loads. The DEMaP has been developed to address these barriers and enable the market to make informed investment decisions without risking significant development costs. Crucial to this is the development of a web-based portal called the London Heat Map, which is an interactive platform displaying information that can be used by policy and decision-makers to facilitate the development of new decentralised energy schemes.

Energy demand maps have been created as part of this chapter and are analysed in the following sections. The dense urban environment in the CoL areas and diverse energy demands may create viable circumstances for delivering cost-effective decentralised energy schemes.

5.2 Existing and Planned Decentralised Energy Infrastructure

A description of existing and planned decentralised energy systems and their characteristics is presented in **Appendix 1** and their locations are shown on **Figure 5.1**.

The most relevant of these is the Citigen network in the City. Citigen serves numerous City of London buildings including the historic Guildhall, the Barbican Arts Centre, the Guildhall School of Music and Drama, the Museum of London and London Central Markets (Smithfield) as well as other major commercial customers.

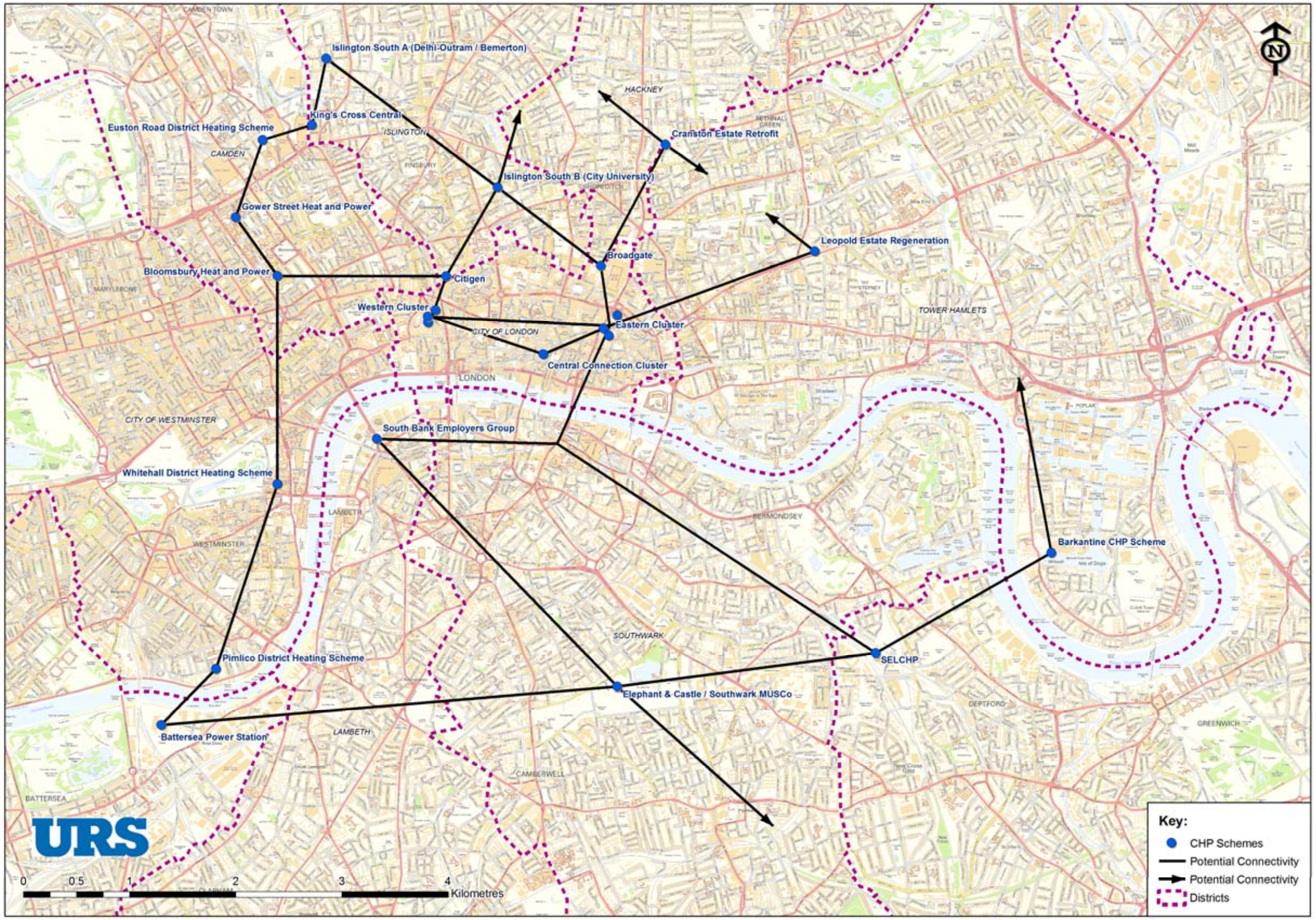
The current installed capacity is 30MWe with planning granted for an installed capacity up to 90MWe.

Citigen has expressed an interest in expanding the delivery of services for heating, cooling and power to additional consumers/customers, and would consider connection to other energy centres.

In addition to the existing schemes some key planned decentralised energy schemes have been identified that could contribute to an enhanced heating, cooling and power network. These are shown in **Figure 5.1**.

The London Borough of Islington (LB Islington) has undertaken an assessment of what could be achieved in terms of the roll out of district heating by 2014. The assessment has determined that four potential schemes are viable in order to serve three identified clusters. Of these, two located in close proximity to the City (Islington South A and B) are considered for potential expansion. The anticipated CHP capacity is 1,416kWe and 6,800kWe, respectively

Figure 5.1 Existing and Planned Decentralised Energy Infrastructure Demonstrating Potential City and City Fringe Area Connectivity



5.3 Benefits of Expansion and Interconnection

The expansion and interconnection of decentralised energy schemes in the City and City Fringe areas are likely to provide benefits in terms of more efficient and optimised operating costs, plant output and economies of scale for future growth.

This will come in the form of interconnection of new schemes, expansion of existing schemes and inter-authority and cross-authority partnerships for delivering decentralised energy.

The benefits of expanding existing or planned decentralised energy schemes depend heavily on deployment being carried out in the right context. Correctly combined demand from a mix of residential, commercial and industrial land uses would provide a relatively steady demand and optimise the operation and efficiency of a system. For example, the connection of a housing estate to an existing district heating network provides an anchor heat load, improving commercial viability.

In terms of the planned schemes, a majority of these are investigating the potential for linking to adjacent development as part of their feasibility studies.

The potential to expand into neighbouring boroughs may offer a way of managing the risk of imbalance associated with a potential gap between supply and demand. The improved load diversity found in larger schemes generally results in better efficiencies and improved carbon dioxide emissions savings.

Although larger systems require a proportionally higher investment in heat networks, designing systems to serve existing building/housing stock in areas where energy demands can be connected early on in the project, with the built-in flexibility to expand to serve the needs of future schemes in neighbouring boroughs, may result in better returns in the long run.

5.4 Energy Demand Mapping

The development of a decentralised energy network in the City and City Fringe areas is based on a baseline analysis of energy demand densities. This analysis aims to highlight areas with high current (2007) and forecast (2026) energy demand densities.

This analysis is known as energy demand mapping. Energy demand mapping illustrates the energy demand density across a geographic area and is an invaluable tool in spatially identifying decentralised energy opportunities, i.e. where the implementation of decentralised energy networks is most viable.

The energy demand density maps produced for the City and City fringe areas contain information on the gas and electricity consumption densities in 2007 for commercial/industrial and domestic consumers. A consideration of the demand for gas and electricity from domestic uses is relevant to support load diversity, i.e. commercial demands are high during the day, whilst residential demands are high early in the mornings and in the evenings.

The forecast demand for 2026 is also mapped following the same pattern of analysis, i.e., gas and electricity consumption for commercial/industrial and domestic uses.

The mapping exercise was undertaken utilising BERR MLSOA (Middle Layer Super Output Area) data for 2007. The forecast energy demand was mapped based on the floorspace and unit growth calculations for the City and Central London boroughs, undertaken by URS for the City of London Carbon Footprint Study.

Non-Domestic Land Use

Our analysis of the scale and spatial arrangement of non-domestic gas and electricity demand densities in 2007 and 2026 for the City and City Fringe areas is shown in **Figures 5.2** and **5.3** (gas), and **Figures 5.4** and **5.5** (electricity).

With regards to the City of London, a breakdown in the non-domestic gas and electricity demand densities is shown in **Figures 5.6** and **5.7** (gas), and **Figures 5.8** and **5.9** (electricity).

City of London 2007 – The eastern part of the City demonstrates the highest gas and electricity consumption densities (700kWh/m^2 and 140kWh/m^2, respectively). Additionally, central and western parts of the City demonstrate medium gas and electricity consumption densities (400 – 530kWh/m^2 and 80 – 110kWh/m^2, respectively). This distribution of gas and electricity consumption densities is explained by the concentration of high rise buildings in the eastern part of the City and significant medium rise development in the central and western parts of the City.

City of London 2026 – A greater proportion of the eastern part of the City demonstrates the highest gas and electricity consumption densities (735kWh/m^2 and 175kWh/m^2, respectively). Additionally, central and western parts of the City demonstrate medium gas and electricity consumption densities (400 – 530kWh/m^2 and 110 – 145kWh/m^2, respectively). This distribution of gas and electricity consumption densities is anticipated due to the likelihood of an increasing density of high rise development in the eastern part of the City. Significant medium rise development in the central and western parts of the City dictate increased medium gas and electricity consumption densities.

City fringe areas 2007 – The gas consumption densities are fairly low (120 – 320kWh/m^2), whilst the electricity consumption densities in the LBs of Camden, Islington and Tower Hamlets, and Westminster City Council, predominate (90 – 220kWh/m^2).

City fringe areas 2026 – The gas consumption densities are fairly low, with the exception of Westminster City Council (465kWh/m^2) and the LB of Camden (400kWh/m^2), whilst the electricity consumption densities in the LB's of Camden, Islington and Tower Hamlets, and Westminster City Council, predominate (125 – 455kWh/m^2).

Figure 5.2 City and City Fringe Areas – Non-Domestic Gas Demand Density 2007

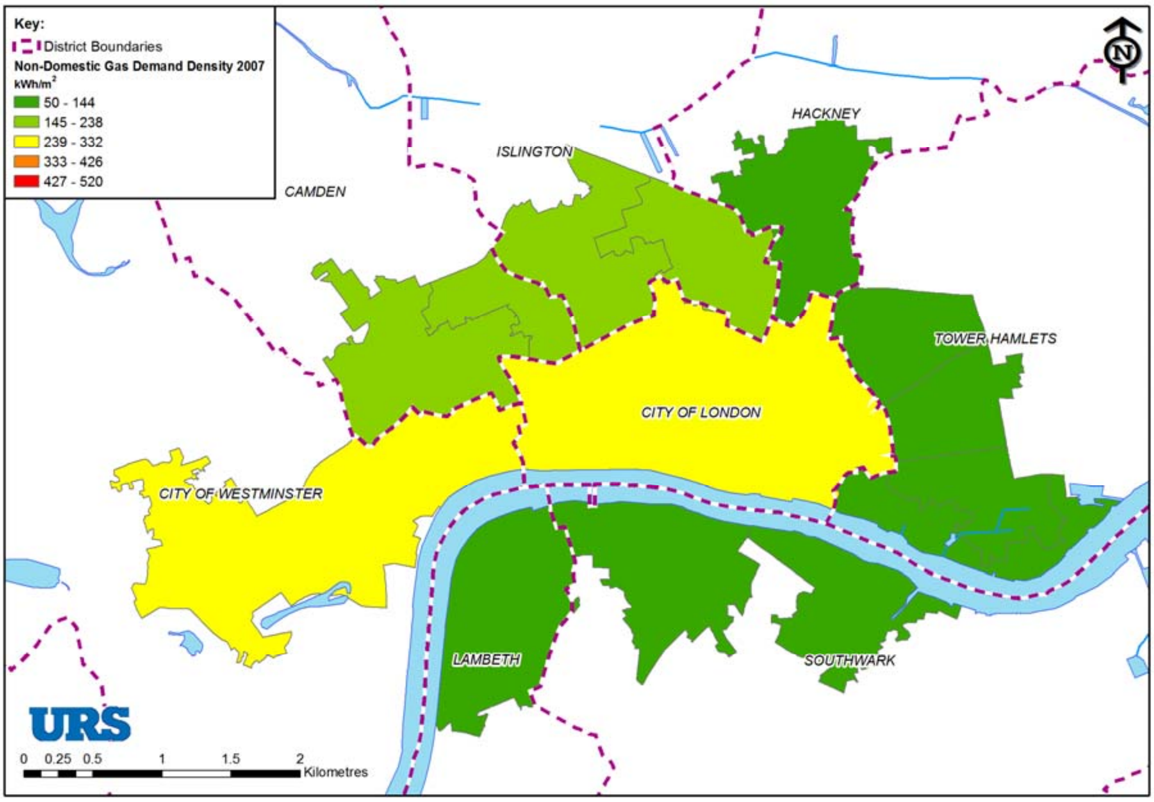


Figure 5.3 City and City Fringe Areas – Non-Domestic Gas Demand Density 2026

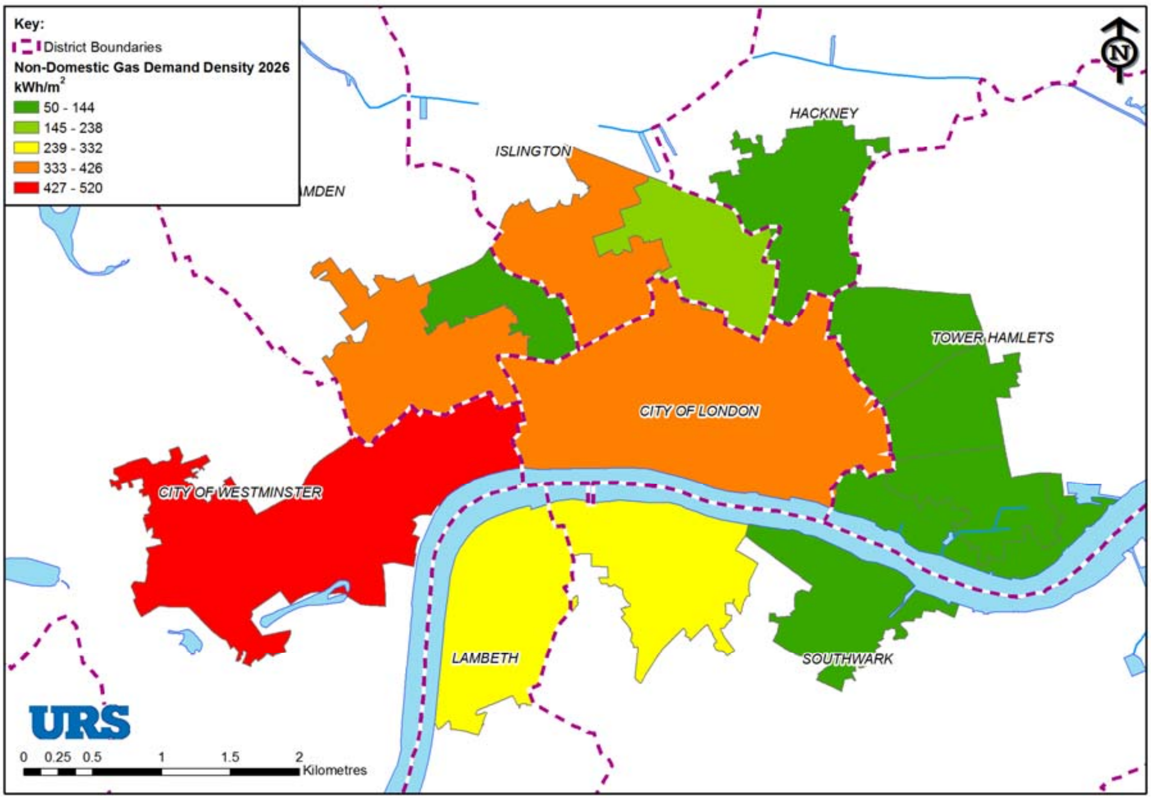


Figure 5.4 City and City Fringe Areas – Non-Domestic Electricity Demand Density 2007

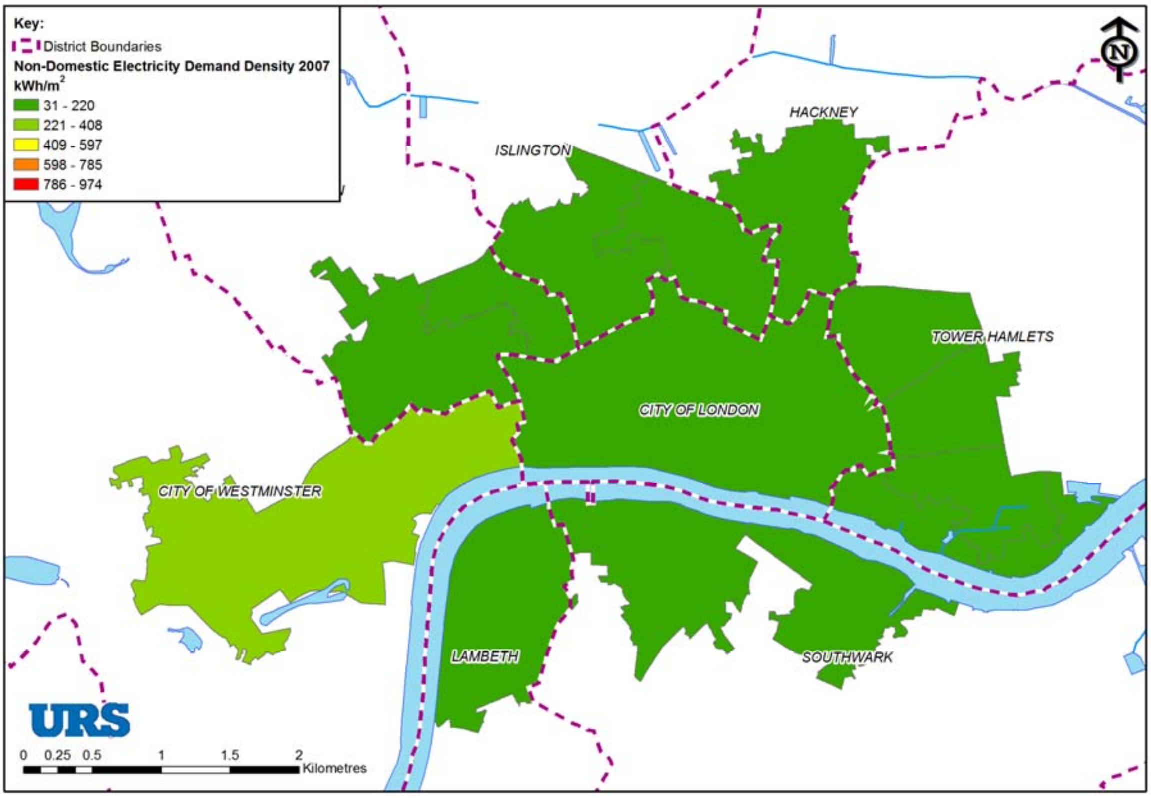


Figure 5.5 City and City Fringe Areas – Non-Domestic Electricity Demand Density 2026

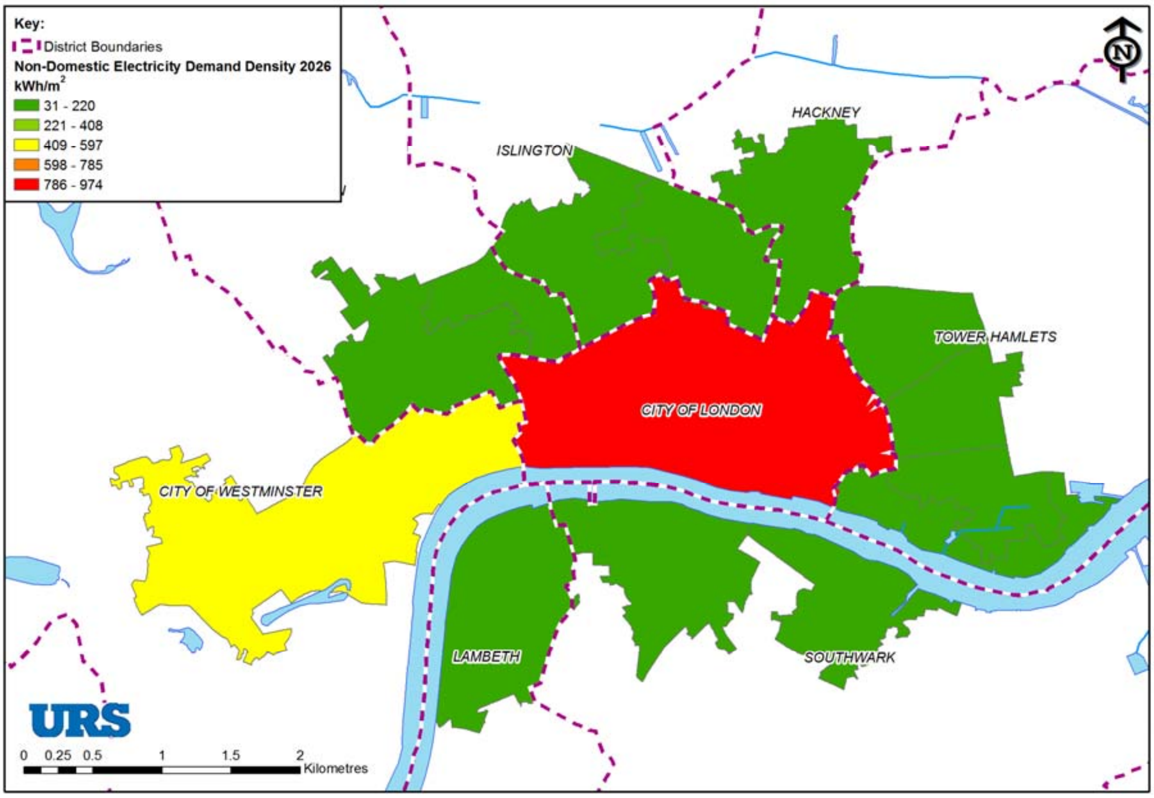


Figure 5.6 City of London – Non-Domestic Gas Demand Density 2007

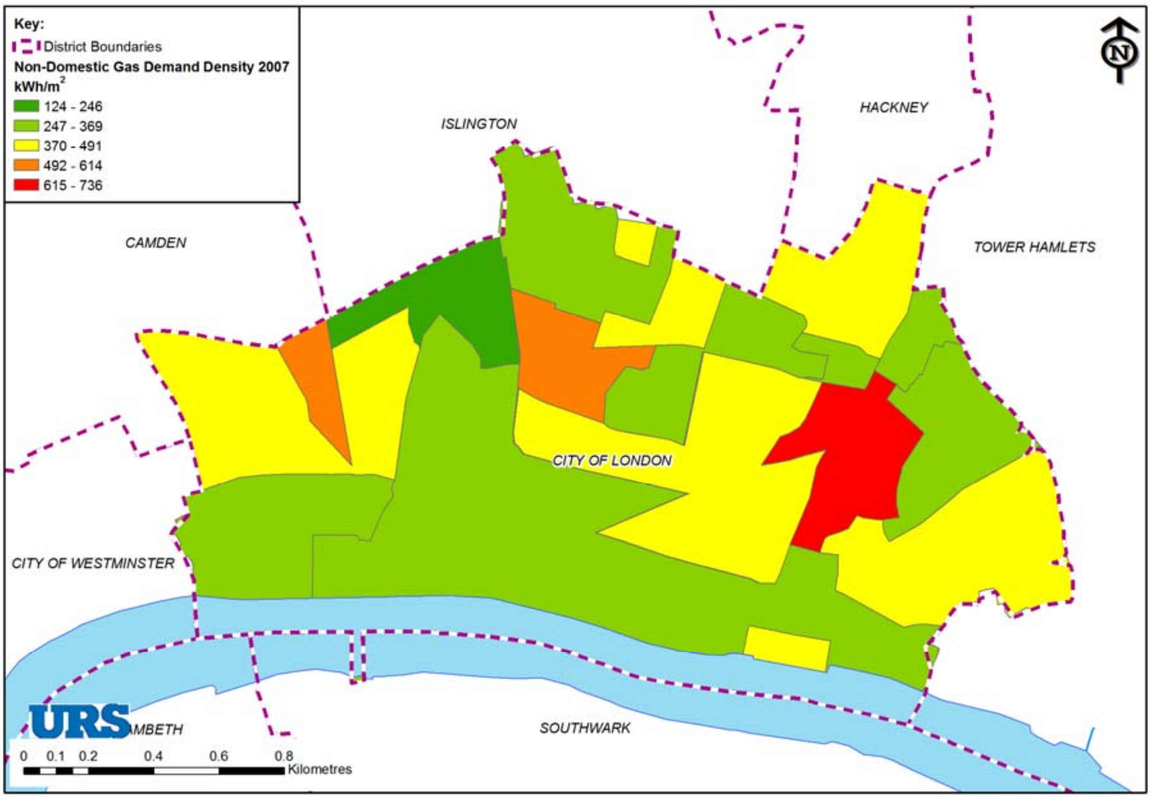


Figure 5.7 City of London – Non-Domestic Gas Demand Density 2026

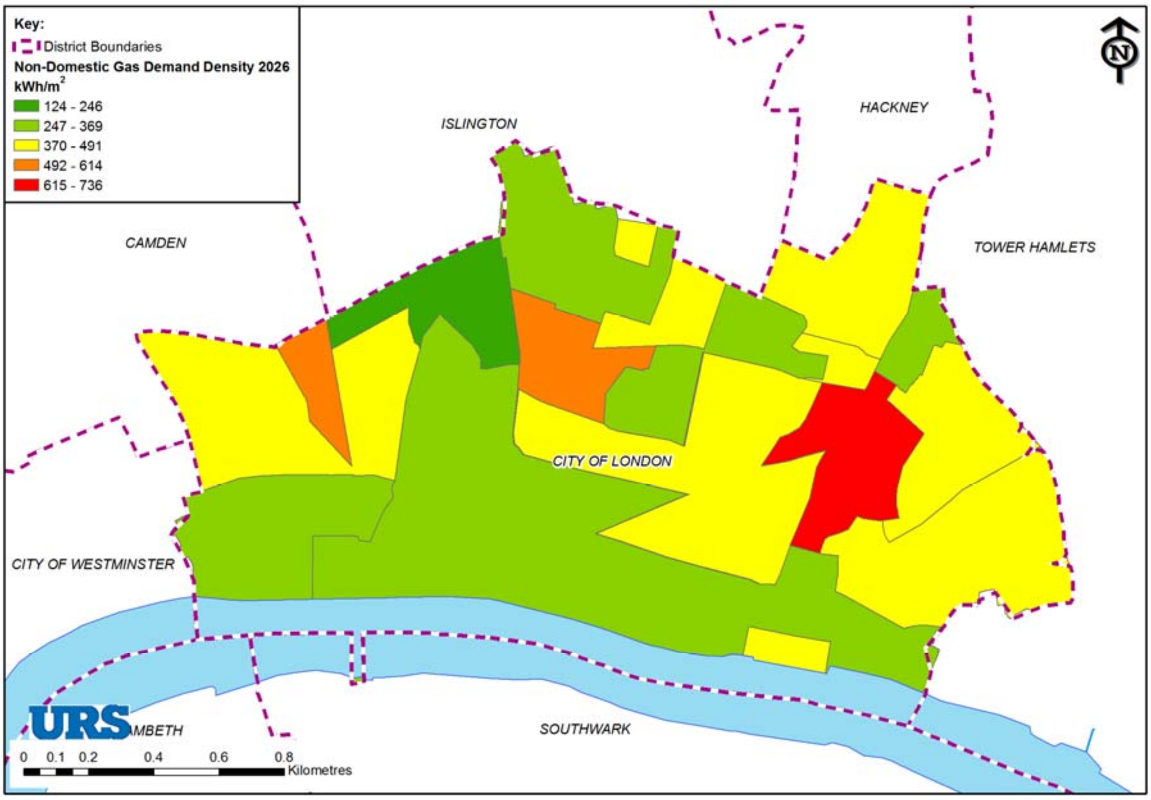


Figure 5.8 City of London – Non-Domestic Electricity Demand Density 2007

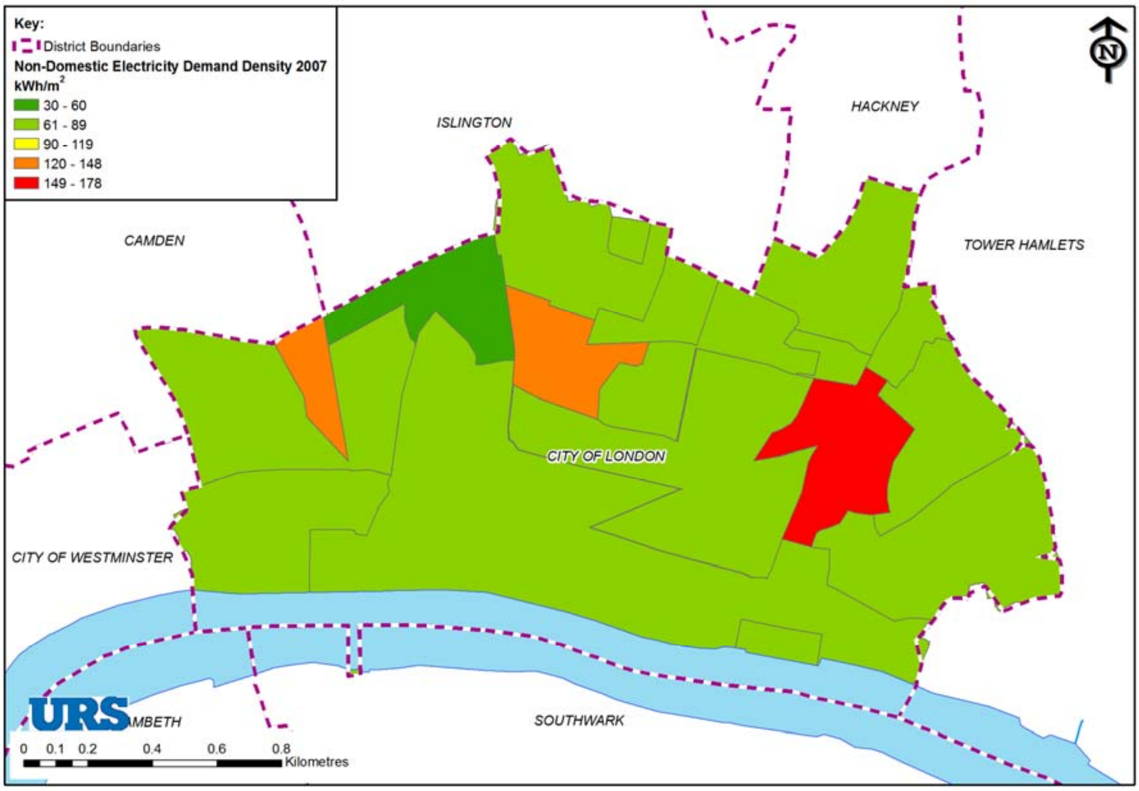
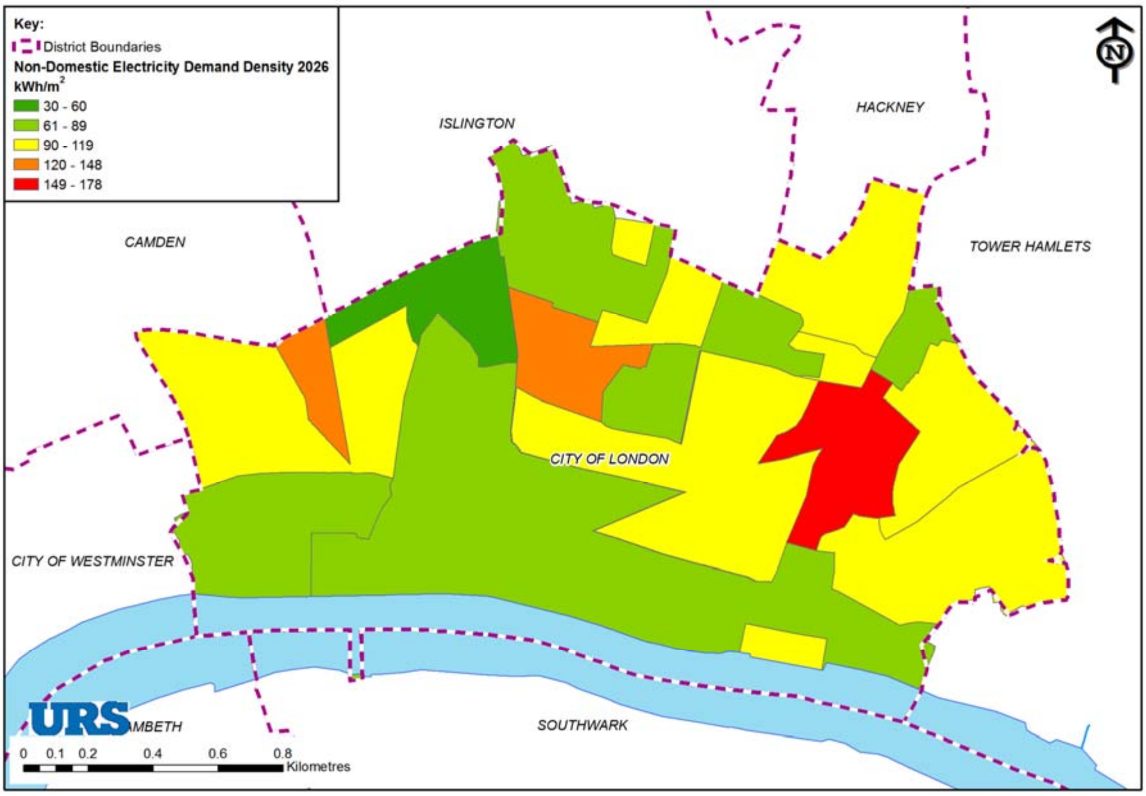


Figure 5.9 City of London – Non-Domestic Electricity Demand Density 2026



Domestic Land Use

Our analysis of the scale and spatial arrangement of domestic gas and electricity demand densities in 2007 and 2026 for the City and City Fringe areas is shown in **Figures 5.10** and **5.11** (gas), and **Figures 5.12** and **5.13** (electricity).

City of London 2007 – Generally, as anticipated, the domestic gas and electricity consumption densities in the City are low (22kWh/m^2 and 12kWh/m^2, respectively). This is due to a low housing density (5,720 units).

City of London 2026 – Again, as anticipated, the domestic gas and electricity consumption densities in the City are low (22kWh/m^2 and 12kWh/m^2, respectively). Very little growth in the gas and electricity consumption densities is noted for the forecast growth up to 2026.

City Fringe areas 2007 – Greater gas consumption densities are noted in the LBs of Camden and Tower Hamlets (65 – 75kWh/m^2), whilst greater electricity consumption densities are noted in the LBs of Camden, Tower Hamlets and Southwark (30 – 40kWh/m^2). This is indicative of higher domestic land use intensity in these areas, predominantly driven by high density housing estates.

City Fringe areas 2026 – Greater gas consumption densities for the LBs of Islington, Hackney and Tower Hamlets, and Westminster City Council (65 – 115kWh/m^2) are noted, whilst greater electricity consumption densities are shown in the LB's of Islington, Hackney and Tower Hamlets, and Westminster City Council (30 – 45kWh/m^2).

Other Land Uses

The location of a range of public buildings (such as hospitals and educational facilities), leisure facilities, hotels, and commercial buildings that form part of the Better Buildings Partnership (BBP) is shown in **Figure 5.14**. These buildings offer an opportunity to serve as anchor heating/cooling demand customers and help even out demand.

Figure 5.10 City and City Fringe Areas –Domestic Gas Demand Density 2007

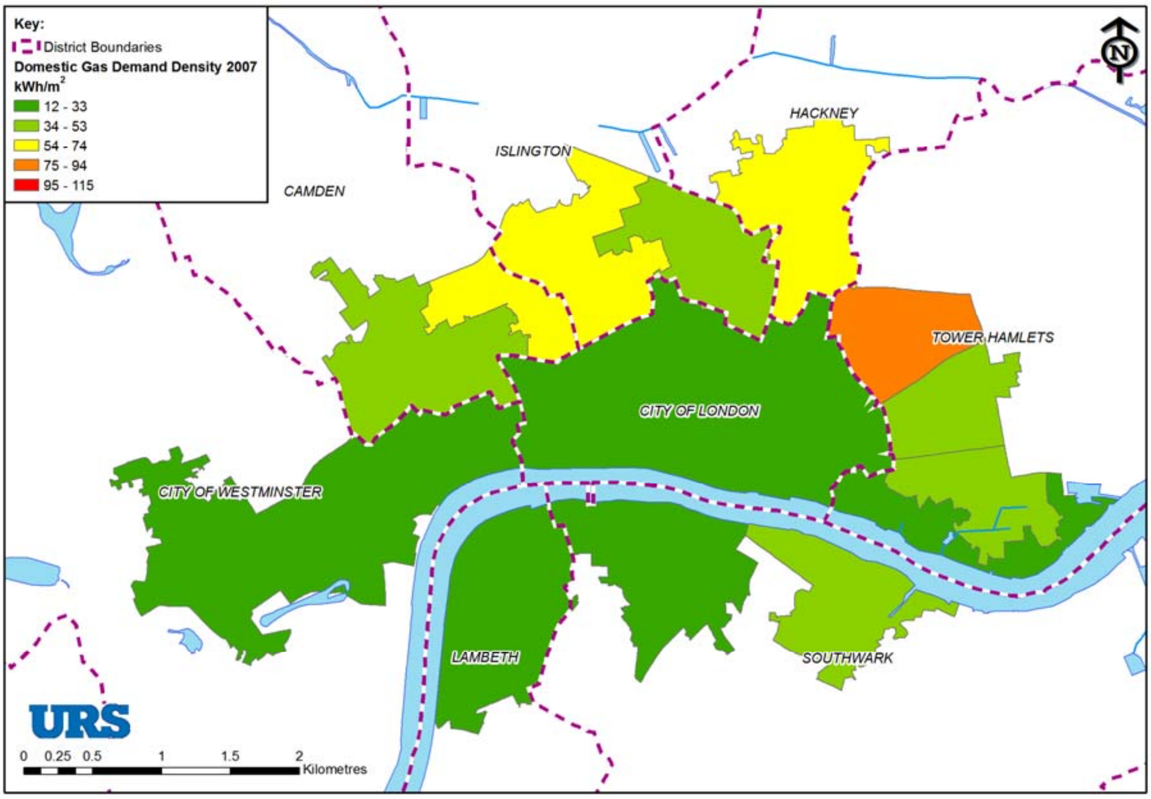


Figure 5.11 City and City Fringe Areas –Domestic Gas Demand Density 2026

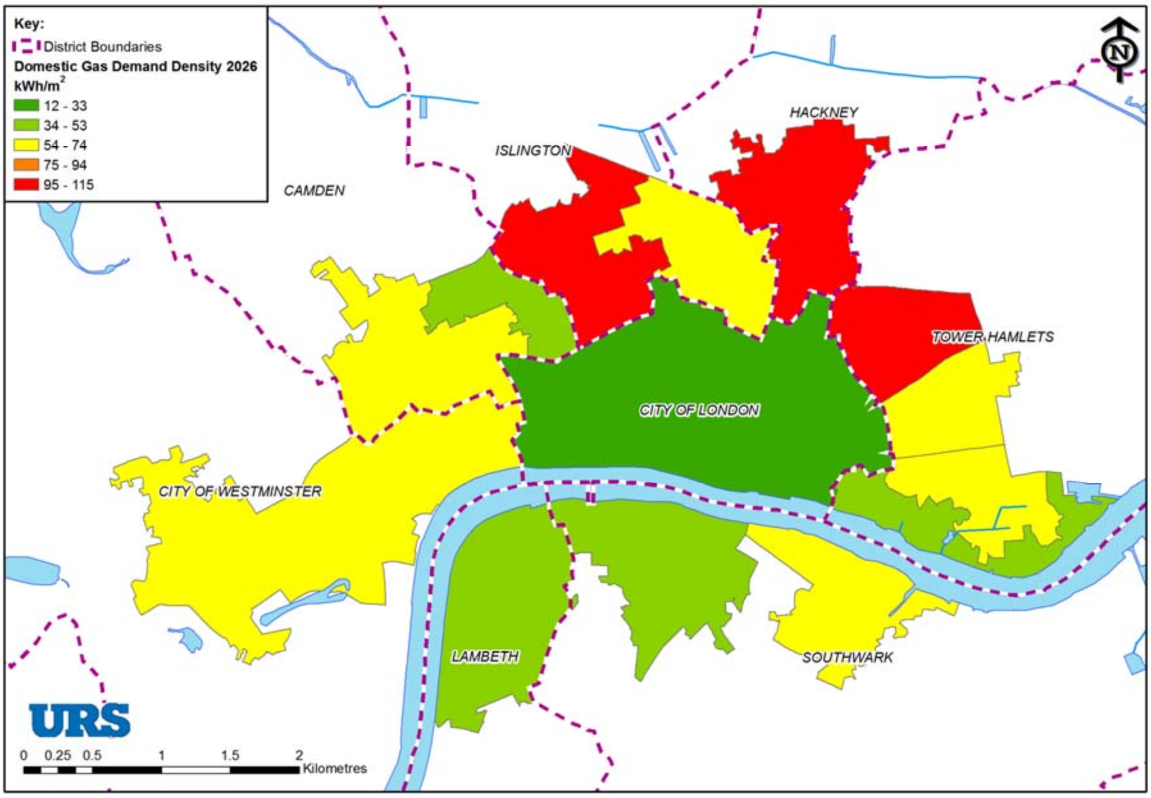


Figure 5.12 City and City Fringe Areas –Domestic Electricity Demand Density 2007

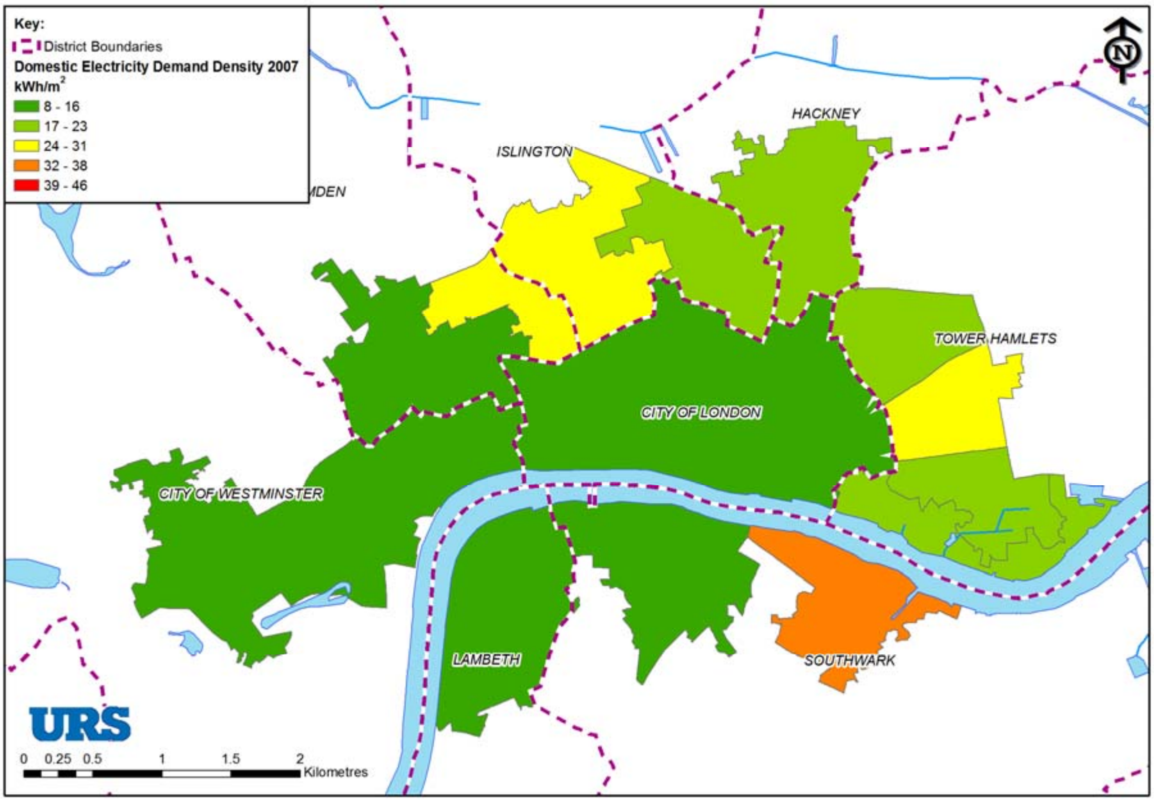


Figure 5.13 City and City Fringe Areas –Domestic Electricity Demand Density 2026

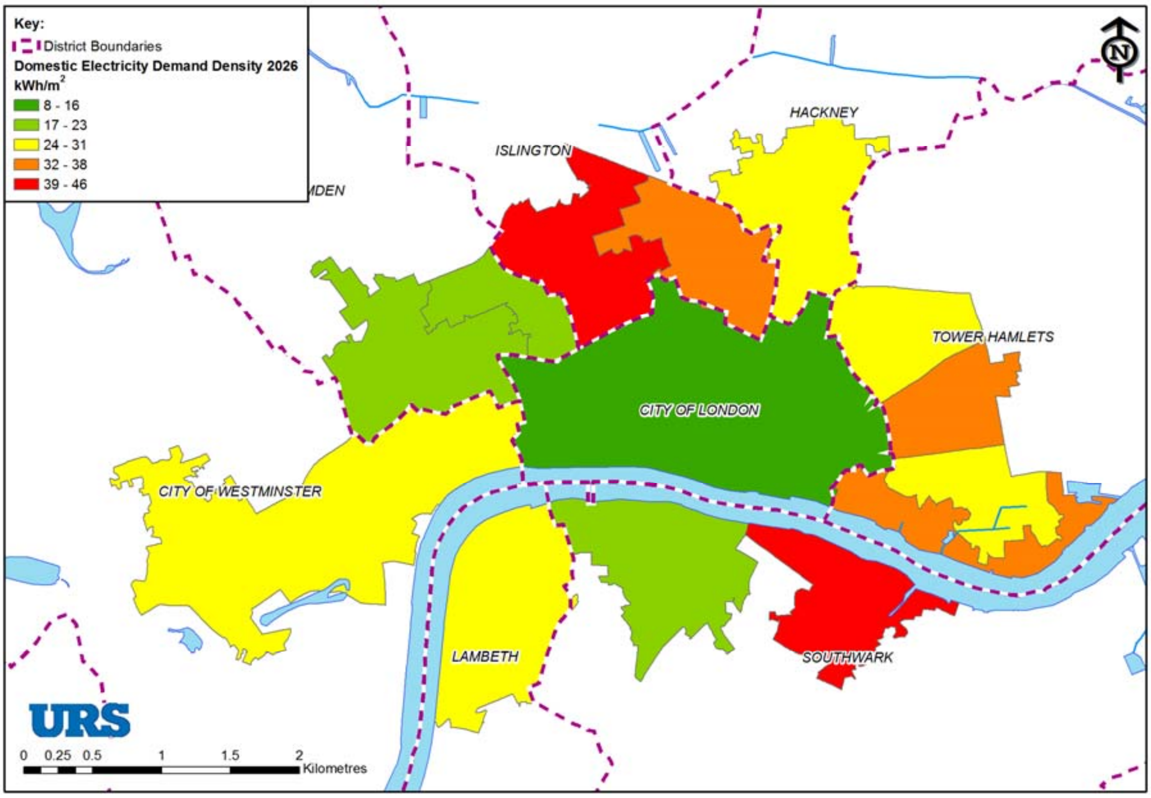
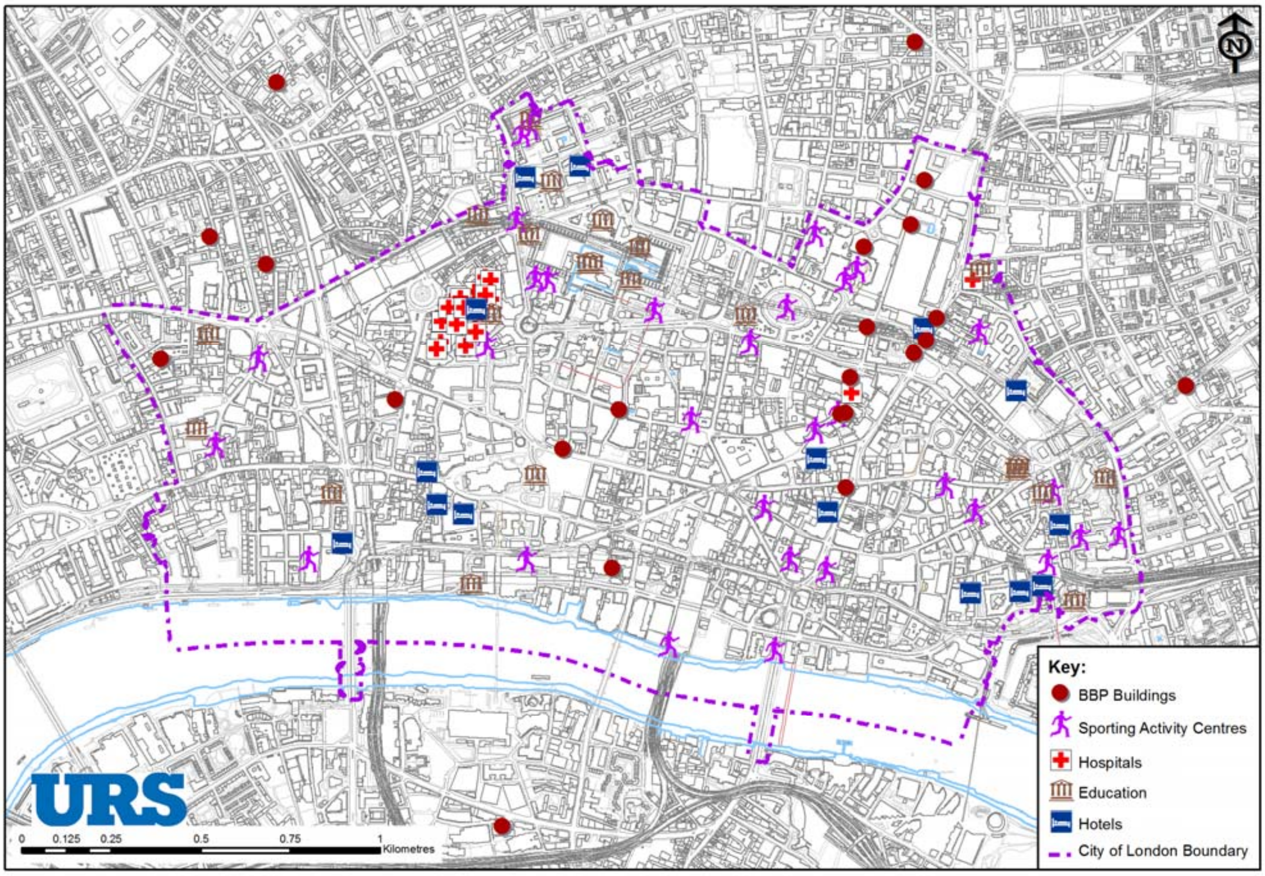


Figure 5.14 Other Land Uses



5.5 Decentralised Energy Plant Capacity

Annual energy consumption profiling is the next step into determining the optimum decentralised energy plant capacity. The data taken into account when carrying out this analysis is as follows:

- The electricity and gas consumption data[14] for the City of London (domestic and commercial/industrial)
- The forecast electricity and gas consumption data, based on the predicted growth in commercial floorspace and residential units[15] for the City of London
- The proportion of gas consumption attributed to the space and domestic hot water (DHW) heating demand for the domestic and commercial land use (based on typical energy consumption end use breakdown)
- The proportion of electricity consumption attributed to the cooling demand for the commercial land use.

The mixture of commercial/industrial and domestic land uses indicates that the City of London is dominated by commercial land use. This is further demonstrated by the forecast 'Annual Heating/Cooling Consumption Profile', shown in **Figure 5.15**, where it can be seen that the space and DHW heating demand for office buildings is substantially higher than that for the housing stock. Accordingly, it is the energy demand profile of the commercial office buildings that should guide the determination of the most appropriate decentralised energy plant capacity.

The energy consumption profile of the commercial/industrial building stock was estimated based on representative energy consumption end use breakdown for typical commercial office use in the City (i.e. a prestige air conditioned, trader type servicing provision). This was estimated after taking into account the actual heating and cooling base loads of six large office buildings in the City of London[16] (**Figure 5.16**).

Figure 5.15 Annual Heating and Cooling Consumption profile for the City of London

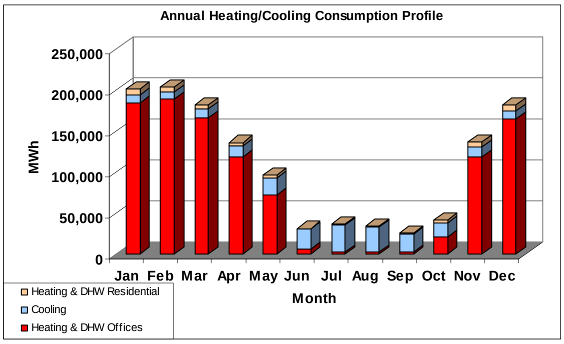


Figure 5.15 indicates that there is minimal space and DHW heating demand for office buildings between June and September. However, a cooling demand is demonstrated for office buildings throughout the year. The relatively constant cooling demand is the key driver in determining that the most appropriate decentralised energy (CCHP) plant capacity to meet the current and forecast energy demand in the City of London.

Figure 5.16 demonstrates the typical daily total cooling demand profile for the City of London (mid-season type parameters).

If all of this demand could be captured, the baseload cooling demand indicates a CCHP capacity of 50MWe/70MWth is appropriate for the City of London.

The initial CCHP sizing exercise offers an opportunity to support not just the energy demand requirements City of London but also the energy demand requirements of the City Fringe areas. The capacity has been assessed on the basis of an optimal sizing arrangement and considers the current and forecast energy consumption of the entire City of London.

If other land uses (as discussed above) can be connected this could help increase the base load requirements and overall efficiency.

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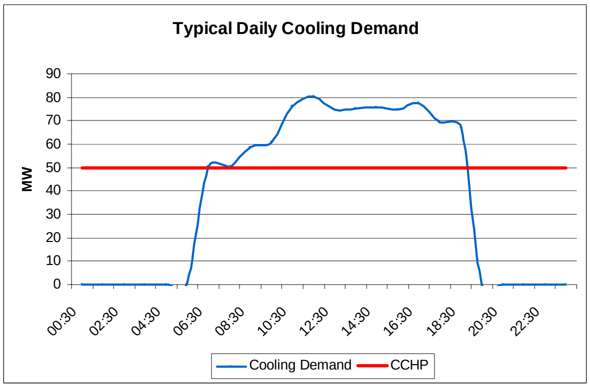
[14] BERR, 2007
[15] URS calculations for City of London Carbon Footprint Study 2008
[16] British Land, Broadgate Estates Site-Wide Energy Strategy, Study Appraisal of Energy Supply Options, September 2007, HOARE LEA Consulting Engineers

Figure 5.16 Estimated total cooling demand for the City of London



5.6 Connectivity and Viability

Estimating the optimal CCHP capacity and delivering a decentralised energy network is well understood where the buildings to be connected are known. The efficient operation of the identified 50MWe CCHP scheme assumes both new developments and existing buildings will be connected.

This assumption may not potentially reflect the actual situation for a number of reasons.

The first issue is the realistic quantification of anchor customers which are necessary to support the financial viability of a decentralised energy network. The location and type of potential anchor customers have been identified in **Figure 5.14**.

However, the compatibility of existing buildings to connect to a decentralised energy network must be assessed to determine feasibility. It should be assumed that only a proportion of existing buildings will allow for connection to a decentralised energy network due to incompatibilities of the building services arrangement with a decentralised energy network. It may be that only when major refurbishment is triggered in existing buildings will the connection to a decentralised energy network become feasible.

In assessing potential demand from surrounding public sector housing we have also considered the potential for a decentralised energy network to alleviate fuel poverty. Further details are given in **Appendix 2**.

CHP/CCHP installations over recent years have also been driven by, and located within, new property development. While decentralised energy schemes can be viable in new development there are limitations as to what capacities could be delivered to support surrounding development. Incorporating CHP/CCHP into a new development, even where undertaken under a common ownership and co-ordinated construction programme, can be challenging. The challenge is much greater when contemplating creating strategic decentralised energy networks which involve connections to multiple new developments and existing buildings.

In contrast to the provision of electricity and gas, there is currently no heat supply legislation/regulation to protect consumers. In the absence of heat supply regulations, guarantees of service or a heat regulator to protect consumer interests, new developments tend to incorporate a low or zero carbon energy source but this is nearly always provided on or near site and specifically to serve the development, rather than in the form of a decentralised energy network connection.

These limiting factors for existing and new-build properties are anticipated to result in a difference between the potential anticipated demand in the City and the actual anticipated demand.

There are also a number of policy drivers that suggest increased interest in and demand for suitably priced CHP systems. The policy framework is outlined in Section 2 and examples of relevant drivers include national, regional and local planning policy and schemes such as the CRC and forthcoming Renewable Heat Incentive (RHI).

5.7 Conclusion

A demand assessment has been undertaken for the City and City fringe areas. A profile analysis of the gas and electricity consumption has determined that an appropriate CCHP plant capacity of 50MWe/70MWth could be an appropriate size of capacity to plan to serve the City and City fringe areas provided certain conditions of take-up are met.

The potential to expand into neighbouring boroughs may offer a way of managing the imbalance risk associated with a potential gap between supply and demand, particularly when considering the existing Citigen 30MWe CCHP capacity.

6 CONSTRAINTS ANALYSIS

6.1 Introduction

The purpose of this section is to identify the physical and associated constraints to developing an extended pipe subway and/or decentralised energy network. Key constraints identified include:

- Foundations
- Existing utilities
- Existing tunnels
- Archaeology
- Consents for street works.

Information on some of these constraints, such as the historic Ministry of Defence tunnels infrastructure, has been difficult to access and may only come to light once specific proposals are put forward.

6.2 Foundations

The City's existing utility infrastructure network generally follows the City's road network, located beneath the roads and roadside pedestrian walkways. The roads network is shown in **Figure 6.1**. Buildings and their foundations are located on most of remaining land in the City. We anticipate that for most new pipe subways it will be easier to build pipe subways beneath public roads (and possibly public building spaces) than it is to build under privately owned property.

Foundations refer to the part of a building or structure located below the surface of the ground. Their purpose is to distribute the weight of the building or structure and all live loads over an area of sub grade large enough to prevent settlement and collapse[17]. In general, design of foundations of buildings is determined by a number of factors such as the size and structure of the building and environmental constraints such as the nature of soil. Newer and taller buildings tend to have deeper foundations and piles, going as deep as 30 to 40m below ground.

Extending the pipe subways network is likely to involve work digging underneath streets. Foundations are thus unlikely to be a significant constraint as the width of the foundations is not likely to extend into the streets. There are however, likely to be constraints posed if extension works are to be conducted closer to the buildings.

6.3 Existing Utilities

The City's existing utility infrastructure network suffers from congestion below ground in many locations (see **Figure 6.1** for most constrained streets). This presents a challenge because there is limited space to divert existing pipes/ducts to allow for digging the new pipe subways. Ideally then, a new pipe subway should be located where there is sufficient space to relocate the existing utility infrastructure while tunnels are being dug.

Non-cut and cover technologies for digging new tunnels will help avoid issues of needing to divert existing utilities. However the existing sewer system is generally located beneath other utilities and there may be issues of fitting in new tunnels with the sewer system.

Local sewers are typically located around 4-6m below street level – a similar depth to that of any new pipe subways, and therefore the City's existing sewer network presents a constraint to the development of an extended pipe subway network.

It is possible that some existing sewers could need to be temporarily diverted or permanently rerouted – as was the case when the City laid many of its existing pipe subways.

Thames Water have been contacted with respect to obtaining sewer network records and this information will be considered in further detail during the options appraisal stage, to help inform options for an extended pipe subway network.

Utilities located in the City's existing cable tunnels potentially are also an issue. As these cables and pipes generally go in to headwalls (see pictures in Section 3) care will be needed to locate them to avoid damage during construction of extensions to the existing tunnels[18].

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[17] ASDC: The International Association of Foundation Drilling

[18] Application of HSG47 (Avoidance of Danger from Underground Services) provides guidance as to best practice when working in the vicinity of underground services.

6.4 Existing Tunnels

Spare capacity in existing tunnels is a potential opportunity (see Section 3) but existing tunnels can also be a constraint on the development of new tunnels.

In particular information from EDF suggests that the Circle Line is a significant constraint on bringing in new capacity to the City. Its shallow depth and alignment together with the Thameslink route create a restrictive collar around the City (see **Figure 6.1**). Generally the space above the Circle Line is too congested to put in additional utilities cables and there is a significant cost in taking new connections under the Circle Line.

Although the Circle Line is operational it is possible that there is spare space to potentially use for utilities[19]. However the use of existing LU assets might create issues that could be difficult to address:

- 24/7 maintenance cannot be guaranteed
- Issues during installation, might be restricted to engineering hours only
- Legal constraints
- Ownership constraints.

A number of the other existing tunnels, such as the Post Office Tunnel, are probably too deep to be economically used for local distribution.

6.5 Archaeology

Any excavation for the proposed tunnel network could potentially affect archaeological remains.

Archaeological remains in the City can be present up to 6m below the surface. Proposals for extending the pipe subway network may therefore affect scheduled monuments. Consent is necessary for any work that may affect a monument or its setting. There is a presumption in favour of the preservation of monuments in situ, i.e. to remain undisturbed. Scheduled monuments are shown in **Figure 6.1**.

A more detailed archaeological assessment will be needed at a later stage to assess the routes of the proposed tunnels. This can be used to inform a discussion on the acceptability of the impact on archaeological remains, alternative solutions that leave archaeological remains undisturbed where appropriate, and an appropriate mitigation strategy.

Unexploded ordnance can also be a constraint/additional cost.

6.6 Consents for Street Works

Tunnelling operations, including potential relocation of the existing utilities networks, may involve works at street level with associated disruption. Closing or restricting routes for use by pedestrians and vehicular traffic has associated wider economic costs, including to local businesses[20]. These impacts may lead to political sensitivities and additional costs to the tunnel developer in terms of negotiations over permits and disputes[21].

6.7 Conclusion

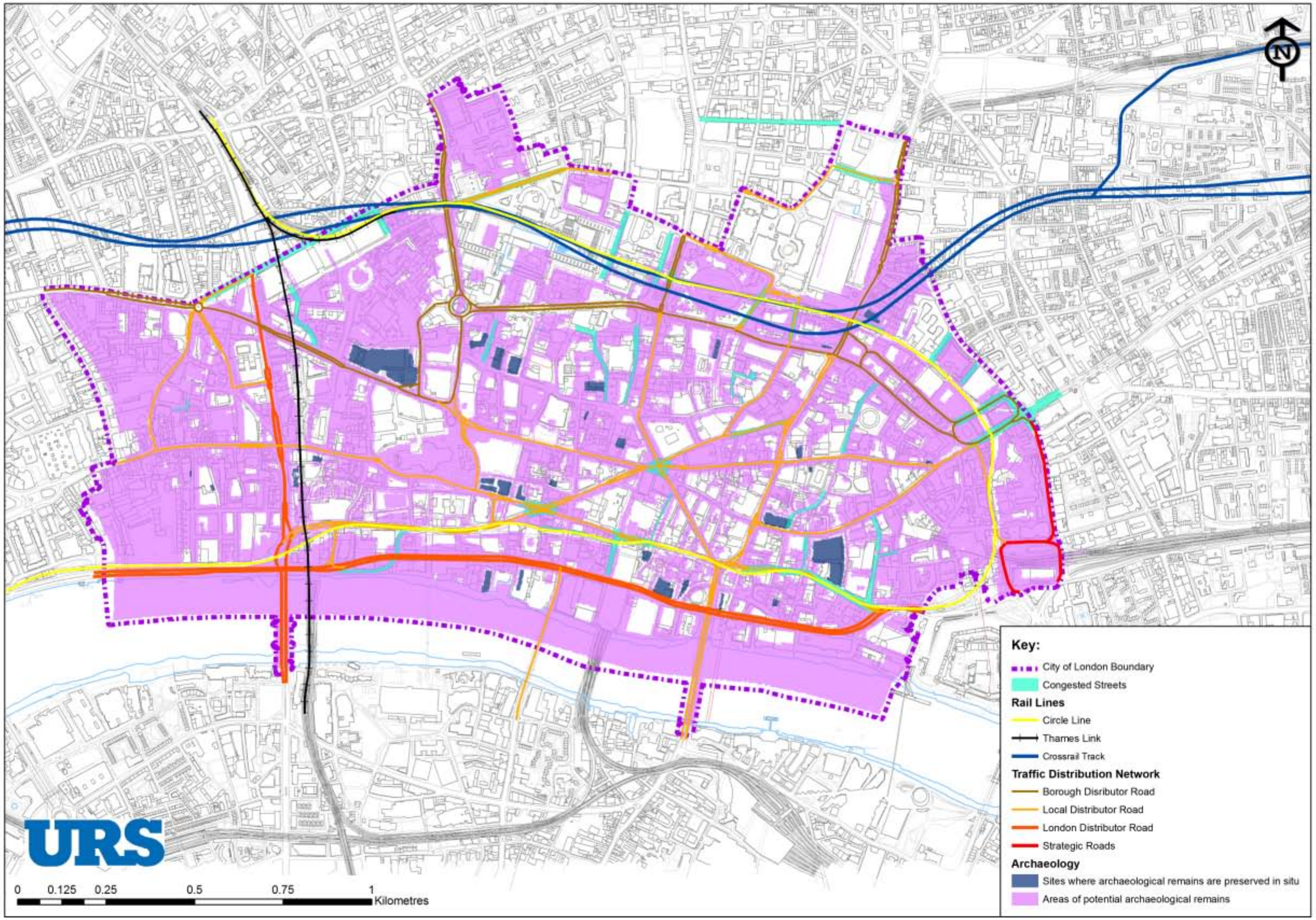
Foundations, existing utilities, tunnels networks and archaeological remains could all pose constraints on options for expanding the City's tunnels network and/or decentralised energy systems. While it is difficult to predict the severity of the individual constraints at this stage, detailed assessments of each should be conducted at a later stage of the process.

[19] The Circle Line was built as a cut & cover box and we understand that the underground trains do not take up all the space created.

[20] Transportation is said to be one of the key priorities for business and a top 10 issue for incoming businesses to an area. (Cushman and Wakefield (2009), European Cities Monitor).

[21] A survey by London First indicated that 74% of businesses highlighted the reduction in the impact of roadworks on traffic as a main concern (London First (2009), Congestion and Roadworks in London: A Business Viewpoint, GLA)

Figure 6.1 Physical Constraints



7 TECHNOLOGIES

7.1 Introduction

This section reviews technologies relevant to the design and construction of both tunnels and decentralised energy. The technologies indicated will be relevant to development of options and minimisation of costs.

7.2 Tunnel Technologies

In order to link individual elements of existing underground structures to a connected system new horizontal and vertical structures will be necessary to link existing assets.

Underground construction is in general an expensive, time consuming and disruptive activity. Out of several technologies that can deliver the necessary underground space the following are deemed most appropriate for these connector tunnels and are competitive for this application.

Cut and Cover

For shallow stretches of new pipe subway tunnels or short links between existing subways cut and cover methods might be the most cost effective, especially if no man entry needs to be provided. The construction operation involves excavating a trench, providing the route for the pipes and closing it again.

If man entry is needed to provide access and maintainability of the pipes within the pipe subway or box culvert, construction becomes more complex since the size of the underground space increases substantially.

The surface would be opened up and steel sheeting or piles can be utilised to support the excavated trench. In some cases temporary trench support can be utilised.

A roof slab on structural pile walls can provide early decking for resurfacing to reduce disruption time to traffic. Within the created opening a concrete structure can be constructed providing the underground space after backfilling and covering this concrete box. The concrete box can be cast to withstand the loads of the backfill and surface traffic. Disruption time can only be reduced, not eliminated.

All cut and cover techniques involve digging from the surface, and as this would mean digging up of roads in the City, traffic would need to be detoured. All existing services and utilities would need to be identified, surveyed, relocated, and reconstructed or incorporated into the newly constructed pipe subway tunnels along the entire stretch of the new tunnel. A large number of existing utilities are expected to be found within the CoL. Structures such as Victorian water mains and sewers are likely to be susceptible to disruptions caused by new construction.

Trenchless Technologies

Pipe jacking and micro tunnelling (small diameter Tunnel Boring Machines, TBMs) , are techniques for installing underground pipelines, ducts and culverts.

In pipe jacking powerful hydraulic jacks are used to push specially designed pipes through the ground behind a shield at the same time as excavation is taking place within the shield.

Small diameter TBMs use a steel shield not only to excavate the ground but also to allow for the tunnel lining to be assembled from (pre-cast concrete) segments.

Both methods provide a flexible, structural, watertight and finished circular pipeline as the tunnel is excavated.

There is nearly no maximum technical length limit. However, there is a minimum length (usually a few hundred metres) from which these highly mechanised techniques start becoming competitive against less mechanised options (i.e. hand mining).

Alignment of the pipe subways can be chosen to be located clear of shallow existing utilities and would need to be carefully threaded through the busy CoL underground and above or beside other deeper tunnels. No utility relocation along the alignment is necessary.

In order to install branches or stretches of a pipe subway using this technique, thrust and reception pits need to be constructed, usually at positions specifically chosen off busy streets, free of major utilities providing manholes and connections to existing parts of a network. Pit sizes will vary according to the excavation methods applied. Depending on size, surface access, ground conditions and depth of the pits techniques for their construction will be locally chosen.

Hand Mining Technologies

Hand mining techniques, such as Sprayed Concrete Lining (SCL) and traditional timbering have in common that they use little mechanized equipment, are labour intensive and have a sequential excavation pattern. They are usually competitive for short stretches of tunnels (box headings up to 10m, SCL up to 100m) and should be used for connections and/or branches of the deeper parts (20m below ground) of the pipe subway.

Whereas SCL utilizes sprayed concrete to immediately provide a stiff support (thin ovoid shell) around the excavated opening, box headings rely on heavy concrete and steel support for short square-shaped openings and connections.

Inherent to all mining techniques is that the entire extent of the operation is below ground and can be below existing utilities, allowing them to remain untouched. However, starting structures are necessary, which are usually at positions specifically chosen off busy streets, clear of major utilities.

Vertical Structures

For the pipe subway network deep existing structures will have to be connected to shallow new or existing branches. These vertical structures can also serve as starting shafts for branch constructions. Shaft technologies differentiated by the nature of the shaft lining are:

- Precast segmental lining
- SCL lining
- Steel sheeting

Often these techniques are combined within the same shaft structure to benefit from their individual advantages.

7.3 Tunnel Development Timeframes

The time from the conceptual idea of a new tunnel to it being put into service can roughly be divided into the following seven phases:

- Alignment studies
- Site investigation (geology, hydrogeology)
- Conceptual design
- Approval in principal (permits, utility relocation)
- Detailed design
- Construction (shell)
- Outfitting.

Each phase is dependent on the boundary conditions of the individual tunnel stretch such as:

- Stakeholders (neighbours)
- Alignment (right of way)
- Geology
- Hydrogeology.

Whereas duration and construction cost can generally be estimated, the rest of the design work and permitting and approval processes need more detailed project related work to show the full amount of time and effort necessary to receive approval for the individual project sites.

Rules of thumb on construction times are as follows:

- Horizontal extended structures
  - Cut and Cover: (100m in 30 working days[22])
  - Pipe Jacking: (100m in 10 working days[23])
- Vertical connection structures / pits
  - Cut and Cover
    - Shaft sinking technologies: Precast lining, SCL lining, secant pile lining, and raise boring and steel sheeting.
- Construction time is very much dependent on location, access, geology, depth and technology.

7.4 Decentralised Energy Technologies

The table set out in **Appendix 3** draws upon our experience of implementing CHP technologies on a large scale and in an urban context. A series of considerations are set out for each technology option, including:

- A description of the technology and plant arrangement
- Advantages and disadvantages
- Current situation
- Future opportunities
- Capital and operational expenditure
- Energy centre space requirements
- Benchmark costs
- Net present value.

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[22] Assuming coherent stretch of 100m, 2m deep
[23] Assuming continuous stretch of 100m between two pits, pit construction not included.

These considerations are discussed based on available data and take into account deliverability within the City or City Fringe areas. A summary is presented below.

Combined Heat and Power (CHP)

CHP denotes the principle of the simultaneous generation of usable heat and electricity. Conventional power generation usually dissipates the heat generated using cooling towers, wasting a considerable amount of energy. With CHP, this heat is used for domestic or commercial heating or for process heat demands. Combined Cooling, Heat and Power (CCHP) denotes the principle of the simultaneous generation of usable heat and power, with a proportion of the heat being used to generate cooling via an absorption chiller plant.

CHP installations can typically convert between 75% and 90% of the energy in the fuel into electrical power and useful heat. This compares very favourably with conventional power generation, which has a delivered energy efficiency of around 30-35% due to the non-utilisation of the waste heat energy, and distribution losses in the grid infrastructure.

Biomass CHP

Biomass replaces fossil fuels and can help to reduce other greenhouse gas emissions, particularly methane emissions, by diverting woodfuel waste from landfill.

Wood is present in all three of the main waste stream classifications: municipal, commercial/ industrial and construction/demolition. It is also the main constituent of arboricultural waste from tree surgery operations in London. These waste streams give rise to approximately 127,000 tonnes per year[24]. The potential for woodfuel from forestry operations around London has been estimated at 2,195 oven dried tonnes per year within London (from 6,700 ha of woodland), and at 63,441 oven dried tonnes per year around London (40km radius)[25].

Combustion of biomass has traditionally been used in stoves, but use in boilers is increasingly common because of improved efficiencies and reduced air quality impacts.

Biomass can also be used in CHP plants, and for generating electricity. Heat is a by-product of the electricity generation process from biomass. Utilisation of this by-product through a local heat distribution network can improve operational efficiencies, leading to a significant increase in carbon dioxide emissions savings.

The sale of electricity from biomass CHP generation can also provide a source of income: 2 ROC/MWh (ROC value is £45/MWh), whilst the FiT is 9p/kWh, with a bonus of 5p/kWh if the electricity generated is exported.

Anaerobic Digestion Biogas CHP

Anaerobic Digestion (AD) is a process that uses micro-organisms to convert biomass feedstock to biogas. The process can use a wide variety of feedstocks, including the organic waste streams associated with residential and commercial processes. The biogas can be burned for heat and/or power production, or be compressed and used as a transport fuel.

Biogas replaces fossil fuels and can help to reduce other greenhouse gas emissions, particularly methane emissions, by diverting organic waste from landfill.

The City is carrying out food waste collections from their four estates (this includes Barbican collections which are currently being rolled out). The tonnage collected is approximately 4.2 tonnes per month. Funding has been sought to extend this to all private housing blocks and this could increase the tonnage to around 10 tonnes per month. The largest potential relates to commercial food waste collections and the City has recently commenced a trial with around 10 businesses. This has huge potential but a drawback is that the price of collections are high due to distance food waste then has to be transported – presently being transported to Bexley. A requirement for closer waste handling facilities has been expressed by the City as this would be beneficial to support the comprehensive roll out of organic waste collections.

The sale of electricity from biogas CHP generation can provide a source of income: 2 ROC/MWh (ROC value is £45/MWh), whilst the FiT is 11.5p/kWh, with a bonus of 5p/kWh if the electricity generated is exported.

Syngas Derived from Gasification CHP

[24] Based on a recent study conducted by Bioregional and the London Tree Officers Association
[25] Taken from the Future Energy Solutions 2002 Study

Gasification produces a gas (or syngas – synthetic gas). This is utilised in a gas turbine/engine process. Gasification differs from mass burn because the waste is heated in a high temperature process the decompose waste into simple gaseous molecules (primarily hydrogen, carbon monoxide and carbon dioxide).

Gasification technologies are capable of higher levels of efficiency of electricity generation than combustion technologies, with cleaner flue gases and residues.

The sale of electricity from biogas (AD) CHP generation can provide a source of income: 1 ROC/MWh (ROC value is £45/MWh).

Incineration

Incineration is the combustion of waste in an excess of oxygen. Incineration is used throughout industry, particularly for medical waste and high-hazard material. Incineration and other thermal waste treatments can reduce the volume of Municipal Solid Waste (MSW) by 90% and its weight by 75%. The UK has about 60 incinerators burning MSW, chemicals, clinical waste and sewage sludge. Thirteen of these burn MSW, and two use Refuse Derived Fuel (RDF). After incineration, the waste is converted to carbon dioxide, water vapour and ash (this varies in chemical composition based on the make up of the waste).

7.5 Conclusion

Generally the most feasible technology for the City is natural gas fired CCHP plant. This is due to limited resource availability of biomass from City operations (e.g. tree surgery, etc.) and key strategic sites being identified outside of the City's boundaries; and the uncertainty of whether Anaerobic Digestion (AD), gasification and incineration (i.e. EfW) facilities could be supported within or near the City's boundaries.

8 ENERGY CENTRE LOCATIONS

8.1 Introduction

An energy centre should be located in close proximity to sites with a continuous heat load. Consequently, areas most suited to an energy centre are those identified based on the densities of heat demand, locations of existing heat networks, and locations of key existing building 'anchor tenants'.

Furthermore, adequate land within the City is required to accommodate a decentralised energy centre. This may be particularly challenging in an area where land prices are high.

8.2 Approach and Criteria

Areas with increased current and forecast heat demand represent large single point demands and therefore offer a potentially appropriate location for establishing an energy centre. Such areas may include clusters of public buildings, such as:

- Hotels
- Hospitals
- Housing estates
- Schools; and
- Leisure facilities.

After identifying potential areas within the borough, more specific locational criteria have been applied to screen for potential sites. These criteria include:

- Size: sites must be of sufficient size (i.e. 15,000m^2 – 25,000m^2) based on an installed CCHP capacity of 30 – 50MWe. This size range can be either a footprint or multi-storey area, or a site that can be developed to accommodate this floorspace provision. Land use needs to be considered, i.e. industrial, in order to support a planning application.
- Proximity to the City: sites to generally be within a 1km range of Bank
- The eastern cluster of the City is likely to demonstrate the greatest energy demand, thus sites identified in or around the eastern cluster including the City Fringe areas could be deemed appropriate
- Investigate the potential of locating energy centres in proximity to housing estates, including those that will be subject to major refurbishment in the near future
- Opportunities should be sought to re-use and expand existing decentralised energy infrastructure, consistent with the Mayor's 'Powering Ahead - Delivering low carbon energy for London' report which discusses a number of such schemes in and around the City of London. As illustrated in Figure 5.1 in this report.
- Investigate the potential of locating the energy centres in existing/redundant infrastructure subject to major refurbishment boiler houses. Opportunities to extend the existing structure also offers benefits and should be considered
- Opportunities should be sought to re-use existing buildings (e.g. redundant/derelict warehouses)
- Potential sites should have adequate buffer zones between them and the nearest residential (or other sensitive) properties/receptors (buffer zones could be car parking, landscape planting, open space, etc.)
- Sites should have adequate access arrangements
- Sites can be located at basement, grade or roof level, provided there is suitable access for plant maintenance/replacement
- Sites should not be immediately surrounded by tall buildings as this will impact on chimney heights. The chimney height will need to be greater than the adjacent building(s) to ensure there is no air quality impacts
- Under used railway sidings should be assessed as potential energy centre locations where there is appropriate access
- The City of London owned Storage Depot, Great Eastern Street, Shoreditch should be assessed as a potential site noting that redevelopment will be required to support the floorspace requirements.

8.3 Findings

Nineteen potential sites for the development of a new energy centre have been identified by GVA Grimley: five of the six sites are located to the north of the City, and one to the south east. These sites are indicated in Figure 8.1

Bishopsgate Goods Yard, Shoreditch High Street, EC2

The Site is located on the northern edge of the City of London and Shoreditch. It comprises of

69,702 m2 (750,000 sq ft) of brownfield land which has remained unused for some 40 years.

It lies within the borough of Hackney, and Tower Hamlets and is bounded by Shoreditch High Street to the west, Bethnal Green Road to the north, Brick Lane to the east and Quaker Street to the south.

The freehold is currently owned by Hammerson/Ballymore, who also own a 750,000 sq ft development site on Fore Street, EC2, immediately south of Moorgate Station. It has been suggested that in order to obtain planning permission for this second development site, it may be necessary to undertake a planning obligation which provides for space at Bishopsgates Good Yard to be set aside for the development of amenities and services that serve the City as a whole. Thus, making an ideal location for an additional power station to supply the City.

The site is located on the north eastern fringe of the city, in a predominantly residential area. Subsequently the area surrounding the site is relatively low rise in comparison to the other identified sites and would mean that the extra cost of raising chimney heights would be avoided.

The site has also been identified as a major regeneration opportunity in existing and emerging planning guidance including:

- City Fringe Area Action Plan (London Borough Tower Hamlets).
- South Shoredicth SPD & Emerging Core Strategy (London Borough Hackney).
- Draft City Fringe Opportunity Area Planning Framework (Greater London Authority)

Two major trunk roads lie to the north western corner of the Site, Commercial Street – A10 and the A129 – Bethnal Green Road providing good accessibility to and from the Site.

Trinity

The primary site is 28,461 sq m (306,351 sq ft) in area, located to the south east of the City in Aldgate. The Site is owned by Beetham and has been earmarked for future office development. In addition there is potentially a further 700,000 sq ft of development land also in the ownership of Beetham.

The site is bounded by Goodman's Yard to the south, Aldgate High Street to the north, Mansell Street to the east and Minories to the West.

Citygen (London) Ltd, 47 – 53 Charterhouse Street, EC1M 6PB

This is currently an energy plant, operated by E-ON that is partly under utilised. The site consists of floors that are approximately 50m x 50m. The plant contains a total 9 floors, of which 6 are currently fully utilised and 2 are partly utilised as is the capacity in the basement.

Leonard Street / Tabernacle Street

Located to the south east of Old Street station. The Site consists of derelict offices and warehouse buildings; a car park located at sub-basement level. The Site is bounded by a mixture of office and residential buildings which are of low-medium height.

Royal London Hospital, Whitechapel Street

Tower Hamlets, E1 2AD

The Site has an area of 83,249.24m^2. It is publicly owned, and has previously been developed but is now vacant. The Site has good road access, situated on the A11, with three bus routes passing the Site. The Site is located opposite Whitechapel tube station. (PTAL Rating 6a).

News International Site 2, Pennington Street

Tower Hamlets,E1W 2SG

The Site has an area of 50,792.86 m$^{2.}$ The Site's current and previous land use is offices. The Site has been allocated in the local plan for mixed use including housing. The Site is privately owned. The nearest station is Shadwell DLR, half a mile from Site. Bus routes are local to the Site (Ptal Rating 6b).

Aldgate Union South, Braham Street, E1 8DS

The Site area 13,901.83 m^2 . The site is privately owned, currently used as offices. The Site has been located in the local plan for redevelopment. Proposed use employment B1 and Retail A1 A2 A3 A4 A5. Excellent road access, situated along the A111, with bus routes. Short walk to Aldgate East tube station.

Dunbridge Street, E2 6EJ

The Site area is 28,005.36 m$^{2.}$ The land is currently used, and allocated in the local plan with planning permission where development has not started. The land's previous/current use is industrial.

Site description – PA/02/00117 demolition of building and erection of buildings up to 5 storeys to provide 2 ground floor commercial units B1 with 24 residential units above.

Three bus routes travel along Bethnal Green Road, a five minute walk from the site. Bethnal Green Rail station is close to site (Ptal 3).

Old Truman Brewery, 91 Brick Lane, E1 6QR

The Site has an area of 38,136.82 m$^{2.}$ The Site has previously been developed and it is now vacant. The Site has been designated for a proposed mixed use scheme, and has been allocated in the local plan for redevelopment. Preferred Use: Employment B1: Retail A1 A2 A3 A4 and Public Open Space. Possible contamination on site.

The no. 67 bus route travels along nearby commercial street. The nearest tube station is Aldgate East tube, half a mile away.

City Road Basin, Wharf Road, N1 8JX

The Site has an area of 47,585.69 m^2 . The Site currently consists of vacant buildings. The Site has been allocated in the Local Plan for redevelopment. The Site is an Area of Opportunity A016 Nature conservation area NC4 (Regents Canal East). The site is located off City Road, near Angel.

Some parts of the Site have been granted planning permission (PO60679 for 2 flats granted 12.06.06/ development started for P022771 to provide 83 units as part of a mixed development scheme) PO502729.

News International Car Park Site, Vaughan Way, E1W 1YN

The Site has an area of 20,401.82 m^2 . The site is currently in use, and allocated in the Local Plan for development. The Site is currently used as a car park, and is owned by the Local Authority – Tower Hamlets. The Site is located adjacent to Tobacco Docks Shopping Village.

Prior planning applications provide for the erection of two buildings up to 13 and 27 storeys. However, planning status is still pending a decision and a development brief has been requested to ensure the Site is developed coherently. Residential uses are suitable at eastern end of the site with mixed residential and commercial uses.

Nearest station is Shadwell DLR, half a mile from site. Bus routes local to site.

Tobacco Dock 2, E1W 2SG

The Site has an area of 23,570 m$^{2.}$ The Site is privately owned and currently used for light industry. The Site has been allocated in the Local Plan for redevelopment. The Site have potential contamination.

Royal Mail, Phoenix Place, WC1X 0DA

The Site has an area of 11,773.08 $m^{2.}$ The Site is currently used by the Royal Mail, for storage and warehousing. The Royal Mail are reviewing its operational needs across the sites and it is likely that land will become available for redevelopment. The Site is situated to the south of Kings Cross, off Gray's Inn Road. The site is 0.4 miles from King's Cross mainline rail and tube station; 3 bus routes along nearby Gray's Inn Road.

St. Lukes Library, Lever Street, EC1V 2PU

The Site has an area of 18,961.75 $m^{2.}$ The Site is currently used for indoor recreation. The Site has been allocated in the local plan for redevelopment, however the most recent planning application for this has been withdrawn. The Site is located between Angel and Old Street, off the City Road.Good access to roads, located off City Road (A501); 4 bus routes along City Road and bus routes along Lever Street pas the site; Old Street Tube Station is 0.4 miles away.

Fruit and Wool Exchange, Brushfield Street and Commercial Street, E1 7NF

The Site has an area of 9,742.57 $m^{2.}$ The site was previously used for retailing bit is now used as a car park. The Site has been allocated in the local plan for redevelopment. Demolition of existing buildings and structure and redevelopment to provide a basement and lower ground floor plus six storey mixed use development comprising A1 B1 and A3.

The Site is located along Commercial Street (A1202), which has one bus route. Other bus routes local to site. The nearest station is Aldgate East tube, a five minute walk from site. Old Spitalfields Market is located adjacent to the Site. Possible contamination issues.

Finsbury Square, EC2A 1AD

This site comprises of approximately 3,560 m2 (38,320 sq ft) of open space, located to the north of the City and is currently used as an underground car park.

The freehold is owned by The Corporation of London and the Site is currently let to NCP, who operate the 258-space underground car park.

There is a degree of flexibility in NCP's current lease, and this sight may become vacant in the near future, thus being potentially available for redevelopment. However it is unlikely that such a site will provide enough space/ headroom for an energy centre. And, as with the HAC playing fields there is likely to be restrictions on the flue height.

No.10 Finsbury Market/ Appold Street EC2

The Site comprises 2 5,684 m2 (61,166 sq ft) of land that is currently used as an electricity sub-station and already houses existing works on the site. The site is both owned and occupied by EDF energy.

The site is bounded by Pindar Street to the south, Finsbury Market to the North, Clifton Street to the west and Appold Street to the east. It is best accessed from the east via Appold Street. B roads surround the site; however, there are two major trunk roads located directly north of the site – Great Eastern Street – A52-2 and Shoreditch High Street – A1209.

It is thought that there would be little or no available space here to provide for an additional power sub-station. In respect of location, it is though inappropriate to be located next to a direct competitor.

Hearn Street, EC2 3LS

The site comprises 3 1,561 m2 (17,773 sq ft) of derelict and mixed use warehouses, that currently offer a redevelopment opportunity. The Site is both owned and occupied by EDF energy. An electricity sub station is currently located to the south and south eastern corner of the site.

It is bounded by Hearn Street to the south, Plough Road to the east, Curtain Road to the West and Hewett Street to the north. Principal vehicular access would be via Plough Road to the east of the Site which adjoins the A10 at the junction of Commercial Street and Great Eastern Street.

Whilst this site provides better access in terms of location compared with 10 Finsbury Market, it is again located next to an EDF energy centre and therefore unlikely to seem a viable site.

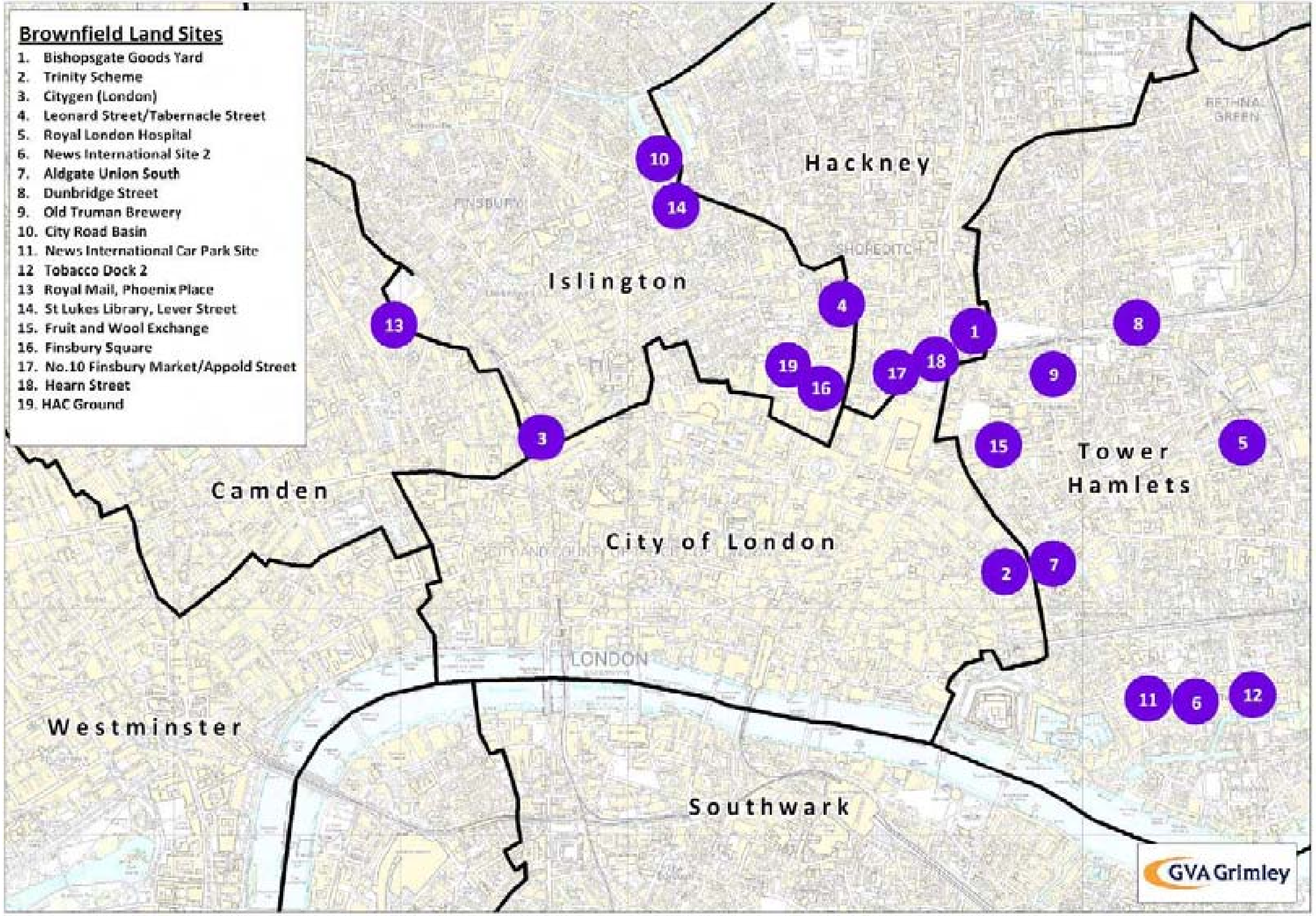
HAC Ground, EC1 2BQ

This site comprises of 24,609 m2 of open space, currently used as playing fields. It is located to the north of the City and is bounded by Chiswell Street to the south, Bunhill Row to the west and City Road to the east. The site's principal vehicular access would be from City Road at the north eastern aspect of the Site or Chiswell Street to the south.

Bunhill Fields Burial Ground is located directly north of the Site, which could act as an adequate buffer zone between the energy centre and residential developments located within proximity to the Site.

The Freehold is owned by the Ministry of Defence. The Site has underground storage, currently used by the HAC for the storage of tanks and heavy duty military machinery. Due to this fact it is unlikely that a new energy centre can be located here. Similarly there are also height restrictions on the flue as it comes close to or within St Paul’s viewing corridor.

Figure 8.1 Potential Sites for Energy Centres



9 COSTS

9.1 Introduction

There are likely to be significant costs incurred in developing pipe subways and decentralised energy. An assessment of unit costs is presented below. These unit costs are used as a basis for calculating overall costs of options.

9.2 Tunnel Costs

Capital Expenditure (CAPEX)

Tunnelling capital costs can be divided into:

- Hard costs for the actual construction of the structures.
- Soft costs for design, liaising with stakeholders, permits, site investigations, traffic management, utility relocation, monitoring, and emission control, etc.

The hard costs can generally be estimated up front and are dependent on:

- Construction technique
- Depth (for cut and cover)
- Size of the structure
- Geology and hydrology.

Soft tunnelling costs are critically influenced by:

- How many stakeholders are to be dealt with
- Who the stakeholders are
- Amount and nature of utilities
- Amount and nature of surface traffic.

The costs can only be estimated meaningfully for individual locations during more detailed design work.

A matrix of estimated tunnelling costs is presented in the tables below.

Table 9.1 Tunnelling Costs

Structure	*Technology*	*Man entry design (pipe subways) £/metre*	*Non-man entry design (ditches) £/metre*
Horizontal Structures	Cut & cover	10,000	150
	Microtunnelling / Pipejacking	5,000	2,500
	Hand mining (SCL)	8,000	n/a
Vertical Structures	Shaft construction	12,000	n/a

Table 9.2 Tunnelling Costs per Connection

Connection structures	*£ per connection*
Between shallow structures	100,000
Between shallow and deep structure	500,000

The costs above are approximations only. A more comprehensive cost estimate should be obtained from detailed design work.

A broad indication of the cost for design work is 10-15% on top of pure construction cost estimates.

At this stage we take a 50% contingency/optimism bias on top of pure construction cost estimates. This allowance includes utilities diversion costs.

Operational Expenditure (OPEX)

Operating costs are assumed to be £80/m/per annum, based on high level benchmarking on the maintenance costs for the BT Tunnels nationally (which suggests a maintenance cost per metre of some £60 to 100/m/year, which equates to 1.05% to 1.75% per annum of capital cost). This accounts for a profit margin.

Operating costs without a profit margin would be lower, in line with the City's current operating charges to utility companies for electricity, lighting, maintenance and repair costs within the City's existing pipe subways.

The City's current pipe subway operating charges are very low – only around £12/metre/annum.

9.3 CCHP Costs

Capital Expenditure (CAPEX)

A high level analysis of the potential benchmark costs associated with delivering various sizes of CCHP energy centre up to 50MWe has been undertaken.

The capital expenditure benchmark costs associated with a 50MWe gas fired CCHP plant are (respectively):

- £110 million total cost

- £4,500/m^2 cost per m^2 of the energy centre.

Generally economies of scale and efficiency imply that a larger scheme would deliver higher carbon dioxide emissions savings and better long term investment returns.

Smaller scale systems have lower efficiencies, while the relative transaction costs to establish them may be higher. This is due the fact that development costs to establish a decentralised energy network are similar when a certain scale has been reached. Transaction costs of smaller projects can be disproportionately high as these are often inelastic with respect to project size. Any investment requires initial feasibility work and these costs do not vary significantly with the project size.

Larger schemes also have improved economics over the long term; economies of scale dictate that capital and maintenance costs per unit output fall with increasing scale, resulting in smaller total investment to supply a given amount of energy.

Accordingly, the energy centre benchmark costs demonstrate a reducing trend as the CCHP plant capacities increase, thus economies of scale are experienced with increased plant capacity.

These costs have been prepared in the absence of a detailed design, specification and scope, and costs allowances for risk, infrastructure and associated on-costs need to be considered. It is estimated that a deviation of ± 30% could apply to this baseline costing analysis.

The following tables and figures demonstrate the trends in capital expenditure against installed CCHP capacity and the economies of scale in terms of capital expenditure per square metre (£/m^2) of energy centre provision.

Table 9.3 CCHP Plant Costs - Installed Capacity

CCHP Project	*MWe*	*Total Project Cost (£M)*
Benchmark Tesco	5	18
Benchmark (Confidential) Energy Centre	10	22
EON (Sheffield)	25	60
SEMBCORP (Teeside)	34	65
EON (Lockerbie)	44	90
Npower (KENT)	50	160
EON (Bristol)	150	300

Figure 9.1 CCHP Plant Costs Trends

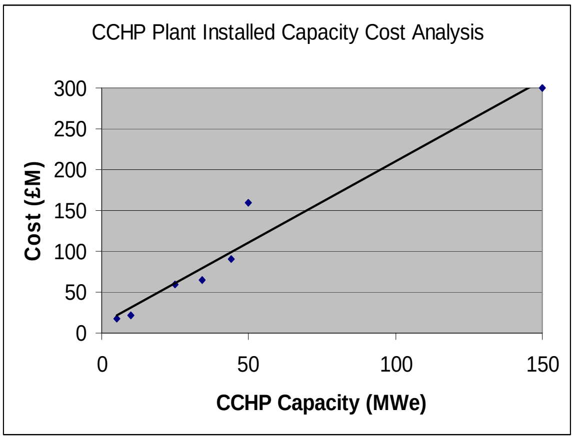
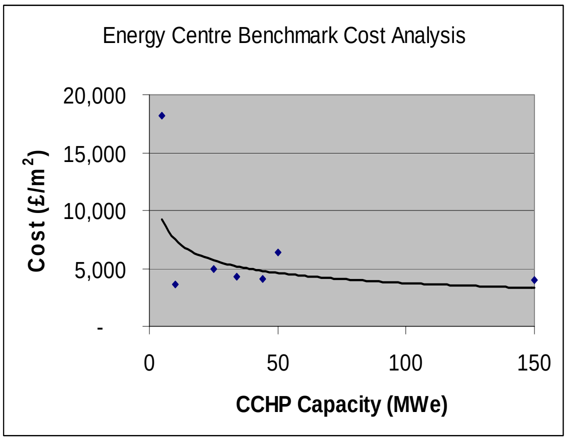


Table 9.5 CCHP Energy Centre Size and Costs on an Installed Capacity Basis

CCHP Project	*MWe*	*Energy Centre (circa m^2)*	*Unit project cost (£/m^2)*
Benchmark Tesco	5	1,000	18,200
Benchmark (Confidential) Energy Centre	10	6,000	3,617
EON (Sheffield)	25	12,000	5,000
SEMBCORP (Teeside)	34	15,000	4,333
EON (Lockerbie)	44	22,000	4,091
Npower (KENT)	50	25,000	6,400
EON (Bristol)	150	75,000	4,000

Figure 9.2 Trend in Energy Centre Costs



These costs are taken from completed developments and so incorporate design costs and contingencies/optimism bias.

In addition to these costs there will be costs associated with the purchase and preparation of suitable site(s).

Operational Expenditure (OPEX)

A life cycle costing exercise has been undertaken for a 50MWe/70MWth CCHP energy centre. It is estimated that the operational expenditure (OPEX) over a 40 year life will be circa 56% of the CAPEX, i.e. £61.6M based on a CAPEX of £110M. This takes account of both routine maintenance and capital maintenance (plant replacement). A detailed breakdown of the analysis is shown in Figure 8.3.

Figure 9.3 50Mw CCHP Indicative Whole Life Cost

Routine Maintenance	*Cap Cost* *£'000*	*Yr 1-10* *%*	*Yr 11-20* *%*	*Yr 21-28* *%*	*Yr 28-40* *%*	*Total* *£'000*	*% of Capex*
Process / MEICA	90,675	0.40	0.40	0.40	0.60	16,684	
Buildings & Civils	42,645	0.20	0.20	0.20	0.30	3,921	
Sub Total						20,608	15%
Capital Maintenance							
Process / MEICA	90,675	0.50	0.80	1.10	2	39,262	
Buildings & Civils	42,645	0.25	0.40	0.55	1	9,233	
Sub Total	133,320					48,495	36%
Total Routine & Capital Maintenance						69,102	52%
Add Optimism Bias for Maintenance					35	24,186	
Whole Life Cost Total	166,650					93,288	56%

Note: Totals may not add up due to decimal rounding

9.4 Wider Economic Costs

In addition to the costs likely to be directly incurred by a tunnel and CCHP developer, mentioned above, there will be wider costs incurred and saved involved in achieving a comprehensive decentralised energy and pipe subways network.

The construction phase may incur considerable costs from disruption at street level. Costs could include:

- Continued cost to businesses due to the disruption from street works
- Costs to TfL from transport disruption
- Wider business and societal costs from disruption to travel
- Administration costs for the City (though partly recovered through existing requirements on utilities companies).

These costs are considered further in the appraisal of options.

9.5 Carbon Costs

Under CRC the entry calculation for £/tonne CO_2 equivalent is £12 but there is an speculation in the industry that, after year five (2015) the cost could rise to circa £45/tonne. Given the similar timeframes for building a pipe subway network this could be a more appropriate figure to use.

Organisations at the top of performance league table will receive bonuses to their payments, and those at the bottom will be charged penalties for their poor performance. The adjustments start at +/-10% and will increase over five years to +/-50%.

10 LEGAL CONTEXT

10.1 Introduction

This section summarises issues and around a legal framework for tunnels and decentralised energy infrastructure. It also highlights key financial issues and opportunities, exploring the financial feasibility of an extended pipe subway network using decentralised energy.

10.2 Pipe Subways: Legislation and Powers

Powers to Install Pipe Subways

The City of London (Various Powers) Act 1900 (the '1900 Act') enables the City to install receptacles for pipes and wires in, over or under the City's streets. We understand that several kilometres of pipe subway were constructed under these powers in the early part of last century.

In addition to the 1900 Act, Section 2 of the Local Government Act 2000 enables the City to do anything it considers likely to promote the economic, social and environmental well-being of the Square Mile unless explicitly prohibited elsewhere in legislation. This power (the 'Well Being Power') is intended to be all-embracing and, in practice, the extension of the pipe subway network is very likely to fall within at least one of the three objectives of economic, social or environmental well-being.

The City may need to acquire land or property rights to extend the pipe subway network. The City has compulsory purchase powers under various legislation including under the Town and Country Planning Act 1990 ('TCPA'). Section 226 of the TCPA enables the City to compulsorily acquire land if it considers that the acquisition will facilitate development or improvement of the Square Mile or that it is necessary to achieve the proper planning of the area. The procedure involves promoting a compulsory purchase order which must be confirmed by the Secretary of State following a public enquiry. Compulsory purchase powers can only be exercised where there is a compelling case in the public interest and should be supported by a robust planning policy framework.

Section 30 of the 1900 Act enables the City to construct works through and across any underground cellars or vaults under any streets. The City must give one months notice in writing to the owner of any underground cellar or vault and compensate the owner for any damage.

Each of the statutory utilities will have broadly comparable powers to do works and acquire land rights in connection with the discharge of their licensed functions and their licensed networks. This could include tunnelling as a means of laying their own regulated infrastructure.

Legislation Relating to Highway Maintenance

In order to reduce the inconvenience caused to road (and other) users caused by the digging up of roads, there is highway specific legislation that governs the way that utilities (and others) are able to conduct maintenance work in the roads of the City.

Firstly, the City may place special designations on streets under the New Roads and Street Works Act 1991. The designation of a street as a protected street, a street with engineering difficulties or traffic sensitive street makes it more difficult for utility companies to install infrastructure in such streets. Naturally, there are limitations on the application of these designations.

Secondly, a new permit system is being introduced under the Traffic Management Act 2004 to require utility companies to obtain permission for street works. Discussions have taken place for operating a common permit scheme across London known as the London Permit Scheme for Road Works and Street Works (LoPS). Under the LoPS, fixed penalty notices will be given where the utility company is working in breach of a permit condition or working without a permit.

Finally, section 33 of 1900 Act enables the City to require utility companies to use a pipe subway instead of breaking up the road in any street where a pipe subway has been constructed.

Charging and Funding for Use of Pipe Subways

We understand that the City is currently seeking financial contributions for pipe subways on a site-by-site basis through planning obligations secured for new City developments under section 106 of the TCPA. Section 106 contributions for tunnel infrastructure are anticipated to be replaced by the Community Infrastructure Levy (CIL) regime, which is scheduled to come into force in April 2010. The City will be able to levy CIL to fund local and sub-regional infrastructure once it has adopted a charging schedule.

We understand that the City also agrees a charge for the use of the subway system, based on the recovery only of expenses for its maintenance. The City has a variety of broader possible charging powers which can be summarised separately.

However, if the costs of laying out new or extending the existing pipe subways were to be rentalised, we understand that the statutory utilities would face difficulty in fully recovering such rentalised costs. This contrasts with the more favourable treatment of the capital costs of a utility undertaking its own tunnelling in order to lay its own infrastructure, so long as such costs are provided for in the relevant price control review by their relevant regulator.

10.3 District Heating: Legislation And Powers

Powers to Install a Decentralised Energy Network (DEN)

The powers that the City have to install a decentralised energy network and to acquire the property rights for this system are similar to those relating to the Pipe Subways. The same ability that exists under the 1900 Act and the Well Being Powers are also likely to encompass the installation of a decentralised energy network by the City. Similarly, the powers under s226 of the TCPA which are discussed above are likely to encompass compulsory acquisition for the purpose of establishing a decentralised energy network. Compulsory purchase powers can only be exercised where there is a compelling case in the public interest and should be supported by a robust planning policy framework.

Encouraging Use of a Decentralised Energy Network (DEN) via the Planning System

It is generally recognised that there is significant potential to increase the carbon efficiency of space heating by using common (district) heating networks and making use of available waste heat (eg. from power generation and industrial processes). Accordingly, the EU Commission's Cogeneration Directive sets a target (transposed into UK law) to promote the uptake of combined heat and power (CHP). There are a variety of UK policy instruments intended to encourage the uptake of CHP and other forms of distributed generation.

The Government has identified decentralised and renewable or low carbon energy as one of the principle means of meeting the UK's carbon emissions reduction targets. Both national planning policy and regional planning policy states that local authorities can expect new development to connect to an existing decentralised energy network or be designed to enable connection to such a network in the future.

A new set of planning policies under the Local Development Framework regime will be produced by the City that will aim to establish the expectation for new developments to connect or be designed to connect to a decentralised energy network and provide appropriate incentives:

- Planning conditions or planning obligations can be used to ensure compliance with planning policies, including:
- Ensuring the construction of elements of schemes which enable the use of decentralised energy networks;
- Imposing specific targets for the reduction of carbon emissions, with connection to a decentralised energy network being a possible mechanism of achieving this; and
- Requiring a proportion of a scheme's energy to be secured from decentralised and renewable or low-carbon energy sources.

Any requirement for new development to secure energy from decentralised energy sources must be fair and reasonable. The Planning and Climate Change supplement to Planning Policy Statement 1 states that any such requirement should not restrict occupiers to using one energy provider in perpetuity. In the absence of specific heat regulation or a heat regulator to protect consumer interests the City needs to be sensitive to possible heat consumer concerns. See further below (sections on Regulation and Competition).

Regulation

As mentioned above, there is currently no heat-specific regulation to protect consumers, whether in relation to price or performance. This means, arguably, that consumer confidence may be weaker and translate into a reluctance to take what are perceived as 'novel', unregulated connections. Therefore, in the absence of a heat-specific regulator, adequate consumer confidence must be ensured by other means. This can be achieved, in part, through pseudo-regulation under contract. The relevant contract can constrain the heat supplier's ability to change the terms of customer connection/supply agreements and its ability to change pricing in a way that impact adversely on customers. This approach does require that someone takes on the role of a pseudo regulator, enforcing these protections. An alternative way of protecting consumers is through system design to allow competition between alternative heat suppliers and prevention of a heat monopoly.

Facilitating Connection to a DEN

Sections 61A to 61C of the TCPA enable the City to make local development orders to grant planning permission for certain types of development. Local development orders could be used to authorise any works connected with the installation of, or connection to, a decentralised energy network. The use of local development orders to secure renewable and low-carbon energy supply systems is encouraged by the Planning and Climate Change supplement to Planning Policy Statement 1 and the London Plan.

Specifically, the GLA's London Plan expects boroughs' development plan documents to require all developments to demonstrate that their heating, cooling and power systems have been selected to minimise carbon dioxide emissions by giving priority to solutions in the following order of preference:

- Connection to existing CCHP/CHP distribution networks;
- Site-wide CCHP/CHP powered by renewable energy; and
- Gas-fired CCHP/CHP

In addition, there is likely to be increasing recognition of the carbon benefits of district heating connection through Part L of the Building Regulations (moving first towards 'zero carbon' domestic then non-domestic buildings and recognising "allowable solutions" such as district heating), Energy Performance Certificates and Display Energy Certificates.

Charging for Use of a District Heating Network

There is no heat specific regulation and no regulation, beyond general consumer protection and competition laws, that constrain who can sell heat or what they charge.

The City has broad powers sufficient to allow it to charge for use of a district heating network that it has provided – and it does this already with Citigen.

Using Planning Contributions and Grant Funding to Meet Construction Costs

The Government's consultation documents on the CIL regime specifically envisage that local authorities can use CIL to fund district heating systems. The draft CIL regulations enable local authorities to pass CIL funds to a third party to apply to the provision of infrastructure. Payments under section 106 agreements may already be used to contribute towards district heating systems.

As part of its commitment to deliver decentralised energy across London, the London Development Agency (LDA) has allocated up to £16 million for decentralised energy over the next four years (from 2009/10) to identify and facilitate potential projects and to leverage private sector finance on key strategic schemes.

It is also expected that a further £64 million will be made available through the Joint European Support for Sustainable Investment in City Areas fund (JESSICA) to unlock the development of decentralised energy in London.

Allowing Competition – Third Party Access Issues

In respect of heat, there is currently no statutory 'right' for any competing generator/supplier to be given access any district heating system. Their ability to do so is, therefore, entirely reliant on contractual negotiation unless or/until new regulation is introduced. For third party access to a heat network to work for the benefit of consumers and commercial operators would require a complex set of rules to ensure proper and reliable functioning of the system, equivalent to those in place in respect of the electricity or gas systems.

The pipe subway network could be used to lay out a private wire network. This is an electricity distribution network that does not require a distribution licence. This could be used as a flexible and comparatively cheap way of providing commercial customers with power where connections to the regulated electricity networks may be slow and/or expensive because of capacity constraints on the existing network.

The use of private wires also benefits electricity generation and supply businesses embedded in the private wire network for a number of reasons. These include giving a monopoly over supply to connected consumers by physically denying them the choice of alternative energy providers. This gives the generator/supplier certainty of revenue but may also give rise to broader concerns for the City (and other stakeholders) about a risk of the monopoly position being abused.

There is little to suggest any competition issue currently exists sufficient to excite regulatory (Ofgem or Competition Commission) interest in any particular private wire network. However, if Government policy promoting distributed generation is successful, and the private wire model were widely used to deliver certainty of revenue, the number of private wire connected customers could rise to a level where real competition issues and regulatory intervention do arise.

Also, preventing competing suppliers from obtaining access to any electrical distribution network is prohibited as a general rule under EU law. UK electricity regulation applies this rule through conditions in distribution licences. However, the UK Class Exemptions Order allows electrical distribution without a licence in a number of scenarios, including for certain small-scale, on-site generation and for distribution to commercial customers. Exemption from the requirement to hold a licence inadvertently disapplies the general rule that consumers should be able to choose their supplier.

The Citiworks ruling in the European Court of Justice (ECJ) clarified that the operator of virtually any electrical distribution system must allow third party access to his system on transparent and non-discriminatory terms. The ECJ ruled that the Electricity Directive requires that third party access to all electrical distribution and transmission systems must be allowed (with very few exceptions). The Directive applies in the case of virtually all electricity distribution systems, regardless of size or configuration. The ECJ ruled that the Directive did not permit a national law to allow certain operators of energy supply systems to be exempt from the requirement to allow access to their distribution networks.

The ruling brings into question the validity of the UK's Class Exemptions Order. At the time of writing, the Order is still being reviewed and a revised draft should be published for consultation shortly. Whilst the original purpose of the review was to improve clarity in the drafting, the expectation is that the revised Order will introduce rules on third party access. This will close the legal loophole available to unlicensed operators.

With the closing of this loophole, it is no longer considered prudent to build a business case for distributed generation solutions which are dependent for their financial viability on a private wire created monopoly. Apart from any transitional regime that may be introduced for existing private wire networks under the review of the Order, a private wire solution is unlikely, in the future, to be a reliable means to keep out competition in supply where multiple customers are connected.

As such, distributed generation business models now generally assume only that contractual ties and competitive pricing will secure revenue or they default to a base assumption that all or part of a generator's electrical output will be exported and sold on the wholesale market to a licensed supplier.

This also impacts on private wire networks driven by the consumers themselves. The third party access rules should be applied here also. However, provided non-discriminatory and transparent terms are offered to any supplier wishing to access the network and connected customers, no breach should arise. Of course, no supplier will wish to access a network unless there is an interested potential customer – and this risk should be low if the private network was driven by customer demand in the first place.

Economic Incentives

The provision of strategic heat infrastructure in a densely developed urban area will be both complicated and expensive – there being numerous technical obstacles and competing property interests to overcome. The supply of low carbon heat through a district heating system may benefit from revenue support if:

- Heat is derived from a combined heat and power station, in which case a cross-subsidy may be available from the sale of Levy Exemption Certificates (which can be used to offset a business customer's climate change levy burden) derived from the renewable electricity exports;
- Heat is derived from a renewably fuelled CHP, in which case a cross-subsidy may be available from the sale of Renewables Obligation Certificates derived from the renewable electricity exports;
- The plant generating the heat is caught within the EU ETS (so only applicable to very large – greater than 20MW – plant), in which case they receive a slightly more favourable entitlement to carbon allowances than electricity generating plant which is non-CHP. However, if they increase output to meet a growing demand they will have to buy additional carbon allowances;
- From April 2010, a heat customer who is caught within the CRC Energy Efficiency Scheme (CRC) imports heat, this is treated as having zero carbon emissions (from the customer's perspective). However, if the heat generator is also caught within the CRC, the generator will have to report associated emissions and will have to factor this into their heat cost;
- From April 2011, the heat generator is supplying renewably fuelled heat, in which case they may be entitled to receive an incentive payment under the impending Renewable Heat Incentive (RHI).

Unfortunately, the evidence is clear that the existing incentives are not sufficient in themselves to encourage the laying of strategic, shared heat infrastructure on a large scale. It remains to be seen what impact the CRC and RHI will actually have but we do not anticipate these providing sufficient additional incentive.

11 FINANCIAL MODEL

11.1 Financial Model Framework

The costs and benefits of developing an extended pipe subway network and/or a decentralised energy network need to be weighed up within a robust financial model. KPMG have developed a financial model by identifying costs and revenues associated with the scenarios. The financial model assesses three outcomes/perspectives which are described below:

1 - Maintain Current Infrastructure ('Do Nothing')

This scenario identifies the current costs that are incurred by utility companies through the use and extension of infrastructure in the City. It assumes no new tunnels and that utilities companies continue to lay cables by digging up streets.

This approach assesses the cost and revenue position from the view of the utilities companies.

2 - Utility Company Base Case

In this approach the tunnel operator will derive revenues through space rental income which it will charge to all users of the tunnel infrastructure. There is likely to be significant capital costs early on in this approach whilst the network and tunnels is under construction.

The test is for the rental charge to be set at a level which makes the utility company indifferent between their current operations (i.e. digging up the streets and wider constraints on their ability to attract new customers and generate revenue) and paying a rental charge to use the network.

3 - External Costs/Benefits

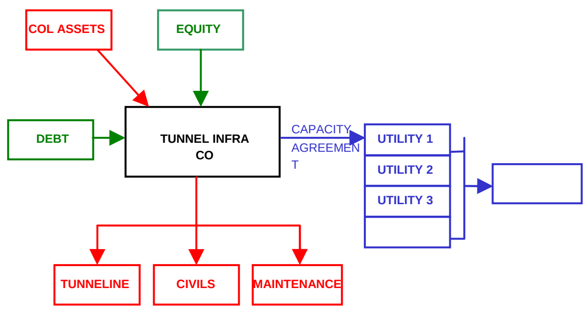
This approach identifies the external benefits and costs that may potentially be realised compared to a base case scenario. An example of a benefit in this approach is the decrease in disruption to commuters and businesses in the City of London by not digging up of the roads. Such benefits will not factor in the decisions of utilities companies but could be relevant in justifying public sector investment.

11.2 Delivery Model Options

Below we set out some potential commercial structures that might form the basis of a viable solution. These could be separate or combined dependent on the technical solution and the appetite of potential stakeholders.

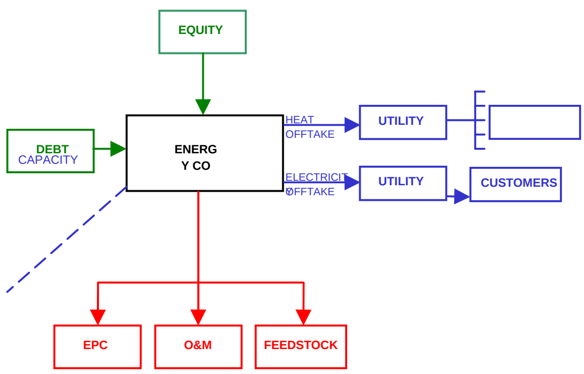
In the first of these (**Figure 11.1** below) the existing City of London pipe network assets are transferred to a special purpose infrastructure company 'Tunnel InfraCo' to manage. This entity would raise the debt and procure the relevant upgrade, operation and maintenance sub-contracts for the tunnel network with the revenue to support these being derived by charging capacity payments to the various utilities using the tunnel network. The utilities would in turn get their revenue from the end user customers.

Figure 11.1 Tunnel Infrastructure Company



One such utility could be a new 'Energy Co' as shown in **Figure 11.2** below. In this second structure the special purpose company is the energy supplier itself, contracting with the utilities to sell the heat and power that is generated from a new decentralised energy CHP system procured through sub-contracts with and Engineering, Procurement and Construction (EPC) contractor. It would maintain the assets and be responsible directly for the energy production.

Figure 11.2 Energy Company



In both scenarios the equity owners of the special purpose vehicles would need to be sufficiently robust and properly incentivised to ensure smooth operation of the system to protect the revenue streams that support the debt. This could include both private and public sector entities with a vested interest in the system and it is likely that stakeholders in the two project vehicles would be comprised of different interested parties. In the InfraCo option one could imagine more involvement of specialist tunnelling companies whereas perhaps a utility company might be more attracted to the second structure. In both cases particularly where hat entity also had the benefit of the sub-contract work.

Sub-contractors in both scenarios would need to provide certainty as to the delivery of the services and also to the price paid for those services in order to give prospective funders comfort that their debt is protected and similar certainty will be required to the power and heat offtake contracts.

As part of the further work in this area we will seek to develop these models and others.

11.3 Conclusions

A resilient utility infrastructure depends upon revenue from use of system charging, connection charging, and/or other revenue support in order to be financially viable. The financial model is thus structured so as to help identify the viability of the proposed decentralised energy network when compared to current alternatives. It assesses feasibility via three options:

- Maintain current infrastructure (Do Nothing)
- Rental tipping point
- External costs/benefits.

In the UK, heat generation, distribution and supply are bundled together in one single business unit. The business model therefore addresses this constraint. It sets out some potential commercial structures that might form the basis of a viable solution. The two options considered are:

- Transferring the existing City of London pipe network assets to a special purpose infrastructure company ‘Tunnel Infra Co’ to manage. This entity would raise the debt and procure the relevant upgrade
- Maintaining the energy supplier as the special purpose company, contracting with the utilities to sell the Heat and Power that is generated from a new decentralised energy Combined Heat & Power system procured through sub-contracts with and EPC contractor.

12 NEXT STEPS

The next stages of work include:

- Stage 3: Options Development and Appraisal
- Stage 4: Final Reporting

This baseline report provides the tools to conduct the development and appraisal of options for an extended pipe subway and/or decentralised energy network.

The options appraisal will focus on the technical financial and legal cases relevant to the three areas of:

- Tunnels infrastructure and technologies
- Decentralised heating infrastructure and technologies
- Utilities infrastructure

The appraisal of delivery options will be a key aspect of this next stage of work. Soft market testing with ESCOs will help to inform questions of viability and deliverability.

APPENDICES

APPENDIX 1 – EXISTING DECENTRALISED ENERGY SYSTEMS

Table A1.1 Existing Schemes, Characteristics & Potential for Expansion

Scheme	*System output and coverage*	*Generation and efficiencies*	*Condition of existing network*	*Connections to end users*	*Expansion potential*
Citigen	The CCHP plant consists of two 15.8MWe/12.5MWth diesel/natural gas fired CHP engines and provides district heating and cooling (via absorption chillers) to CoL buildings and other commercial buildings, with the electrical power being exported to the grid and traded through the parent E-on group.	The heat and electrical power generation efficiency is 70%. The system produces approximately 60,000MWh of heat (including output from auxiliary boilers), 32,000MWh of electricity, and 30,000MWh of chilled water per year.	The pipework is between 350mm and 80mm in diameter, and Citigen mainly use routes through subways, underground car parks and basements. This has been a big advantage due to avoiding trenching in public highways and ease of access for maintenance. Citigen is investing in improving plant efficiency and performance by minimising pipework and cables under roads.	Citigen serves numerous City of London buildings including the historic Guildhall, the Barbican Arts Centre, the Guildhall School of Music and Drama, the Museum of London and London Central Markets (Smithfield) as well as other major commercial customers.	Citigen has expressed an interest in expansion and the delivery of services for heating, cooling and power to additional consumers/customers, and would consider connection to other energy centres. The current installed capacity is 30MWe with planning granted for an installed capacity up to 90MWe. This offers a possible route to support predicted growth in the City and City Fringe Areas (see Section 6.3).

Scheme	*System output and coverage*	*Generation and efficiencies*	*Condition of existing network*	*Connections to end users*	*Expansion potential*
Bloomsbury Heat and Power & Gower Street Heat and Power	Bloomsbury – The primary CHP plant capacity is $4.5MW_e$. Gower Street – $3MW_e$ CHP with a potential for an additional $1.5MW_e$ generation capacity (2 x $1{,}475kW_e$ electrical Caterpillar CHP units). The heat and power schemes serve 450,000m^2 of educational and research facilities.	Approximately 58,000MWh of heat and 33,000MWh of electrical power is currently generated. 36% gross electrical efficiency and 45% thermal efficiency.	No information available.	The heat and electrical power supplies from the two schemes are supplied under long term Public Private Partnership (PPP) contracts. Clients include the University College London (UCL) main campus, School of Oriental and African Studies (SOAS), Institute of Education, Birbeck College and various other colleges of the University of London. The core scheme includes UCL Hospital as a separate party, added by Utilicom to increase the thermal base load.	According to Utilicom the potential exists to expand the scheme to accommodate third party heat loads in order to increase financial and operational viability and all new UCL developments, where viable, will be connected.

Scheme	*System output and coverage*	*Generation and efficiencies*	*Condition of existing network*	*Connections to end users*	*Expansion potential*
Whitehall & Pimlico	Westminster has two large heat networks, both over 50 years old, and each recently underwent a major retrofit for CHP plant operation. These are Pimlico and Whitehall district heating schemes. Pimlico – District heating plant consisting of three $8MW_{th}$ dual fuel (natural gas/gas oil) boilers installed by Dalkia Utilities Services; two $1.6MW_e$ gas fired CHP engines; and	Whitehall – District heating scheme providing heat to 23 Government office buildings in Whitehall, amounting to 270,000m^2 of floor space. Pimlico – The three boilers generate heat in the form of hot water, supplying 10.3MWh of heat per year. Electrical power is exported	Pimlico – Distribution is by means of a pumping station and more than three miles of distribution pipework. A tunnel passing beneath the Thames, which connects Battersea Power Station to Pimlico, is still serviceable and contains redundant pipework.	Pimlico – The PDHU (Pimlico District Heating Undertaking) scheme is owned by City West Homes (formerly the Housing Department of the City of Westminster) and currently serves 3,250 residential units on the Churchill Gardens Estate, around 50 commercial premises (mainly small shops, pubs etc), two schools and a health centre.	Opportunities to support inter-connection between the PDHU and Whitehall district heating schemes. Opportunity to investigate a cross-boundary/river connection/partnership with the anticipated Battersea Power Station development. Links with the Vauxhall/Nine Elms/Battersea (VNEB)

Scheme	*System output and coverage*	*Generation and efficiencies*	*Condition of existing network*	*Connections to end users*	*Expansion potential*
	a 2,500m^3 thermal accumulator. Whitehall – Electricity is generated by a gas turbine unit producing 4.7MW of electrical power and 9MW of heat. The normal fuel source is natural gas but the CHP unit has the ability to run on oil.				Opportunity Area (OA) Energy Masterplan (see Section 4.3, Battersea Power Station).
South East London CHP (SELCHP)	CHP plant consists of a single 35MW$_e$ steam turbine generator. At least 40MW of heat available with low carbon content.	Electrical power is exported, however the surplus heat is not currently utilised.	A commercial evaluation is currently under way looking at the viability of a district heating network.	SELCHP is operated by Veolia Environmental Services. The scheme is designed to handle up to 420,000 tonnes per year of municipal solid waste (MSW), which can generate the equivalent energy consumption of 48,000 homes.	Potential to utilise the waste heat by-product from the electricity generation process to serve the surrounding area and facilitate a sustainable infrastructure connection to the existing Barkantine CHP Plant, and the prospective Elephant & Castle/Southwark MUSCo (Multiple Utilities Services Company).
Barkantine Combined Heat and Power	CHP plant consists of a 1.3MW$_e$/1.6MW$_{th}$ CHP gas engine, four 1.4MW gas fired boilers and two 105m^3 thermal storage vessels. The gas fired boilers are only used to meet peak demand on cold winter days and to meet the heat demand when the CHP engine is unavailable (top-up and back-up boiler plant operation).	The Barkantine Heat and Power Company (BHPC) supplies 8,000MWh of heat and exports 5,500MWh of power per year. The overall efficiency of the scheme is 82%. The thermal storage accounts for 4.5MWh of heat.	2.4km district heating network.	The CHP plant at Barkantine is owned and managed by the Barkantine Heat and Power Company (BHPC) which is part of EDF Energy's generation portfolio. This scheme is a retrofit community energy network using CHP plant to service over 700 dwellings on an East London estate, a nearby leisure centre/swimming pool and the local primary school.	The LDA is currently liaising with a Canary Wharf users group with regard to the development of CHP networks in the area and a future link to a longer term heat network from Newham. The redevelopment of the Westferry Printing Works and industrial premises at Greenwich View site could contribute to the provision of heat and power for this area along with the extension of the Barkantine CHP plant.

Table A1.2 Planned Decentralised Energy Systems

Scheme	*Location*	*Characteristics*
Islington South A (Delhi-Outram / Bemerton)	Islington	South Cluster A includes Caledonian Road Pool, Bemerton Estate and Delhi Outram Estate. Two possible energy centre locations are identified. There is insufficient space in the existing boiler plantrooms but spaces adjacent to these offer an opportunity for plantroom extensions or containerised/packaged plant. At Delhi Outram there is a large open space at the rear of the existing boiler plantroom. At Bemerton space exists in a large open plan garage. A side wall of the garage adjoins one of the Bemerton boiler plantrooms. The anticipated CHP capacity is 1,416kW$_e$.
Islington South B (City University)	Islington	South Cluster B includes the Ironmonger Road Baths, Finsbury Leisure Centre, Stafford Cripps Estate, City University (Northampton Square), Kings Square Estate, Brunswick Estate and Finsbury Estate. The main City University boiler plantroom at Northampton Square has the potential for expansion through an adjacent store room. City University appear keen to participate in a joint scheme. This anticipated CHP capacity is 6,800kW$_e$.
Euston Road District Heating Scheme	Camden	The proposed district heating scheme has a planned CHP capacity of 2 – 3MW$_e$. It would serve existing Camden Council estates, nearby public buildings and a number of other commercial buildings, with the potential to connect to the proposed King's Cross Central scheme, expanding along Euston Road. The area-wide district heating network will extend from Regent's Park in the west to Caledonian Road in the east. Construction is planned to start within the next few years and represents an opportunity for private sector investment. The Euston Road district heating scheme is looking for additional nearby buildings and sites for connection. The viability of this scheme is dependent on upgrading the Bloomsbury and Gower Street Combined Heat and Power schemes to ensure a number of existing and proposed buildings are connected. Existing buildings in this area which could potentially be connected to such a scheme, including local authority housing, are: the British Library, Camden Civic Offices and Town Hall, the Wellcome Buildings and Regents Place. There are also a number of major new developments planned and under construction, including the areas around Euston and King's Cross Stations (British Land and Argent respectively), such as UKCMRI (a new medical research facility) and a new headquarter development for Unison on Euston Road. Expansion west to Regents Place (British Land) is likely to follow later (the Euston development is expected to be completed 2015 – 18) and, due to the distance, would be reliant on the connection of existing buildings along Euston Road to ensure viability.
South Bank Employers Group	Lambeth	The LDA has funded the South Bank Employers Group (SBEG), in conjunction with South Bank University, to look at the potential for an extensive decentralised energy scheme across London's South Bank. The scheme would connect major energy users to a district heating network. SBEG will develop a detailed study on delivery options for an area wide scheme with procurement scheduled for 2010/11.

Scheme	*Location*	*Characteristics*
		Existing public and private buildings such as St Thomas' Hospital, the South Bank Arts complex and Shell buildings are all possible heat customers, as well as a number of planned high density mixed use developments. The SBEG have now suggested a number of feasible delivery options and the SBEG and the LDA's Decentralised Energy Delivery (DED) unit are in discussions on how to progress the scheme.
Cranston Estate Retrofit	Hackney	The scheme will connect over 500 residential units to a decentralised energy network consisting of approximately 1km of heat network piping and a natural gas CHP engine. The residential units are split over three estates within Shoreditch: Cranston, Wenlock and Thaxted. The LDA is supporting the LB Hackney (securing funding routes) with the development of a Shoreditch district heating scheme. Part of the project will be delivered as part of Hackney's Decent Homes Programme over the coming year. The Cranston Estate Retrofit scheme is looking for additional customers that could be included within the scheme.
Leopold Estate Regeneration, Mile End	Tower Hamlets	Poplar Harca, a Registered Social Landlord, will be redeveloping a significant part of its residential estate. The feasibility of delivering decentralised energy has been assessed considering possible solutions ranging from installing decentralised energy in only new build sites to including additional nearby heat loads, such as an existing school and a new primary health care unit. Poplar Harca tendered for construction, management and operation of a biomass decentralised energy system and a number of possible consortia members responded. Additional significant heat loads are being sought for connection to reduce per unit costs.
King's Cross Central	Camden	As part of Argent's redevelopment of King's Cross Central (KXC) with London and Continental Railways and DHL, a decentralised energy system will be delivered and principally powered by gas fired CHP and boiler plant, with supplementary biomass boiler and a fuel cell plant. It will serve the newly developed site and also has the potential to connect with other nearby users. An ESCo has been created to construct the heat generation unit and interface with customers, with a second company owning and operating the heat distribution network. The development consortium will be funding the initial costs and this investment will be repaid as new users are connected, and through electricity and heat sales. King's Cross Central is looking for nearby developments that could potentially link into the system.

Scheme	*Location*	*Characteristics*
Broadgate Estates	Hackney	British Land is investigating site-wide opportunities for reducing carbon dioxide emissions at Broadgate Estates. The assessment indicated that a gas-fired Combined Cooling Heating and Power plant (CCHP), i.e. the provision of absorption chiller plant linked to CHP, would offer the most cost effective energy supply option for reducing carbon dioxide emissions. Although available studies focus on the properties managed by Broadgate Estates, as part of the broader context, the opportunity and feasibility of incorporating connections to buildings within Broadgate managed by others are being considered, taking into account that larger schemes can offer greater economies of scales and greater interest to ESCos who might be prepared to finance and operate the schemes.
Elephant & Castle / Southwark MUSCO	Southwark	The Elephant & Castle / Southwark MUSCo (Multiple Utilities Services Company) decentralised energy scheme is intended to deliver electricity, heat and hot water for 9,700 residential units and 38,000m^2 of commercial space, including the two major urban regeneration sites: the Elephant & Castle and Aylesbury. The Elephant and Castle regeneration scheme is to consist of approximately 160,000m^2 of residential, mixed use and culture/leisure developments, of which around 20% have already received planning consent. The decentralised energy service will be delivered through a CHP facility. LB Southwark has selected a consortium (PFI) led by Dalkia to deliver a decentralised network of power, heating, cooling, water (Veolia) and fibre optic communications infrastructure (Independent Fibre Networks). The electricity, heat, cooling and hot water services will be generated through tri-generation. The scheme will be privately financed by the consortium, which will also be responsible for design, build and operation. LB Southwark will provide land for the energy centres and will seek to recover value once the scheme becomes profitable. The economics for this project and the ability to privately finance it are driven by the scheme's capacity to guarantee and generate early heat revenues by connecting to existing loads and ensuring early development is fit for connection, as well as selling electricity to the grid. The project is currently in development; the first early developments ready for connection are due to complete in 2011.
Battersea Power Station	Wandsworth	The Greater London Authority (GLA) has prepared an Opportunity Area Planning Framework (OAPF) for the Vauxhall, Nine Elms, Battersea Opportunity Area (VNEB OA). Battersea Power Station (BPS) is included in the VNEB OA Energy Masterplan and is identified as a key energy supply provider for OA-wide district heating network. The LDA has taken a keen interest in this development and will look to pursue the export of heat from the Battersea Power Station (BPS) site to support the OAPF ambitions. The VNEB OA lends itself to district heating as a low or zero cost carbon dioxide emissions mitigation technology, due to the scale, diversity and density of the regeneration activity within the area. Another ambition set out in the OAPF is to deliver anaerobic digestion within the VNEB OA to enable the production and distribution of biogas. The VNEB OAPF Energy Masterplan recommends that the BPS plant will incorporate a connection to PDHU in order facilitate the transfer of heat across the river. The PDHU scheme is already connected to the OA via existing 300mm diameter district heating pipework installed in a tunnel beneath the Thames. The pipework is owned by PDHU (Pimlico District Heating Undertaking). Whilst there may be a conflict in exporting heat to Pimlico and not the Vauxhall/Nine Elms/Battersea area, the

Scheme	*Location*	*Characteristics*
		development of these areas will be subject to a longer lead in time than the currently anticipated extension of the Pimlico district heating scheme.

APPENDIX 2 – DECENTRALISED ENERGY NETWORKS AND FUEL POVERTY

Potential to Alleviate Fuel Poverty

In order to consider the potential for a decentralised network to contribute to alleviating fuel poverty, a mapping exercise has been undertaken that demonstrates the Index of Multiple Deprivation (IMD) 2007 by Lower Super Output Area (LSOA) and the connection opportunities for existing and planned decentralised energy infrastructure. This is represented by **Figure A2.1**. The map shows that areas with highest areas of deprivation (0 – 20% deprivation ranking) are found in the London boroughs surrounding the City, such as the LB's of Tower Hamlets, Islington, Hackney, Southwark, Camden and Lambeth.

The locations of existing and planned decentralised energy schemes are associated with areas exhibiting low income/deprived areas. Examples include the Cranston Estate scheme on the border of Hackney and Tower Hamlets, the Leopold Estate Scheme in Tower Hamlets and the two South Cluster schemes in Islington. These schemes have central government, regional and local authority funding support through programmes such as the Community Energy Saving Programme (CESP), London Green Fund (see below), etc.

The general financial model utilised by ESCo's is based on achieving tariffs that mimic current gas and electricity tariffs. Decentralised energy systems may not offer a significant contribution to combating fuel poverty unless subsidies are put in place. Currently, public sector funding is being applied both to initiate and de-risk projects through initiatives such as the London Green Fund and the Joint European Support for Sustainable Investment in City Areas (JESSICA) Fund. The London Green Fund will make investments in initiatives, including decentralised energy, that tackle climate change, while JESSICA is an initiative led by the European Commission and European Investment Bank (EIB) which gives Member States the option of using some of their EU grant funding to make repayable investments in projects to regenerate urban areas.

Another approach may be the development of community energy projects that are based on the ESCo model, owned and developed by the community they serve. These may have financial benefits in deprivation areas, such that any savings associated with bulk fuel purchasing and high efficiency plant may be passed on through lower energy tariffs. Additionally, community heating provided from CHP can enable the electricity generated to be sold directly to residents at cheaper rates.

Case Study: Barkantine CHP

The Barkantine CHP and district heating system is located in the London Borough of Tower Hamlets[26]. It has acted as a catalyst for regeneration through the redevelopment a local derelict site to provide heat and power to the Barkantine Estate and wider community in the Isle of Dogs. The CHP plant was operational at the end of February 2001, while customers were receiving heat by November 2000. The energy centre now serves over 700 dwellings, a nearby leisure centre/swimming pool and the local primary school. The scheme has been awarded the Transco Industry Award for Best Use of Gas in recognition of its environmental goals and energy efficiency. The scheme was procured through £6m in Private Finance Initiative (PFI) credits under the pathfinder scheme from the Department of Food and Rural Affairs (DEFRA), which was instrumental in allowing Tower Hamlets to have the necessary financial capital to award the DBFO concession. The centre is currently owned and managed by the BHPC, part of EDF Energy's generation portfolio.

The Barkantine decentralised energy scheme has considerably reduced business and residential customers' heating and hot water bills. Each flat is equipped with an individual heat meter. Residents connected to the heat network are offered a discounted electricity tariff if they choose to receive their electricity from BHPC. BHPC are looking for opportunities to expand the scheme and have plans to connect several private developments in the future[27]. It is essential that the public sector continue to act as anchor tenant heat loads to kick start build out of decentralised energy schemes by ensuring economic viability.

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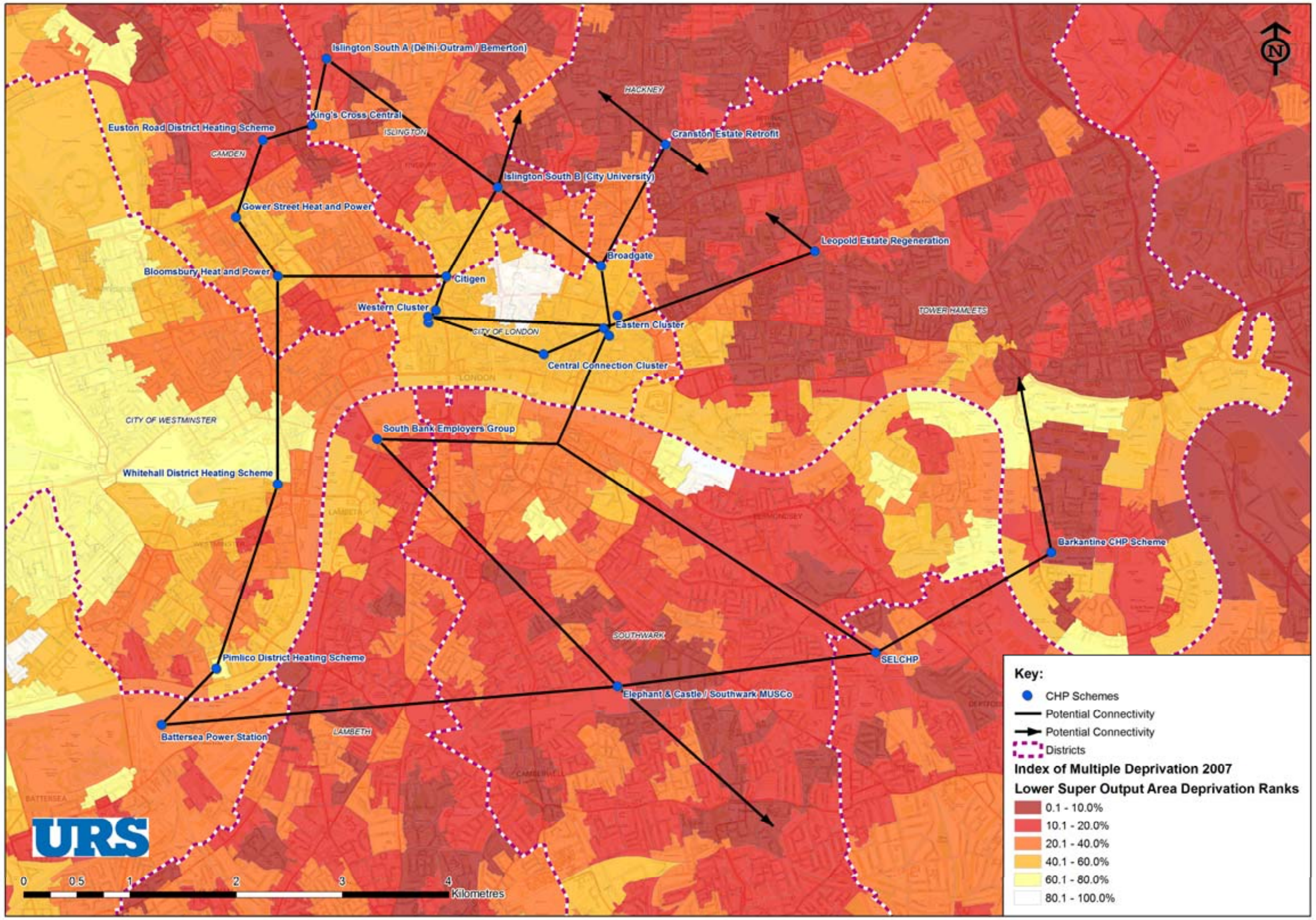
[26] Case Study "Barkantine Combined Heat and Power Plant", London Climate Change Agency, April 2008
[27] Cutting the Capital's Carbon Footprint - Delivering Decentralised Energy October 2008

The redevelopment of the Westferry Printing Works and industrial premises at the Greenwich View site could contribute to the provision of heat and power for this area along with the extension of the Barkantine decentralised energy scheme[28].

[28] www.towerhamlets.gov.uk/idoc

Figure A2.1 Existing and Planned Decentralised Energy Infrastructure & Connection Opportunities for Deprived Areas



APPENDIX 3 – DECENTRALISED ENERGY TECHNOLOGIES

Energy system:		
CHP	**Description**	Combined heat and power (CHP) denotes the principle of the simultaneous generation of usable heat and electricity. Conventional power generation usually dissipates the heat generated using cooling towers, wasting a considerable amount of energy. With CHP, this heat is used for domestic or commercial heating or for process heat demands. Combined Cooling, Heat and Power (CCHP) denotes the principle of the simultaneous generation of usable heat and power, with a proportion of the heat being used to generate cooling via absorption chiller plant.
	Type of Plant	Gas Turbine/Gas Engine
	Advantages	- CHP installations can typically convert between 75% and 90% of the energy in the fuel into electrical power and useful heat. This compares very favourably with conventional power generation, which has a delivered energy efficiency of around 30-35% due to the non-utilisation of the waste heat energy, and distribution losses in the grid infrastructure.
	Disadvantages	- Increased noise levels are experienced due to the plant being located near the end use. - Generally small-scale thermal electricity generation has low efficiency compared to large-scale generation. - Not ROC/FiT eligible.
	Current situation	The Citigen CHP network serving parts of the City is an existing asset. The Citigen scheme plays an important part in determining the feasibility of implementing a decentralised energy network for the CoL. The CCHP plant consists of two 15.8MWe/12.5MWth diesel/natural gas fired CHP engines and provides district heating and cooling (via absorption chillers) to Corporation of London buildings and other commercial buildings, with the electrical power being exported to the grid and traded through the parent E-on group. The distribution pipework ranges between 80 – 350mm in diameter. The distribution pipework is mainly routed through subways, underground car parks and basements. This has been a big advantage due to avoiding trenching in public highways and ease of access for maintenance.
	Future opportunities	A CCHP plant capacity of 50MWe/70MWth has been determined as appropriate to meet the energy demand requirements of the City and City Fringe Areas (see Section 5.6, Energy Profiling and Scale of Demand for Decentralised Energy Supply).
	Capital costs (CAPEX)	The capital expenditure is estimated to be circa £110M (see Section 8.3, Capital Expenditure).
	Space requirements and energy centre benchmark costs	Circa 25,000m^2 of energy centre provision will be required. The energy centre benchmark cost is in the order of £4,500/m^2.
	Whole Life Costing (OPEX)	56% of CAPEX over 40 years, i.e. £61.6M.
	Net present value (£/tonneCO_2)	Circa £1,750 per tonne CO_2 saved.

Energy system:		
Biomass CHP	Description	Combustion is well suited to relatively dry materials such as wood and woody grasses. Traditionally, this has been in stoves but use in boilers is increasingly common because of improved efficiencies and reduced air quality impacts. It is also used in Combined Heat and Power (CHP) plants, and for generating electricity. Large scale (>2 MWe) biomass CHP usually uses conventional steam turbine generating technology.
	Type of Plant	Steam Turbine
	Advantages	- Heat is a by-product of the electricity generation process from biomass. Utilisation of this by-product through a local heat distribution network can improve operational efficiencies, leading to a significant increase in carbon dioxide emissions savings. - A CHP plant should be located in close proximity to sites with a continuous heat load (sites with domestic and non-domestic uses provide a balance of demand across the day). - Biomass replaces fossil fuels and can help to reduce other greenhouse gas emissions, particularly methane emissions, by diverting woodfuel waste from landfill. - The sale of electricity from biomass CHP generation can provide a source of income: 2 ROC/MWh (ROC value is £45/MWh), whilst the FiT is 9p/kWh, with a bonus of 5p/kWh if the electricity generated is exported (see Section 9.4).
	Disadvantages	- Air quality impacts would require the incorporation of appropriate NOx abatement technologies and filtration systems. - Purchase and installation costs for biomass boilers are presently relatively high. - The bioenergy market is relatively new so care is required to match supply and demand. - Costs vary depending on factors such as scale, access to skilled labour, use of appropriate machines and road access. - The cost and complexity of obtaining a grid connection can be a barrier to local electricity production.
	Current situation	Wood is present in all three of the main waste stream classifications: municipal, commercial/industrial and construction/demolition. It is also the main constituent of arboricultural waste from tree surgery operations in London. These waste streams give rise to approximately 127,000 tonnes per year[29]. The potential for woodfuel from forestry operations around London has been estimated at 2,195 oven dried tonnes per year within London (from 6,700 ha of woodland), and at 63,441 oven dried tonnes per year around London (40km radius)[30]. Strategic biomass schemes have been identified in London (see also Appendix 1.1 – CHP Connectivity): Elephant & Castle Area and Old Kent Road Gas Works, Tower Hamlets/Newham Site, Beckton Thames Water Site, SELCHP, Edmonton, etc.[31]

[29] Based on a recent study conducted by Bioregional and the London Tree Officers Association
[30] Taken from the Future Energy Solutions 2002 Study
[31] London Wind & biomass Study, London Energy Partnership, 2006

	Future Opportunities	No strategic biomass schemes have been identified within the City of London. Biomass opportunities are not considered feasible as strategic sites have already been identified in London that are best placed to support the application of this technology.

Energy system:		
CHP powered by biogas derived from Anaerobic Digestion (AD)	**Description**	Anaerobic Digestion (AD) is a process that uses micro-organisms to convert biomass feedstock to biogas. The process can use a wide variety of feedstocks, including the organic waste streams associated with residential and commercial processes. The biogas can be burned for heat and/or power production, or be compressed and used as a transport fuel.
	Type of plant	Gas Turbine/Gas Engine
	Advantages	- The sale of electricity from biogas (AD) CHP generation can provide a source of income: 2 ROC/MWh (ROC value is £45/MWh), whilst the FiT is 11.5p/kWh, with a bonus of 5p/kWh if the electricity generated is exported (see Section 9.4). - Biogas replaces fossil fuels and can help to reduce other greenhouse gas emissions, particularly methane emissions, by diverting organic waste from landfill.
	Disadvantages	- Added on-costs of storage and handling, treatment, specialised combustion equipment, etc. - AD is relatively expensive and requires a major capital investment. Waste water from the process may contain a high concentration of metals, nitrogen and organic materials. - Because of the complex association of different types of bacteria, digesters have a higher risk of breakdown and may be difficult to control. - Contamination of the organic waste streams (e.g. plastics) poses operational risks.
	Current situation	A food waste collection trial (twice weekly door step collection) covering 200 properties in Middlesex Street started in October 2006, and this has recently been expanded to 400 houses. If the pilot is a success the trial is likely to be extended to all suitable households (about 50% of the total number of households) in the City. Further, the City collects green waste from 150 small gardens and open spaces within the City boundaries. This is currently all landfilled (it is too contaminated with litter to be suitable for composting), but the City is assessing options for sorting it to remove litter and then composting the remaining material[32]. The City is also carrying out food waste collections from their four estates (this includes Barbican collections which are currently being rolled out). The tonnage collected is approximately 4.2 tonnes per month. Funding has been sought to extend this to all private housing blocks and this could increase the tonnage to around 10 tonnes per month. The largest potential relates to commercial food waste collections and the City has recently commenced a trial with around 10 businesses. This has huge potential but a drawback is that the price of collections are high due to distance food waste then has to be transported – presently being transported to Bexley. A requirement for closer waste handling facilities has been expressed by the City as this would be beneficial to support the comprehensive roll out of organic waste collections.

[32] Municipal Waste Strategy for the City of London 2008 – 2020, 2008

	Future opportunities	The City's ability to fulfil the provision of a waste facility within the City's boundaries will be addressed by the City Planning and Transportation Department who will be conducting a feasibility study to inform the City's Local Development Framework. If following the feasibility study it is found that construction of a facility within the City boundaries is not possible, the City will need to send waste to a facility in another authority. A planned mechanical biological treatment (MBT) plant in Southwark has been identified as a facility that could support the utilisation of the City's organic waste stream to support AD activities in London. It is anticipated that the plant should be fully operational by 2012.

Energy system:		
CHP powered by syngas derived from Gasification	**Description**	Gasification produces a gas (or syngas – synthetic gas). This is utilised in a gas turbine/engine process. Gasification differs from mass burn because the waste is heated in a high temperature process the decompose waste into simple gaseous molecules (primarily hydrogen, carbon monoxide and carbon dioxide).
	Type of plant	Gas Turbine/Gas Engine
	Advantages	- Gasification technologies are capable of higher levels of efficiency of electricity generation than combustion technologies, with cleaner flue gases and residues. - The sale of electricity from biogas (AD) CHP generation can provide a source of income: 1 ROC/MWh (ROC value is £45/MWh) (see Section 9.4).
	Disadvantages	- Added on-costs of storage and handling, treatment, specialised combustion equipment etc.
	Current situation	The main source of waste collected in the City is from commercial premises. The City has a requirement to offer a waste collection service to commercial companies, and any waste which the City collects through this service is classified as municipal solid waste (MSW). It should be noted that in other authorities, the largest source of waste is that collected from households[33].
	Future opportunities	The City's ability to fulfil the provision of a waste facility within the City's boundaries will be addressed by the City Planning and Transportation Department who will be conducting a feasibility study to inform the City's Local Development Framework. If following the feasibility study it is found that construction of a facility within the City boundaries is not possible, the City will need to send waste to a facility in another authority. The Riverside (Belvedere) energy from waste (EfW) facility has been identified as a facility that support the utilisation of the City's MSW stream to support gasification activities in London. The Riverside EfW facility has received planning permission and is expected to start operation in 2010. Thus it should be able to take all of the City of London's residual waste from 2011.

[33] Municipal Waste Strategy for the City of London 2008 – 2020, 2008

Energy system:		
Incineration	**Description**	Incineration is the combustion of waste in an excess of oxygen. Incineration is used throughout industry, particularly for medical waste and high-hazard material. Incineration and other thermal waste treatments can reduce the volume of Municipal Solid Waste (MSW) by 90% and its weight by 75%. The UK has about 60 incinerators burning MSW, chemicals, clinical waste and sewage sludge. Thirteen of these burn MSW, and two use Refuse Derived Fuel (RDF). After incineration, the waste is converted to carbon dioxide, water vapour and ash (this varies in chemical composition based on the make up of the waste).
	Type of plant	Steam Turbine
	Advantages	- The sale of electricity from incineration processes can provide a source of income: 1 ROC/MWh (ROC value is £45/MWh) (see Section 9.4).
	Disadvantages	- Air quality impacts. - Noise impacts.
	Current situation	The main source of waste collected in the City is from commercial premises. The City has a requirement to offer a waste collection service to commercial companies, and any waste which the City collects through this service is classified as municipal solid waste (MSW). It should be noted that in other authorities, the largest source of waste is that collected from households[34].
	Future Opportunities	The City's ability to fulfil the provision of a waste facility within the City's boundaries will be addressed by the City Planning and Transportation Department who will be conducting a feasibility study to inform the City's Local Development Framework. If following the feasibility study it is found that construction of a facility within the City boundaries is not possible, the City will need to send waste to a facility in another authority. Send waste to the Riverside (Belvedere) energy from waste (EfW) facility (this has received planning permission and is expected to start operation in 2010; it should be able to take all of City of London's residual waste from 2011). The residual waste would be transported to this facility by river.

[34] Municipal Waste Strategy for the City of London 2008 – 2020, 2008

APPENDIX 4 – CASE STUDIES

A4.1 Introduction

Countries such as Denmark, the Netherlands and Finland have been generating energy from decentralised networks for decades. They have in place policies and regulations to improve economic and technical feasibility of their energy networks in addition to further reducing CO_2 emissions. More recently countries including Sweden and the UK are looking to strengthen their policies to promote viability in this regard. The following case studies highlight best practice in implementing decentralised energy networks.

A4.2 Denmark

Denmark serves as a useful model for establishing a district heating network. The uptake of connection to district schemes is high and widespread throughout Denmark. Approximately 60% of all households are heated with heat from district-heating plants and co-generation plants, from which heat is piped directly to consumers.

Denmark's extensive district heating networks currently supply 60% of heat demand in the country – up from only 5% in 1952. Copenhagen and other larger Danish cities have much higher heat coverage, typically 95% to 98%[35]. The oil shocks of the 1970s were the first impetus for Denmark to switch to decentralised energy networks that could better offer security of energy supply. This led on to concerns in the 1980s over the negative environmental and health impacts of coal and in the 1990s with increased concern over climate change and greenhouse gas emissions from centralised, fossil fuel based power plants.

The government's Energy Plans have therefore increasingly focused on security of supply, energy savings through decentralised and low carbon energy supply, environmental awareness, and global environmental goals, including active support for the Kyoto protocols.

Following on from the 1990s, national and local government policies helped lead to modern district heating becoming the cornerstone in Danish heat supply. The strategy used by Denmark to promote district heating (DH) and CHP based on biomass was supported by the implementation of economic incentives (subsidies, taxation, investment grants, etc.) and regulation (governmental and municipal powers to regulate power stations and zoning of district heating).

The government's carbon tax on all energy production was highly effective, and according to an International Energy Agency review of Danish energy policy in the October 1998:

'The price of electricity to Danish households is the second highest of IEA countries, while the price to industry is about the middle of the range. Without the taxes, electricity prices were among the lowest in Europe'[36].

An important regulatory means was the introduction of heat supply planning, the aim of which was to raise the DH market share from 30% to about 60% and to increase the market share of individual gas boilers from 0% to 15% by year 2000. National statistics from the Danish District Heating Association indicate that around 98% of all district heating consumers pay less for their heat compared to heat from household-based oil boilers.

Today in Denmark district heating covers more than 60% of space heating and water heating. In 2007, 80.5% of this heat was produced in combined heat and power plants. Heat recovered from waste incineration accounted for 20.4% of the total Danish district heat production[37]. The largest district heating system in Denmark is in Copenhagen. The network serves 97% of the population. The consumer price of heat from the network is approximately €49 per MWh plus taxes (2009).

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[35] Bealy (2000) 'Green urbanism: learning from European cities'; and Dansk Energy (2009).
[36] "Government Policy", Chapter 8, Energy Policies of IEA Countries, Denmark, 1998 Review, op. cit.
[37] Danish Ministry of Energy (2007), Energy Statistics

A further breakdown[38] of the types of fuels used for district heating reveals that in 2007, the distribution was:

- 46.6% renewable energy (biomass being 39.4%)
- 26.4% natural gas
- 22.4% coal and
- 4.6% cent oil.

Demark has district heating networks provided by the municipalities and connection is mandatory.

The Heat Supply Act from 1979 (revised extensively in 1990, 2000 and 2005) empowers the Minister for Energy to ban the use of electric heating in new buildings located within a district heating or natural gas supply network.

Municipalities may also require those already connected to the district heating network to remain so 241 of Denmark's 275 local authorities make use of this competence.

The local authorities are the central players in the public heat-supply. They develop heating plans and have responsibility for expanding district heating and for implementing any changes made necessary by amendments to the regulations in the law on heat supply.

In practice, the ban and obligatory connection made it possible for local authorities to ensure that energy supply companies' earnings were not undermined by an insufficient number of connected consumers, in turn ensuring that investments made were not lost.

There is a lot to be learnt from the Danish model, as the key is certainty of revenue. This is achieved through mandatory connection, long term contracts, a sufficiently robust policy framework that ensures certainty of connections and a business model that can offer below market prices for a heat commodity.

The Copenhagen example demonstrates that district heating is a versatile, adaptable form of supply. It is also flexible in terms of choice of production plant and the fuels used[39].

In conclusion, factors that led to the rapid expansion of decentralised energy in Denmark include:

- Strong energy policy and central Government support
- 'Least cost' energy planning and cost benefit analysis, including assessment of non market impacts, the planned/external benefits of security of supply and of reducing carbon emissions
- Strict zoning of decentralised heat networks and encouragement of local authorities and utilities to implement least-cost projects
- High taxation on fossil fuels for heating
- Decentralised energy infrastructure required public involvement and support
- Large scale decentralised heat demands required long term investments (and government involvement e.g. where there are long-term payback periods)
- Benefits can be large in terms of economy, environment and security of energy supply.

While the UK does not have all of these factors as well aligned or as well developed as in Denmark, there are a number of signs that we are heading in this direction.

A4.3 Finland

Finland also demonstrates that strong policies and locally focussed incentives will prove successful in growing towards a low carbon economy. District heating is the most common form of heating in Finland and accounts for 50% of heating and covers close to 2.6 million people. Almost 95% of apartment buildings and most public and commercial buildings are connected to the district heating network[40]. In 1993 28% of electricity used in Finland was generated in CHP plants, with industrial plants producing

38 Danish Energy Agency (2007), Energy Statistics 2007
39 Clinton Foundation (2009), C40 Cities – Climate Leadership Group – Best Practices
40 Energiateollisuus (2009), District Heating

46% and district heating plants 54% of this total. District heating warms 44% of the buildings in Finland, and 72% of district heat was produced by CHP in 1993.

The authority of Kotka in particular is popularly noted as a best practice example. Through implementing a package of incentive measures and looking for new forms of energy generation Kotka is saving 390,000 tons of CO_2 emissions each year through district heating and combined heat and power production (CHP) using renewable and recycled sources, as well as natural gas[41]. The local government has proved that district heating can be beneficial for both customers and the vendor.

A4.4 United Kingdom

UK: Woking

Woking Borough Council has successfully implemented a range of measures that promote sustainable and renewable energy generation across the borough. The Council is widely acknowledged as being the first UK authority to have adopted a comprehensive Climate Change Strategy on a scale that is likely to meet targets of 60% reductions of CO_2 equivalent emissions by 2050. It has implemented measures including[42]:

- Use of sustainable CHP sources of energy in the borough.
- Increased use of photovoltaic and renewable energy.
- Incorporating, at the next review of the Local Plan, planning policies which ensure that new development in the Borough reduces carbon emissions
- Introducing a local award scheme to recognise any developments that incorporate features which contribute to the long-term aim of sustainable development, including reducing CO2 equivalent emissions and mitigating against climate change.
- Adopting a target of purchasing 100% of the Council's electrical and thermal energy requirements from sustainable sources and 20% from renewable sources by 2010/11.

Through this the borough has developed a network of over 60 local generators, including cogeneration and tri-generation plant, photovoltaics and a hydrogen fuel cell station, to power, heat and cool municipal buildings and social housing. Many town centre businesses are also connected to this local energy supply. The development of a fund for energy expenditure has led to financial savings of approximately £5.4 million up to 2005. Overall the borough has succeeded in reducing CO_2 emissions within the Council's own buildings by 82% and energy consumption by 52%[43].

UK: Nottingham

Nottingham City Council is one of the 25 largest users of renewable energy in Europe. This is due to the presence of one of the largest Energy Services Companies (or ESCOs) in the UK. Enviroenergy Limited is wholly owned by Nottingham City Council which operates the District Heating Scheme. It converts domestic and commercial waste collected in the area to energy, and has been supplying around 5,000 households and 150 businesses since the 1970s[44]. By burning household waste the scheme is reducing by around 90% the volume of waste which has to go to landfill sites.

Nottingham City Council is to expand its district heating system into the Southside Regeneration Zone using £1.5 funds by the government.

UK: Barkantine Energy Centre – London

The Barkantine Energy Centre is a retro-fit community energy network using Combined Heat and Power (CHP) to service over 700 dwellings on an East London estate, a nearby leisure centre/swimming pool and the local primary school. The London Development Agency (LDA) is currently liaising with a Canary Wharf users group with regard to the development of CHP networks in the area and a future link to a

[41] Clinton Foundation (2009), C40 Cities – Climate Leadership Group – Best Practices
[42] Woking Borough Council (2008), Climate Change Strategy
[43] Clinton Foundation (2009), C40 Cities – Climate Leadership Group – Best Practices
[44] The State of Nottingham

longer term heat network from Newham. The re-development of the Westferry Printing Works and industrial premises at Greenwich View site could contribute to the provision of heat and power for this area along with the extension of the Barkantine CHP plant.

The Barkantine Energy Centre consists of a 1.3 MWe/1.6 MWth CHP gas engine, four 1.4 MWth gas boilers and two 105 m3 of thermal storage. The gas boilers are only used to meet peak demand on cold winter days and to meet the heat demand when the CHP engine is unavailable. he Barkantine Heat and Power Company (BHPC) supplies 8,000 MWh of heat and exports 5,500 MWh of power per year. The overall efficiency of the scheme is 82%. The thermal storage can store 4.5 MWh of heat.

The CHP plant at Barkantine is owned and managed by the Barkantine Heat and Power Company (BHPC) which is part of EDF Energy's generation portfolio.