GREATER**LONDON**AUTHORITY

Decentralised energy capacity study

Phase 3: Roadmap to deployment

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Glossary

ASHP	Air source heat pump
BRE	Building Research Establishment
CCGT	Combined cycle gas turbine
CCS	Carbon capture and storage
CHP	Combined heat and power
COP	Coefficient of performance
CO_2	Carbon dioxide
DE	Decentralised energy
DECC	Department for Energy and Climate Change
DEMaP	Decentralised energy masterplanning programme
DEPDU	Decentralised energy project delivery unit
DNO	Distribution network operator
EMR	Electricity market reform
EfW	Energy from waste
GIS	Geographic information system
GLA	Greater London Authority
GWh	Gigawatt hour
IEA	International Energy Agency
LDO	Local Development Order
LTHW	Low temperature hot water
MTHW	Medium temperature hot water
MW	Megawatt
MWe	Megawatt electric

MWth	Megawatt thermal
OAPF	Opportunity Area Planning Framework
RE	Renewable energy
RHI	Renewable Heat Incentive
VLTHW	Very low temperature hot water

Executive summary

This report forms part of a regional assessment of the potential for renewable and low carbon energy in Greater London and has been commissioned by the Greater London Authority (GLA) and funded by the Department for Energy and Climate Change (DECC). It considers the deployment of decentralised energy (DE), focusing solely on those technologies connected to heat networks, and comprises Phase 3 of the regional assessment. An assessment of the technical potential and deployment potential of DE technologies was made in Phase 1 and Phase 2 of the study respectively.

The potential

The Phase 2 report suggests that the Mayor's target to supply a quarter of London's energy demand from renewable and low carbon sources is achievable, provided appropriate national policy support is in place. This requires a combination of energy efficiency measures, microgeneration RE systems and the use of combined heat and power plants (CHP) linked to heat networks. The analysis also demonstrates that DE using heat networks can provide economically viable emission reductions of 0.8MtCO2/yr by 2031 at a cost of around £8billion (discount rate of 7%). £6billion of this cost is in heat network infrastructure. The carbon savings are based on a comparison with the predicted carbon intensity of grid electricity in 2031; emission reductions against 2010 levels of carbon intensity would be significantly greater.

The challenge

Widespread heat networks are unlikely to develop quickly as they represent significant capital investments and take a long time to plan and construct. This report outlines a roadmap to deployment and identifies six key steps, from the initial phases of heat network establishment, through further growth, load diversity and interconnection to switching the input fuel from natural gas to low and zero carbon sources of heat. At present most heat networks are developed around small- and medium-scale gas-fired CHP units. The number, scale and geographic coverage of these schemes will need to be significantly scaled-up and connected to larger-scale networks to deliver on the Mayor's target.

Establish schemes

Establishing a network of small-scale schemes which can grow and be interconnected represents the first challenge. This is likely to be in new developments or centred on sites under single ownership (e.g. universities, hospitals). These schemes represent manageable levels of offtake risk (e.g. certainty over future heat sale revenues) and can act as catalysts for wider area schemes through interconnection. In the few cases where more extensive heat networks have been developed in town and city centres the public sector, usually though local government, has played a leading role. Establishing these types of schemes, serving multiple buildings with a diversity of heating demands, represents the key to more widespread deployment of heat networks.

New connections and load diversity

Ensuring that DE schemes can grow and add capacity is essential. New connections increase revenues and provide greater load diversity which allows CHP units to operate more efficiently, reducing costs and increasing carbon savings. Networks must therefore be planned for the long-term and in a coordinated way. This requires a clear framework for managing risk, particularly offtake risk and the risk of stranded assets. Options include regulation of connection or incentives, but without a clear approach network deployment will not occur at the scale required. Public sector buildings should also connect to heat networks where feasible, recognising the wider public interest, and building retrofit schemes should assess whether buildings are in an area with deployment potential for heat networks and ensure retrofits enable such connections.

Interconnection

Interconnection of smaller-scale schemes is a critical step to ensure heat networks can be linked to larger-scale and lower carbon heat sources, which can offer heat at a significantly lower cost. The heat network element of DE systems has a forty year life, compared to a typical 15-year replacement cycle for gas CHP. As smaller schemes come to the end of their useful life, the opportunity arises to interconnect networks rather than invest in plant replacement. Common technical standards for networks is a low cost measure that will facilitate future interconnection and designing networks with low operating temperatures facilitates the connection of waste heat sources and large-scale heat pumps. In outer London boroughs, where interconnection of small-scale DE schemes is limited by heat demand density, priority should be given to smaller-scale sources of low carbon heat such as energy from waste using advanced thermal treatment and anaerobic digestion plants.

Low and zero carbon sources

Transitioning to lower carbon heat sources represents one of the key drivers for prioritising DE, as many low and zero carbon heat sources require large-scale plants to operate most efficiently. Only interconnected heat networks or large industrial users are able to make effective use of energy from waste, biomass CHP and waste heat from existing power stations. Smaller-scale schemes are, however, necessary to establish heat networks. As these networks grow and are interconnected, larger-scale gas-fired CHP will need to come on stream and provide low carbon heat until at least 2031. Beyond this, and depending on the carbon intensity of grid electricity, a transition to zero carbon fuels will be required.

This could include the capture and long distance transmission of waste heat from new build low or zero carbon power stations located outside London. This is a very long term approach and subject to significant levels of uncertainty. However, the Phase 2 report shows that heat transmission networks of up to 70km in length could make a significant contribution to the demand for heat in London. Whilst there are clearly major issues such as cost, routing and delivery models to be addressed, there are no significant technical barriers to this approach. Heat losses in long distance transmission networks would be around 2%.

The use of heat storage allows DE systems to make further effective use of low and zero carbon heat and electricity generation. By using large hot water tanks linked to heat networks, DE systems can maximise the proportion of heat supplied by low carbon sources for a given heat network, displacing higher carbon peak load plant; participate more freely in the electricity market; and play a role in managing electricity supply and demand by absorbing intermittent and off-peak generation from renewable sources.

Strategic planning for DE

The deployment of heat networks requires significant policy support and leadership across all levels of government. Without a coordinated, strategic and attractive proposition for private sector investment, the widespread deployment of heat networks switching to larger, lower carbon sources of heat will not be possible. Heat network development is most viable in the central boroughs and outlying town centres. However, this is only the case when the cost of capital is low – which, in turn, is only available to low risk investments, or those backed up by organisations with good financial covenants (e.g. boroughs, central government) - and revenue streams are high. Despite being a proven technology with widespread deployment in Scandinavia and North America, heat networks still present a high risk investment in the UK.

The effort to obtain and guarantee sufficient customer connections – and hence guarantee heat load – is speculative. Heat networks face competition from incumbent utility networks (gas and electricity) to provide heating. These networks benefit from having been established through state ownership and regulation as monopoly services. A clear framework for managing offtake risk, and attracting greater private sector investment, is required to achieve high levels of DE deployment. Options include regulation of connection and incentives for connection.

Similarly, policy measures should also focus on optimising income streams from DE, particularly for small-scale embedded generators using gas-fired CHP to enable initial deployment. Existing support, such as exemption from transmission use of system charges ('embedded benefits') and the Renewable Heat Incentive (RHI), must be continued. Proposed policy measures such as Carbon Price Support should provide proper recognition of the carbon reduction potential of DE technologies and the Electricity Market Reform provides an opportunity for fairer licensing and reduced distribution charging for DE (e.g. Licence Lite proposals).

At a national level, policy should recognise the important role of heat networks in reducing emissions and managing demand on the electricity distribution network. Policy should also recognise natural gas-fired CHP as a transition technology, critical to the establishment of heat networks, which can deliver significant emissions reductions over the period 2011-2031. Beyond this a switch to sources such as biomass, waste and waste heat from power stations is required.

Role of the GLA

The GLA should continue its strategic role, setting out where heat networks should be prioritised to ensure comprehensive coverage of smaller-scale heat networks which can grow and be interconnected. Specific schemes will be brought forward by the London boroughs and developers, working with energy companies; however cross-borough boundary systems will require coordination.

In addition, the GLA performs a critical coordinating role and should work with government, the London boroughs, energy companies and developers to (a) identify and safeguard sites which could support CHP plants in the short to medium term as well as house new large-scale CHP in the longer term; (b) develop procurement and financing models and a set of common technical standards to facilitate future interconnection; (c) reduce installation costs for heat network operators, and (d) ensure new power plants are designed to operate as CHP plants, future proofing connection to heat networks.

Finally, the GLA provides an important capacity building function and it should maintain support for boroughs through the DE masterplanning programme (DEMaP) and DE project and delivery unit

(DEPDU) as well initiating the development of technical standards with industry, disseminating best practice on heat network design and collating a robust cost database for the assessment of heat network viability. Through its buildings retrofit programmes, the GLA is also in a position to ensure retrofits enable connections to heat networks in areas with deployment potential for DE.

Role of boroughs

The London boroughs have a key role to play in establishing new DE schemes. Boroughs can provide political and planning support, and guarantee heat loads and land for energy centres, all of which de-risk the delivery of DE schemes. They can also work to ensure good geographic coverage of heat networks and maximise the availability of residual waste as a low carbon fuel source.

Boroughs should develop local approaches to managing offtake risk, through borough- and stakeholder group-led project development. Where appropriate boroughs should also consider opportunities to own heat network infrastructure, and hence provide the low cost of finance and de-risking required to realise the deployment potential identified in Phase 2. Development of the heat generation and operational responsibilities could be undertaken by the private sector, with public sector assets divested once projects are fully operational and generating net incomes.

Further work

Further work is required to better understand some of the issues relating to DE deployment, particularly the use of heat pumps serving both individual buildings and heat networks. More data on the actual performance in use of heat pumps and the potential for improvements in performance is required. Research into the impact on peak demand levels of electrifying heating is also needed, as is a better understanding of the opportunity to use heat networks to facilitate demand management through storage. A more detailed assessment of the potential for heat to be imported into London from surrounding low or zero carbon power stations is also required before this could be recommended as a future strategy option.

Conclusion

DE using heat networks represents a important opportunity for the delivery of low and zero carbon heat. The infrastructure is technology neutral and can harness heat from a variety of sources. This flexibility together with the ability to store energy can enable heat networks to capture otherwise wasted sources of energy and help manage demand. A clear policy framework is required to facilitate the initial deployment of a greater number of small-scale DE schemes and their interconnection to allow large-scale, low cost, low and zero carbon sources to be utilised effectively.

1 Introduction

This report forms part of a regional assessment of the potential for renewable and low carbon energy in Greater London and has been conducted by the Greater London Authority (GLA) with funding from the Department for Energy and Climate Change (DECC). It considers the deployment of decentralised energy (DE), which comprises Phase 3 of the regional assessment. The overall approach is based on a standardised methodology developed for DECC (referred to as the 'DECC methodology') which has been modified to reflect Greater London's urban nature (the tailored methodology). An assessment of the technical potential and deployment potential was made in Phases 1 and 2 of the study respectively.

The Phase 2 report demonstrates that the Mayor's target to supply 25% of London's energy from DE by 2025 is achievable, provided appropriate national policy support is in place, and that DE can provide significant reductions in carbon emissions on an economic basis, even when the carbon intensity of electricity is significantly lower than 2010 levels. The aims of Phase 3 are to build on this analysis in order to:

- Consider how the transition from small-scale DE schemes to the larger, lower carbon heat sources identified in Phase 2 can happen
- Identify conditions required to achieve the deployment potential
- Set out barriers and risks which may constrain deployment

For the purposes of the study renewable energy (RE) has been defined as renewable sources arising within London (unless otherwise stated). DE has been defined as using heat networks to transfer heat from generation sources to areas of demand. This report does not consider the deployment of RE not connected to heat networks.

1.1 Realising the potential

Phase 2 concludes that DE has the potential to supply over 25% of London's demand for heating and electricity, with significant reductions in carbon emissions depending on fuel source and the carbon intensity of electricity from the national grid. Table 1-1 shows the results of the five scenarios that are modelled in the Phase 2 analysis. Note: Carbon savings are for 2031 and scenarios assume different rates of grid electricity decarbonisation.

Energy delivered (GWh/year)	BAU	National	Regional	Coordinated	Ambitious
Total renewable energy	3,041	3,790	5,512	5,292	8,392
Renewable energy linked to heat networks	488	9,819	687	4,996	9,529
Decentralised energy (not including renewable energy sources)	3,680	3,874	4,604	19,048	20,374
Total	**7,209**	**17,483**	**10,803**	**29,336**	**38,295**
% of London's energy demand	5.4%	16.1%	9.9%	27.0%	35.2%
Carbon savings (MtCO_2/yr)	**1.0**	**2.7**	**1.9**	**1.8**	**4.6**

Table 1-1: Combined deployment potential from Phase 2 study (Table 3-3 in Phase 2 report), 2031

This report builds on the outcomes of the Phase 2 report to explore how the Mayor's target to supply 25% of London's energy from DE by 2025, can be most effectively realised. The discussion is structured around the framework shown in **Error! Reference source not found.** which sets out a roadmap for the growth and deployment of DE systems. This framework has been derived from evidence in countries with high levels of market penetration of DE, notably in Scandinavia[1 2 3]. Transition to low carbon sources of heat has occurred in many of these cases, with planning underway to complete a transition towards zero carbon heating by 2050[4 5].

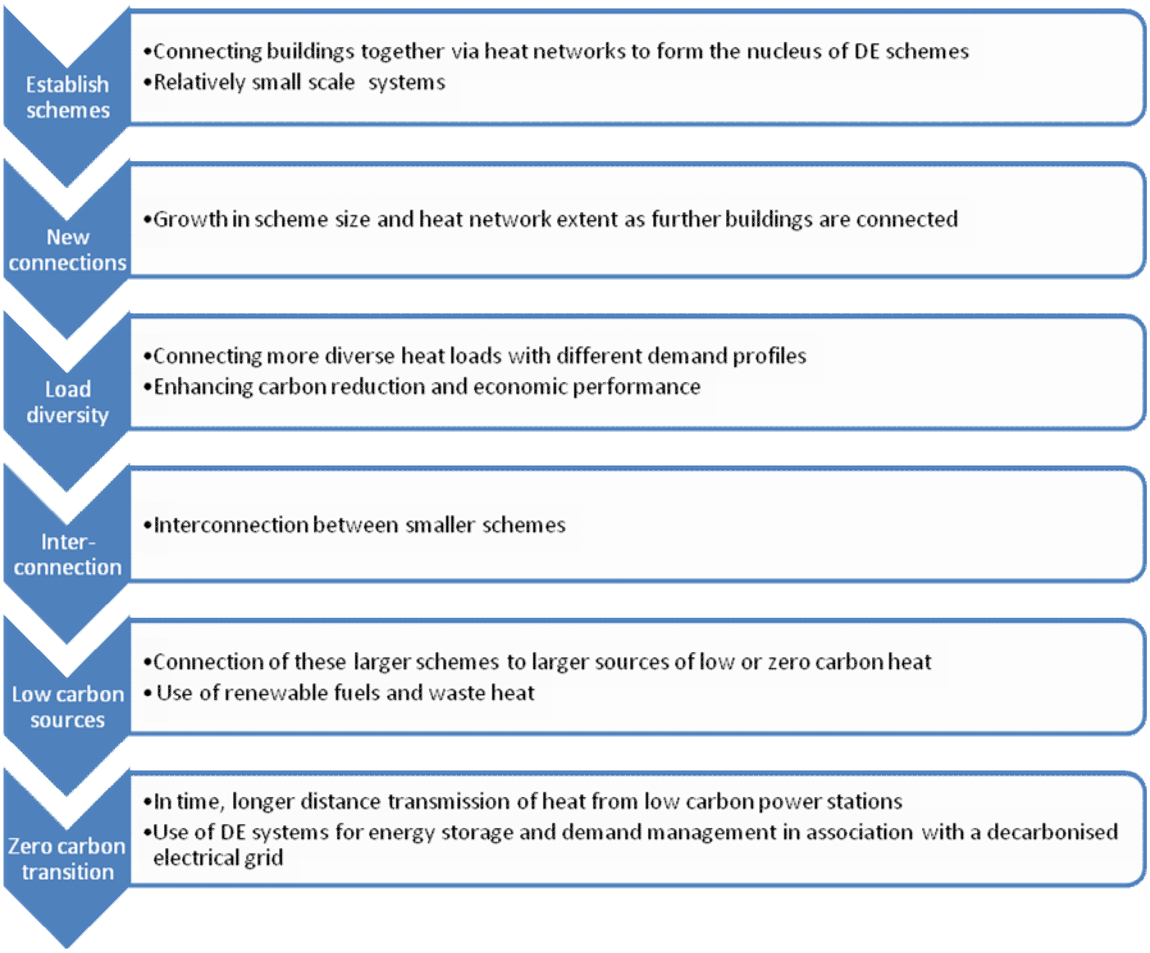

Figure 1-1: Overview of the roadmap for realising the potential of decentralised energy

1.2 Key questions for decentralised energy deployment

Table 1-2 identifies some of the key challenges relating to the future deployment of DE, for both heat distribution and heat generation, which are addressed in Section 3 of this report. These are likely to arise in the course of the deployment of DE, particularly in relation to the findings of the

[1] Hammer, F. (2000) Danish district heating – lessons learned: http://www.energy.rochester.edu/dk/dea/dh/lessons.htm
[2] DBDH (2010) Danish district heating history: http://www.dbdh.dk/artikel.asp?id=464&mid=24
[3] Petersen, E. (2000) Development of Danish district heating: http://www.energy.rochester.edu/dk/dea/dh/dev.htm
[4] Helsingin Energia (2009) Climate programme towards a carbon-neutral future: http://www.helen.fi/pdf/Kehitys_en.pdf Further details: http://www.helen.fi/energy/monipolttoaine.html
[5] Ramboll (2010) Heat plan Denmark: http://www.copenhagenenergysummit.org/Low%20Carbon%20Urban%20Heating,%20Heat%20Plan%20Denmark%20paper.pdf

Phase 2 report which identifies a number of "conditions precedent" that are required for DE deployment at scale:

- A policy framework which enables the management of connection to heat networks (offtake risk) to achieve a minimum level of market penetration, within a given area. This is necessary to create greater certainty around the economic return associated with heat networks, currently a 'high risk, low reward' investment[6]. Without sufficient certainty, lower cost sources of finance, identified as a key requirement in Phase 2, are unlikely to be available. In the Phase 2 report, a market penetration of 70% was assumed which is likely to require some form of regulation
- A level playing field in terms of carbon based incentives for DE technologies compared with micro-generation and large-scale electricity generating systems, perhaps based on the cost of emissions abatement
- Widespread institutional support at borough level, including the connection of public buildings, political support, planning policy support, long term covenant (i.e. assurance that schemes will operate over the long term) and de-risking of larger-scale projects (such as funding of feasibility and procurement work).

In the short- to medium-term, it is likely that DE potential will be based on using natural gas fired combined heat and power (CHP) plants and existing waste heat sources. However, there are some key questions arising from the Phase 2 report about how this potential could be realised:

- How can DE systems develop from small-scale, gas engine based schemes into larger, more financially viable schemes, which make use of larger-scale, lower cost, sources of low carbon heat?
- What are the risks to delivering this, and specifically does DE have a role if the electrical grid is decarbonised?

[6] London First (2008) Cutting the capital's carbon footprint: http://www.london-first.co.uk/documents/Cutting_the_Capital's_Carbon_Footprint_FULL_Low_res_FINAL.pdf

Heat distribution
How does offtake risk affect deployment and what opportunities are there to manage this?
Is interconnection of heat networks likely and if so how, and when, should this happen?
Is there an optimum scale for heat networks, bearing in mind future transition to low carbon heat sources?
Do lower temperature networks offer increased performance and should they be prioritised?
Can older buildings be retrofitted to be compatible with heat from lower temperature heat networks?
Do heat losses from longer distance heat transmission networks (>15km) preclude their use?
How much of a barrier is the cost of heat networks and can this be mitigated?
Do advances in heat network design (lower temperatures, new materials) have implications for deployment?
Heat generation
Does the economic viability of small-scale gas fired CHP prevent the development of heat networks which could transition to lower carbon sources of heat in the future?
How will heat generation plant transition away from natural gas to lower grade, lower carbon fuels (waste, biomass etc) and waste heat?
What role does gas fired CHP have as electricity supplies are decarbonised?
What are the scales of low carbon heat sources and how large will heat networks need to be to accommodate such technology?
Are there other barriers associated with low carbon heat sources
Can low grade heat be captured and used?
How much land is required for larger-scale DE energy sources?
What is the role of heat storage?
What role does ground heat capture and storage (HCS) have?
Can heat networks provide a way of managing demand on the electrical network?

Table 1-2: Key challenges for decentralised energy deployment

2 Barriers to deployment

2.1 Overview

This section introduces the barriers associated with the deployment of DE schemes. In particular, it focuses on those barriers in the context of a transition towards the level of DE deployment identified needed to meet the Mayor's target. The following sub-sections summarise the types and scales of DE schemes according to the classification developed in the GLA's Powering Ahead report[43]. A further category has been added to characterise possible use of large-scale remote sources of heat outside of London. Barriers which apply at each of the scales are summarised in the smallest-scale system to which they apply, but are not subsequently repeated. These scales are as follows and are used throughout the report:

- Type 1: Community-scale – CHP plants located in a building, serving up to 3,000 homes
- Type 2: District-scale – Dedicated energy centre serving up to 20,000 homes on multiple sites
- Type 3: Wider area network – Longer distance network linking major heat source(s) to around 100,000 homes
- Type 4: Heat captured and transmitted from power stations outside London.

2.2 Type 1 schemes

Type 1 networks are small-scale systems, between 0.3 and 3MW$_e$, consisting of CHP units in building plant rooms. These can serve one or more buildings up to approximately 3,000 residential units, or equivalent, in a local area. Examples include the Barkantine Heat and Power[7] and the King's Cross[8] schemes. The latter is planned to grow as neighbouring development is constructed. A schematic of a typical Type 1 scheme is shown in Figure 2-1. Table 2-1 summarises the barriers associated with the deployment of Type 1 schemes.

Figure 2-1: Type 1 network schematic

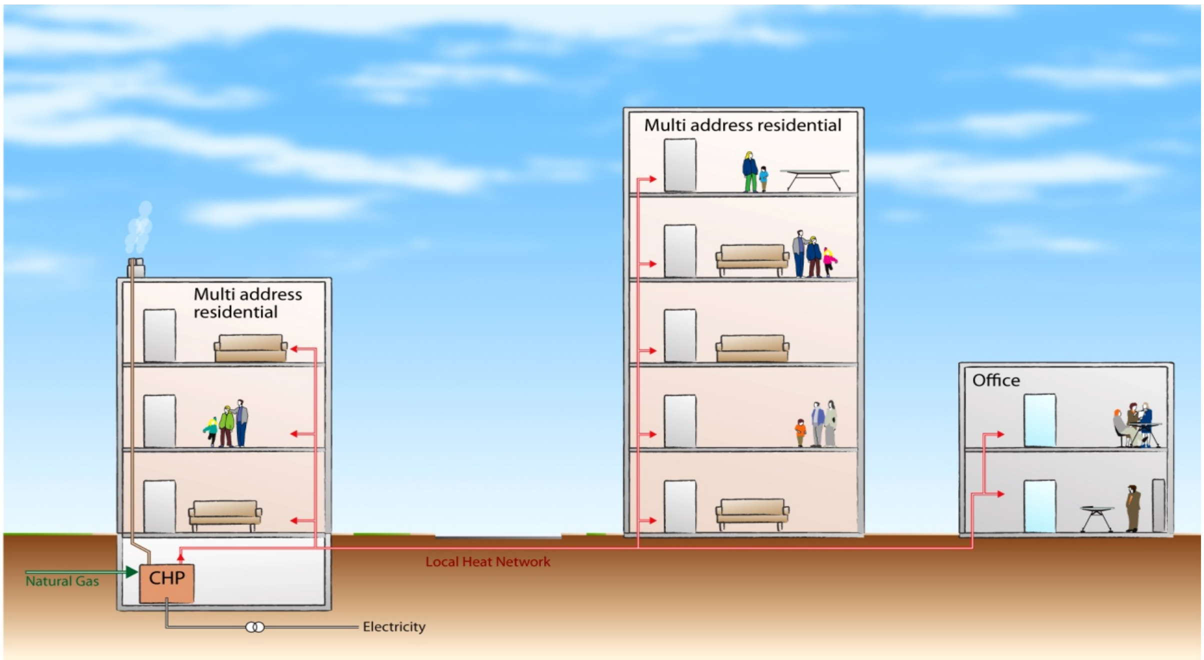

Figure 2-2: Type 1 network profile

[7] Dalkia (2011) Barkantine district heating system: http://www.dalkia.co.uk/docs/case/localauthorities/Barkantine%20.pdf
[8] Argent (2011) King's Cross: The energy centre explained: http://www.kingscrosscentral.com/energycentre

Type 1	Heat generation and fuel supply	Heat networks	Consumer connections
Technical	Small schemes unable to use low carbon fuels cost effectively	Heat losses can be high in low heat demand density areas	Expensive to retrofit residential buildings Diversity of building types required to give even load profile Heat load in new developments is low
Economic	Low export price for power generation Future fuel price uncertain Social landlords are unable to recover the investment in plant through rent increases, even if overall bills for tenants are lower High running costs of small plant	High initial investment costs Incumbent heat sources (gas, electricity) do not have to fund infrastructure capital investment Return is low, so difficult to offset capital cost High cost of pipework and civil engineering in the UK	Limited or no fiscal incentives for existing buildings to connect High standing charges to give revenue stream certainty Load develops over time, revenues limited in early years Debt recovery difficult No price protection for consumers other than general competition law Heat sale agreements must be long term to recover investment
Deployment	Changing policy introduces uncertainty whether gas fired schemes can meet future building regulations Planning policy may require low carbon plant from year 1, limiting longer term return on investment and carbon savings Phasing of new development means that DE systems sized to serve initial phases may be a sub-optimal solution in the final build out. However, investing capital in systems to serve future phases leaves risk of stranded assets	Supply chain and installation market is not competitive due to low market volume	Heat demand may not materialise Customers may be stranded if energy company fails High transaction costs to arrange connections

Table 2-1: Summary of barriers to deployment of Type 1 schemes

2.3 Type 2 schemes

Type 2 networks represent medium size CHP units, between 3 and 40MW_e based in a separate energy centre. A typical schematic is shown in Figure 2-3. They can serve several areas of demand and anchor loads, about 3,000 to 20,000 residential buildings, or equivalent, linking them with an extended heat distribution system. Heat sources include large-scale gas engines, biomass heat only boilers, energy from waste (EfW) or local waste heat from industry. Operational examples include the Olympic Park[9] and Citigen[10] schemes. Table 2-2 summarises the barriers associated with deployment of Type 2 schemes.

Figure 2-3: Type 2 network schematic

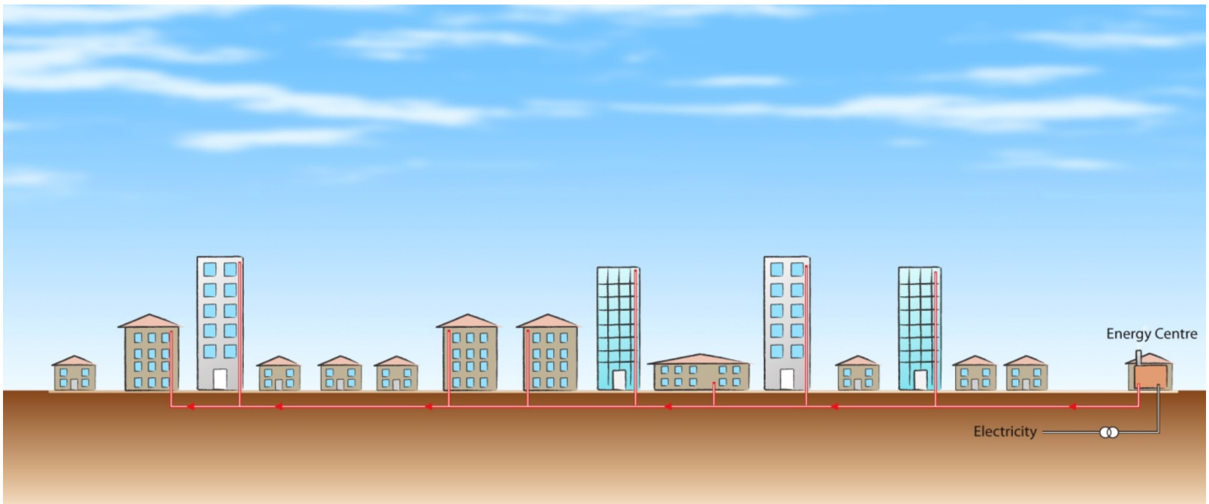

Figure 2-4: Type 2 network profile

[9] ODA (2011) Energy centre: http://www.london2012.com/making-it-happen/infrastructure/energy-centre.php
[10] Eon (2011) Citigen: http://www.eon-uk.com/generation/citigen.aspx

Type 2	Heat generation and fuel supply	Heat networks	Consumer connections
Technical	Timing of decision over plant replacement/retention may reduce potential for interconnection of smaller schemes Sufficient plant capacity required to serve expanded larger scheme. Constraints such as space, planning permission and environmental consents may restrict expansion	Question of whether interconnection is lower cost than plant renewal Physical route for connection must be available	Heat systems may have different technical parameters
Economic	Scheme operator needs to recover investment in original plant/scheme which may take 10 years+	Expensive to route networks through public highways	Large number of consumer connections are difficult to develop and coordinate at the same time without regulation around connection (heat offtake risk)
Deployment	Timing of decision points around interconnection becomes crucial	Increased physical risk to asset integrity from third parties over longer distance connections	No facilitating body tasked with undertaking a co-ordination role and de-risking larger-scale projects and interconnections Heat supply agreements may be owned by the original scheme operator and require transfer

Table 2-2: Summary of barriers to deployment of Type 2 schemes

2.4 Type 3 schemes

Type 3 networks consist of large-scale generators and industrial sources of waste heat linked to areas of demand suitable for district heating via longer distance heat transmission lines, serving the equivalent of 100,000 homes. This includes large heat customers such as industry and commercial centres, and smaller-scale heat networks (e.g. Type 1 or 2 schemes). Heat sources include larger-scale natural gas CHP plant (typically combined cycle gas turbine (CCGT)), waste heat from existing power stations or larger EfW plant. Examples include the London Thames Gateway Heat Network[11], which is under development, and the system linking buildings in the Upper Lee Valley to the Enfield Power Station[12].

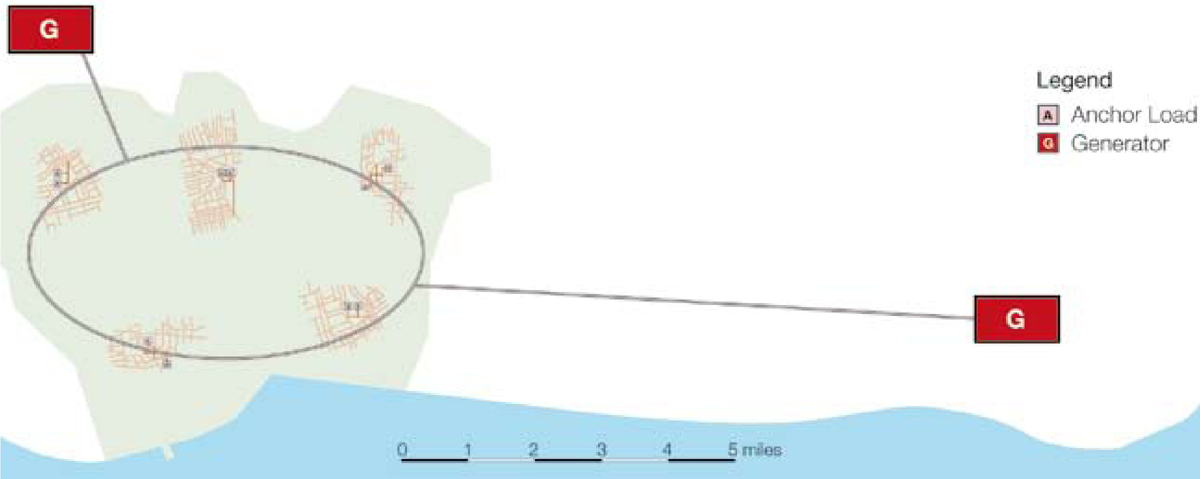

Figure 2-5: Type 3 network schematic

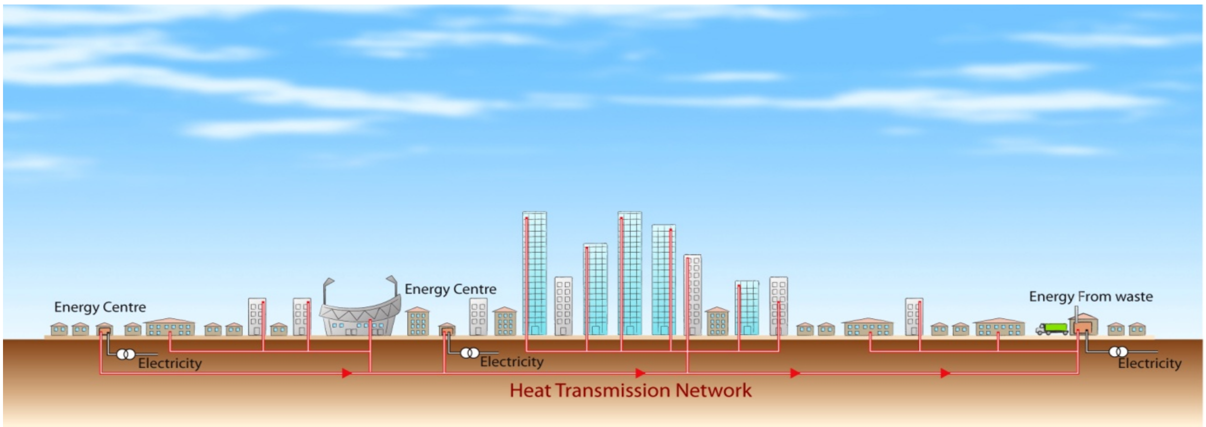

Figure 2-6: Type 3 network profile

[11] LDA (2011) London Thames Gateway Heat Network: http://www.ltgheat.net/heat-network/
[12] AECOM (2011) Enfield heat mapping study, p20: http://www.londonheatmap.org.uk/Content/uploaded/documents/070311-mjt-Enfield%20Heat%20Mapping%20Study%20(FINAL%20ISSUED).pdf

Type 3	Heat generation and fuel supply	Heat networks	Consumer connections
Technical	Large-scale of heat demand required to make use of heat	Physical routing of network becomes more difficult	Larger variety in type of building to connect, requiring higher temperature network operation
Economic	Even though return on investment may be possible risk averse heat generator may not be willing to engage	High initial investment costs Until schemes are built and operating with substantial revenues from heat supply these schemes will be viewed as high risk investments, particularly given the high capital investment cost and lack of policy support	Management of consumers requires utility company capability
Deployment	Heat generator may not view this as core business therefore lack of management attention / low priority Electricity market requires short term approach to trading strategy which may make generators unwilling to commit to providing heat	Major disruption to existing infrastructure corridors	Assembly of sufficient heat loads to support this scale of heat network is a long term process and requires strategic planning and co-ordination Large number of people dependent on scheme for basic needs (heat and hot water) – perceived as a risk by heat generators

Table 2-3: Summary of barriers to deployment of Type 3 schemes

2.5 Type 4 schemes

Type 4 networks represent large-scale generators remote from London (up to 100km), supplying heat through large capacity transmission heat mains into a city-wide network of transmission lines distributing heat to smaller schemes. This would be dependent on the development of new low or zero carbon power plants sufficiently close to London and would use the large amounts of waste or low carbon[13] heat available from such plants. Examples might include the new nuclear plant at Bradwell[14], or replacements for the power plants which are nearing the end of their lives at Tilbury (2015)[15] or Kingsnorth (2015)[16 19]. Tilbury was fuelled by coal but is due to switch to biomass fuel in 2011[17]. Kingsnorth is being considered as a trial site for carbon capture and storage (CCS). Consideration of a CCS cluster in the Thames Estuary area has been undertaken which lists both plants and would support a switch to low or zero carbon operation[17].

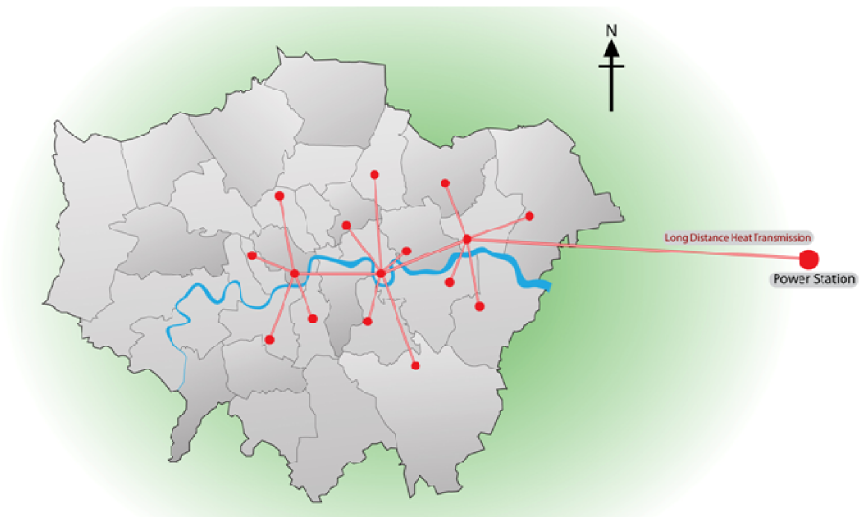

Figure 2-7: Type 4 network schematic

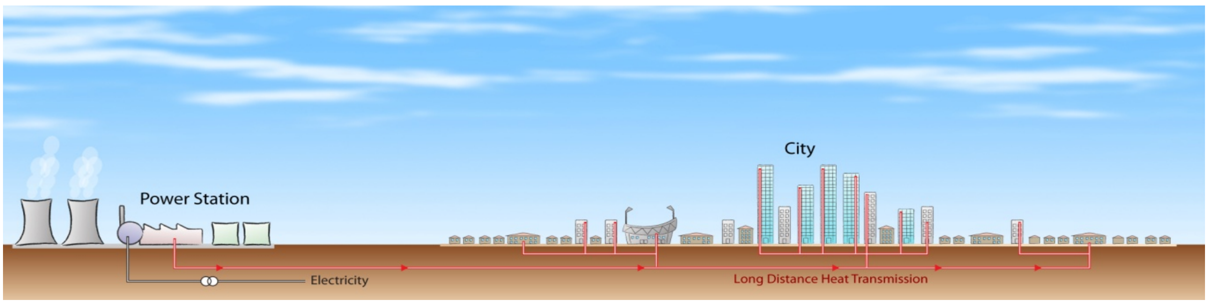

Figure 2-8: Type 4 network profile

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[13] Heat extraction from thermal cycle power plants implies a slight reduction in electrical efficiency, meaning the carbon intensity of the heat produced is dependent on how the lost electricity production is assigned (e.g. based on the additional fuel use in the plant, or based on additional electricity generated by the marginal plant on the electricity network). It could be considered low or zero carbon depending on the carbon intensity of the fuel source or type of marginal plant

[14] DECC (2011) National policy statement for nuclear power generation (EN-6), Volume I, p33: http://www.decc.gov.uk/assets/decc/11/meeting-energy-demand/consents-planning/nps2011/2009-nps-for-nuclear-volumeI.pdf

[15] RWE (2011) Tilbury Power Station: http://www.rwe.com/web/cms/en/97606/rwe-npower/about-us/our-businesses/power-generation/tilbury/

[16] DECC (2011) National policy statement for fossil fuel electricity generation (EN-2), p8: http://www.decc.gov.uk/assets/decc/11/meeting-energy-demand/consents-planning/nps2011/1939-nps-for-fossil-fuel-en2.pdf

[17] Eon (2011) Capturing carbon, tackling climate change: A vision for a CCS cluster in the South East, p7, p13: http://www.eon-uk.com/images/Thames_cluster_report_-_April_2009.pdf

Type 4	Heat generation and fuel supply	Heat networks	Consumer connections
Technical	The technology for carbon capture and storage plant is still developing and it may not be possible to access waste heat at sufficiently high temperatures	Heat transmission lines would be amongst largest and longest ever constructed Controlling water hammer requires careful design Physical scale may require routing via tunnel as the only feasible option into London to connect with Type 2 and 3 heat networks	No direct consumer connections at this scale
Economic	Power station plant would need to be constructed as CHP plant from the outset (e.g. with condensing/extraction steam turbine). This increases capital cost, with no certainty the plant will operate in CHP mode	Large capital investment only viable in the absence of affordable natural gas, over the longer term	n/a
Deployment	Completely dependent on the deployment of large-scale low carbon power plant	Large risk associated with this investment, possible only with national level regulation and policy support	n/a

Table 2-4: Summary of barriers to deployment applying to Type 4 schemes

3 Decentralised energy deployment

3.1 Overview

This section addresses the barriers identified in Section 2. Heat distribution networks and heat generation are considered jointly using the deployment framework set out in Section 1:

Figure 3-1: Outline of the roadmap for realising the potential of decentralised energy

Heat networks are central to the wider deployment of DE systems and a transition to lower carbon sources of heat. They allow:

- The capture and distribution of low grade heat from low or zero carbon sources
- The opportunity to change the heat source(s) by reconfiguring or replacing heat production.

Although heat networks are central to the wider deployment of DE systems, they only deliver environmental and economic benefits when connected to low carbon or low cost heat sources. Deployment of heat networks in the short- to medium-term, and the associated emission reductions, should therefore be supported by evidence that in the longer-term heat networks can be connected to low and zero carbon sources of heat. Specific heat generation sources are not considered in detail, except where their deployment materially affects the wider deployment of DE.

Table 3-1 sets out the structure of this section in relation to the deployment framework. Key factors relating to the deployment of DE are analysed in the order in which they become relevant to the wider deployment of DE.

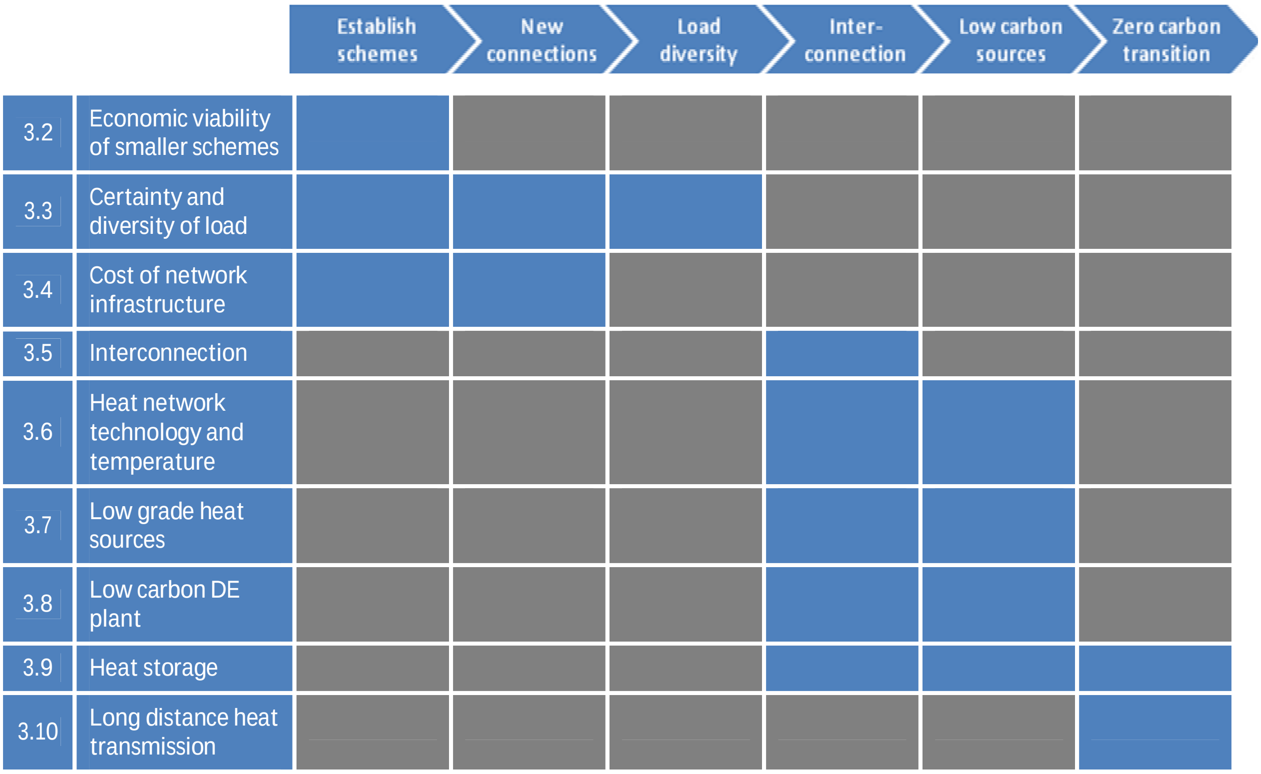

Table 3-1: Decentralised energy deployment framework matrix

3.2 Economic viability of small-scale (Type 1 and 2) schemes

The Phase 2 modelling demonstrates some key issues with respect to the scale and economic viability of DE, which include:

- Large-scale heat generating technologies produce heat at a lower cost than small-scale technologies, even when the cost of heat networks is included. This is supported by an International Energy Agency (IEA) study [18] and the results of previous studies into the potential for CHP which include London[19]
- Large-scale plant provides the lowest carbon intensity heat of all the natural gas fuelled CHP plant
- The size of heat networks required to support large-scale heat generating plant is considerable.

The majority of new build DE being established in London consists of Type 1 schemes using natural gas engine CHP plant[20] which have lower electrical efficiencies and higher unit costs and carbon emissions, compared to large-scale technologies such as natural gas fired CCGT[21]. The widespread deployment of these small-scale systems are, however, needed to aggregate heat loads, develop networks and allow larger-scale schemes to be established. In order to encourage the widespread deployment of Type 1 and Type 2 schemes some form of incentive or recognition of the associated and longer-term benefits, such as reduced carbon emissions, is required. This could take several forms, which have been previously summarised[22, 23]. Broadly these are as follows:

- Proper market access for generation of electricity from DE schemes, particularly small-scale schemes, leading to a greater share of the retail value of power generated
- Recognition of heat networks under the RHI, with support for DE based on a sliding scale against the carbon intensity of the heat produced
- Recognition of the carbon emission savings associated with DE under the Electricity Market Reforms (EMR)
- Capital cost contributions (grant funding, exemptions to taxation)
- Proper recognition of reduced load on electrical transmission and distribution networks

Maintaining RHI and increasing revenues to embedded generators using gas engine CHP through fairer licensing and reduced distribution charging should be a priority to ensure ongoing deployment of DE schemes beyond new developments. The Phase 2 modelling shows that an increase in

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[18] IEA (2005) A comparison of the cost of large-scale and distributed CHP and district heating: http://www.iea-dhc.org/010601.html
[19] BRE (2003) The UK Potential for Community Heating with Combined Heat & Power: http://www.energysavingtrust.org.uk/business/Publication-Download/?oid=180001&aid=441477
[20] LSBU (2009) Monitoring the London Plan Energy Policies Phase 3, Part 1 report: http://static.london.gov.uk/mayor/priorities/docs/lon-plan-energy-policies-monitoring-1.pdf
[21] Even with this plant there is a significant benefit in utilising larger-scale engines, as the difference between the electrical efficiencies of gas engines greater than 100 kWe output and 1,000kWe output is significant (around 10%).
[22] DECC (2011) CHP benefits and support mechanisms: http://chp.decc.gov.uk/cms/assets/pdf/chp_focus/Workshops-2011/CHP-Benefits-Support-Mechanisms.pdf
[23] London First (2008) Cutting the capital's carbon footprint, full report, p20-21: http://www.london-first.co.uk/documents/Cutting_the_Capital's_Carbon_Footprint_FULL_Low_res_FINAL.pdf

revenues of around £20/MWh (based on the energy prices in the Coordinated action scenario) makes a significant difference to the viability of DE schemes. Such an increase in revenue could feasibly be obtained by realising more of the retail value of electricity generated by DE schemes to the CHP plant operator. Enabling DE plant operators to sell power into the retail markets using a 'License Lite'[24] approach would meet this objective, as would charging lower distribution use of system costs to embedded generators such as DE plants.

However, this approach is dependent on 'supplier services' being available where larger, licensed suppliers take on compliance requirements on behalf of the DE plant operator in return for a payment. At present it is unclear whether existing suppliers will offer this service at a price which is affordable. Should these services be unavailable this will act as a further barrier to entry for smaller participants in the electricity and heat supply markets. Regulation to address this provides an alternative to direct support, with the additional benefit of promoting choice in the electricity market.

[24] 'Licence Lite' is a proposed approach to enable smaller generators to have better access to the electricity market by enabling them to become licensed as electricity suppliers and retail electricity direct to consumers. The proposals involve relieving small generators / suppliers of the risks and complexities of participation in the electricity market (notably removing the requirement to be parties to the Balancing and Settlement Code and other industry agreements) on condition that they sign a market interface agreement with a fully licensed supplier. The result should be that small generators / suppliers can access the retail value of their power generation which in practice they are unable to do at present. The market interface agreement (known as a 'Supplier Services Agreement') would provide for a fully licensed supplier to comply with the relevant industry codes in place of the 'Licence Lite' holder, in return for some form of consideration. The willingness of fully licensed suppliers to enter into Supplier Services Agreements, or to do so at an economic price in the absence of any regulatory requirement, is yet to be tested.

3.3 Certainty and diversity of load (offtake risk)

The certainty of heat load, also described as the offtake risk, is critical to the viability of heat networks. A report by DECC (2010) on the potential and costs of district heating networks shows that the estimated cost of heat from heat networks is highly sensitive to assumptions about the level of uptake[25]. It impacts on the deployment of heat networks in new build developments and in connecting to existing buildings. For new build developments the main challenge is the rate of build out. How do developments get to a critical mass of heat load which makes a DE system viable? Operating plant at reduced capacities for the first few years of life can result in lower returns on investment due to reduced efficiency at part load, lower revenues and proportionally higher fixed costs and finance costs. For smaller developments which could be joined to form larger schemes, coordination is a significant barrier, and for the connection of existing buildings coordination of connections, and the associated risk that the effort to manage this is abortive, is the main challenge. This section uses the Phase 2 results to test the sensitivity of deployment potential to the offtake risk and reviews how this is managed in selected case studies. Heat networks take a long time to develop, with the development cycle closely linked to the plant replacement cycle of individual building heating systems.

Sensitivity testing of uptake rate is analysed in Section 4.3.3 in the Phase 2 report[26]. The analysis shows that varying uptake rate between 80% and 40% reduces DE potential by more than 50%. The cost of heat distribution also increases as uptake reduces. In practice, this sensitivity (and the risk of stranded assets) is managed by only building heat network infrastructure where heat loads are sufficiently certain and/or guaranteed. In a given area, therefore, the initial heat offtake must either be sufficiently large, or there must be sufficient future certainty of revenue, to justify the investment in heat networks and generating plant. Even for small-scale heat networks, the investment cost is typically too high for investors to risk stranded assets.

Where heat networks already exist, the marginal cost of connecting additional heat loads can be high compared to connecting to existing natural gas or electrical networks; typically buildings are closer to electricity and natural gas networks and so connection costs are lower. Even where additional reinforcement of gas and electricity networks is required, and the cost of this is funded by the building owner or developer, the costs of connection to gas and electricity networks are regulated. Furthermore, these costs can be recouped by the original funder where reinforcement enables other new connections to be made.

In contrast, a heat network will often require the extension of the main pipework spines specifically to serve the building to be connected. This cost is either funded by the system owner/operator or the building owner/developer. The former is only likely if future revenues deliver a sufficient return on this investment. The latter is more common, particularly where the system owner/operator is risk

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[25] DECC (2010) The potential and costs of district heating networks (a report by Poyry Energy Consulting): http://www.decc.gov.uk/en/content/cms/meeting_energy/district_heat/district_heat.aspx

[26] The Phase 2 modelling assumes that 70% of the heat load is met by the heat network, including peak load boilers (i.e. the uptake rate was 70%). The remaining 30% is assumed to be served by individual building systems.

averse and the lack of certainty over future revenues prevents the system owner/operator from investing in the expansion.

The offtake risk needs to be managed to make networks more cost effective and reduce the uncertainty surrounding their ongoing viability. This can be achieved – as the selected precedents in Table 3-2 demonstrate – through a combination of regulation, incentives and contractual arrangements which encourage the demand for, and supply of, heat:

- Regulation – certainty of connection provided by regulation (with appropriate consumer protection)
  - Requiring buildings above a certain heat demand to connect to the network when their existing heating plant is due for replacement
  - Providing a concession area within which a specific energy company has a monopoly for the supply of heat, or the installation and operation of heat networks
- Incentivisation – sufficiently strong incentives to justify investment
  - High alternative costs (including due to taxation) or lack of alternatives
  - Negative features of alternatives (pollution, poor reliability)
  - Fiscal incentives (e.g. taxation, subsidy)
  - Low energy costs
- Contractual – heat offtake underwritten through contractual framework
  - Control through land ownership (e.g. via leases or land sales)
  - Heat supply agreement between energy company and building owner
  - Building owners jointly procure a DE system.

Case study	Summary of approach to offtake risk	Implications
United Kingdom		
Southampton	*Heat guarantees* • Initial buildings signed up were council buildings, which guaranteed their participation. The council then helped the energy service company with promotion to further customers and made them a statutory utility company within the city limits	• Initially only applicable to buildings under public control • Once established and 'credible', the heat network has grown to include private buildings, including new development
Olympic Park / Stratford City	*Concession agreement* • Within the site boundary the holder of the concession holds the sole rights to supply heating and cooling	• Requires some control over land, or other statutory powers • Regulation of monopoly ownership through contractual agreement. This might require a more formal approach to regulation where consumers connected to the networks are less capable of managing detailed contractual agreements
Pimlico	*Heat guarantees* • Network installation was part of the construction of social housing	• Initially only applicable to buildings under public control • Expansion previously limited but London Plan policies now encourage connection • Major expansion planned through connection to Whitehall, but even between two public sector schemes co-ordination of investment and heat offtake agreements is challenging
International		
Denmark	*Heat planning* • Areas are designated for heat or natural gas • Large heat users (>200kW) are required to connect	• Natural gas network already established in the UK • Lack of popular support for heat networks in the UK may present political challenges
Finland	*Economic incentives* • DE is a lower cost form of heat, due to taxation and a lack of low cost alternatives (e.g. natural gas)	• Relatively low cost natural gas and extensive existing natural gas infrastructure in the UK, limit competiveness of heat networks • Investment costs of heat networks not supported by low cost of capital
The Netherlands	*Free market approach to heat networks, strong incentives for CHP production* • High levels of CHP, but limited market penetration of heat networks	• Focusing incentives on heat generation plant limits the deployment of heat networks

Table 3-2: Managing offtake risk – a comparison of various approaches

Depending on the above listed factors, the degree of certainty required will vary. Regardless of the approach to offtake risk adopted, however, a long term policy, which provides a degree of certainty around investments in heat networks, is required to stimulate their deployment at scale.

Diversity of load

The addition of new connections and the growth of heat networks increases revenues from energy sales and improves the viability of DE schemes. It also increases the load diversity for a given DE system, which in turn increases the amount of energy which can be supplied from efficient low carbon sources such as a CHP plant. These kinds of plants have higher capital costs compared to peak load plant (e.g. gas boilers) and therefore they are sized to run as base load units. For example, gas engine CHP plants need to operate for a large proportion of the year to recoup the investment in them (at least 4,500 hours/year). This is even more critical for biomass CHP and energy from waste plants which have higher capital costs.

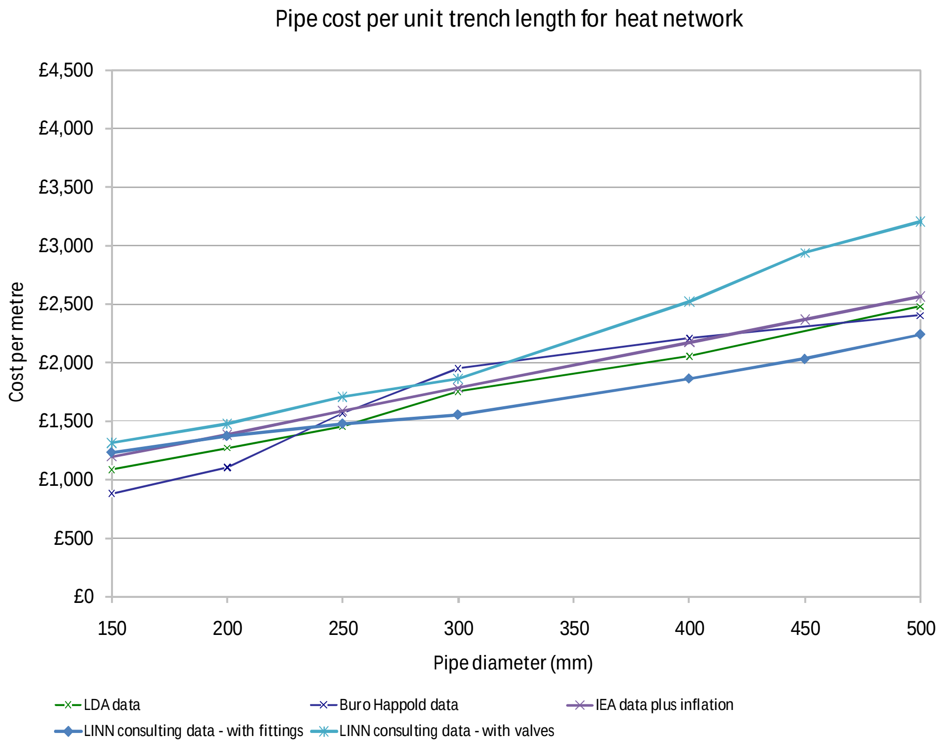
Increased load diversity extends the proportion of the year for which the CHP can be operated. This can result in better returns for a given size of CHP, or allow a larger unit to be installed. Load diversity therefore provides either improved economic viability, reduced emissions and in many cases both. For example in Vienna, CHP plants supply 68% of heat demand, waste heat sources and energy from waste plants supply 27%, whilst only 5% of supply is from peak load plant[27]. Where there is an existing DE scheme, increasing the load diversity can make it more economically viable to run the existing CHP units for longer periods. The interconnection of the Pimlico and Whitehall heat networks provides a good example. The heat load of the former scheme is largely made up of residential dwellings, whilst the latter is predominately office based.

[27] Wien Energie (2009) District Heating & Cooling in Vienna, The "Vienna Model": http://www.copenhagenenergysummit.org/applications/Vienna,%20Austria-District%20Energy%20Climate%20Award.pdf

3.4 Cost of network infrastructure

This section explores the cost of network infrastructure. As set out in the Phase 2 report, the cost of heat networks constitutes by far the largest proportion of the investment cost of a DE system. This investment cost occurs at the beginning of the project development lifecycle and the deployment potential is therefore sensitive to changes in cost estimations as this cost has to be amortised over a period of 40 years. Due to the small size of the UK market for installing heat networks, there is limited data available about the cost of their installation in the UK. Other studies have shown that the cost of network installation in the UK is considerably higher than the equivalent installations in other European countries[28].

Figure 3-2 compares the cost of heat networks from a number of different sources[29]. Heat network costs used in the Phase 2 modelling, are based on the IEA[18] data which is broadly consistent with the other data sets. The comparison shows that costs are higher if networks are designed with valves at branch connections, which allow for a phased construction[30]. Ensuring that networks are should be part of any network standards developed for London in order to limit costs. This suggests that designing networks without below ground valves and limiting the number of phases of network construction in any given project will reduce overall heat network costs. The impact of any costs associated with traffic management and/or utilities diversion will increase these costs further. These aren't modelled here as they will vary widely by site.



[28] DECC (2010) The potential and costs of district heating networks: http://www.decc.gov.uk/en/content/cms/meeting_energy/district_heat/district_heat.aspx
[29] The LINN Consulting data assumes installation in soft ground, rather than under roads
[30] Adding valves increases unit costs significantly as manholes and chambers are required, and large diameter valves are expensive

Figure 3-2: Comparison of heat network costs (Source: LDA, 2009[31]; IEA, 2005[32]; LINN Consulting, 2011[33])

Table 3-3 identifies the main cost drivers for the installation of heat networks in the UK.

Factor	Description	Opportunities to reduce costs
Design of routes	The design of the route will determine the physical length of pipework, it's linearity and infrastructure crossings as well as the ground the pipework will run through	Routes should cross soft ground, follow roads or linear corridors, minimise bends, avoid crossing major trunk roads, avoid privately owned land, and limit railway and water crossings
Cost of material	The cost of pipework material may be higher in the UK compared to other European countries due to the low volumes involved	A larger market for heat networks will drive up volumes and reduce costs Using lower temperature networks and plastic pipework reduces costs
Phased installation	Installation in sections to match phasing of heat loads may require below ground valves increasing network cost	Planning of networks to avoid phasing can eliminate the need for valves
Rights of access for streetworks	Heat network operators do not have statutory undertaker status and must apply for a licence to undertake streetworks, adding cost and programme delay	Allowing heat network operators statutory undertaker status within the locality where their network exists or is to be installed
Crossing infrastructure	Heat network operators face disproportionate charges when their networks need to cross other infrastructure assets as land owners are not required to provide a wayleave (e.g. rail, sewage, waterways, roads, utilities)	As above
Traffic management costs / charges	Under the Traffic Management Act 2004, Transport for London operate a permit regime where utilities are charged for streetworks	Co-ordination with other streetworks
Installation alongside other infrastructure	Large-scale heat network can run alongside other linear infrastructure assets (rail, sewage, waterways, roads, tunnels) but no mechanism exists to facilitate the planning of these routes or a requirement for asset owners to co-operate (where feasible to do so)	Co-ordination with other infrastructure installation or renewal
Civil engineering costs	The UK construction sector has an improving record in terms of the health and safety of its workforce. Best practice working methods for below ground works include extensive safeguards (e.g. edge protection of trenches, rigid step ladder access to trenches, fencing around work sites, separation of pipework) which may increase costs	Co-ordination with other streetworks, particularly those of the local authority where they are also involved with the development of the heat network in question New installation methods requiring less open trenching

Table 3-3: Factors influencing the investment costs of heat networks

Some of the factors outlined above will require changes to national policy or a significant expansion in the market for pipework. In practice, where investments in heat networks are based on commercial discount rates, the network costs would need to be significantly lower in order not to constrain development. Given the critical nature of heat network cost on the viability of DE systems,

[31] LDA (2009) Analysis undertaken as part of London Thames Gateway Heat Network business case study
[32] IEA (2005) A comparison of distributed CHP/DH with large-scale CHP/DH, Figure 6-G (inflation applied @3.5%/annum to 2010): http://www.iea-dhc.org/010601.html
[33] LINN Consulting (2011) Data supplied to Buro Happold Ltd by correspondence based on recent cost management work on heat network project in London. Costs 'with fittings' allows for installation in soft ground and excludes breaking out and reinstatement of road carriageways. Costs 'with valves' includes additional allowance for isolation valves at branch connections and to allow phased construction

further work is required to gather more detailed outturn cost data from installed projects, and to validate DE deployment models using this data. Cross-industry dialogue may also help to identify opportunities for further cost reductions.

3.5 Interconnection

Interconnection of heat networks is a key step in their wider deployment and transition to using lower carbon sources of heat. At present, however, the risks associated with developing extensive heat networks without a strong policy framework lead to the development of smaller, fragmented heat networks serving only those buildings where heat loads can be guaranteed. Important benefits of more widely interconnected heat networks include:

- Larger heat loads enable large low carbon plant such as waste heat from existing power stations, biomass CHP and EfW to be used (e.g. the London Thames Gateway Heat Network[34])
- Increased diversity of heat loads (greater mix of uses and differing times of peak load) allows the most efficient base load plant to provide a greater proportion of the heat demand
- Similarly, an increase in running hours of existing plant by adding more heat demand improves cost effectiveness (e.g. connecting together the Pimlico and Whitehall[35] schemes to allow the gas turbine CHP plant to be operated for longer)
- Improved resilience through provision of additional heat sources, including a variety of fuels (e.g. the interconnection of the energy centres and networks serving the Olympic Park and Westfield Centre near Stratford[9])
- Where heat networks are established, interconnection may be more economically viable than plant replacement

Interconnection may therefore be more cost effective and/or improve environmental performance than replacing plant or increasing capacity in an individual network. This decision will site specific and will likely be triggered by events such as plant replacement, fuel price changes, heat supply contract renewals and new sources of low carbon or low cost heat coming on line.

This section considers the opportunities and barriers related to interconnection of heat networks. Technical and commercial issues are considered, along with the process by which interconnection can happen. It should be noted that at present the market penetration and extent of heat networks in London are both sufficiently low that interconnection is not a short-term barrier. However, it is important to ensure short-term policy and investment decisions do not constrain future deployment potential.

3.5.1 Opportunities and barriers

The interconnection of heat networks presents a number of opportunities and barriers which are summarised in Table 3-4. Many of these barriers can be addressed in the short-term at minimal cost (e.g. common standards) whilst others may require a case by case approach (e.g. commercial terms of interconnection).

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[34] LDA (2011) London Thames Gateway Heat Network: http://www.ltgheat.net/heat-network/
[35] LDA (2011) Whitehall and Pimlico Decentralised Energy: http://www.lda.gov.uk/projects/pimlico-whitehall-decentralised-energy/index.aspx

Opportunities	Barriers	Implications
Technical		
• Increases the scale of heat demand, enabling use of large-scale, lower carbon heat sources • Improves resilience • Standardisation of technology • Increases diversity of loads and increases running hours for CHP units • Improves plant efficiency and reduces heat losses through lower temperature operation	• Network standards may not be compatible (temperature, pressure) • Mixture of direct versus indirect[36] connections requires additional heat exchangers and pumps • Responsibilities for cross-ownership boundary issues (water treatment, location and operation of pumping and network control) • Physical routing of connection • Choice of heat source and control over heat dispatch	• Establish clear network standards for temperature and pressure • Publicise best practice water treatment technologies and case studies, particularly through trade bodies • Safeguard network routes and coordinate with other utility infrastructure • Clear assignment of 'system operator' role
Commercial		
• Future of individual energy services companies after interconnection • Lower operating costs • Lower cost of heat • Increased purchasing power of network operating entity	• Assignment of control and responsibility for maintaining supply • Responsibilities (asset ownership and maintenance) • Timing and triggers for interconnection and/or plant replacement decisions • Cost of connection • Individual scheme investments may not be sufficiently realised or depreciated	• Establish contractual framework for interconnection with clear assignment of responsibilities • Provide platform for recording and exchanging information on network locations and development opportunities • Commercial terms and return on investment must be mutually attractive to scheme owners/operators
Deployment		
• Greater scale of organisation increases opportunities for marketing new connections • Reduces the number of heat production sites • Frees up land or internal space for other uses	• Stakeholder (consumer) management • Downtime associated with connection (unless 'hot working' can be achieved)	• Develop and operate heat networks in accordance with a consumer charter[37]

Table 3-4: Opportunities and barriers of interconnecting heat networks

3.5.2 Technical issues

There are a number of technical issues. However, provided sufficient, it should be possible to manage this issue. In cities where heat networks are widely deployed (e.g. Copenhagen) a mixture of low temperature hot water (LTHW), medium temperature hot water (MTHW) and steam systems have grown over time and subsequently been interconnected using high temperature transmission

[36] Heat networks and buildings directly connected share the same circulating water; indirectly connected networks and buildings are separated by heat exchangers and require separate circulation pumps and water treatment systems

[37] Font Energy (2010) Domestic Customer Charter for Consumers Connected to Communal or District Heating Networks: http://www.chpa.co.uk/medialibrary/2011/04/07/59cd23df/CHPA0010.pdf

networks. Due to an initial lack of technical standards, many of these networks require heat exchangers for interconnection, increasing the operating temperature and resulting in greater heat losses. New systems have the opportunity to prevent such technical issues associated with the interconnection of heat networks, by taking advantage of advances in the design of heat networks and giving sufficient consideration to the specification of technical standards at the initial development phase of heat networks.

Some work is already underway to develop technical standards but more detailed guidance is required which defines key parameters such as temperature and pressure, and direct vs. indirect connection. This includes:

- Updating the Good Practice Guide 234[38], which sets out high level guidance for the development of heat networks[39].
- Work is being undertaken by the Combined Heat and Power Association and Nabarro to develop standardised consumer agreements[40].
- Technical standards for heat network design have been developed for the Barking Town Centre Energy Action Area which could be adapted for wider use across London[41].

The case for district heating network standards is clear and it is likely that the approach being developed to ensure common standards will ensure future interconnectability and the cost benefits this can realise. These standards could be extended to include a customer charter to help placate the introduction of unnecessary regulation. Given the limited deployment of heat networks in London, promotion of any agreed standards may be required to ensure they are sufficiently widely disseminated to become the de-facto approach across the capital.

3.5.3 Commercial models and deployment

Table 3-4 also sets out the issues relating to the commercial and deployment barriers facing the interconnection of heat networks. Key issues which emerge include the opportunity for heat network operators to continue to earn a margin on heat supplied via their networks if they lose income from CHP operation, which will determine whether interconnection is commercially attractive. There are likely to be two main situations where interconnection of networks occurs:

- Connection of two or more Type 1 or Type 2 schemes together into a larger Type 2 scheme (e.g. the proposed Euston Road scheme joining the proposed London Borough of Camden scheme and existing Kings Cross scheme [42])
- Connection of Type 1 or Type 2 schemes into a Type 3 scheme (e.g. London Thames Gateway Scheme[34]).

[38] DETR (2003) Good Practice Guide 234: Guide to community heating and CHP Commercial, public and domestic applications: http://www.chpa.co.uk/medialibrary/2011/04/07/81f83acc/CHPA0003%20Good%20practice%20guide%20to%20community%20heating%20and%20CHP.pdf

[39] CHPA (2011) District heating best practice: http://www.chpa.co.uk/district-heating-best-practice_202.html

[40] CHPA (2011) Standardised heat consumer agreement – Nabarro (CHPA0008): http://www.chpa.co.uk/district-heating-best-practice_202.html

[41] Borough of Barking and Dagenham (2007) Community heating specifications for Barking Town Centre Energy Action Area: http://www.barking-dagenham.gov.uk/Environment/Documents/BTCEEADeveloperGuidanceSept07.pdf

[42] GLA (2009) Powering ahead: Delivering low carbon energy for London: http://www.london.gov.uk/priorities/environment/climate-change/decentralised-energy

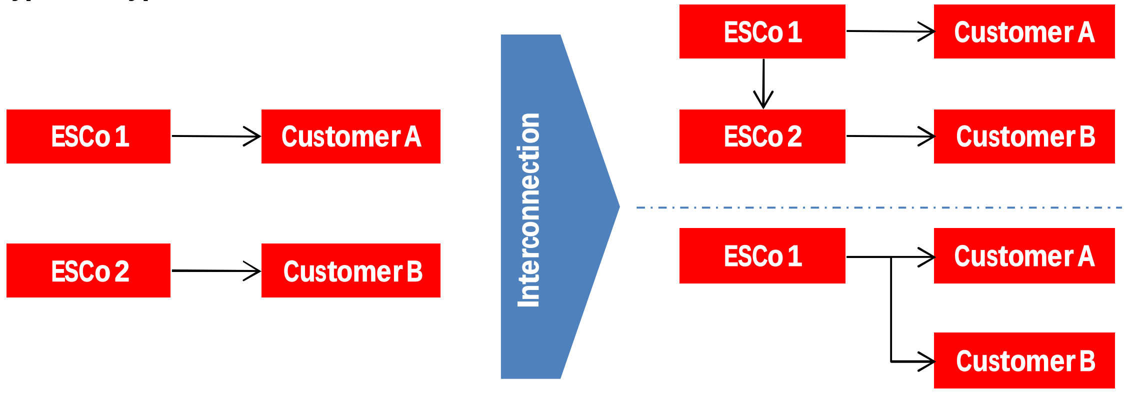
There will be different commercial models, similar to those set out in the Powering Ahead report[43]. Table 3-5 summarises the key types of commercial entities involved in the ownership, operation and interconnection of heat networks. Figure 3-3 and Figure 3-4 set out examples of how interconnection can occur for the two situations described above. In practice the technical and commercial characteristics of the DE systems and entities involved will determine the detail of these relationships and it is not possible to cover the large range of approaches in this study. The intention is to use the examples as illustrations of the process of interconnection.

Entity		Description
ESCo	Energy services company	Single entity responsible for generation, infrastructure and selling energy to customers
GenCo	Generation company	Asset owner and generator of heat (and likely electricity), sold on a wholesale basis
TransCo	Transmission company	Owns heat transmission assets connecting Type 1 and 2 schemes to GenoCo plants
DisCo	Distribution company	Owns and operates local pipework. May also sell energy directly and may also be same entity as a TransCo
HeatCo	Heat company	Buys heat wholesale and sells to customers. Also responsible for metering and billing
AssetCo	Asset owner	Owns assets which are leased to other entity for operation and maintenance
Customers		Purchasers of heat

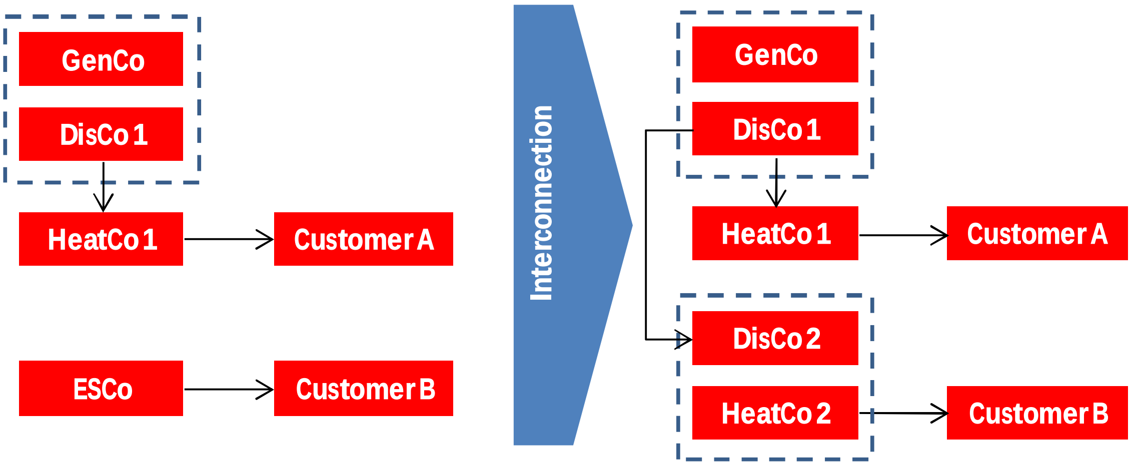
Table 3-5: Definitions of commercial entities involved in the interconnection of heat networks

[43] GLA (2009) Powering ahead: Delivering low carbon energy for London: http://www.london.gov.uk/priorities/environment/climate-change/decentralised-energy

Type 1 to Type 2 interconnection



ESCo 1 sells heat at wholesale rate to ESCo 2. ESCo 2 continues to provide back up heat
OR
ESCo 2 ceases to exist and its assets and customer base are adopted by ESCo 1



ESCo becomes an integrated DisCo and HeatCo only, and buys heat from GenCo/DisCo 1.
ESCo plant is mothballed, decommissioned or adopted by GenCo/DisCo 1

Figure 3-3: Commercial models for interconnection of Type 1 or Type 2 heat networks

The final commercial structure will be dependent on a number of issues, including relative scale, condition of plant and plant replacement cycle, type of plant and its operating strategy, ownership and appetite for risk. Additionally the nature of any wider plans for a Type 3 heat network in the area will also have an effect. Figure 3-3 considers two smaller schemes being interconnected and a larger scheme being connected to a smaller scheme. In the first example a decision about the retention of the second ESCo is required. ESCo 2 can be absorbed into ESCo 1 or ESCo 1 could sell heat to ESCo 2. If the latter option is chosen, ESCo 2 must be able to buy heat at a price that allows it to cover the costs of its own operations and bad debt provision as well as any financing costs and/or repayments. In between these extremes there are options whereby ESCo 2 retains ownership of the heat network assets but these are leased to ESCo 1.

In the second example, a decision to interconnect can be made on the basis that the GenCo plant offers a lower cost or lower carbon heat source than the existing ESCo plant (which may be due for replacement). In this case similar issues arise as in the first example. The interconnected structure shown assumes that the ESCo converts to a DisCo and HeatCo, retaining ownership of the network assets but buying in heat at wholesale rates and selling it on to customers. Again, sufficient margin is required to make this viable.

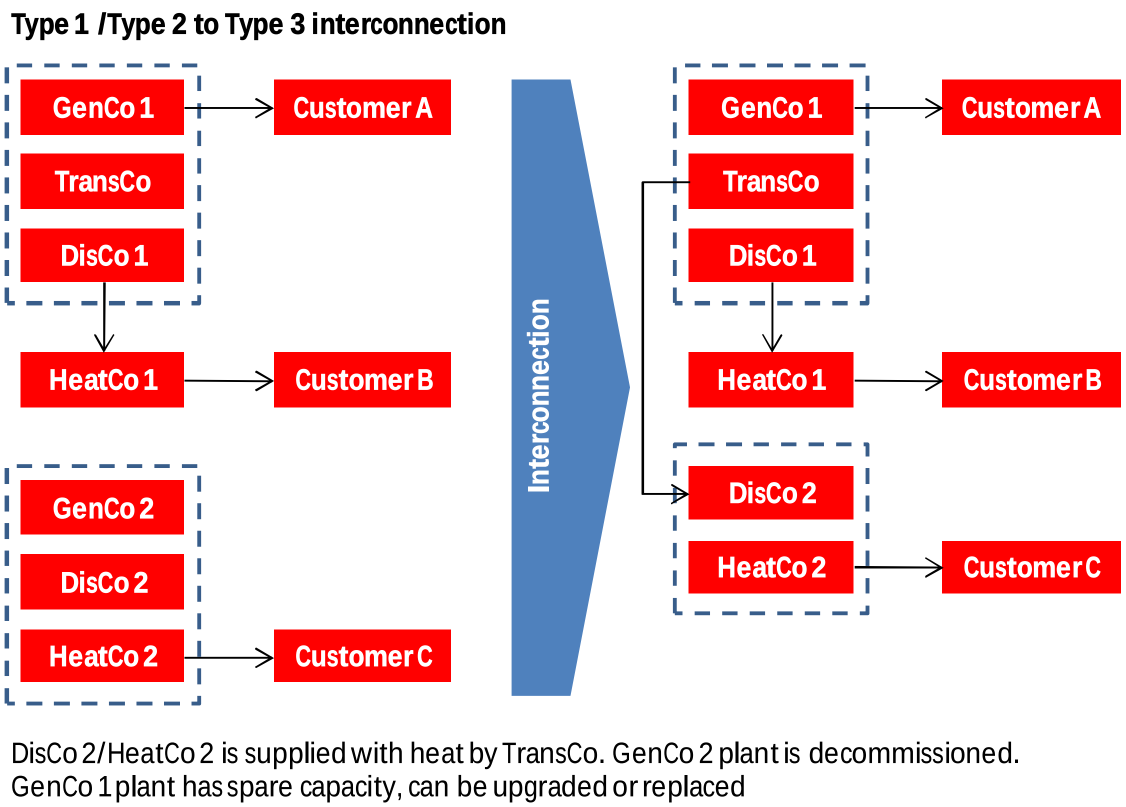


Figure 3-4: Commercial model for interconnection of Type 1/Type 2 heat networks to Type 3 heat networks

The interconnection of smaller schemes to Type 3 heat networks (see Figure 3-4) is likely to prove to be more straightforward than the interconnection of smaller schemes as questions around plant replacement are less likely to occur. The example shown in Figure 3-4 shows a Type 3 and a Type 2 scheme being interconnected, where it is assumed the Type 3 scheme has access to lower cost heat via a transmission network. A connection is made to the DisCo 2 heat network from the TransCo and the GenCo 2 plant is decommissioned.

One issue with heat networks is what happens in the event that the system owner/operator becomes insolvent i.e. who becomes the heat supplier of last resort? In the electricity market each region has a default supplier assigned by OFGEM to supply customers where their supplier ceases to exist. The network operator is a separate company and so the physical supply does not cease in any event. The complexity of the commercial structure of a Type 3 scheme could be perceived as adding risk to this issue. Conversely, a Type 3 scheme may provide increased certainty through:

- Separation of heat supply (ESCo/HeatCo to whom customers pay their bills) and operation (TransCo/DisCo)
- Multiple parties, one of which can be nominated as the supplier of last resort.

Issues around rights of access to install, inspect and maintain plant arise in all cases. These issues also arise in the establishment of heat network projects of any scale where any plant, including networks, is installed in another party's premises or land. However, these are relatively well understood issues which can be captured in project specific contractual agreements e.g. heat supply agreement between a HeatCo and customer. The UK Green Building Council is developing a framework to assist project developers with these issues, which may help to reduce transaction costs[44].

Network evolution

The process of evolution from Type 1 networks to Type 4 depends upon the rate of growth of connections to the network and the rate of plant renewal. Key decisions need to be made around plant replacement and when network growth approaches the capacity of the network to supply heat. Figure 3-5 illustrates the key processes involved.

The process of interconnection will also be driven by the extent to which networks are deployed, and their physical proximity. The Phase 2 modelling results show that the deployment potential in central areas of London is very high; essentially almost all areas of the central boroughs can accommodate heat networks. This implies that widespread coverage in these areas is required. Initially this will need to be driven by aggressive expansion of existing networks as establishing new projects takes several years. Planning for new projects to be developed by 2015 needs to be underway by 2010-12, depending on the scale of construction. Strategic planning to ensure widespread coverage of heat networks is a key requirement of ensuring this coverage. The data gathered from the Decentralised Energy Master Planning (DEMaP) programme[45] is a crucial element of enabling this; it also ensures that gaps are identified allowing areas heat networks to be planned where there is no existing or planned coverage.

Timing of interconnection is dependent on issues such as plant renewal decisions. Type 1 and 2 schemes developed in the period 2011-2015 will require re-powering around 2025-3031. This also coincides with a need to switch from gas fired CHP to lower carbon sources of heat, as electricity supplies are decarbonised. Interconnection of Type 1 or 2 schemes into larger Type 3 networks could be part funded out of plant replacement 'sinking funds'. However, these Type 3 networks will need to be operational in order to allow this, suggesting a project identification and planning process is required from 2015, with implementation commencing no later than 2020 to ensure availability for interconnection by 2025 and transition to low carbon plant by 2031. Where Type 1 and 2 schemes can't be interconnected a switch to smaller-scale low/zero carbon heat sources such as anaerobic digestion or the alternative heat sources outlined in the Phase 1 report should be considered.

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[44] UKGBC (2011) UK-GBC SCI Legal Frameworks Task Group - Interim Report: http://www.ukgbc.org/site/resources/show-resource-details?id=1004

[45] GLA (2011) DEMaP Progress and Opportunities Event: http://www.londonheatmap.org.uk/Content/DEMaPprogressopp.aspx

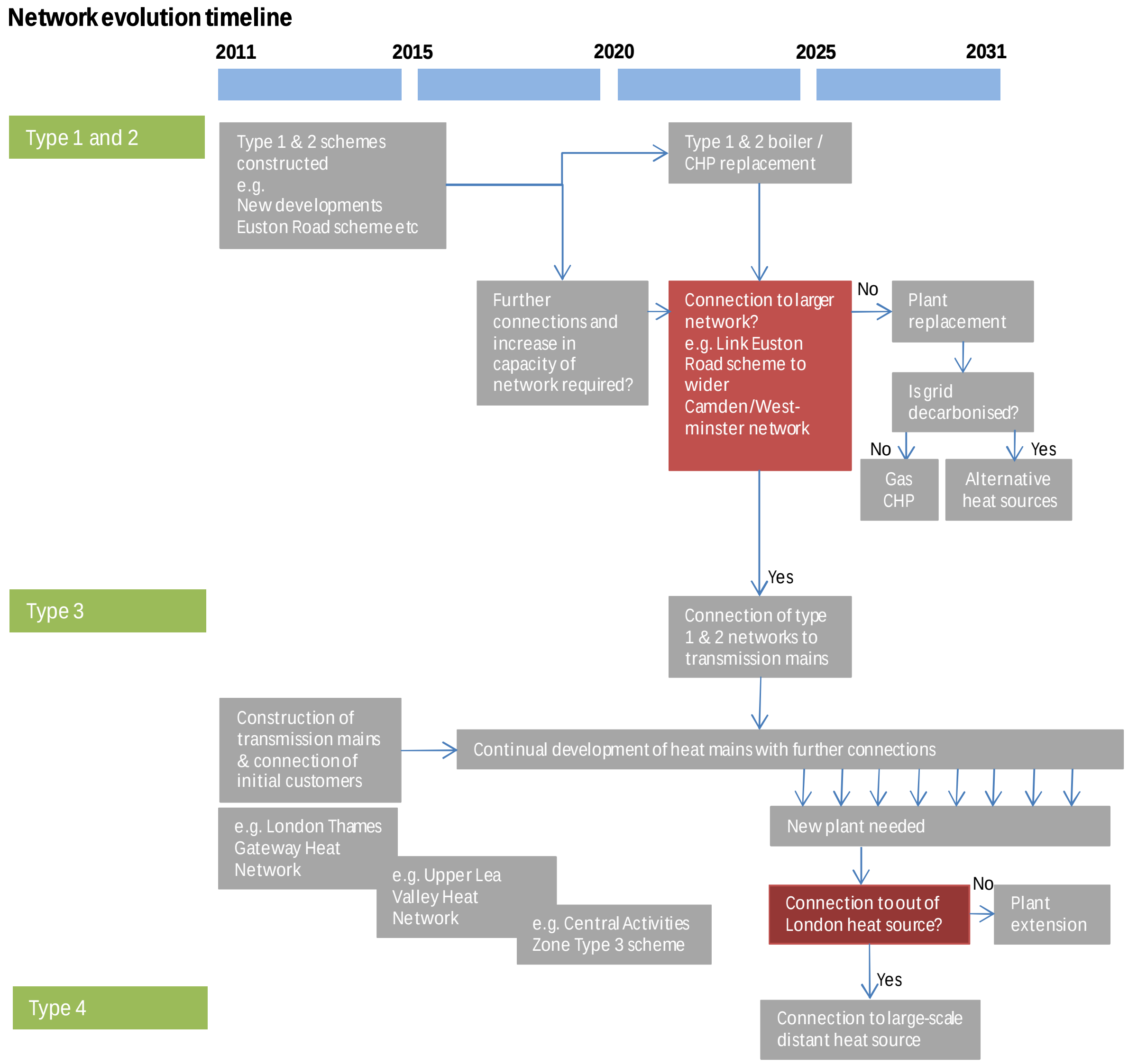

Figure 3-5: Timeline and decision points for network evolution based on plant renewal and growth in heat connections

3.6 Heat network technology and temperature

Heat networks are a well established energy carrier in many countries. However, improvements to design and operation are being made[46] which have implications for the cost and efficiency of heat networks, and therefore the deployment potential of heat networks in London.

Improvements focus on reducing the operating temperatures of heat networks which has the following benefits[47]:

- Reducing network losses
- Enabling use of low carbon heat sources which can only provide very low grade heat
- Reducing the cost of heat network infrastructure, enabling higher levels of market penetration.

Other developments include use of district energy balancing systems which make use of heat networks to balance simultaneous heating and cooling loads of buildings within a given area.

3.6.1 Low temperature networks

District heating networks typically operate at the three main temperature ranges summarised in Table 3-6.

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[46] Olsen (2008) A New Low-Temperature District Heating System for Low-Energy Buildings, The 11th International Symposium on District Heating and Cooling: http://www.annex51.org/media/content/files/publications/Low_Energy_Ddistrict_Heating_S_Svendsen.pdf
[47] BRE (2011) The performance of district heating in new developments: http://www.brebookshop.com/details.jsp?id=326672

Temperature range			Opportunities	Barriers
Name	Flow	Return		
Medium temperature hot water (MTHW)	105-120ºC	50-70ºC	• Used for transmitting heat over long distances (Type 3 systems), • Can provide inputs into a range of lower temperature systems • Can provide driving heat for absorption chillers increasing viability of heat networks	• Limited application for distribution networks • Requires higher pressure system and more insulated pipework with increased capital costs • Leakage is in the form of steam
Low temperature hot water (LTHW)	70-95ºC	45-55ºC	• Typical industry practice design temperature for distribution networks • Capable of supplying existing buildings with high heating system temperatures (typically 82-71ºC)	• Higher losses than lower temperature system • Requires steel pipes
Very low temperature hot water (VLTHW)	45-70ºC	35-50ºC	See Table 3-7	

Table 3-6: Heat network operating temperatures (Source: DBDH, 2011[48])

Operating at lower temperatures reduces heat losses and increases the efficiency of heat generating plant. The opportunities associated with very low temperature heat networks and the barriers to their deployment are summarised in Table 3-7.

[48] DBDH (2011) District heating characteristics (operating temperatures and pressures): http://www.dbdh.dk/artikel.asp?id=462&mid=24

Opportunities	Barriers	Implications
Technical		
• Reduced heat loss, therefore lower operating costs and improved carbon performance • Opportunity to use twin pipe systems, where flow and return pipes are contained in a single outer insulating sleeve, with smaller trenches • Lower temperature heat sources can be used (such as heat pumps linked to waste heat sources) • Lower grade pipework material can be used (e.g. flexible plastic pipework) which require less in-situ installation work (e.g. welding)	• May require pipework to be routed via front gardens to reduce network length and hard dig costs • May not be able to meet heat demands of less thermally efficient buildings due to mismatch with radiator sizes • Less is known about lifecycle of plastic pipework compared to steel pipework • Cannot supply cooling via absorption chillers	• Potential to make DE viable in areas with heat demand densities less than 50kWh/m^2 • Feasibility assessments should consider the use of low temperature heat sources • Building retrofit programmes, including RE:FIT and RE:NEW, reduce heat demands enabling building heating systems to operate at lower temperatures (e.g. flow and return of 70-50ºC rather than 82-71ºC) without reducing comfort levels, making them suitable for connection to low temperature heat networks. Retrofit programmes should include modifications to building pipework to allow future connection to heat networks where heat mapping suggests these are viable
Commercial		
• Reduced capital costs due to smaller trenches, soft dig, lower cost materials and simplified installation • Heat costs can be lower due to lower capital costs and reduced heat losses	• Increased perception of risk due to less well known technology	• Ensure feasibility assessments are conducted using 'best practice' standards of network design and hence lowest possible costs • Dissemination of best practice to engineers and planners
Deployment		
• Network can be built out more quickly • Initial connection costs are easier to absorb	• Low temperature system design experience are even more limited in the UK than for steel heat networks • Limits market penetration in areas with buildings of mixed thermal efficiency	• Where heat networks are including in local development frameworks, lower density areas should not be excluded

Table 3-7: Opportunities and barriers of lower temperature heat networks (Source: IEA, 2008[49])

Ensuring that new systems are built with the lowest possible operating temperatures is likely to enhance their overall efficiency, and ensure network temperature does not constrain opportunities for interconnection. The deployment of lower temperature heat networks, however, is likely to be limited to new build developments and areas of lower heat demand density with mostly residential

[49] IEA (2008) District heating distribution in areas with low head demand density: http://www.iea-dhc.org/reports/pdf/Energiteknik_IEA-Final-report-5.pdf

dwellings. In higher density areas building heating systems will require retrofit to operate at lower temperatures.

3.6.2 District energy balancing

District energy balancing is a further development of low temperature networks and involves using heat networks as low temperature loops to balance heating and cooling load between buildings within a specific area. It makes use of very low temperature heat networks (some with temperatures much lower than conventional VLTHW systems) and so can enable use of very low grade heat (e.g. from sewage treatment plants or heat rejection from air-conditioning) which are otherwise difficult to capture, and typically wasted to atmosphere. The concept is well proven within buildings[50] [51] but recent advances have seen this approach applied to larger new build development schemes, including the Athlete's Village for the 2010 Winter Olympic and Paralympic Games in Whistler, Canada[52].

The system relies on the fact that different types of buildings (retail, residential, offices) often have demand for different types of thermal energy simultaneously. For example retail and office buildings may require cooling energy at the same time of year as residential buildings require energy for space heating and hot water. In this kind of system each building is equipped with a heat pump which either rejects or extracts heat to, or from, the district wide network, depending on its need for cooling or heating. The district wide network is made up of two pipes, one low temperature (0-10°C), and one higher temperature (10-25°C). Exact temperatures vary by application and heat source. A summary of opportunities and barriers of district energy balancing, over and above low temperature networks, is given in Table 3-8.

[50] McQuay (2011) Condenser water heat recovery: http://www.mcquay.com/mcquaybiz/literature/lit_systems/Flyers/CondWater-HeatRec.pdf
[51] Clivet (2011) The concept of Versatemp: http://www.clivet-uk.co.uk/concept.htm
[52] DEC (2010) FOUR STEPS to recovering heat energy from wastewater: http://www.engineeringsustainability.com/wp-content/uploads/WAV-DESS-2009SummerWatermark.pdf

Opportunities	Barriers
Technical	
• Very low heat loss • Extremely low temperature heat sources can be used • Low cost plastic pipework can be used • Doubles as non-potable water network • Very limited water treatment required as minimal corrosion risk	• Requires balanced heating and cooling loads, and thermally efficient buildings • Larger pipework diameters required due to smaller temperature differentials • Independently validated performance data limited due to small number of applications • Need for heat pumps within buildings
Commercial	
• Further reduced capital costs due to lower cost materials and simplified installation	• Increased perception of risk due to less well known technology
Deployment	
• Network can be built out more quickly • Initial connection costs are lower	• Needs to be installed in an area with the right mix of building types

Table 3-8: Opportunities and barriers of a district energy balancing scheme

There are relatively few examples of this type of system at a community or district scale[53], mostly in Canada. Therefore, the opportunity to compare performance with conventional heat networks is limited. Performance claims from the systems which are in operation suggest that around 50% of the thermal energy demand can be met by energy sharing across the network before additional energy is inputted or extracted[52]. This technology could be applicable in London, particularly in new build developments with a mix of residential, commercial and retail buildings which are thermally efficient and where network heat losses may be excessive for higher temperature networks.

[53] DEC (2011) Projects: http://www.engineeringsustainability.com/projects

3.7 Using low grade heat sources

As discussed previously, the initial deployment of heat networks is likely to rely on Type 1 and Type 2 schemes with heat provided by gas fired CHP, typically gas engines. This section shows that by interconnecting heat networks to use larger-scale, more efficient CCGT plants (including waste heat from existing power stations), gas fired CHP can provide low carbon heat up until at least 2031. As the electricity grid is decarbonised, heat from CCGT plants will become more carbon intensive than other sources, but it can act as a transition technology up to 2031. The exact timing of this switch is dependent on the rate of grid decarbonisation.

Heat networks enable the use of low grade heat sources such as waste heat from power stations; however, this heat is usually available at temperatures which are too low to be used directly. In order to use this heat it must be extracted from the power station at a higher temperature with an associated loss in power output. A key factor determining the carbon intensity of waste heat from power stations is the amount of electricity lost when this heat is extracted. This is known as the z-factor, where the z-factor is the number of units of heat gained for every unit of electricity output lost[54]. Heat is available at low temperatures (around 30°C) with almost no losses in electricity output. If heat is extracted at higher temperatures, more electricity is 'lost'. Effectively the turbine is operating as a heat pump, and the z-factor corresponds to its coefficient of performance (COP).

A condensing steam turbine is very efficient at upgrading low grade heat to usable temperatures (>70°C). Typical z-factors for steam turbine plant are given in Table 3-9 for steam pressure equivalent to the highest required for heat networks (around 120°C assuming saturated steam). Less electricity is used in this process than that required to provide the same amount of heat from a heat pump (i.e. the COP is higher) which would be an alternative use of the electricity. If the lost electricity is displaced by power from the marginal electricity plant, which is predicted to be CCGT until 2026[55], then the carbon intensity of the heat is very low (around 0.06-0.07kgCO_2/kWh vs. 0.22kgCO_2/kWh for heat from natural gas boilers)[56]. The cost of the heat is also low as it is based on the lost electricity revenues.

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[54] For CHP plant which include fully or partially condensing (pass-out) steam turbines, electrical efficiency will decline as steam extraction (for heating) increases for a given fuel consumption, so there is a balance between increasing heat recovery and reducing power output
[55] DECC (2010) IAG Toolkit, Table 1: http://www.decc.gov.uk/en/content/cms/about/ec_social_res/iag_guidance/iag_guidance.aspx
[56] This carbon intensity can be considered higher or lower depending on whether the lost electricity is assigned the value of the additional fuel usage, or the value of the additional electricity generation required from the grid marginal plant. The latter was assumed in the Phase 2 modelling, meaning heat from waste heat sources will have a different carbon intensity than stated when the marginal plant is not CCGT

Steam turbine size range	2-5MWe	5-10MWe	10-25MWe	25-50MWe	>50MWe	Air source heat pump
Typical thermodynamic (isentropic) efficiency	65%	70%	75%	80%	84%	COP
Z-factor (@ steam export pressure - 2.4 bar, ~120ºC)	8.1	7.5	7.0	6.6	6.3	2.5

Table 3-9: Z-factors for steam turbine plant compared to COP of air source heat pump (Source: CHPQA, 2007)[57]

In the majority of the scenarios modelled in Phase 2 the most economic sources of heat are those from anaerobic digestion, energy from waste and natural gas CCGT. Under the Coordinated action scenario, the low cost of heat from CCGT means it makes up a large proportion of the heat generation plant, but between 2025 and 2031 the relative carbon intensity of this heat increases as the electricity supply decarbonises. CCGT is therefore the preferred technology in the short- to medium-term but in the longer term CCGT plant will not deliver heat with zero carbon intensity unless CCS power stations can be deployed.

The question of whether large-scale gas fired CHP (including waste heat from sources such as Barking and Enfield Power Stations) has a role in future DE systems in London depends on the rate of heat network deployment versus the rate of decarbonisation of the electricity supply. Deploying heat networks of sufficient extent to support CCGT plant is likely to take at least 5-10 years based on the analysis in Phase 2. Assuming widespread grid de-carbonisation by 2031 (to around 0.2kgCO_2/kWh) would give approximately 20 years of operation for CCGT before a transition is required[58] (see Figure 3-6). At this point the carbon intensity of heat from CCGT becomes higher than that from alternatives (e.g. ASHP) and heat sources such as anaerobic digestion, biomass CHP or waste heat from zero carbon power stations are required. The benefit of using CCGT up until this point is that its low cost heat output enables the wider deployment of heat networks, before a fuel switch is required. New build gas fired power plants are still being planned[59] and are most likely to make up a potential shortfall in capacity due to plant closures, supporting this approach. New build gas fired CCGT in London should therefore be required to be configured as CHP plant (as assumed in the Phase 2 modelling) as this technology is key stepping stone in the transition to zero carbon heat supplies.

[57] CHPQA (2007) Guidance note 28: The determination of z-ratio https://www.chpqa.com/guidance_notes/GUIDANCE_NOTE_28.pdf
[58] 'Heat from CCGT – offsetting fuel use' is constant as this is relative to additional fuel burnt at the power station. 'Heat from CCGT – offsetting marginal grid electricity' increases in carbon intensity as the grid is decarbonised as this assumes the difference between the marginal carbon intensity of the grid and the carbon intensity of electricity from CCGT assigned to the heat offtake
[59] Wyre Power (2011) Wyre Power development: http://www.wyrepower.com/uploads/file/pdf/brochure.pdf

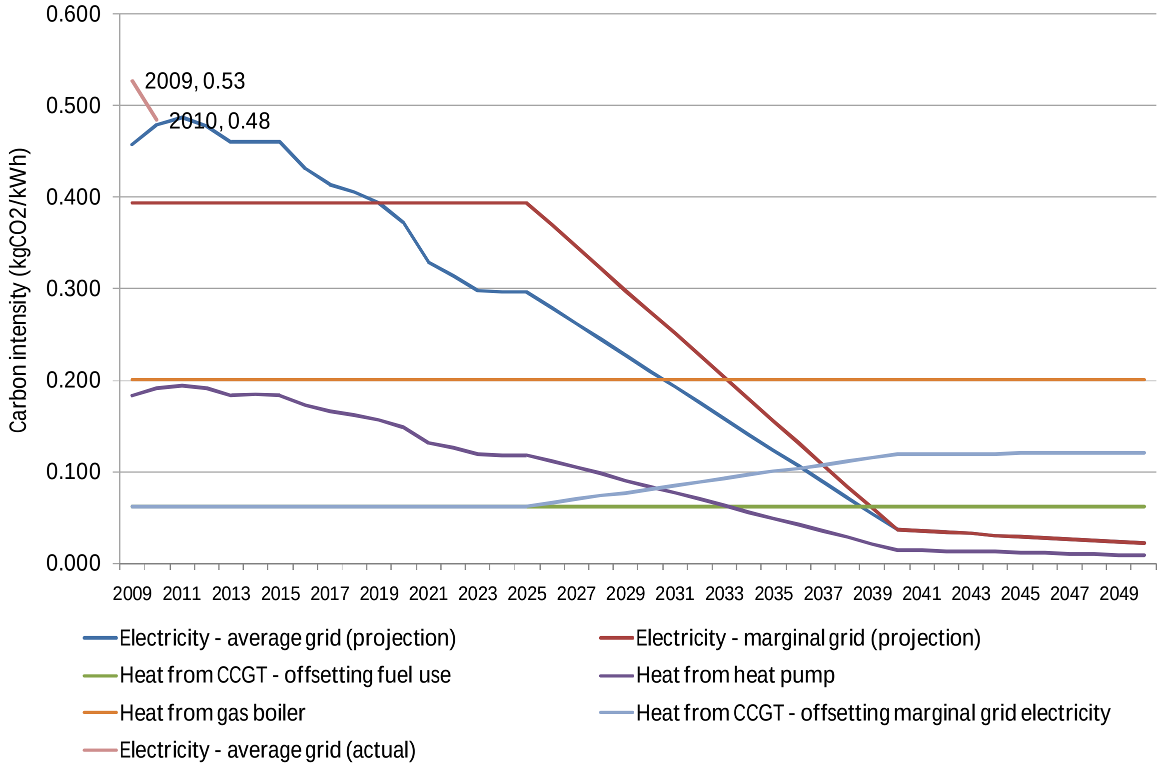

Figure 3-6: Variation of carbon intensity of heat versus carbon intensity of grid electricity (Source: DECC, 2010[55]; CHPQA, 2007[57])

3.8 Low carbon decentralised energy plant

DE technologies vary according to the scale of heat load required for efficient operation. For a typical Type 1 (<3,000 dwellings) scheme the CHP unit is based on generating electricity and recovering heat from an internal combustion gas engine. When more extensive heat networks can absorb larger quantities of heat, a broader range of technologies become feasible giving advantages in terms of flexibility in fuel supply and improved efficiencies. However, many low carbon heat sources can only be utilised effectively when heat networks of Type 2 (3,000-20,000 dwellings) or Type 3 (~100,000 dwellings) scales are available for connection. Type 1 schemes are likely to be limited in the choice of low carbon plant.

Table 3-10 sets out the variety of heat sources identified in the Phase 2 modelling which could be deployed in London in order to deliver the deployment potential (when the output of new build CCGT is constrained to a single plant – equivalent to the proposed extension to Barking Power Station[60]). The table identifies the site areas and the size of heat network (converted into equivalent number of houses) that different technologies require. The sizes are based on the average of the capacity range used in the modelling for the technology in question. This shows that for Type 1 schemes only biomass district heating and gas engine CHP are suitable. For Type 2 schemes, the resulting heat demands are large enough to make use of technologies such as gasification or anaerobic digestion of waste. These technologies also provided the lowest cost of heat in the Phase 2 modelling. These schemes are best suited to lower density areas where the high heat network cost can be offset by the additional income from waste disposal, and where land is more likely to be available. The process of site selection for new waste treatment facilities should be required to consider locations with a high deployment potential for heat networks.

Only Type 3 schemes serving the equivalent of several tens of thousands of units are large enough to make use of the heat offtake from large-scale biomass CHP, waste heat from existing power plant or medium-scale CCGT plant. Due to land availability limitations, these types of plant are unlikely to be located close to areas of high heat demand density, and will require relatively long (>10km) heat networks to link with areas of higher demand. The connection of Barking Power Station to the London Thames Gateway Heat Network is a good example. This issue was addressed in the Phase 1 report, which assumes overall land availability is not a key constraint to energy centre development, except for larger-scale plants, which are expected to be limited in number (see Table 3-10). This means a relatively small number of sites for large heat are required. In order to secure these, however, it is recommended suitable sites for large-scale DE sources be identified and safeguarded.

[60] Barking Power Ltd (2011) Barking Power Station Extension: http://www.barkingx.info/Expansion.shtml

Technology / plant type	Waste through-put per plant (tpa)	Typical output per plant (MW electric where applicable)	Average annual electricity output per plant (GWh)	Typical land require-ment per plant (ha)	Approx. number of houses served per plant	Minimum scale of DE scheme required to use heat output	Number of plants in Coordinated action scenario
Biomass CHP - large	n/a	35	280	4	82,000	Type 3	6
Biomass district heating	n/a	Varies	n/a	0.1	>25	Type 1	Used as supple-mentary heating plant with other technologies
CCGT - medium	n/a	400	2,400	10	230,000	Type 3	1
Gas Engine - small	n/a	1	6	0.1	500	Type 1	60
Gas engine - medium (including multi-engine)	n/a	10	58	1	8,000	Type 2	0
Anaerobic digester	12,000	5	40	0.6	7,000	Type 2	3
Energy from waste - gasification	50,000	10	80	1.5	20,000	Type 2	14
Waste heat from existing power stations	n/a	175	n/a	Depends on existing plant configuration	72,000	Type 3	1

Table 3-10: DE technologies and scales of heat demand and land requirements (data from Phase 2 modelling of the Coordinated action scenario with CCGT capacity limited)

Lower carbon plant such as biomass CHP and energy from waste tend to require large sites for energy centres as the fuel is not supplied via pipeline and must be stored on site. A single large plant, such as CCGT, will require less land area in total than multiple plants but obtaining a suitably large site will be very difficult close to dense areas where the highest deployment potential for heat networks lies. Some waste fuel plants require additional space for waste treatment. Anaerobic digestion process takes 15-30 days to produce biogas from the waste, and such facilities are relatively large compared to their output. Because of the sources of fuels large-scale biomass projects tend to be located close to fuel sources[61] or large port facilities[62], and new energy from

[61] Eon (2011) Steven's Croft Biomass Power Station: http://www.eon-uk.com/generation/stevenscroft.aspx
[62] Welsh Power (2011) Nevis Power - Development, Construction and Operation of a new 50MW Biomass Generation Site at Newport Bay: http://www.welshpower.com/index.php?page=nevis

waste facilities have been located in less dense areas[63]. As AD and gasification plants are smaller-scale they could be deployed closer to where waste is generated, and where heat is required.

[63] Cory Environment (2011) Riverside Resource Recovery Energy from Waste Facility: http://www.coryenvironmental.co.uk/page/riversideresourcerecovery.htm

3.9 Heat storage

Heat networks with thermal storage can decouple generation from supply, allowing heat to be delivered when needed. This provides additional flexibility and resilience to a DE system and offers significant cost savings and carbon benefits. Heat storage is typically undertaken in large water filled insulated tanks. This minimises heat losses by reducing the surface to area ratio compared to multiple smaller stores in buildings. Large-scale thermal stores are installed in many cities in Denmark, reaching 65m in height[64] and a height-to-width ratio of 1.5. The largest thermal store in Germany is 30,000m^3 in volume[65]. Such stores can also be used to pressurise the heat network. Typically they are located on the same site as the CHP plant, compared to which land requirements are relatively small. Heat storage can provide supply balancing to help manage short-term fluctuations in energy demand as well as daily and seasonal variations by incorporating flexibility into when heat is supplied and used. This also facilitates the use of heat networks in managing electricity supply.

- Separation of heat generation and heat demand, allowing DE plant to fully participate in the electricity market by switching off at time of low demand and generating at times of peal demand[66]
- Maximising the amount of heat supplied from CHP or other low carbon heat sources via the heat network, and hence increasing carbon savings, by displacing output from peak load plant
- Peak lopping short term back up, reducing the investment in peak load plant and providing resilience
- Opportunity to use heat storage for demand management on the electricity network (e.g. by absorbing excess electricity from wind generation, or off-peak generation from nuclear plants).

Heat stores linked to heat networks can also act as short term ‘dump loads’ for excess electricity. When surplus electricity is available, from either base load plant (e.g. nuclear power stations) or peak output from intermittent renewable technologies (e.g. wind turbines) during periods of low electricity demand, heat can be generated using heat pumps or electrode boilers and stored for later use. The Electricity Market Reform (EMR) proposals include the prospect of negative prices for electricity[67], due to increased intermittent generation, which can make this option economically attractive. As well as using excess electricity, DE can facilitate demand management on the electricity market by operating steam turbines in backpressure mode overnight (maximising heat

[64] Petersen, M., Agaard, J. (2004) Heat accumulators, p2: http://www.energymap.dk/Cache/03/0347cf9a-32da-429a-a1ca-2dbc68431158.pdf
[65] IEA (2005) Dynamic heat storage optimisation and demand side management, p71-75 : http://www.iea-dhc.org/Annex%20VII/8dhc-05-06_dynamic_heat_storage.pdf
[66] CHPA (2010) Integrated Energy The role of CHP and district heating in our energy future, p21: http://www.chpa.co.uk/medialibrary/2011/04/07/8de0aeaf/integrated_energy_low_res.pdf
[67] DECC (2010) Electricity Market Reform consultation: http://www.decc.gov.uk/en/content/cms/consultations/emr/emr.aspx

production) and storing heat, then switching to condensing mode (maximising electricity production) during periods of peak electricity demand. This is an approach used in Denmark[68].

In the short term, however, one of the greatest benefits of heat storage is enabling low carbon plant, such as CHP, to supply a larger proportion of the heat demand in a given heat network. This is very similar to increasing load diversity, as outlined in Section 3.3. Charging a thermal store from a CHP plant during periods of low heat demand allows this heat to be discharged to meet peak loads. This extends the proportion of the year which the CHP can be operated for, so a larger CHP plant can be selected. This results in reduced gas boiler load, reducing emissions an improving the economic viability of the low carbon plant. Investments in peak load and back-up plant can also be reduced.

The Energy Technologies Institute is currently undertaking a review into the potential to capture heat from large-scale power stations on a seasonal basis[69]. Seasonal fluctuations in heat demand could be balanced by using heat output from base load power plant to charge aquifers during the summer. Heat would be extracted over the winter for space heating, supplied via heat networks. Inter-seasonal storage from large power plants requires extremely large capacity stores, meaning below ground storage using aquifers is the most economic option. This is only likely to be economic should natural gas no longer be widely available for space heating. Two factors mean that this technology is less likely to be applicable in London:

- There are sufficient large power stations within 100km of London to satisfy the heat demand from the deployment potential of heat networks . This means that on any given day enough heat can be produced to match peak demand, therefore negating any benefit from inter-seasonal heat storage
- Hydro-geological conditions in the South East are not well suited to the requirements for large, deep aquifers. Aquifers in London are too close to the surface to store higher temperature heat and these aquifers are protected for use as potable water supplies.

There are examples of Type 2 networks in London which have thermal storage and this has already provided benefits by allowing flexibility during initial operation when the heat loads are highly variable (e.g. Olympic Park uses above ground insulated hot water and chilled water tanks as thermal stores; and Barkantine Heat and Power uses a similar hot water store) [70,71]. It is even more critical that Type 3 schemes should be installed with thermal stores in order to benefit from the opportunities listed above.

Constructing large thermal stores in central areas of London, however, is likely to be difficult due to high land values[72]. For example the Citigen scheme does not have sufficient space to incorporate a large scale thermal store, though this could increase the running hours of the CHP plant. However, the cost and availability of land for energy centres in dense central areas is a constraint to the deployment of Type 1 and 2 schemes in general, and not just associated with thermal storage. The

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[68] DECC (2011) District Heating - International Experience: Copenhagen District Heating System in Denmark, Europe: http://chp.decc.gov.uk/cms/district-heating-international-experience/

[69] Buro Happold (2011) ETI Heat Capture and Storage Study: http://www.burohappold.com/projects/project/energy-technologies-institute-eti-heat-capture-and-storage-study-89/

[70] Maybank, R. et al (2011) Providing community energy for the London 2012 Olympic Park, *Proceedings of the Institution of Civil Engineers*, doi: 10.1680/ener.11.00005, p5: http://www.icevirtuallibrary.com/docserver/fulltext/ener164-071.pdf?expires=1311886544&id=id&accname=guest&checksum=3AC8D91B5019BA002AE19CB20B044A4B

[71] Central London Forward (2010) Challenges to Achieving Low Carbon and Decentralised Energy in Central London, p41: http://www.centrallondonforward.gov.uk/download/decentralised-energy-report.pdf

[72] Central London Forward (2010) Challenges to Achieving Low Carbon and Decentralised Energy in Central London, p56-57: http://www.centrallondonforward.gov.uk/download/decentralised-energy-report.pdf

Phase 1 report concludes that lack of land for energy centres is not a significant barrier provided heat networks can be used to link larger-scale plants located in less dense areas to central London. Clearly in dense central areas this is an issue and may constrain deployment until such networks can be established. New build schemes such as the Kings Cross scheme have incorporated thermal storage, but this has been housed in costly basement space in a building specially designed to house the store[73]. This is unlikely to be feasible in most retrofit situations. By connecting stores to Type 3 schemes they can be located remotely from such areas.

[73] Argent (2011) Kings Cross, The energy centre explained: http://www.kingscrosscentral.com/energycentre

3.10 Long distance heat transmission

Long distance heat transmission provides a potentially large source of low or zero carbon heat from large-scale power stations located outside of London, with low levels heat loss as a proportion of total heat supplied. Figure 3-7 shows the existing power stations within a 100km radius of London. In Phase 1, the technical potential of using waste heat from zero carbon power stations located outside of London was estimated at 18% of London's heat demand in 2010. In Phase 2, the Ambitious action scenario assumes a very large contribution of heat generated outside London. Other articles also identify this resource as a means of providing a significant amount of low carbon heat[74].

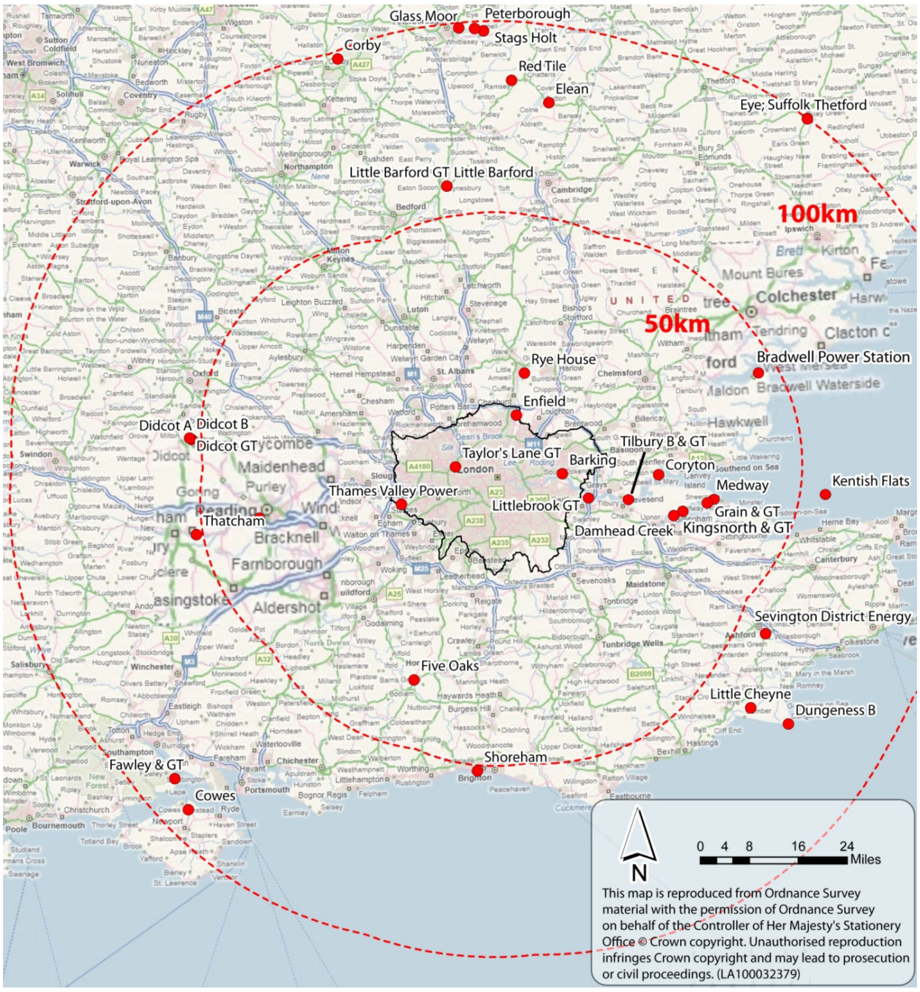

Figure 3-7: Electricity generation sites close to London (Source: DECC 2010[75])

[74] Orchard (2008) Harness this heat, *Building Services Journal*, March 2008
[75] DECC (2010) Digest of UK energy statistics: http://www.decc.gov.uk/assets/decc/Statistics/publications/dukes/311-dukes-2010-ch5.pdf

Heat loss in heat transmission networks

Heat loss from transmission pipelines, as a proportion of total heat supplied, is inversely proportional to the length of the network. The larger the quantity of heat being delivered, the smaller the heat losses are. Because of this, long transmission pipes accessing large-scale heat sources outside of London may be feasible. Table 3-12 shows that 500MW and 1,000MW of heat capacity delivered over a distance of 100km suffers losses of 1.5% and 1.0% respectively; over 200km these losses are doubled. Heat losses from such networks are, therefore, not a significant barrier to deployment.

	Transmission length (kW)				
		50	**100**	**150**	**200**
Transmission Capacity (MW_{th})	**250**	1.6%	3%	5%	6%
	500	0.8%	1.5%	2%	3%
	750	0.5%	1.1%	1.6%	2%
	1000	0.5%	1.0%	1.4%	1.9%

Table 3-11: Heat loss from long distance transmission pipelines (Source: Buro Happold, 2011)[76]

Deployment constraints

It is highly unlikely that such networks can be developed before 2020 as new zero carbon plant is unlikely to be in operation before then. Furthermore the Phase 2 modelling shows these systems will only provide heat in a cost competitive way when gas prices are above £100-120/MWh, approximately three times their levels in 2011. In the longer term, however, these heat sources constitute a potentially very large source of zero carbon heat which can only be captured using heat networks. As the deployment potential of heat networks in London is realised, therefore, the opportunity to connect to zero carbon heat from outside London should be considered as part of a long term strategic approach to heat provision. As with all new technologies, there are a number of very significant challenges associated with long distance heat transmission which would need to be resolved in order to use heat from outside London – an overview of the key deployment barriers is provided in Table 3-13. Further work is required to better establish the likely costs and viability of new tunnel infrastructure required to route large diameter pipework into London to connect to Type 2 and Type 3 schemes.

[76] Buro Happold (2011) Heat loss calculations undertaken using steady-state equations for pre-insulated steel pipework

Opportunities	Barriers	Implications
Technical		
• Access to large technical potential of waste heat from future zero carbon sources • Does not rely on natural gas as a fuel • Can offset peak heat load from electrical network, reducing requirement for additional electrical generating capacity	• Lack of large-scale heat demand • Heat losses from long distance transmission lines • Low grade nature of heat available • May require large thermal stores to balance peak electricity and heat loads • Physical route for large diameter heat pipework and resulting high capital costs	• Requires the development of extensive heat networks within London • Can be addressed using modern district heating pipework. Can be limited to 2-5% even on long distance networks with sufficiently high capacity • Extracting higher grade heat from steam turbine cycle is more efficient than using heat pumps to convert the amount of electricity production lost from the steam turbine into heat • Plant has to be designed to accommodate CHP operation from the outset • Running large diameter heat mains (1,000-1,600mm diameter) into London at street level to connect with Type 2 and 3 schemes will not be possible, requiring an alternative route (e.g. deep bore tunnel, routing via other infrastructure assets). Such infrastructure is not without precedent both in London, Dublin and Denmark[77 78 79]
Commercial		
• Low cost of heat from such sources • Low operating costs	• High investment cost • Infrastructure needs to be heavily utilised to generate return on investment • No established business model in the UK	• Precedents exist under varying policy frameworks in other European Union countries • Heat transmission only viable with alternative heat prices above £100/MWh
Deployment		
• Can offset other infrastructure investment, such as electrical network reinforcement	• Requires extensive deployment of heat networks • Dependent on the deployment of zero carbon power station plant • Heat is a by product and not the main driver for power plants	• Risks to deployment of nuclear and CCS plant may not be well understood until at least 2015 • Deployment of zero carbon plant after 2020 at the very earliest • Limited influence over planning decisions

Table 3-12: Overview of deployment barriers to importing heat from power stations outside Greater London

[77] National Grid (2011) The Lower Lea Valley powerlines undergrounding project: http://www.nationalgrid.com/NR/rdonlyres/1EB3F913-0FDB-47D7-B4FE-A9474E64B72E/36542/UGCaseStudy3.pdf (the Lower Lea Valley tunnels cost the equivalent of £19,000/m)
[78] COWI (2011) Dublin makes the switch to district heating: http://www.cowi.com/menu/NewsandMedia/News/Newsarchive/Pages/Dublinmakestheswitchtodistrictheating.aspx
[79] COWI (2011) Copenhagen district heating tunnel: http://www.cowi.com/menu/project/BridgeTunnelandMarineStructures/Tunnels/Boredtunnels/Pages/copenhagendistrictheatingtunnel.aspx

4 Decentralised energy deployment roadmap

4.1 Overview

This section builds on the discussion of barriers to deployment in Section 3 and considers the roles of key actors and timescales involved in the process of delivering DE systems in order to develop recommendations and an initial roadmap for deployment.

4.2 Realising the deployment potential

The scale of heat networks required to realise the higher levels of DE is very substantial. The results of the Coordinated action scenario from Phase 2 of the study imply around 3,600km of network needs to be installed between 2011-2031. This requires a long-term strategy and an average build out rate of some 180km/yr, or just under 500m per day. A high-level timeline for the deployment of DE between 2011 and 2031 is shown in Figure 4-1. It shows the inter-relationship between policy, DE scheme deployment, interconnection and transition to low and then zero carbon heat sources. It is important to note that any timeline set out in this context is necessarily general and therefore indicative. However, there are some key timing constraints which will dictate the deployment of heat networks. These include:

- Plant replacement cycles of 10-20 years depending on the type of equipment (e.g. 10-15 years for gas engine CHP including major overhaul, 15-20 years for packaged commercial boiler plant)
- Heat network lifetime of at least 40 years, meaning that any return on investment may be based on this cycle, which in turn requires 2-3 plant replacement cycles
- At the higher levels of DE deployment potential modelled in Phase 2 (i.e. Ambitious action scenario), which assume the use of large-scale zero carbon power stations located outside London, consideration has to be given to the associated long lead times involved. It is unlikely that new nuclear plant will be built, and on-line, prior to 2020 at the earliest[80]. Likewise significant CCS capacity is not expected until 2025[81].

Time is a key factor in the development of heat networks. The infrastructure itself takes time to install but more importantly the buildings to be connected will be available for connection at different times over many years. Existing buildings are typically not viable to be connected until a major plant replacement investment is already required, and new development can only connect when it is built. For both existing and future developments, if the window of opportunity for connection is missed, then it may be another 10-20 years before the next opportunity arises again (i.e. when the plant needs replacing again, or other major renewal or expansion occurs). Furthermore, it rarely occurs that the planned spatial sequence of connections matches the temporal sequence of opportunities. In other words, you might find that the earliest connection opportunity is for a building or development site located some distance from your energy centre. Since construction of a long pipe route to connect that single distant site is unlikely to be viable, it

[80] EDF Energy (2009) Bradwell Nuclear New Build Newsletter http://www.british-energy.com/documents/Bradwell_Newsletter_April_09.pdf
[81] DECC (2011) 2050 Pathways Analysis, Response to the Call for Evidence, Part 2, Table B1: http://www.decc.gov.uk/assets/decc/Consultations/2050/1344-2050-pathways-analysis-response-pt2.pdf

may be necessary to provide an interim heat supply solution to that site, which is designed for future connection when the network does arrive.

This means that significant interconnection of Type 1 and Type 2 schemes will be less likely until plant is due for replacement, or other factors make the lower running costs of larger plant sufficient to offset the investment in heat network extensions. Type 3 schemes are likely to depend on the interconnection of such schemes and so significant deployment will be limited to beyond 2020. Connection to zero carbon plant is unlikely until well beyond 2025.

In dense central areas the availability and cost of land for energy centres may represent a further constraint to the development of Type 2 schemes. Without deployment of such schemes, interconnection and deployment of Type 3 schemes will be very limited. Type 3 schemes can overcome land availability constraint by siting larger heat generation plant remotely from central areas. Siting energy centres in dense areas could therefore be considered a transitional arrangement until more extensive heat networks are deployed. There is an opportunity for the GLA and boroughs to take a lead in identifying and safeguarding suitable sites. Working with other public sector bodies, such as Transport for London, and social housing providers offer opportunities in this respect.

The impact of financing costs is the same as for any capital investment: repayments on a loan begin as soon as it is made, but the revenue stream only commences once the network is installed and buildings are connected. Therefore schemes need to ensure a sufficient quantity of demand is connected early in the project life cycle and to consider carefully the opportunity for deferring or phasing the installation of the network and other capital expenditures.

When a heat network connects to a building it effectively replaces the on-site heating plant, saving both money and space, especially in new buildings. This avoided cost can provide a resource to support the connection cost from the nearest network distribution pipe to the site being connected. In simple terms, if the cost of connection is less than the cost of installing an on-site heating system, then the connection will be viable for the building owner. If it is greater than the on-site option, the connection will not be made (unless mandated through regulation or planning policy). For existing buildings, the same principle applies, except that in this case the potential for avoided costs occurs when the existing plant is nearing the end of its life, or when the building is undergoing major alterations. That means that all buildings, whether existing or new, have a “window of opportunity” for connection. If that window is missed, it may take a period of 10-15 years before the next opportunity arrives.

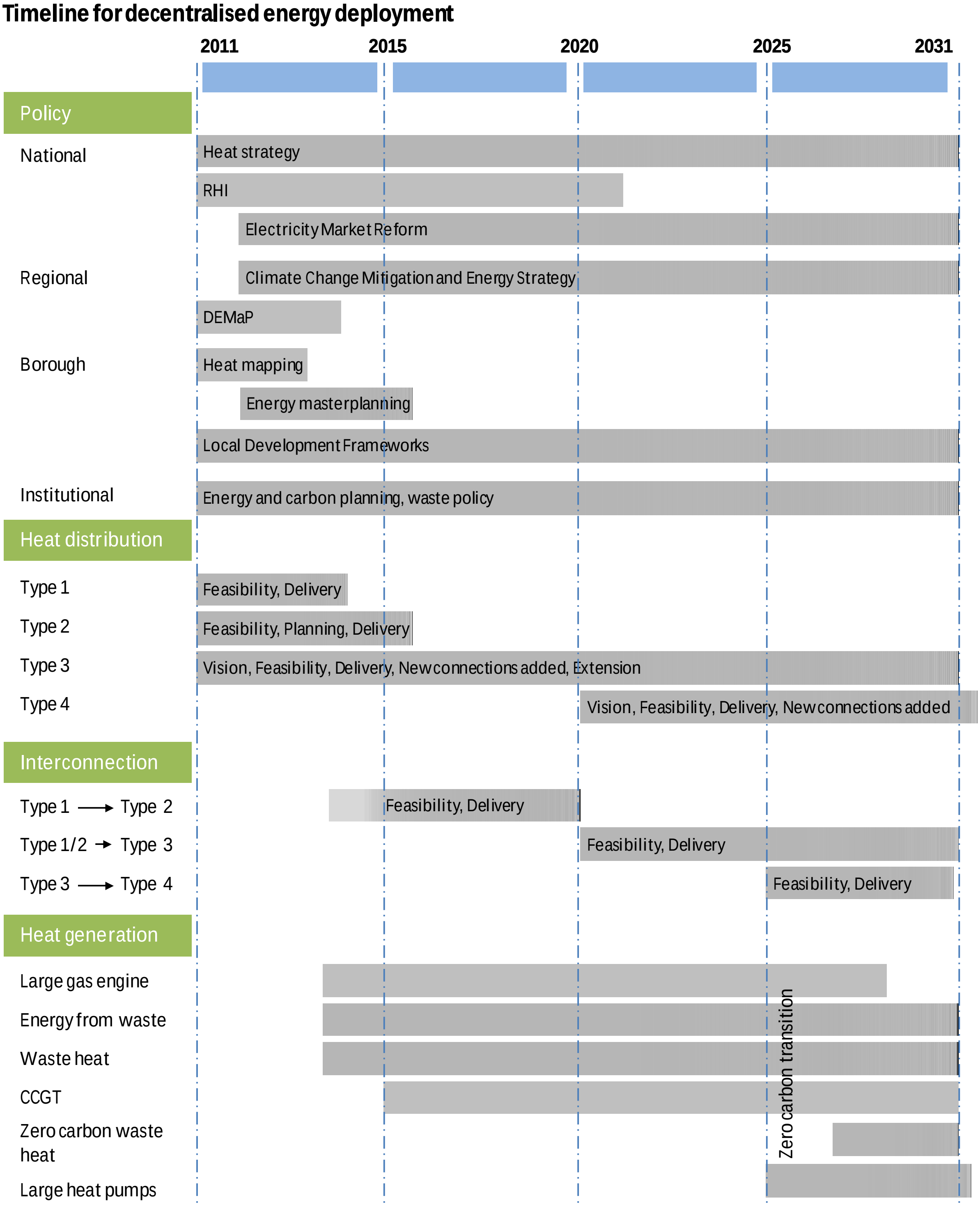

Figure 4-1: Decentralised energy deployment timeline

Figure 4-2 summarises key stakeholders and their roles in the DE deployment process described above. It sets out actions by stakeholders in relation to policy, planning and implementation. The role of the boroughs and the GLA shows the interrelationship between setting strategic policy, overseeing strategic projects and project development at local level.

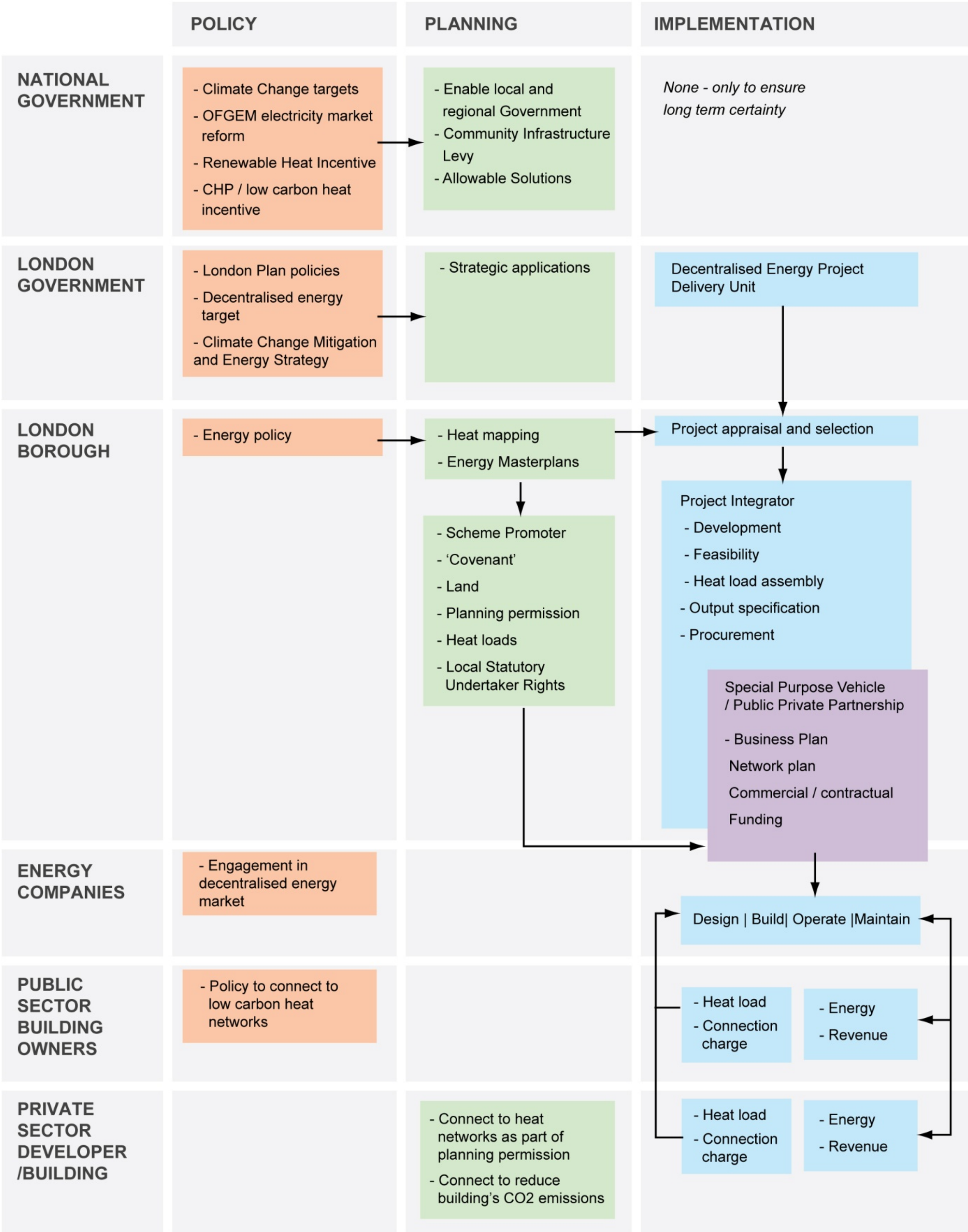

Figure 4-2: Decentralised energy deployment key stakeholders and roles

4.3 Key stakeholders and roles

Using Figure 4-2 as a framework, this section summarises the key roles of national government, the GLA, London boroughs and energy companies in planning for and securing the delivery of DE networks in London.

4.3.1 National government

In order to meet the deployment potential identified in the Phase 2 report, widespread deployment of Type 1 and 2 schemes are required, and are likely to be based on technologies which require support. Furthermore, the long timescales involved in developing DE projects, and the long periods until a return on investment is obtained, mean that long-term certainty of support is also needed. Any uncertainty over policy will discourage investment, particularly in schemes where offtake risk is more difficult to manage (e.g. larger, mixed use, multiple customer schemes).

At a national level, therefore, policy should show recognition of the potential role for heat networks – as an energy carrier – to reduce emissions and manage demand on the electrical network, particularly by storing energy and utilising low grade fuels and waste heat. Policy should also recognise natural gas-fired CHP as a transition technology. Maintaining RHI and increasing revenues to embedded generators using gas engine CHP through fairer licensing and reduced or cost reflective distribution charging should be a priority to ensure ongoing deployment of DE schemes beyond new developments in the short to medium term.

Two of the major issues which are fundamental barriers to the deployment of DE are:

- Managing offtake risk – providing increased certainty for DE schemes
- Allowing DE a level playing field against central generation – providing an attractive investment

Other issues such as supply chain constraints, perception of risks (technology, construction etc), legal transaction costs and others could be considered secondary to these more fundamental barriers. With a sufficient level and certainty of return it is likely that a market for DE would develop and find the most optimal approach to these secondary issues.

Managing offtake risk is a difficult issue unless a strategic commitment can be made for DE nationally, in which case connection could be mandated under certain circumstances. A less intrusive approach would entail incentivising connection by offering lower cost energy supplies, which would also have the benefit of dealing with concerns around monopoly supply.

Ensuring that new policies, such as Carbon Price Support and the Electricity Market Reform proposals, do not disincentivise investment in DE must be considered as a minimum. Continuing the level of support afforded to DE projects by exempting fuel used for heat production from charges under the Carbon Price Support mechanism has been proposed as a means of providing some support, although it is not thought to be sufficient on its own[82].

Other opportunities may include consideration of the market for supplier services under the so-called 'Licence Lite' electricity supply licence for small generators/suppliers. At present the barriers to entry for smaller-scale DE schemes to participate in the electricity market mean that DE scheme operators can only access low value offtake contracts in the wholesale market. These do not fully

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[82] 2011 (CHPA) Consultation on a Carbon Price Floor: support and certainty for low-carbon investment: http://www.chpa.co.uk/contented/media/1a536904/CHPA%20CCL%20reform%20FINAL%20response%2011-February-%202011.pdf

recognise the value of embedded generation or allow smaller generators / suppliers to participate in the retail market and require DE schemes to compete with older generating plant which has already been written down and operates on a marginal cost basis.

A CHP scheme connected to the electricity grid and to a district heating network will generate income streams from both the power and the heat. A major barrier to the viability of CHP schemes is associated with the value of the electricity generated. The revenue potential from electricity sales depends on the value of electricity used on site and/or exported from the site. In most cases, a CHP operator will not be an electricity licence holder under the Electricity Act and consequently will be able only to use generated electricity on site or to sell it on to the grid, i.e. to the distribution network operator (DNO). The DNO purchases the exported power at the wholesale price, resulting in a very modest revenue stream for a CHP operator from the electricity which is surplus to the on-site requirements at the time it is generated. On the other hand, power from the CHP which is used on site has the effect of displacing grid electricity which would have been purchased at the much higher retail price. At present becoming an electricity supply licence holder is prohibitively expensive for relatively small scale CHP generators, but the regulatory framework is currently under review by DECC and OFGEM, and options to enhance CHP may become available in the future. One option would be to allow an organisation which owns a number of buildings on different sites to pay on a net basis, where surplus power exported from a CHP would be credited against power imported to supply a different building owned by that organisation. This would have the effect of increasing the amount of the power output from the CHP which carried the higher retail value. Another option, introduced recently by OFGEM, is a 'Licence Lite' arrangement to allow organisations owning generation plant (e.g. a local authority) to operate under the full licence owned by an electricity supply licence holder. At the time of writing this option is being considered by a number of London boroughs in partnership with the LDA but as yet no licence lite is known to have been sought or granted.

4.3.2 GLA

The GLA should continue its strategic role, setting out where heat networks should be prioritised to ensure comprehensive coverage of smaller-scale heat networks which can grow and be interconnected. Outlying DE schemes which will be more difficult to connect to Type 3 schemes due to the lack of heat loads in between should plan to use smaller-scale low carbon sources of heat such as energy from waste and anaerobic digestion, which can also provide the lowest cost of heat. Specific schemes will be brought forward by the London boroughs and developers, working with energy companies; however cross borough boundary systems will require coordination. The London Thames Gateway Heat Network is an example of this approach.

In addition, the GLA performs critical coordinating and capacity building functions, highlighted below:

- Identify and safeguard sites which could support CHP plants in the short- to medium-terms as well as house new large-scale CHP in the longer term. As a transition to lower carbon sources of heat and away from gas CHP is required by 2031, the GLA should work with boroughs and energy companies to identify sites which could house new large-scale CHP plant, particularly large-scale biomass systems. These should be located in areas with access to river transport, and adjacent to Type 2 and Type 3 DE schemes. Concentrating biomass usage in larger plants enables use of technologies such as selective catalytic reduction and advanced filtering techniques to reduce NOx and particulate emissions. Such plants would also be subject to proper regulation. As heat network deployment and interconnection progress, at an appropriate time the GLA should identify and safeguard opportunities to link London to large-scale heat sources such as those in the Thames Estuary.

- Develop procurement and financing models to assist boroughs in the development of commercial and legal structures for procurement of, and investment in, DE systems. The variety of options in this regards is very large, and always likely to have certain scheme specific feature; however boroughs must be informed clients when developing such structures. The GLA should also work with boroughs to develop senior level champions to drive DE deployment, as previous studies have identified this as a critical factor[83].
- Develop common technical standards for network design with the CHPA and other stakeholders to facilitate future interconnection. This would be a relatively low cost measure with the potential to significantly reduce costs in future. Designing networks with the lowest possible operating temperatures future proofs the connection of waste heat sources and large-scale heat pumps, as well as reducing losses.
- Identify and support opportunities for the development of DE in London using the planning system, e.g. require new developments to connect to existing local district heat and cooling networks where feasible, or to use site-wide heat networks and, where appropriate, install CHP system; ensure new power plants are designed to operate as CHP plants, future proofing connection to heat network; and encourage boroughs to work with neighbouring authorities to identify cross-boundary opportunities, in particular, within Opportunity Area Planning Framework (OAPF) areas.
- Build on existing GLA support mechanisms such as the DE masterplanning programme (DEMaP) and the recently established DE project and delivery unit (DEPDU). DEMaP will continue to provide support for heat mapping[84], and capacity and policy support to London boroughs while the European Local ENergy Assistance (ELENA) facility funded DEPDU will seek to undertake commercial and technical development work to turn existing and emerging high level opportunities into more well defined projects for the private sector participation.
- Disseminate best practice on heat network design and collating a robust cost database for the assessment of heat network viability. This should also consider the potential for efficiency improvements and cost reductions through using low temperature heat network technology.
- Ensure building retrofit enables connections to heat networks in areas with deployment potential for DE, through programmes such as RE:FIT.

4.3.3 Boroughs

The London boroughs have a key role to play in planning for, and securing delivery of, new DE schemes. In particular the central London boroughs where the majority of DE potential resides will need to continue with their efforts to develop Type 1 and Type 2 heat networks, and with efforts to plan Type 3 networks (e.g. London Thames Gateway Heat Network, Enfield / Upper Lea Valley area

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[83] ARUP (2011) Decentralised Energy Masterplanning Manual, Low Carbon Frameworks Programme: www.arup.com
[84] A heat map is a spatial plan of existing and planned building heat demands, and DE networks and generation equipment. The objective of a heat map is to enable the user to quickly identify opportunities for developing or expanding DE networks.

study). Boroughs can provide political and planning support and guarantee heat loads and land for energy centres, all of which de-risk the delivery of DE schemes. They can also work to ensure good geographic coverage of heat networks and maximise the availability of residual waste as a low carbon fuel source. Much work is underway but effort is required to ensure that funding and support are not withdrawn given the current pressure on local government budgets. Increasing local government expertise and capacity in respect of energy planning is also likely to be required.

Establishing a supportive planning policy framework is an essential requirement for the successful delivery of a DE network. PPS1 Supplement specifies that local requirements to implement decentralised energy should be outlined within development plan documents, rather than supplementary planning guidance, to ensure policy reaches Examination in Public as well as effective compliance from developers. The Local Development Framework Core Strategy should therefore set out the high level framework with subsequent detail contained in other Development Policy Documents or Supplementary Planning Documents.

Other spatial planning instruments available to boroughs include the use of OAPFs and Local Development Orders (LDOs) to enable heat network deployment. An LDO is an instrument that allows the local planning authority to create a blanket planning permission in the absence of specific planning applications. This will remove some of the risk associated with seeking planning consent for heat network pipe routes. The UK's first heat network LDO was developed as apart of the London Thames Gateway Heat Network Project development.

Boroughs should develop local approaches to managing offtake risk, through borough- and stakeholder group-led project development. Public private partnerships can enable the public sector to coordinate and plan heat networks in this way, with limited government investment. Where appropriate boroughs should also consider opportunities to own heat network infrastructure, and hence provide the low cost of finance and de-risking required to realise the deployment potential identified in Phase 2.

The requirement for low cost finance (e.g. prudential borrowing) is essential given the reduction in DE potential above discount rates of 6-7% identified in the Phase 2 modelling. Development of the heat generation and operational responsibilities could be undertaken by the private sector, with public sector assets divested once projects are fully operational and generating net incomes. Some public funding of initial feasibility and procurement work is likely.

Using waste resources which cannot be otherwise reused, recycled or composted can meet a significant proportion of London's energy demands. Boroughs should therefore seek to coordinate energy and waste policies, recognising the potential value of waste treatment facilities in providing low cost heat to catalyse DE development, and consider procurement of such facilities to require development of a DE system. The process of site selection for new waste treatment facilities should be required to consider locations with a high deployment potential for heat networks.

As well as identifying opportunities for DE systems as part of the DeMAP process, boroughs should also identify opportunities for district energy balancing. There will be areas which have a mix of heating and cooling demands throughout most of the year, particularly new office and retail developments nearby to residential heating demands. Boroughs should require new developments to consider this technology as part of any DE viability assessment.

4.3.4 Private sector

Private sector involvement in delivery will be required to access the large capital investments required to realise DE potential which, even under the lower deployment scenarios, runs into several billion pounds. The private sector brings capital for investment as well as relevant expertise and experience in developing and running energy plants. Additional expertise includes energy trading, customer service and energy retail experience[85].

Energy companies should work closely with the GLA and boroughs to develop energy masterplans and procurement and financing models. New projects should be developed around a set of common technical standards, coordinated by the GLA and industry bodies. Networks should be based on the lowest operating temperatures possible, particularly in new developments with low heat loads where network losses can outweigh carbon savings from gas-fired CHP. Thermal storage should be integrated to allow future flexibility and maximise environmental benefits. New projects should also be logged on the London Heat Map portal. Energy companies should consider opportunities for interconnection in a transparent way, recognising the long term nature of this possibility. Project design and planning should consider transition to sources of heat other than natural gas beyond 2025-2031.

4.4 Key projects for initial deployment

It is not within the scope of this report to identify individual project opportunities. This process is being developed by the GLA and boroughs through the DEMaP and DEPDU programmes. However, there are some key strategic projects (Type 2 and above in scale) which will need to be realised and/or significantly expanded to deliver widespread deployment. A mechanism is required to encourage heat offtake from existing and planned schemes, otherwise the prospects of this happening are limited.

Some key schemes are identified in Table 4-1. Type 2 schemes should be developed on an ongoing basis. The only Type 3 scheme currently under development is the London Thames Gateway Heat Network scheme, but other large-scale transmission networks need to be planned in order to provide sufficient heat load for future, larger-scale low carbon heat sources.

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[85] OFGEM (2011) Retail Market Review: http://www.ofgem.gov.uk/Markets/RetMkts/rmr/Pages/rmr.aspx

Status of project	Type of project		
	Type 2	Type 3	Type 4
Existing	• Olympic Park • Citigen • Pimlico • Whitehall • Barkantine • King's Cross	n/a	n/a
Under development	• Euston Road (UCL / Kings Cross etc) • Exhibition Road • South Bank Employers Group • Southwark / Elephant and Castle • Greenwich Peninsula • Islington District Heating Schemes • Brent Cross-Cricklewood • SELCHP / Southwark • Royal Free / Camden	• London Thames Gateway Heat Network • Upper Lea Valley Heat Network •	n/a
Opportunity	• Nine Elms / Vauxhall / Battersea Power Station • White City • Wembley	• Riverside Resource Recovery (Belvedere) Central Activities Zone Link Network	• Thames Estuary Transmission Network

Table 4-1: Key projects for deployment of heat networks 2011 to 2020 (Source: GLA, 2009)[86]

[86] GLA (2009) Powering ahead – delivering low carbon energy for London, p33-42: http://www.london.gov.uk/priorities/environment/climate-change/decentralised-energy

6 Further work

6.1 Overview

This study shows that DE has a significant potential to generate low carbon energy in London. There remain, however, a number of outstanding areas regarding the potential for switching to zero carbon heat sources by 2031, and beyond, which need to be better understood, particularly around cost, the role of heat pumps and importing heat from outside Greater London.

6.2 Realising the deployment potential up to 2031

Cost uncertainty

The cost of heat networks is the largest constituent part of the cost of DE system and increasing the certainty of cost estimates used in both policy modelling and for assessments of the viability of DE projects should be considered a priority. This is to a certain extent linked to the lack of experience of construction and operation of large-scale (e.g. Type 2 or Type 3 schemes) heat networks in relation to DE systems in the UK. One significant issue on which the availability of data for comparison is limited is the cost increase associated with working in central areas where existing services already cause congestion beneath roads. Threading heat networks through such areas could significantly increase costs as diversions of existing services may be required, or special working practices adopted to avoid damage to live services. This would significantly reduce the deployment potential identified in the Phase 2 modelling. The incorporation of heat network services into multi-utility duct networks could mitigate this impact, as well as reduce continuing disruption from roadworks. There are some existing pipe subways in the City of London, and the former Post Office Railway offers a strategic link across central London. A previous study concluded that such networks would require changes to utility regulation to enable boroughs to recover the capital costs through rental charges[87].

Role of heat pumps

Significant questions remain regarding the role of heat pumps in relation to heat networks. These questions include:

- What evidence is there regarding the actual performance in use of heat pumps, including comparing individual building heat pumps with large-scale heat pumps linked to heat networks? Recent evidence suggests that the performance of small-scale heat pumps needs to improve to offer carbon savings, at least in the short to medium term[88]
- Does any performance improvement of larger-scale heat pumps offset the potential heat losses from heat networks?
- What is the peak load placed on the electrical network by switching heat demand from natural gas to electricity? The highest daily gas demand over the winter of 2010-11 was 5,798GWh in February, equivalent to an average load over the day of 240GW (including power station

[87] URS (2009) City of London Decentralised Energy and Pipe Subways Study, Baseline Report: http://www.londonheatmap.org.uk/Content/uploaded/documents/CoL%20DEPS%20Baseline%20Review%20website.pdf
[88] AEA/NERA (2010) Decarbonising Heat: Low-Carbon Heat Scenarios for the 2020s, Report for the Committee on Climate Change http://downloads.theccc.org.uk.s3.amazonaws.com/4th%20Budget/fourthbudget_supporting_research_NERA-AEA_Decarbonising_heat.pdf

demand)[89]. Annually over a third of gas use is in the domestic sector, and during peak heating demand periods this proportion is significantly higher, suggesting a heating load of at least 80GW, equivalent to an additional electrical load of over 30GW assuming heat pumps with a COP of 2.5 are used to convert electricity to heating. But, COP in mid winter is likely to be significantly lower, further increasing the load. 30GW is equivalent to around 50% of the current maximum load on the UK national grid system of 60-65GW[90]

- Can the electrical network cope with such peaks and how much reinforcement and peak load plant is required; or, should storage be prioritised to mitigate this effect and if so how much is required?
- Heat pump deployment is constrained by the poor thermal efficiency of dwellings in London. Heat networks can address this in high density areas by supplying sufficiently high grade heat. However, in low density areas they are not viable, emphasising the need for energy efficiency retrofit to dwellings to enable wider heat pump deployment.
- Heat pumps may be viable sources of heat for use in DE systems, but this is highly dependent on the extent of network development, electricity prices and whether large-scale heat pumps can provide a sufficiently high performance improvement beyond individual building systems to in order to offset heat network losses

Low and zero carbon heat imported from outside Greater London

The long term potential to import large quantities of low carbon heat from outside Greater London was identified in the Phase 2 report. It was found to have enough economic potential to be worthy of consideration, however a great deal of further work will be required to determine how realistic an option this is. Key barriers and questions include:

- Only economically viable in the event of a significant increase in the cost of, or other constrain on the use of, natural gas
- Establishment of low carbon power stations in the Thames Medway area would be required and is unlikely before 2020-25
- The feasibility of routing large diameter (>600mm) heat network pipework into London would need to be determined
- Actual cost of such long distance transmission networks (there are none in the UK at the time of writing, and very few on this scale anywhere in the world)
- The effect on the electricity market of operating such plants in CHP mode would need to be considered.

[89] DECC (2011) Digest of United Kingdom energy statistics, p99 http://www.decc.gov.uk/assets/decc/11/stats/publications/dukes/2306-dukes-2011-chapter-4-natural-gas.pdf
[90] National Grid (2005) GB Seven year statement, Table 2.1: http://www.nationalgrid.com/uk/library/documents/sys05/default.asp?sNode=SYS&action=&Exp=Y

7 Conclusions

7.1 Future role of heat networks

This study demonstrates that DE has the potential to make a significant contribution – on an economic basis – to the supply of energy in London. It suggests that the Mayor's target of 25% DE by 2025 is achievable. However, realising this level of ambition will require strategic planning and a supportive policy framework to help address the barriers outlined in this report including, and most critically, managing offtake risk.

7.2 Roadmap for decentralised energy deployment

A deployment process for DE has been mapped which shows that initial phases of network establishment and growth could be followed by interconnection and transition to using large low carbon sources of heat:

Establish schemes

The initial development of DE schemes is centred around areas under the control of a single land owner (universities, hospitals, large new build developments) and schemes being developed by local authorities as part of their climate change and fuel poverty strategies. These schemes could act as catalysts for wider area schemes through interconnection but they will need to be significantly scaled up to deliver the deployment potential identified in the Phase 2 report. GLA should take a strategic planning role, ensuring that boroughs enable widespread coverage of heat networks in those areas where heat networks are viable. This should include a gap analysis of the projects being developed under the DeMAP programme and the deployment potential identified in Phase 2 of this study

New connections and load diversity

Ensuring that DE schemes can grow and add capacity is essential. Networks must be planned for the long term and benefit from the low cost finance required to ensure they are economically viable. This requires a clear framework for managing risk, particularly offtake risk and the risk of stranded assets. Uncertainty surrounding the security of future revenues is preventing private sector investment. Managing this offtake risk is currently undertaken through long term heat supply agreements or control over land ownership. To enable greater deployment of DE some form of incentive (through lower energy costs) or regulation (to mandate in some circumstances or otherwise encourage connection) may required, as low levels of take up significantly increase the unit cost of heat supply.

Interconnection

The heat network element of DE systems has a forty year life. As Type 1 and Type 2 schemes require their heat generation plant to be replaced decisions will be required about investment in interconnection or plant replacement. Larger, lower carbon heat sources can offer significantly lower cost heat. Where coordination problems can be overcome interconnection offers significant economic benefits, increasing the deployment potential of DE. There is a clear role for the GLA and boroughs to enable private sector investment in these Type 1 and 2 schemes, but also to plan interconnection through wider cross boundary Type 3 schemes

Low carbon sources

Transitioning to lower carbon heat sources represents one of the key drivers for prioritising DE. Many low carbon heat sources require large-scale plants. Only interconnected heat networks or large industrial users are able to fully utilise the quantum of energy available from technologies such as energy from waste, biomass CHP and waste heat from existing power stations. Higher cost and higher carbon sources of heat used to establish heat networks can be replaced having served their purpose as a transition technology. Up until 2025-2031 large-scale gas fired CHP will continue to provide lower carbon heat than gas boilers or heat pumps, and can continue to act as a transition technology until around 2031.

Zero carbon transition

Beyond 2031 a switch to heat sources lower in carbon than gas CHP will be required to continue delivering carbon savings in line with the national and London targets to achieve an 80% reduction in CO_2 emissions on 1990 levels by 2050. Should this accompany a rise in natural gas prices (due to supply shortages or environmental policy), larger-scale heat networks offer opportunities to capture and use supplies of waste heat from new build low or zero carbon power stations located outside London. This is a very long term approach and subject to significant levels of uncertainty but the Phase 2 report shows it could provide a significant contribution to the Mayor's DE target.

7.3 Barriers and risks

The public sector has a key role in delivery through the planning, and at least initially delivery, of DE schemes. This role is critical in establishing DE systems as viable sources of low carbon heat. Should this involvement be withdrawn high levels of deployment are highly unlikely in the current policy environment.

There are high levels of risk associated with investments in heat network development, which is why they are often lead by the public sector. In order to access private sector investment these risks must be mitigated.

The low return on investment from DE systems makes them unattractive to private sector investors under the current policy environment, outside of certain sectors. The lack of access to the electricity market for small-scale generators exacerbates this effect as the revenue from electricity sales is a key factor viability of DE schemes.

There is a risk that new technologies and reductions in heat demand through energy efficiency and a warming climate reduce the economic viability of heat networks.

There is a need for continuing public sector involvement and policy support to ensure that the initial stages of DE deployment continues to build scale towards a stage where interconnection occurs and low carbon heat sources can be connected. At this stage, with the deployment of heat networks already de-risked, the economics of DE become much more attractive.

7.4 Further work

Further work is recommended to better understand some of the issues relating to DE deployment, including:

- How the low carbon gap can be addressed in London e.g. the shortfall between the deployment potential identified for heat networks and heat pumps against predicted levels of heat demand
- More robust data regarding the cost of installation of heat networks in parts of London, particular where there is variation in below ground congestion due to existing infrastructure
- A detailed assessment of the potential for heat to be imported into London from surrounding power stations, particularly those sites where zero carbon plants (CCS or nuclear) are planned
- More data on the actual performance in use of heat pumps and an understanding of whether their performance is likely to significantly improve beyond that achieved in recent trials
- The opportunities for DE to provide electricity system demand management services.

APPENDICES

Appendix A: Major sewage plants, landfill sites and bus depots in London

Site	Type	Postcode	X	Y
Beckton	Sewage plant	IG11 0AD	544349	182590
Crossness STW	Sewage plant	SE2 9AQ	548400	181100
Mogden	Sewage plant	TW7 7LR	515529	174896
Beddington	Sewage plant	CR0 4TH	530006	166069
Hogsmill	Sewage plant	KT1 3BW	519345	168266
Deepham	Sewage plant	N9 0BD	535800	193000
Longreach	Sewage plant	DA1 5	554760	175169
Riverside	Sewage plant	RM13 8RH	551100	182100
Rainham	Landfill site	RM1 9DA	552400	179100
Harmondsworth	Landfill site	UB7 0AE	506043	177890

Table 7-1: Major sewage treatment plants and landfill sites in London

Name	Postcode	Name	Postcode	Name	Postcode
Alperton	HA0 4PZ	Enfield	EN3 4SZ	Perivale (West)	UB6 7RL
Ash Grove	E8 4RH	Fulwell	TW2 5NP	Plumstead	SE28 0BJ
Barking	IG11 9RY	Fulwell	TW2 5NX	Poplar	E16 2ES
Barking	IG11 8UE	Grays	RM20 4DB	Potters Bar	EN6 5BE
Battersea	SW8 3HE	Harrow	HA2 6EH	Putney	SW4 6ST
Beddington	CR0 4XH	Harrow Weald	HA3 6EJ	Rainham	RM13 9BU
Beddington	CR0 4XB	Hayes	UB3 4QT	Rainham	RM13 9BU
Belvedere	DA17 6BT	Hayes	UB3 1DQ	Romford	RM1 1DS
Bexleyheath	DA7 6BX	Holloway	N19 5RR	Shepherd's Bush	W12 8DA
Bow	E3 2QP	Hounslow	TW3 1PA	Stamford Brook	W4 1SY
Brentford	TW8 8LZ	Hounslow Heath	TW4 6BL	Stamford Hill	N16 6SS
Brixton	SW2 4TB	King's Cross	N1 0AX	Stockwell	SW4 6ST
Bromley	BR2 8NH	Lea Interchange	E10 5PB	Sutton	SM1 1QJ
Camberwell	SE5 9LU	Leeside Road	N17 9LR	Thornton Heath	CR7 6AU
Catford	SE6 2XA	Leyton	E10 6AD	Tottenham	N15 4JB
Clapton	E8 1DU	Mandela Way (East)	SE1 5SS	Twickenham	TW1 1DU
Cricklewood	NW2 6JP	Merton	SW19 1DN	Upton Park	E6 1DS
Croydon	CR2 6EL	New Cross	SE14 5UH	Uxbridge	UB8 1RG
Croydon	CR9 4ND	Northumberland Park	N17 0XB	Walworth	SE5 0TF
Dagenham	RM9 6QJ	Norwood	SE27 0DQ	Waterloo	SE1 8TE
Dartford	DA7 6BU	Orpington	BR6 6DA	Waterside Way	SW17 0HB
Edgware	HA8 7AN	Palmers Green	N13 5UR	Watford (Garston)	WD2 6NN
Edgware	HA8 7AN	Park Royal	NW10 6DN	West Ham	E16 4SA
Edmonton	N18 3QX	Peckham	SE15 3SE	Westbourne Park	W9 2BA
Willesden Junction	NW10 5QJ	Perivale (East)	UB6 8DW	Willesden	NW10 2JY

Table 7-2: Bus depots in Greater London[91]

[91] Transport for London (2010) London bus garages: http://www.londonbusroutes.net/garages.htm