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City of London Corporation

North-East Square Mile Heat Network Study

Final output report

May 2025

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Document Verification

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Glossary of terms

Term	Definition	Term	Definition
ACC	Air-Cooled Chiller	CHP	Combined Heat and Power
ASHP	Air-source heat pump: equipment that uses electricity to capture heat in air, uplift its temperature and deliver it to buildings; multiple units of heat are produced for each unit of electricity consumed	Cluster	A collection of several buildings located in proximity to each other
ATES	Aquifer Thermal Energy Storage	CoL	City of London
AZP	Advanced Zoning Programme	CoLC	City of London Corporation
BAC	Barbican Arts Centre	COP	Co-efficient of performance
BMS	Building Management System: centralised control system that monitors and manages building functions such as heating, cooling, and ventilation	DC	Data Centre
CAPEX	Capital expenditure	DESNZ	Department for Energy Security and Net Zero
CBHS	Cross Boundary Heat Sharing	DHN	District Heat Network
CBHSS	Cross Boundary Heat Sharing Study	DHW	Domestic Hot Water

Glossary of terms

Term	Definition	Term	Definition
ESCo	Energy Service Company	HP	Heat pump: equipment that uses electricity to capture heat in water or air, and uplift its temperature; multiple units of heat are produced for each unit of electricity consumed
Ex Halls	Barbican Exhibition Halls and Cinemas	HSA	Heat Supply Agreement
gCO_2e/kWh	Grams of carbon dioxide equivalent greenhouse gas emissions per kilowatt-hour	IRR	Internal Rate of Return
GHNF	Green Heat Network Fund	LA	Local Authority
GLA	Greater London Authority	LAEP	Local Area Energy Plan
GYE	Guildhall Yard East	LBH	London Borough of Hackney
HEX	Heat Exchanger	LBTH	London Borough of Tower Hamlets
HMT / HM Treasury	His Majesty’s Treasury	LCOH	Levelised Cost of Heat
HNZ	Heat Network Zone	LZC	Low/Zero Carbon

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Glossary of terms

Term	Definition	Term	Definition
NESQM	North-East Square Mile	TES	Thermal Energy Storage
NPV	Net Present Value	TfL	Transport for London
NZM	National Zoning Model	UKPN	UK Power Networks
OPEX	Operational expenditure	WCC	Water-Cooled Chiller
PCG	Parent Company Guarantee	WHR	Waste Heat Recovery
PHEX/HEX	Plate Heat Exchanger	WSHP	Water-Source Heat Pump
RAG	Red Amber Green	ZC	Zonal Coordinator
REPEX	Replacement expenditure	ZHN	Zonal Heat Network
TEM	Techno-Economic Model		

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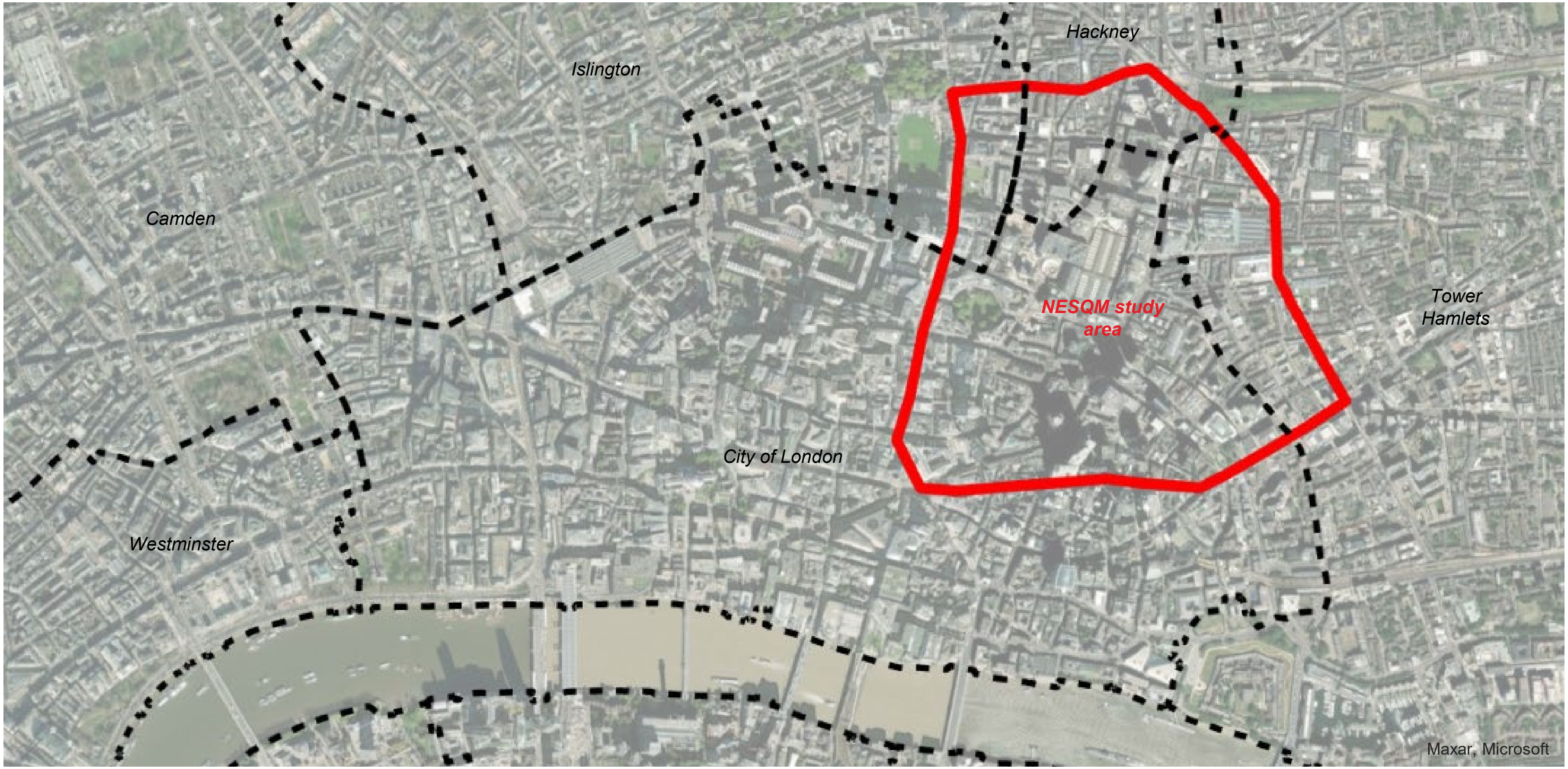
1. Introduction



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1. Introduction
The study aims to develop and appraise a district heating and cooling network proposal for the Northeast Square Mile

Study aims

This report is developed for the two studies below.

NESQM heat network feasibility study

The City of London Corporation (CoLC) has committed to achieving Net Zero emissions in the City of London (CoL) by 2040. Thermal energy demands of buildings are one of the largest sources of emissions both across the UK and in the Square Mile, with buildings predominantly heated by natural gas

District heating and cooling networks, which centralise energy supply plant and deliver energy to buildings through large water pipes in the ground, are expected to play an important role in decarbonising Building's energy demand in the UK. These networks can deliver economies of scale, enable use of highly efficient low-carbon sources of heat, optimise waste heat recovery opportunities from centralised cooling systems, and diversify peak loads to reduce costs.

Arup was appointed to complete this network feasibility study, with **aims to develop and techno-economically appraise a preferred scenario for construction of a low-carbon district heating and cooling network to decarbonise buildings in the northeast quadrant of the Square Mile** – known as the Northeast Square Mile (NESQM). The NESQM study area is shown in red on the previous page.

Note that **the study was split into 2 Stages**, with findings from both presented in this report**.** Stage 1 entailed the identification of key loads, sources, and potential energy centres, and initial network options were developed and evaluated for progressing in Stage 2. Stage 2 refined network options and performed techno-economic modelling to appraise each scenario.

Cross-Boundary Heat Sharing Study (CBHSS)

While the NESQM feasibility study focuses within the CoL boundary, London's local authorities and the Greater London Authority (GLA) recognise the need for collaboration between local authorities to effectively roll out heat networks across London.

Rather than developing separate networks in each London local authority, developing interconnected systems across boundaries could offer benefits such as sharing of waste heat sources and plant spaces, maximising plant utilisation, and diversifying loads. These benefits could make interconnected networks more cost-effective and lower carbon.

In particular, given the City of London's large summer cooling loads and the neighbouring London Borough of Hackney (LBH) and London Borough of Tower Hamlets' (LBTH) higher proportion of residential developments, which tend to consume notably more heat in the summer than office buildings, an opportunity may exist to utilise significant amounts of excess cooling waste heat from the Square Mile in across-boundary heat network in LBH and LBTH.

While Arup delivered the NESQM study, LBH appointed consultants BuroHappold to complete a separate feasibility study in parallel for the Shoreditch area of Hackney, adjacent to the NESQM.

Given the potential heat sharing opportunity and the aligned timeframes of the two heat network feasibility studies, CoLC and LBH have collaborated to undertake a Cross-Boundary Heat Sharing Study to explore the opportunity to interconnect the two potential heat networks. Arup has been appointed to complete this study in addition to its work on the NESQM feasibility study; CoLC are leading the CBHSS. **The CBHSS aims to investigate the techno-economic and commercial opportunities, constraints, and risks in the development of heat networks crossing the local authority boundaries.** The study will culminate in technically and economically appraising a preferred cross-boundary heat network scenario, with commercial options for delivering the network and the purchase and sharing of heat across the local authority boundary evaluated and assessed.

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1. Introduction

Other studies inform this work, such as the CoL LAEP; heat network zoning is set to accelerate network development

Context – other studies and programmes

Other studies

CoLC and others have previously completed several studies that inform the NESQM and CBHSS projects.

In 2023, CoLC completed the development of its Local Area Energy Plan (LAEP), which explored a range of technologies and scenarios with a whole-systems approach to set out a pathway to deliver CoLC's target for a net-zero Square Mile by 2040. This saw heating and cooling demands modelled for every building in CoL, and potential sources of waste heat mapped, to understand the local energy system. The LAEP identified the NESQM as the highest heat demand density part of the Square Mile and therefore highlighted it as a high priority for future heat network development. The plan recommended seven priority intervention areas for CoLC, which included *decarbonising heat* and *implementing waste heat capture and exchange.* The NESQM and CBHSS will aim to address both these intervention areas.

A significant heating and cooling network already exists in the Square Mile. The Citigen network, operated by E.ON, is located to the west of the NESQM boundary. The network supplies several significant heat loads in the CoL, such as the Barbican Arts Centre and Guildhall. While the network includes some heat pump capacity, it is currently mostly fossil fuel-based, with gas combined heat and power (CHP) engines and boilers providing most of its heat.

Ramboll was commissioned to carry out a feasibility study on the Citigen decarbonisation roadmap, which concluded that the low carbon roadmap appears to be economically viable. The proposed roadmap aims to decarbonise and expand Citigen within the Square Mile, achieving the required carbon threshold by 2027 and maintaining it through to 2042. The study also highlights the challenges in sourcing adequate Low Zero Carbon (LZC) heat for the expanded network, leading to reliance on electric boilers, CHP, and gas boilers.

Heat network zoning

Department for Energy Security and Net-Zero (DESNZ) is set to introduce Heat Network Zoning(HNZ) regulations in 2025. These regulations are expected to transform the heat network industry and significantly accelerate network development. The policy will see zones defined across England where heat networks are assessed to provide the lowest cost low-carbon solution for decarbonising heating. Certain types of buildings within zone will be mandated to connect to heat networks.

By driving development of networks where most appropriate, the policy aims to ensure consumers have access to the lowest cost future heating solution. Designating zones provides greater certainty to project developers, and mitigates common risks associated with network development such as security of demand, scaling opportunities, and ownership models.

The City of London Corporation (CoLC) is also participating in the Advanced Zoning Programme (AZP), which aims to identify opportunities to accelerate the scale and pace of identified zonal heat network delivery once the HNZ regulations are in place. The proposed project developed as part of AZP involves the expansion of the E.ON Citigen network, with Phase 1 of this opportunity meeting a heat demand of 160 GWh/year.

The whole of the City of London was identified as a Heat Network Zone in the North London Zoning model output, published in September 2024. According to AZP1 outputs, 1,000 buildings in the City of London were identified as Buildings Required to Connect to a heat network under Heat network Zoning, with a high concentration of these buildings within the Square Mile.

1. Introduction
The NESQM is a unique area; it is highly space constrained and dominated by offices, including iconic skyscrapers

Context – location

The NESQM study area is situated in central London, falling mostly within the Northeastern corner of the City of London. The study area also intersects the neighbouring London Boroughs of Hackney and Tower Hamlets. The full extent of the study area is illustrated in Figure 1.1.

The NESQM is a key global financial district. It houses various iconic buildings such as the Gherkin and Liverpool Street Station, with others like 20 Fenchurch Street (the Walkie Talkie) and 52 Lime Street (the Scalpel) located just outside the boundary to the south. The Square Mile overall is home to 8,000 residents, welcomes over 500,000 people commuting to work each day and receives 10 million visitors annually. The Square Mile is a heavily built-up area and, as such, space limitations are key constraints to installing energy infrastructure.

Commercial, high-rise buildings dominate the NESQM study area, accounting for 70% of the over 1,300 existing individual buildings. The majority of the area's residential buildings are situated in the Hackney and Tower Hamlets sections of the NESQM boundary. Several data centres are situated in and around the study boundary, presenting opportunities for waste heat recovery. Despite the space constraints in the area, there is a significant level of planned new development throughout the NESQM at various stages of planning.

As mentioned previously, the existing Citigen heat network lies the west of the study boundary. As such, all buildings and heat sources in this region are assumed to fall within the remit of the Citigen network and are excluded from the scope of this study.

The unique context of the NESQM presents a specific set of opportunities and constraints in designing a district heat network to serve the area.

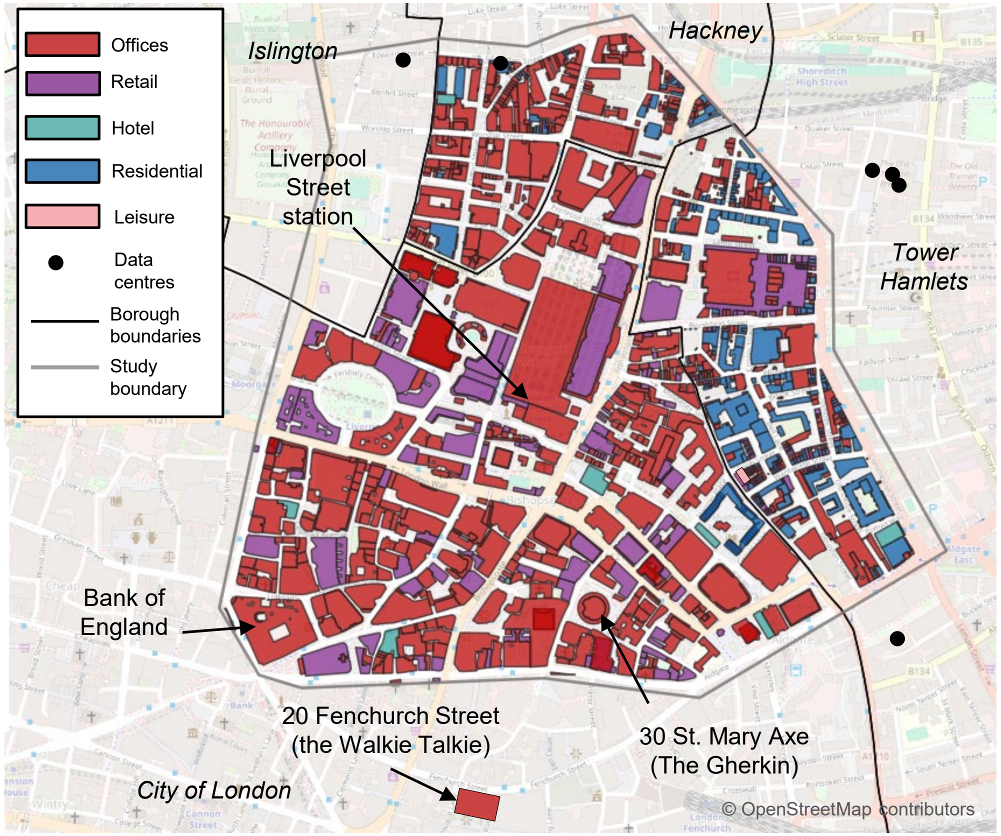

Figure 1.1: NESQM study area, including key buildings surrounding the study boundary.

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1. Introduction

The Shoreditch feasibility study looked at network options in North and South Shoreditch, feeding into the CBHSS

North and South Shoreditch networks

BuroHappold were commissioned by the London Borough of Hackney to investigate the feasibility of a heat network in the wider Shoreditch area.

The feasibility study boundary is illustrated in Figure 1.2. A critical constraint to network development is the City Road, which bisects the study boundary. As such, the Hackney network feasibility study explored separate network options divided by the City Road: North Shoreditch, South Shoreditch and a fully integrated option

The North Shoreditch includes a higher proportion of LBH residential blocks but has a lower linear heat density, which limits its commercial attractiveness. However, the inclusion of the LBH council blocks makes this area a priority for delivering low-carbon, affordable heat to Hackney's residents. Additionally, various planned developments in the North provide a good opportunity for housing energy centres.

The South Shoreditch is more commercially attractive due to its higher concentration of large private heat consumers and the availability of waste heat sources (e.g., transformers, data centres). However, spatial availability is more limited due to its central location. The Bishopsgate Goodsyard redevelopment has been identified as a central opportunity for an energy centre for the South Shoreditch network.

South Shoreditch is identified as part of the scope for this study, considering its proximity to the Square Mile. Cross-boundary stakeholder engagement has been conducted between Arup, Hackney Feasibility Study consultant Buro Happold, Hackney Feasibility Study project manager Arcadis, the London Borough of Hackney, and the City of London Corporation to ensure knowledge transfer while the two studies were conducted simultaneously.

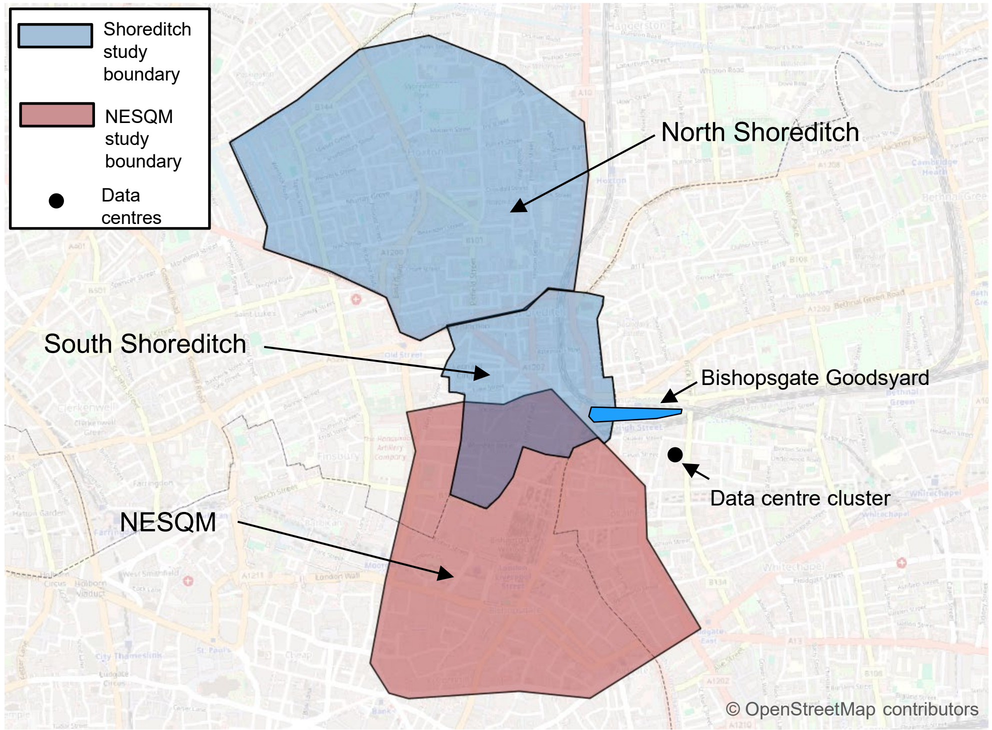

Figure 1.2: Shoreditch heat network feasibility study boundary and NESQM study boundary.

2. Demand assessment

2. Demand assessment

Commercial buildings dominate the annual and peak heating and cooling demands in the NESQM study area

Demand assessment introduction

An assessment of the heating and cooling loads of buildings across the NESQM study area was performed to characterise and prioritise potential loads for a heating and cooling network in the area.

The assessment involved a baselining exercise to establish the heating and cooling demands from existing buildings, followed by detailed hourly profiles for different building types to understand the seasonality and distribution of peak demands throughout the year. This revealed a 162 MW peak heating load in winter for 363 GWh heating demand, and a 166 MW peak cooling load in summer for a 196 GWh cooling demand. Commercial developments make up most of area's demand, contributing 71% and 79% of annual heating and cooling loads respectively.

Based on these results, buildings were assessed and prioritised for connection to the explored network. The prioritisation criteria are explored later in this section. This prioritisation fed into the NESQM network options explored in Section 5, supported by hourly dispatch modelling to understand the contribution of different supply options.

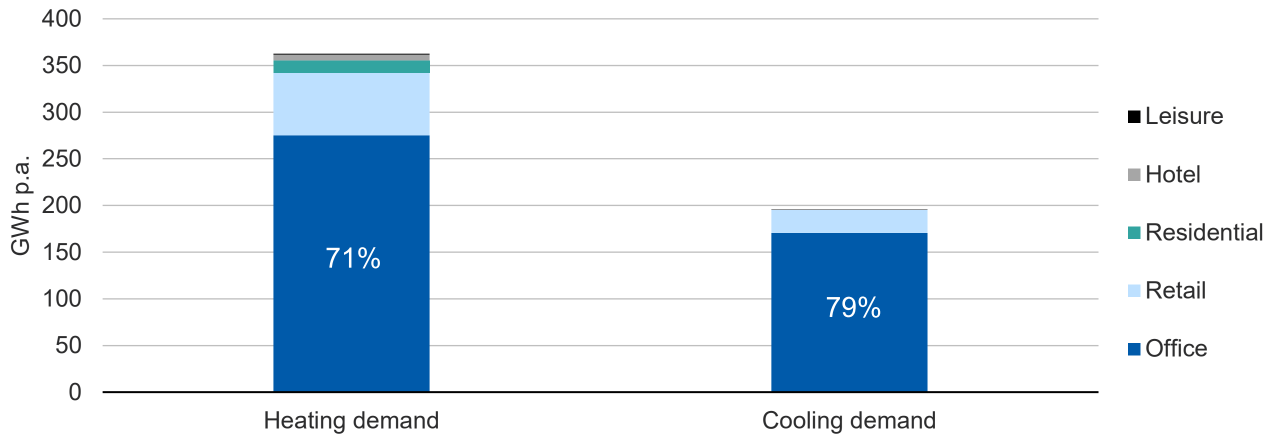

Figure 2.1: Heating and cooling annual load by building typology within the NESQM study area

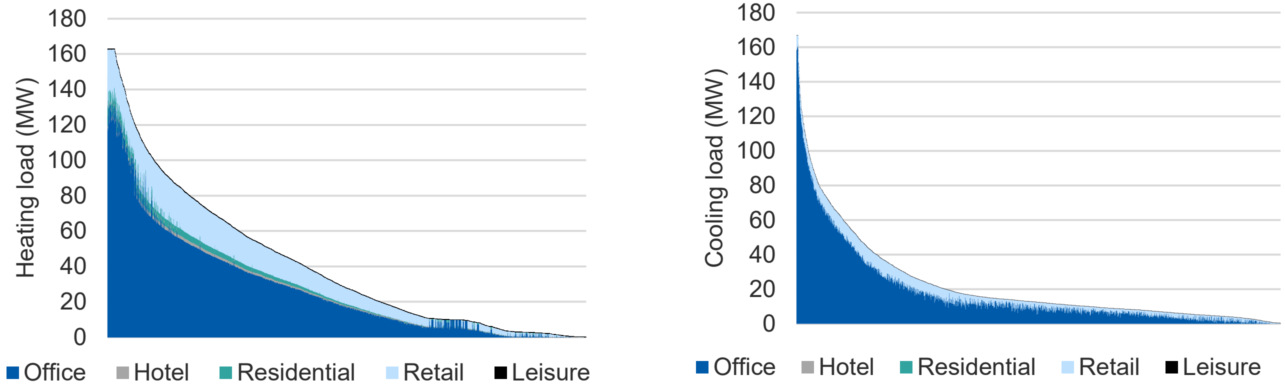

Figure 2.2: Heat and cooling load duration curve by building typology within the NESQM study area

2. Demand assessment

A "re-baselining" exercise was performed to improve overall confidence in the accuracy of existing demand estimates

Existing buildings – establishing a baseline

Various datasets were combined to evaluate the heating and cooling demands for existing buildings across the NESQM. For existing buildings within CoL, the heating and cooling demands modelled in the City's LAEP were available. Demands for existing buildings within Tower Hamlets and Hackney were sourced from National Zoning Model datasets from the Advanced Zoning Programme (AZP) study.

Stakeholder engagement returned 24 Requests-for-Information (RFIs) from specific buildings within and around the NESQM. This information included metered consumption data from existing buildings and modelled data from energy statements for new builds.

Through the process of combining these datasets, each data source was assigned a confidence score, assessing the reliability of the data. As RFI information returned for existing buildings was based on actual metered consumption data, this data was assigned the "highest" confidence score and superseded any modelled data for these buildings. Data modelled for CoL's existing buildings through the LAEP process underwent numerous iterations of quality assurance and received a "medium" confidence score. The National Zoning Model, which is required to mass-produce demand estimates across all of England, is less detailed than the modelling used in the LAEP, resulting in the AZP datasets being assigned a "low" confidence score. To increase the overall confidence in the existing building demand calculations, a "re-baselining" exercise was performed to adjust the LAEP data for commercial buildings according to insights gathered from the RFI responses. Figure 2.3 illustrates the high-level "re-baselining" methodology. The adjusted LAEP data was assigned a "high" confidence score.

A breakdown of annual heat demands by data source and confidence score is shown in Figure 2.4. The difference between the initial and adjusted baseline is illustrated in Figure 2.5, showing that the LAEP and AZP data underestimated cooling demand compared to the re-baselined results, likely due to generic assumptions that did not capture the large cooling loads in office buildings in CoL, as revealed by RFIs.

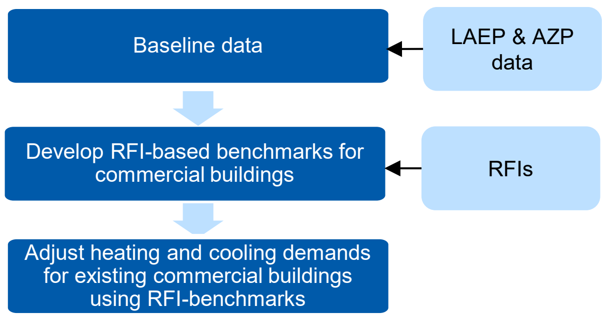

Figure 2.3: Overview of "re-baselining" methodology, used to increase the confidence in the heating and cooling demands for existing commercial buildings.

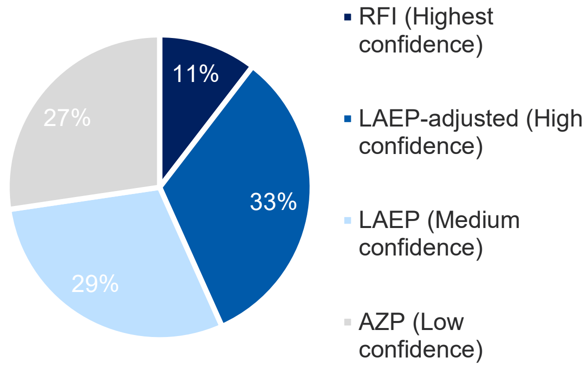

Figure 2.4: Breakdown of baseline heating demand by data source and confidence level, post "re-baselining".

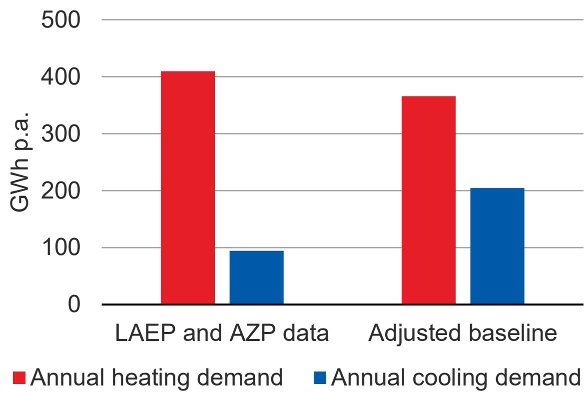

Figure 2.5: Comparison between the initial baseline and adjusted baseline (post "re-baselining") heating and cooling demands for existing buildings within the NESQM

2. Demand assessment

The cumulative impact of new developments on total demands is a limited net reduction over time

Changes to demand over time - new developments and climate change

To account for demolitions and the construction of new developments, phased changes to the baseline heating and cooling demands was considered.

The cumulative impact of new developments on the total heating and cooling demand across the NESQM is outlined in Figure 2.6. This **presents a limited net reduction over time** as the new developments are constructed, because of the demolition of existing buildings and increased standards for new buildings' thermal demands. By 2035, heating demand decreases by just 2% compared to 2025, while cooling demand drops by 4%. Data received from CoL's planning portal was used to estimate the demands for permitted new-builds and new developments at the pre-application (pre-app) planning stage. Best practice industry benchmarks were applied when calculating the demands for new buildings.

Future changes to climate may significantly alter thermal energy demands. Future climate parameters developed in the City of London LAEP were used to adjust the existing building demands. Figure 2.7 presents the projected 13% decrease in heating demand and 58% increase in cooling demand by 2050 due to the impact of climate change. These changes illustrate the potential impact of climate change on the future operation of the network, which will be further assessed in the next stage for the selected preferred option.

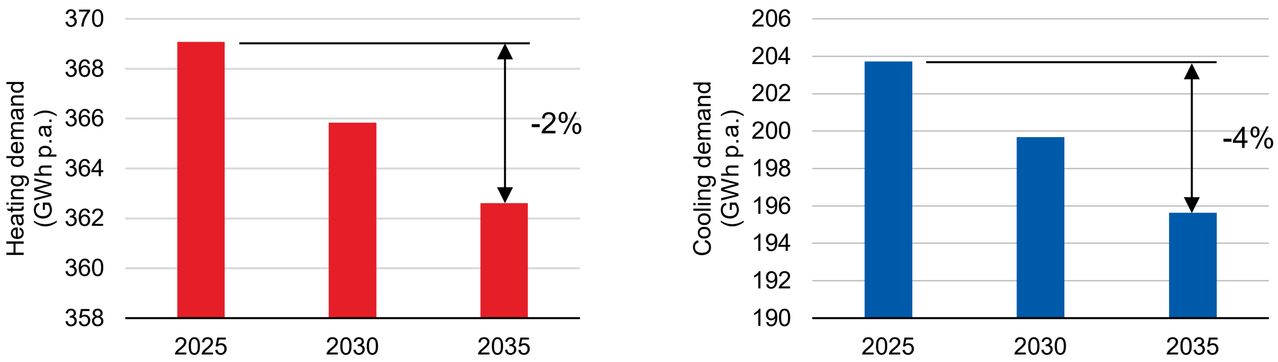

Figure 2.6: Change in NESQM study area heating and cooling demand over time, as existing buildings are demolished and new buildings, both approved at the pre-application stage, are constructed; note that the y-axes do not start at zero for these charts

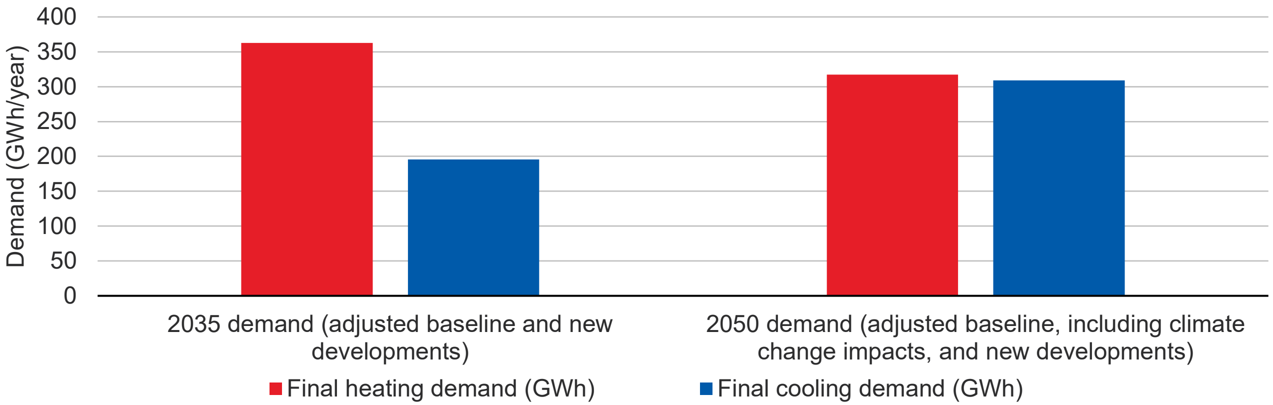

Figure 2.7: Indicative impact of climate change on the NESQM study area's heating and cooling demands; note that increase in cooling demand shown is related to climate change only - additional cooling load due to change of building use (e.g., the development of new data centres or server rooms) has not been considered

2. Demand assessment

Buildings in the NESQM were assigned a level of priority for connecting to a potential network – highest, high, low

Demand mapping and prioritisation

Existing and new **buildings across the area were assigned a level of priority for connecting to a potential network**. Three priority levels were defined: ‘highest’, ‘high’ and ‘low’. The criteria for each category is summarised in Table 2.1.

The “highest” priority buildings were selected based on several criteria, including the level of engagement as indicated by whether an RFI response was received; engagement with the study indicates willingness to connect to the network and possibly even host or share plant. New developments, either approved or pre-app, will be designed to allow for the provision of equipment for connection to future heat networks due to London Plan planning requirements; these buildings would be straightforward to connect and are therefore also assigned as “highest” priority. Lastly, residential heat loads greater than 100 MWh p.a. were also considered “highest” priority as these have potential to provide diversity within the demand profile of the network in a predominantly commercial area, which may increase the utilisation of cooling waste heat.

Other buildings with heat demands exceeding 750MWh p.a. were categorised as “high” priority as these represent potential anchor loads which would likely be economically beneficial to connect. All remaining buildings may be less attractive to connect and were assigned “low” priority.

Priority level	Criteria	Justification
Highest	• RFI response received, and/or; • New build (approved or pre-app stage), and/or; • Residential building or hotel with over 100 MWh p.a. heating load	✓ Stakeholder engagement indicates willingness to connect (and possibly host/share plant) ✓ New builds are designed to be ready to connect to future heat networks ✓ Large residential and hotel loads can provide load diversity and increase use of cooling waste heat
High	• Other building with over 750MWh p.a. heating load	✓ Large anchor loads are economically attractive to connect
Low	• Other existing building	Other smaller loads may be less attractive to connect

Table 2.1: Description and justification of the criteria for the three priority levels for connection to the proposed network.

NB: Each building in the NESQM was assigned a priority level, depending on the matching criteria. Note that Heat Network Zoning exemptions were not considered here, as this will be dealt with in more detail in subsequent AZP stages, with more sight of the exemption process available.

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2. Demand assessment

Majority of the heat loads are "high" priority, attributed to existing buildings with heat loads > 750MWh p.a.

Demand mapping and prioritisation

The distribution of existing and new buildings in the NESQM, with their corresponding priority level for connecting to a potential heat network, are presented in Figure 2.9.

The southern edge of the NESQM border features a cluster of approved new builds. This area also shows high levels of engagement, with most buildings that have returned RFI responses located in the Southern half of the NESQM.

Additionally, there is a concentration of high-priority residential or hotel heating loads in the South-East area of the NESQM and its surrounding boundary areas, indicating potential opportunities for evening and summer heating loads.

As shown in Figure 2.8, most of the heating and cooling demand within the NESQM boundary falls within the "high" priority category. This **means most of the heat demand within the study area is attributed to existing buildings exceeding 750MWh, which can be considered potential anchor loads.**

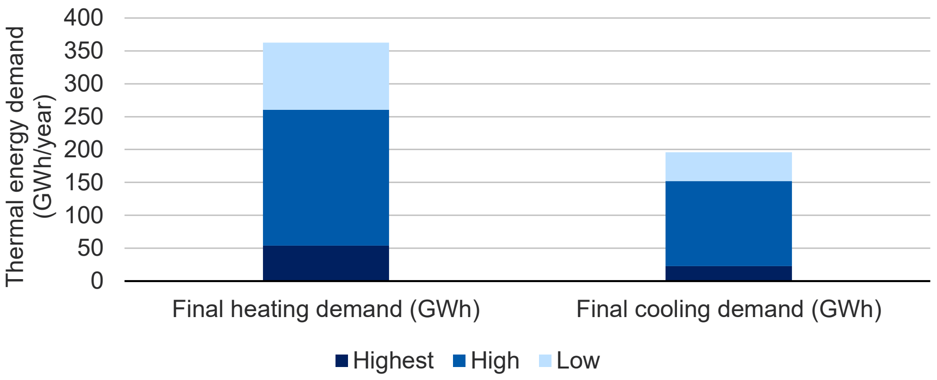

Figure 2.8: Breakdown of heating and cooling demand (assuming construction of all new buildings has been completed) based on connection priority.

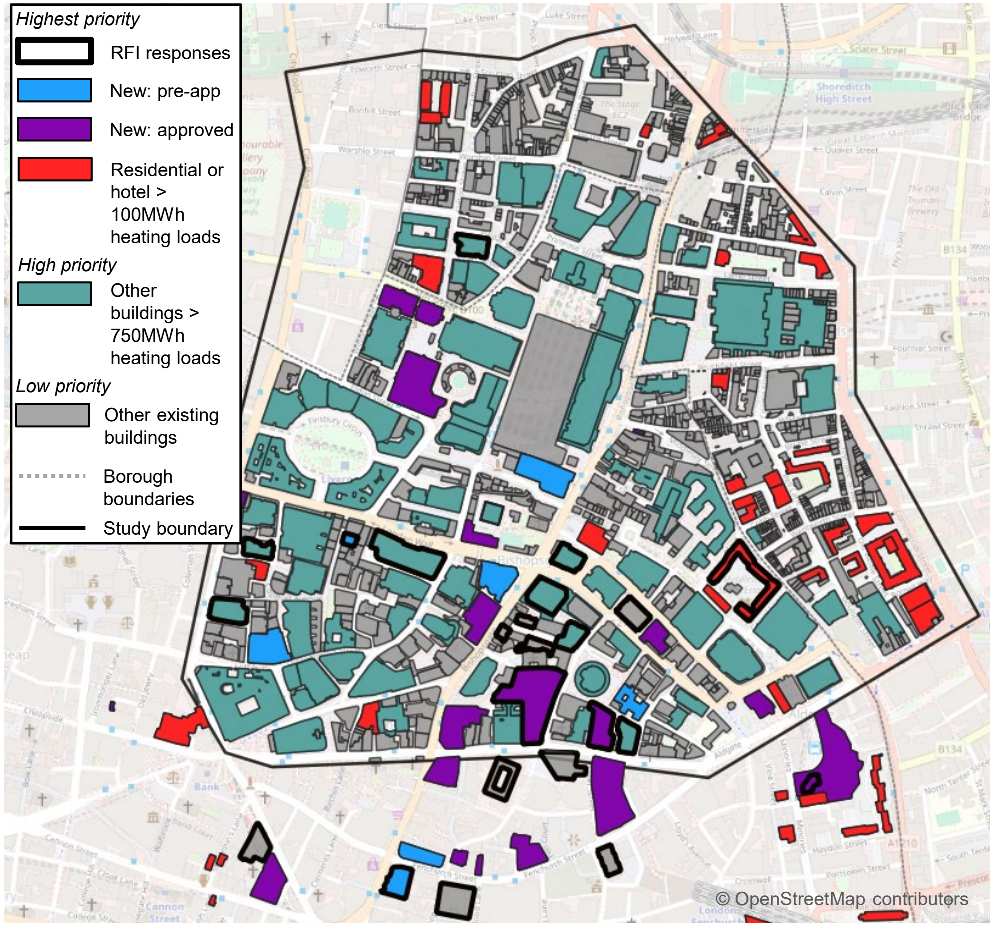

Figure 2.9: Distribution of existing and new builds (both approved and at the pre-app stage) across the NESQM as prioritised for connection to the proposed district heat network

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2. Demand assessment

Heating and cooling loads are dominated by office buildings, with limited diversity of building types

Profiling demands

Hourly profiles were developed to distribute annual heating and cooling demands across every hour of the year. This is key to understanding instantaneous, daily, and seasonal variations to loads to ensure supply and demand are matched within the proposed network.

Peak heating loads occur in winter, with a small average base load present throughout the year. Cooling demands peak significantly in summer and are limited in winter.

There is little diversity in the types of heating and cooling profiles across the NESQM as the area is largely dominated by commercial developments. Retail contributes a limited amount, and residential contributions are near negligible to the overall pattern of demand. While this is a constraint in designing a heat network for the NESQM, it provides an opportunity for exploration in the cross-boundary heat sharing study. The study area of the proposed heat network in South Shoreditch consists of more residential buildings than the NESQM, with the potential to provide a more stable load during the evening and summer when heating drops in commercial buildings.

Building on the findings in this section, the Supply Assessment in Section 3 explores various options for supplying demand in the NESQM through different heat sources.

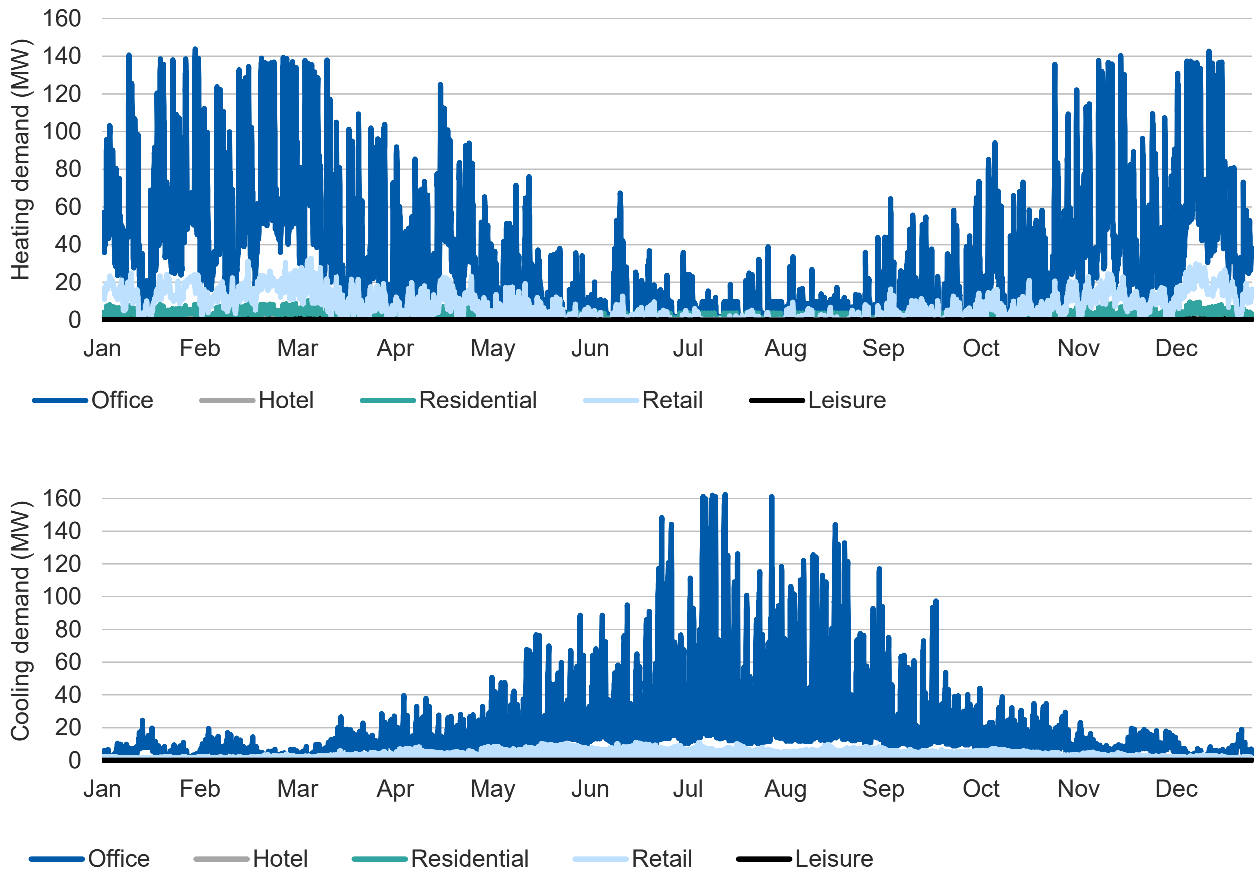

Figure 2.10: Hourly heating and cooling load across different building typologies within the NESQM study area

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2. Demand assessment

Cross-boundary heat sharing has the potential to provide diversity to the office-dominated NESQM

Cross-boundary heat sharing study

Heat demand data for the potential Shoreditch heat network in Hackney was used to assess the cross-boundary heat sharing (CBHS) potential of the NESQM network options.

Figure 2.11 shows the breakdown by building typology of the annual heat load for buildings proposed to connect to the South Shoreditch network. While much of the heat load remains attributed to offices, there is more diversity in the types of buildings than in the NESQM. Residential loads contribute 9% of the total load in the Shoreditch network, which is notably higher than the 4% contribution of residential to NESQM annual demand.

The impact of this higher level of diversity is shown in the hourly demand profile of the South Shoreditch network, provided in Figure 2.13. While the overall heating demand still peaks in the winter months, the increased residential DHW demand provides a consistent load of up to 6 MW throughout the summer.

These preliminary results outline the potential for cross-boundary heat sharing to provide diversity to the commercial dominated NESQM. Potential benefits include enhanced system and carbon performance. Further exploration of CBHS potential is outlined in Section 5.

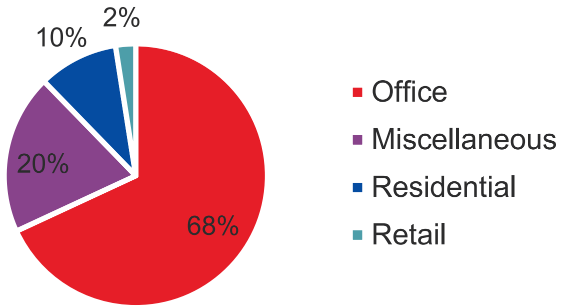

Figure 2.11: Split of demand by building typology in the South Shoreditch heat network.

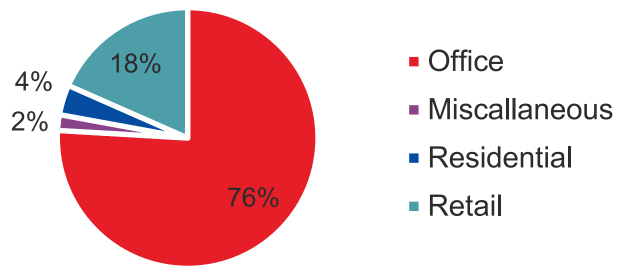

Figure 2.12 Split of demand by building typology in NESQM.

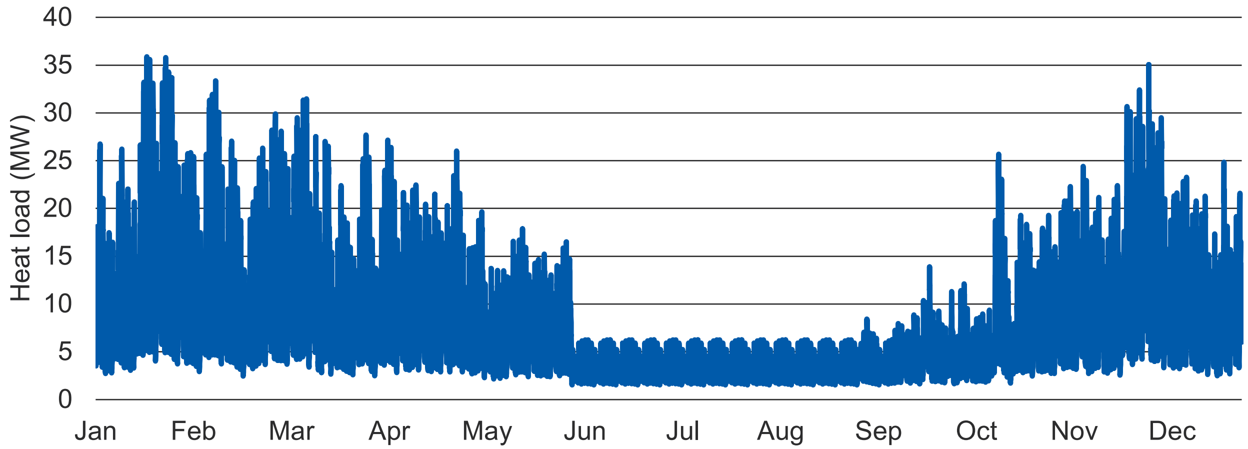

Figure 2.13: Preliminary proposed South Shoreditch heat network heat demand profile

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3. Supply assessment

3. Supply assessment

Potential heat sources were identified in Stage 1, and their available heat capacity was estimated on an hourly basis

Mapping heat sources – Stage 1

Potential low-carbon heat sources in the NESQM area were identified and mapped through a desktop research exercise using a variety of data sources in Stage 1. The available heat capacity of each source was estimated, and this was profiled on an hourly basis to understand how it may match to the area's demand profile.

Figure 3.1 presents the heat source mapping, with 5 types of heat source identified: office cooling systems, data centres (DCs), electrical transformers at UK Power Networks (UKPN) substations, Transport for London (TfL) underground vent shafts, and the subterranean River Walbrook via the sewer network.

All of these sources offer heat at lower temperatures than required to heat buildings. Heat pumps (HPs), which use electricity to power a refrigerant compressor cycle to capture heat and boost its temperature, are needed to boost heat source supply temperatures before feeding into a heat network.

These heat pumps could be installed on-site at each source site if space is available, and the relevant parties come to an agreement. Otherwise, the heat can be extracted using a heat exchanger (HEX) and pumped at its ambient temperature to a nearby energy centre containing the heat pumps to supply the network.

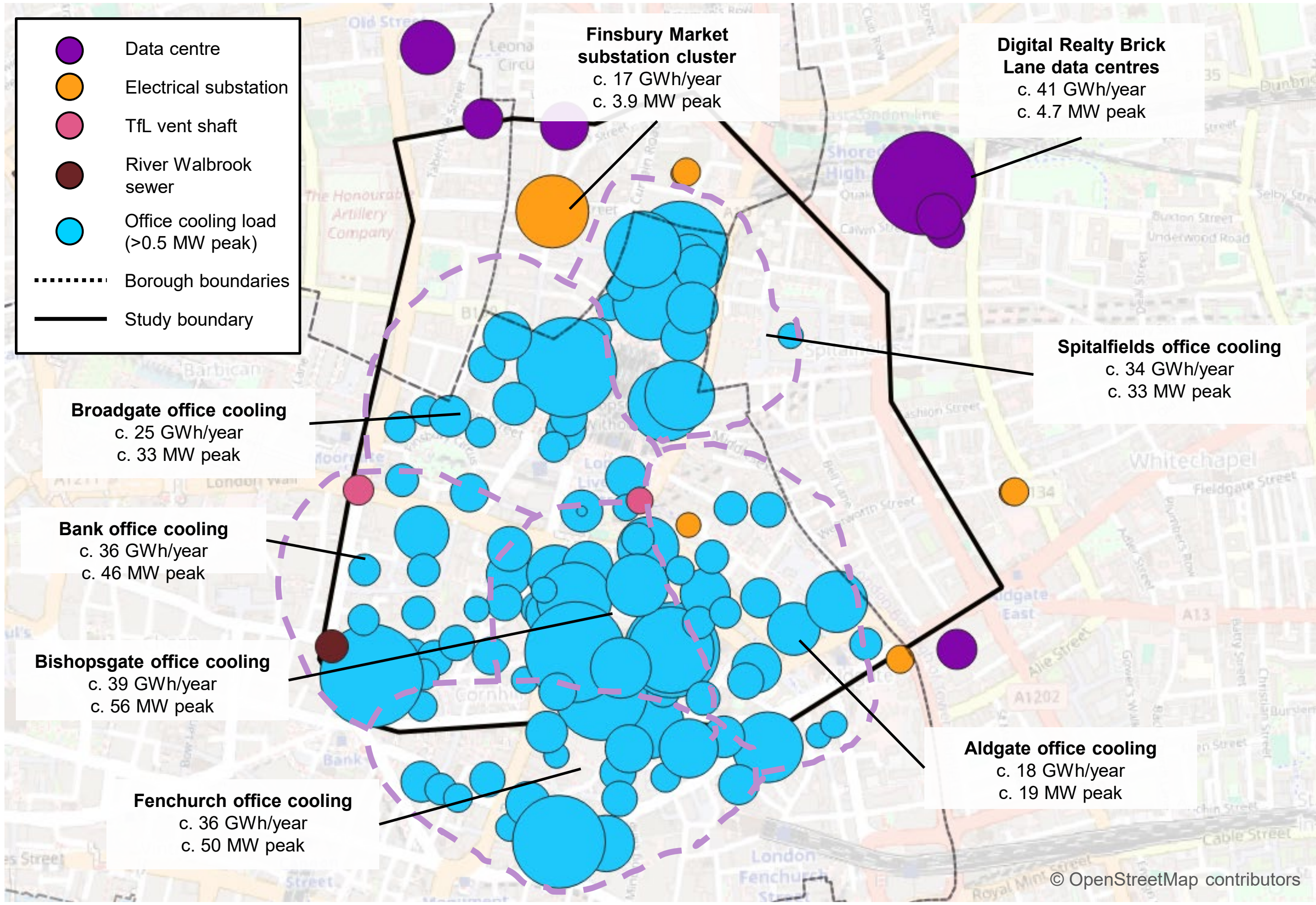

Figure 3.1: Identified heat sources and estimated annual waste heat potential (at source temperature, pre-uplift from heat pump); note that markers are sized proportionally to the annual waste heat estimates.

ARUP

3. Supply assessment

There is abundant heat available from office cooling systems; however, it is poorly matched with the timing of demand

Heat source availability – Stage 1

Figure 3.2 shows the estimated annual waste heat available from all the low carbon waste heat sources presented on the previous page.

Office cooling system waste heat is clearly the most abundant source of heat in the NESQM. However, as illustrated in the cooling and heating demand profiles in Section 2, the availability of this heat is poorly matched to heat demand in the NESQM.

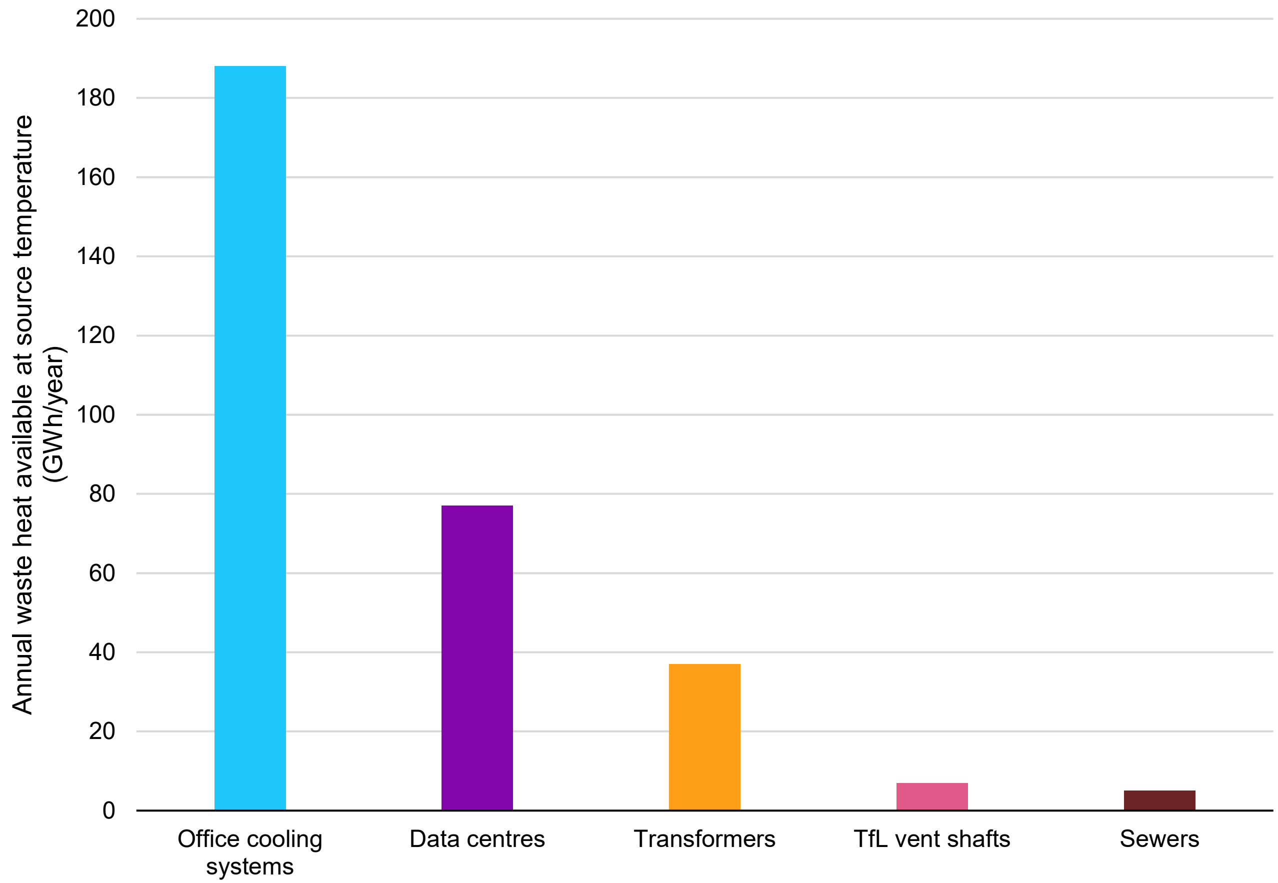

Figure 3.2: Annual waste heat available by source type

3. Supply assessment

The various identified heat sources were assessed using multi-criteria analysis to understand the options to focus on

Assessing heat sources – Stage 1

A multi-criteria assessment methodology to understand which heat sources should be prioritised for consideration was developed. Each supply option was evaluated against four criteria, decided upon in a workshop with CoLC, in Stage 1 to shortlist the most suitable heat sources for this NESQM study. Table 3.1 presents the criteria and how scores were assigned for each criterion. The criteria were weighted equally, and a final score out of 5 was calculated for each heat source so they could be compared. Sources scoring higher than 3 were considered as priority heat sources.

The *location* score indicates the distance of the heat source from potential energy centre locations identified in Stage 1. The hourly heat demand developed for the area's buildings was used to compare to the hourly profiles for each source's available heat capacity for scoring the *seasonality* criterion. Outcomes from correspondence and outreach to stakeholders were used to score the *likelihood to participate* criterion – e.g., if a site had returned an RFI document, it was considered more likely to participate.

Score	Location	Capacity	Seasonality	Likelihood to participate
0	>500m from a potential EC	<0.5 MW	Hourly supply profile never aligns with load	Site has declined to participate
1	400-500m from a potential EC	0.5–1.5 MW	Hourly supply profile aligns poorly with load	Site unlikely to participate
2	300-400m from a potential EC	1.5–2.5 MW	Hourly supply profile aligns somewhat poorly with load	Site somewhat unlikely to participate
3	200-300m from a potential EC	2.5–3.5 MW	Hourly supply profile aligns somewhat well with load	Site somewhat likely to participate
4	100-200m from a potential EC	3.5–4.5 MW	Hourly supply profile aligns well with load	Site likely to participate
5	<100m from a potential EC	>4.5 MW	Hourly supply profile aligns very well with load	Site has expressed explicit desire to participate

Table 3.1: Criteria used for assessment of each heat source, as decided during a workshop with CoLC.

ARUP

3. Supply assessment
The priority waste heat sources represent opportunities for a low carbon heat network development

Priority waste heat sources for Stage 2 – 1/2

Following the Stage 1 review of potential heat sources, three sources – two point-sources and one category – were selected to be the focus in Stage 2:

- Digital Realty's Brick Lane data centre campus
- UKPN's Finsbury Market substation cluster
- Office cooling waste heat recovery

Extensive stakeholder engagement for the sources was conducted, supporting the development of the assumptions summarised in Table 3.3.

Digital Realty's Brick Lane data centre campus

Digital Realty has participated in this study and are a key stakeholder for future development of the network. Commercial negotiations will need to be conducted at a later stage of this project. For the purposes of this study, a 'cost neutral' assumption has been agreed, whereby heat is provided to the network at no cost in exchange for cost neutrality for the data centre (i.e. any additional costs associated with connecting to the network beyond business as usual for the data centre are covered by the network). Therefore, it has been assumed that the heat network will pay for all equipment and running costs associated with connecting the data centres to the network (e.g. PHEX, pipework etc.). Digital Realty has indicated the possibility of providing space for a PHEX but is unable to commit to hosting a full energy centre on the Brick Lane campus.

Additional technical information regarding the three data centres on the campus was provided by Digital Realty and used to inform the underlying assumptions for the annual waste heat profile calculations. **The total annual waste heat recoverable from the Digital Realty data centre campus is 52 GWh/year** (post-uplift by heat pump to network temperature), with **6 MW heat pumps** required to uplift the waste heat to the target network flow temperature.

UKPN's Finsbury Market substation cluster

UKPN was initially engaged and provided high-level insights from the 'Full Circle' project. However, due to the early stage of the study, UKPN was unable to respond to further inquiries regarding technical and commercial assumptions.

A preliminary desktop maps review of the Finsbury Market substation cluster revealed high-level suitability of a similar scheme as the oil-to-water interface design outlined in the Full Circle project. As such, the findings of the 'Full Circle' project were drawn upon to develop the waste heat recovery assumptions in this study. **The total annual waste heat recoverable from the UKPN Finsbury Market substation cluster is 19 GWh/year** (post-uplift by heat pump to network temperature) **with 5 MW heat pumps** required to uplift the waste heat.

ARUP

3. Supply assessment
While Stage 1 considered cooling networks, Stage 2 considers on-site cooling heat recovery to focus on heat networks

Priority waste heat sources for Stage 2 – 2/2

Office cooling waste heat recovery

Stage 1 highlighted the significant potential of office cooling waste heat recovery. **The total potential annual waste heat recoverable from all large office cooling systems in the NESQM, as identified in Figure 3.1, is 240 GWh/year** (post-uplift by heat pump to network temperature), which is **equivalent to the annual demand of approximately 49,000 homes** if all the heat can be recovered.

Two overarching options exist for recovering this heat for use in a heat network. One option is to recover heat on-site from the existing systems of induvial buildings to supply the heat network. The other option is to develop a cooling network alongside the heat network, with cooling plant removed from individual buildings and consolidated in a few energy centres; a greater amount of heat can then be recovered from the centralised cooling plant.

Stage 1's initial analysis evaluated 4-pipe heating and cooling networks, with heat recovered from centralised cooling plant in network energy centres. However, given the severe challenges to network delivery**, it was decided to focus Stage 2 on evaluating heat-only network options in more detail**; therefore**, Stage 2 only considers on-site recovery of cooling waste heat from existing cooling systems** with no cooling network considered. Stage 1's analysis on cooling networks in the NESQM was considered sufficient until a preferred heating network option is selected following the conclusion of other studies like AZP. In the future, options for a 4-pipe district heating and cooling network should be revisited in conjunction with other studies for the preferred network route.

Water-cooled chiller systems, using cooling towers to reject heat, are the most suitable type of on-site system to recover heat from. This is because the cooling tower condenser loop can be tapped into, offering higher temperatures than air-cooled chiller system chilled water loops. Other cooling system types, like variable refrigerant flow (VRF), cannot be tapped into at all.

Therefore, in Stage 2, analysis of the cooling towers in the NESQM was performed to identify a shortlist of prioritised office blocks from the options outlined in Figure 3.1. The RFIs and planning applications for the shortlisted buildings were reviewed to assess the suitability of the cooling systems for heat recovery.

A selection of large cooling towers in the Bishopsgate cluster was identified as being the most suitable based on cooling load, cooling system type and proximity to each other. **The total annual waste heat recoverable from the identified office cooling cluster is 45 GWh/year, with 28 MW heat pumps required to** uplift the waste heat to network temperature. This amount of waste heat is equivalent to the annual heating demand of 9,000 homes, if all the waste heat is recovered.

ARUP

4. Energy centre assessment

4. Energy centre assessment

Stage 1 concluded there are very few spaces available for plant in the area; Stage 2 explored potential ECs further

Initial energy centre assessment – Stage 1

Locations for centralised heating and cooling equipment (such as heat pumps, chillers, boilers, or thermal storage) are crucial for delivering heating and cooling networks. These centralised plant locations are known as energy centres (ECs).

Figure 4.1 presents locations identified in Stage 1 as potential energy centres for hosting new plant for a network. The high value of land in the NESQM area means that it is highly space constrained. There are very few locations available for potentially installing large scale network equipment and, where space is available, it is very limited. The findings from Stage 1 highlighted that **there are no clearly preferrable options that can host large amounts of a network's central equipment**. Instead, **use of multiple distributed energy centres will likely be required,** which may be complex and challenging to control. Incorporation of buildings' existing plant into the network may also be needed to address these space challenges. Stage 2 progressed the exploration of potential energy centre sites further, as outlined in the following pages.

Note:

The potential available outdoor and indoor spaces for all of the pre-app sites are unclear, so estimates are not shown in Figure 3.1.

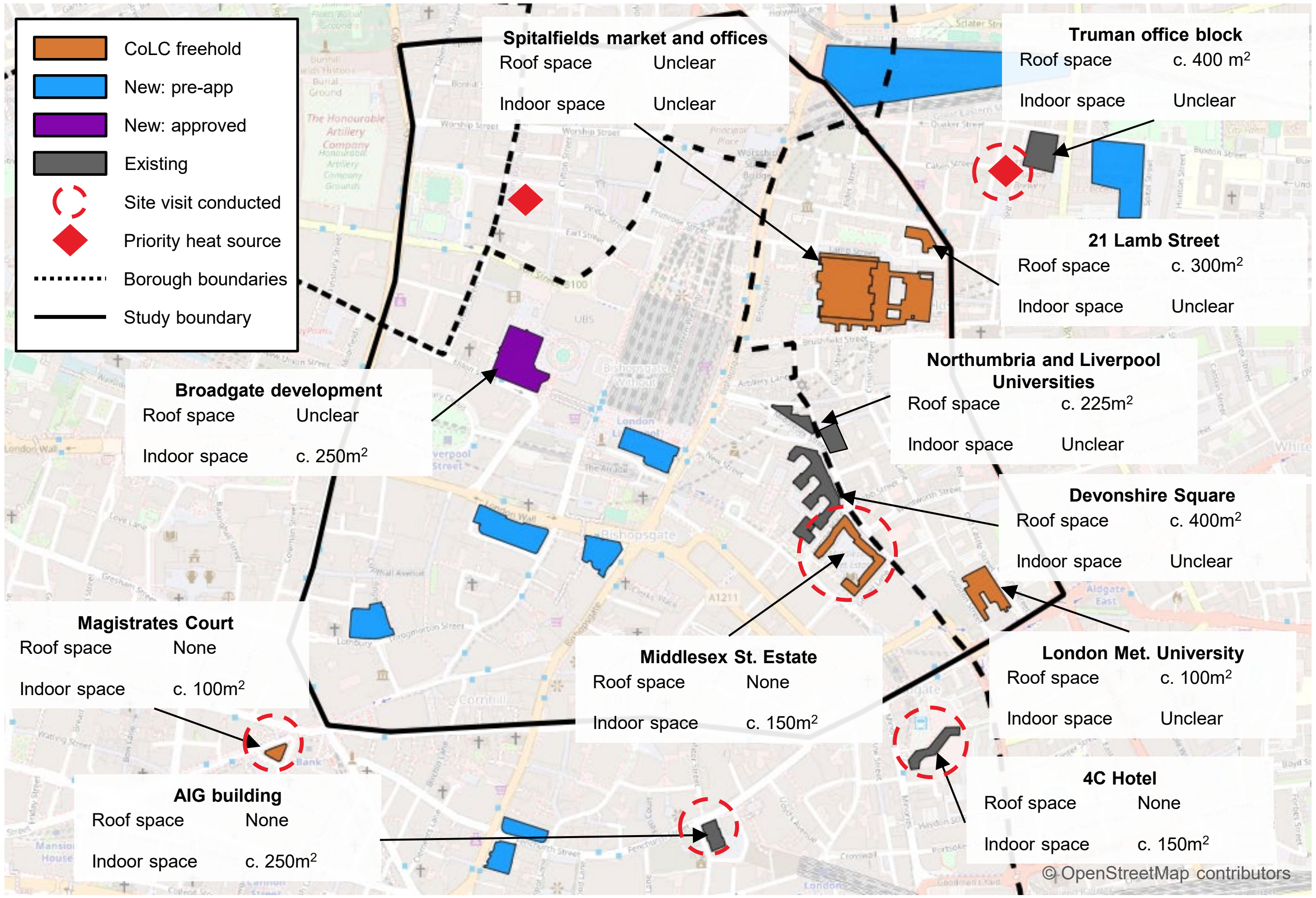

Figure 4.1: Stage 1 potential energy centre sites identified so far, and high-level indicative estimates of space available

ARUP

4. Energy centre assessment

There are very few spaces available for plant in the area; multiple distributed energy centres are likely to be required

Energy centre spatial planning – 1/4

Building on findings from Stage 1, in Stage 2 we developed a strategy for a ‘main’ energy centre to host heat pump equipment, supported by ‘satellite’ energy centres leveraging existing plant within buildings as peaking / resilience equipment.

A key part of progressing this stage of work was more granular spatial planning of the energy centres to overcome the space constraints within the NESQM, and the potential for locating energy centres outside the study boundary as part of CBHSS.

Main energy centres

These “main” ECs consist of temperature-boosting heat pumps, sized according to the waste heat source heat capacity to “uplift” waste heat from the source temperature to the network temperature, with additional air-source heat pumps (ASHPs) installed such that these “main” ECs have sufficient capacity to meet 90% of the network’s heat load. Satellite energy centres distributed throughout the NESQM are required for top-up and resilience as detailed later in this section.

A shortlist of potential main EC locations was identified, focusing on CoLC freehold sites, approved new developments and pre-application development sites, and a few select existing buildings. However, uncertainty remains over which potential EC locations would be viable and how much space would be available for many options, preventing the identification of one or more sites as definitive locations for main ECs. Instead, Figure 4.2 overleaf provides the shortlisted selection of sites within the NESQM prioritized for further investigation for main EC locations. In addition, due to the early stage of this study, the likely interest and commitment of buildings and landowners would also be early stage.

Therefore, it was agreed to proceed with hypothetical locations to enable the analysis for this study. As such, if locations identified in the future are further away from the waste sources, a low temperature infrastructure between the source and uplift will be required.

Stakeholder engagement informed the assessment of potential “main” EC locations, in addition to identified space, accessibility and proximity to heat loads.

As shown in Figure 4.2, **the potential main energy centre sites with the highest prioritisation for further engagement are: Bishopsgate Goodsyard, Middlesex Street Estate, 1 Appold Street, the Broadgate Development and the Truman development**.

Engagement with these sites should be further progressed as the study develops. The full summary of stakeholder engagement for all main energy centre options and recommended next steps is provided in Table 4.1 in the section.

Bishopsgate Goodsyard is highlighted as a key area of focus, having been identified in both this and the Shoreditch feasibility study as an optimal energy centre location. This makes it a strategic priority for decarbonisation in London.

ARUP

4. Energy centre assessment

Main energy centre locations were prioritised based on space availability, ownership and stakeholder engagement

Energy centre spatial planning – 2/4

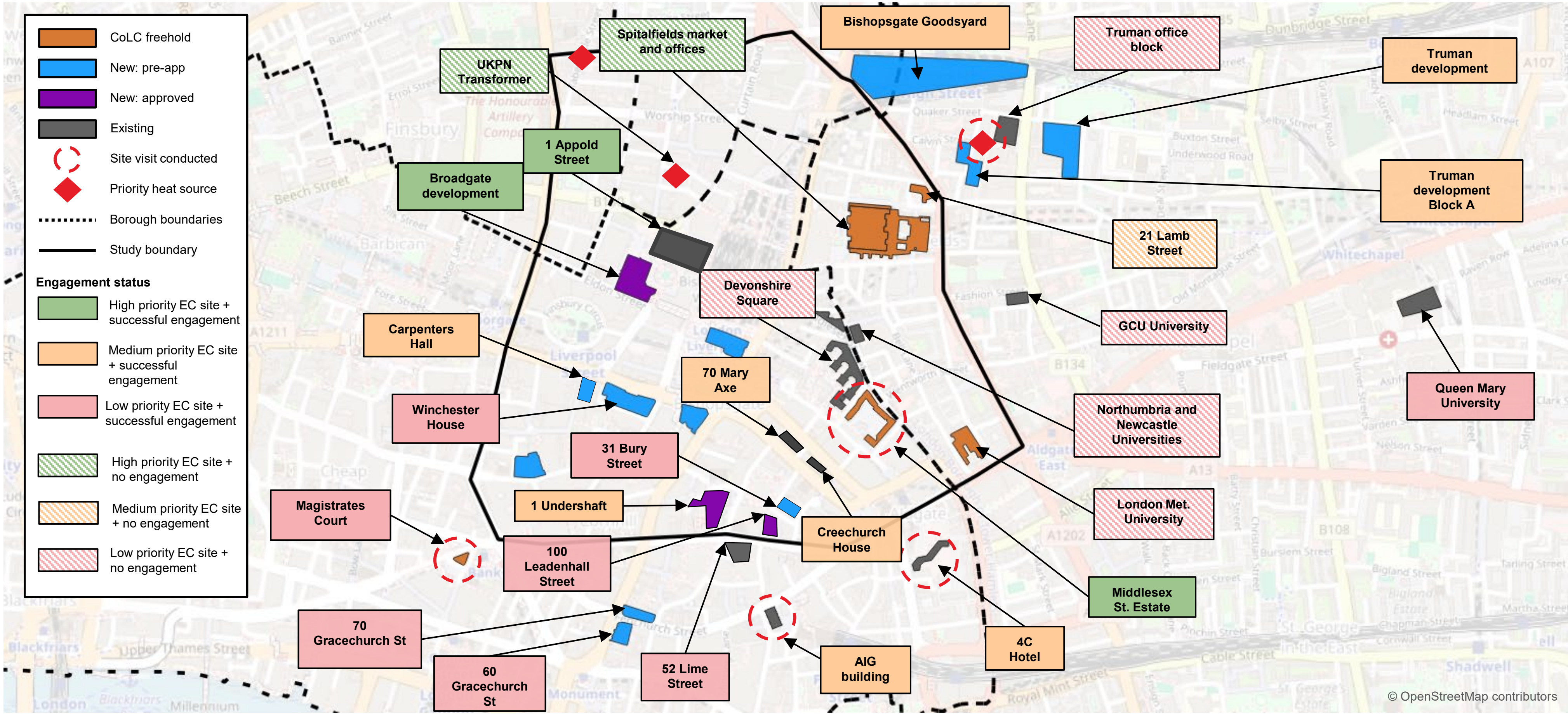

Figure 4.2: Map showing potential main energy centre locations, prioritised based on stakeholder engagement, space availability, accessibility and proximity to heat sources.

ARUP

4. Energy centre assessment

Satellite energy centres distributed throughout the NESQM will incorporate plant from existing buildings as top-up

Energy centre spatial planning – 3/4

Satellite energy centres

Existing buildings older than 15 years were prioritised as potential locations to host satellite ECs. This is because the heating plants in these buildings may be nearing the age of replacement. Additionally, buildings currently using gas-fired boiler heating systems may seek alternative electrified systems (e.g., ASHP) for decarbonization purposes, driven by policy requirements.

The proposed low-carbon heat network could be an appealing option for these buildings. Owners of existing buildings benefit from connecting to and contributing to the network through lowered operational costs, utilization of waste heat, and reduced ASHP plant requirements, as the heat network can provide the buildings' base loads.

The incorporation of ASHP scheduled to be installed by approved new developments is another option for satellite ECs. Approved new developments can integrate ASHPs to the network, providing top-up or peaking capacity. In this way, the new development provides space for a satellite EC, with the network handling investment and maintenance of the plant. Additionally, the building benefits from the provision of low-carbon heat provided by the network.

A full summary of satellite EC options is shown in Figure 4.3. Buildings located within the study boundary that have conducted or are expected to conduct decarbonisation studies should be prioritized for early stakeholder engagement. This will help ensure a holistic, area-wide heat decarbonization strategy is proposed.

Hackney sites

As part of CBHSS, Hackney's planning team was engaged to discuss the potential for sites within Hackney to act as main or satellite energy centres for the network. Potential space was identified on the Shoreditch High Street. A full stakeholder engagement summary of satellite energy centres and Hackney sites is provided in Table 4.2.

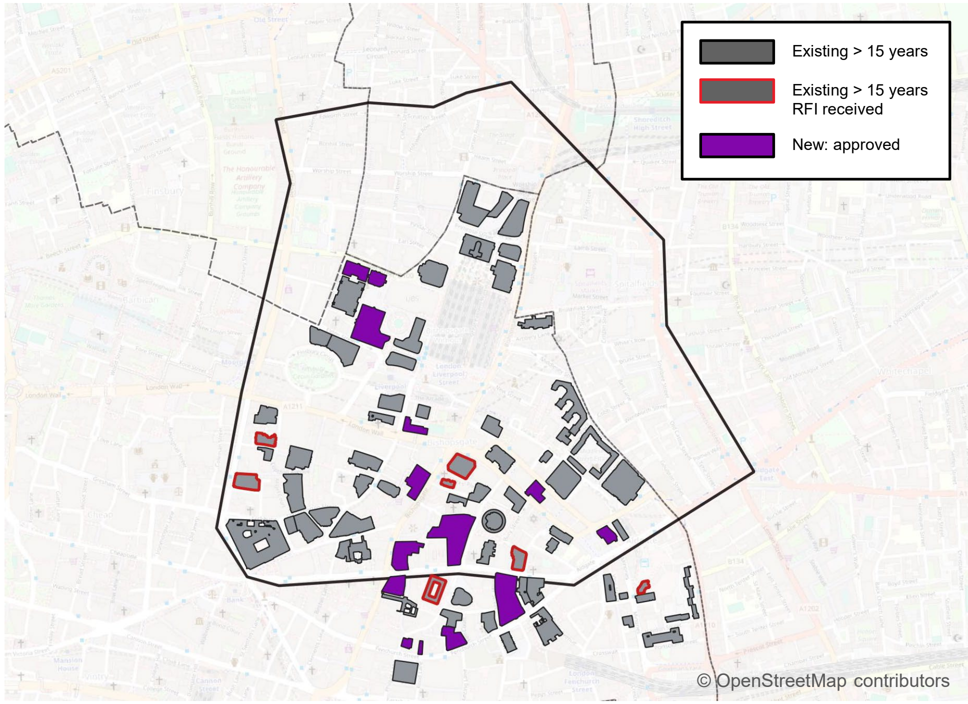

Figure 4.3: Map showing the locations of potential satellite energy centres, including existing buildings > 15 years old and approved new developments.

4. Energy centre assessment
Thermal storage will need to be included in both main and satellite energy centre design

Energy centre spatial planning – 4/4

Thermal storage

Thermal Energy Storage (TES) is crucial for district heating and cooling networks, as it enables storing energy for later use, maximising low-carbon heat sources and minimising top-up needs. Conventional TES uses large water tanks for intra-day storage, which are cost-effective but require substantial space, often over multiple storeys, making them difficult to implement. Other methods like Aquifer Thermal Energy Storage (ATES) offer seasonal storage by storing heat in groundwater, but NESQM's space constraints make ATES challenging to implement. Therefore, tank TES is identified as the best option for NESQM's district heat network thermal storage requirements (although space remains challenging for tank TES also).

The priority waste heat source profiles are shown in Figure 4.4. The available waste heat varies significantly over the year. This is key to CBHSS, as the office cooling provides a significant summer heat supply, requiring a summer heat load, mostly found in residential buildings or hotels.

A full description of the methodology used for network TES sizing, TES space take and the impact of TES to energy centre design is provided in Section 5.

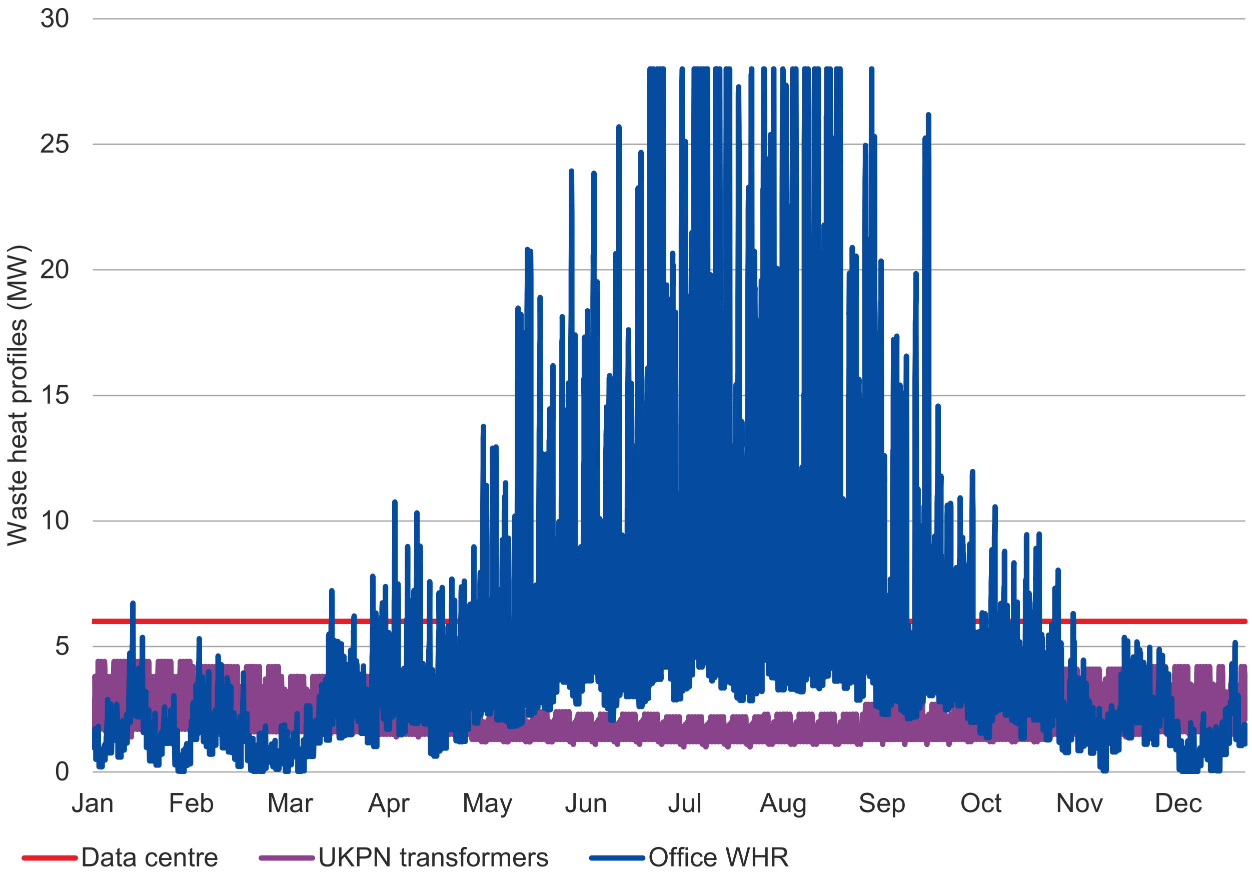

Figure 4.4: Priority waste heat source profiles, as outputted by the main energy centre heat pumps described in the previous pages, post up-lift to network distribution temperature.

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5. Distribution assessment

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5. Distribution assessment

Stage 2 further developed the Stage 1 preferred network options into phased scenarios

Stage 1 Overview

Stage 1 analysed eight network options, considering various levels of ambition regarding connected demand and carbon intensity.

Following a Stage 1 output workshop and interim report review, it was agreed to take the ***Demand Driven ambitious network*** further, demonstrating the full potential of the NESQM, with the ***Supply Driven ambitious network*** taken forward as another Stage 2 scenario.

The ***Demand Driven ambitious network's*** ambition in Stage 1 involved 'highest priority loads' (defined in Section 2) connected together, with any 'high' priority loads located en route also connected. All waste heat sources identified on slide 22, including the Digital Realty data centre campus, the UKPN substation cluster at Finsbury Market and the Bishopsgate office cooling cluster of buildings were considered as supply options in Stage 2.

As mentioned in Section 3, while Stage 1 considered 4-pipe heating and cooling networks, Stage 2 focused more detailed analysis on 2-pipe heat-only networks. Stage 1's cooling network analysis was considered sufficient until a preferred heat network option is selected following the conclusion of other studies like AZP. 4-pipe heating and cooling network options should be revisited in the future once a preferred heat network route has been determined.

Ref	Network option code	Network design category	Demand scenario	Main supply scenario	Peaking supply scenario
1	DD-AS-EB	Demand-driven ambitious	Demand-driven	Ambitious	Electric boilers
2	DD-AS-GB	Demand-driven ambitious	Demand-driven	Ambitious	Gas boilers
3	DD-PS-EB	Demand-driven pragmatic	Demand-driven	Pragmatic	Electric boilers
4	DD-PS-GB	Demand-driven pragmatic	Demand-driven	Pragmatic	Gas boilers
5	SD-AS-EB	Supply-driven ambitious	Supply-driven	Ambitious	Electric boilers
6	SD-AS-GB	Supply-driven ambitious	Supply-driven	Ambitious	Gas boilers
7	SD-PS-EB	Supply driven pragmatic	Supply-driven	Pragmatic	Electric boilers
8	SD-PS-GB	Supply driven pragmatic	Supply-driven	Pragmatic	Gas boilers

Table 5.1: Stage 1 network options, with preferred scenarios highlighted red to be taken forward as the initial basis of analysis in Stage 2.

5. Distribution assessment
Scenarios were developed in Stage 2 for further exploration, based on the most ambitious Stage 1 options

Stage 2 scenarios

The scenarios explored in Stage 2 build on the level of ambition identified in the preferred Stage 1 options. As a starting point, the most ambitious preferred option (referred to as the Ambitious NESQM network in this report) was explored. This network, with the addition of the South Shoreditch network explored as part of the CBHSS, is broken down into clusters and associated with phasing in Figure 5.1. This breakdown is based on the type of buildings and proximity of heat sources. These phased clusters fed into the development of scenarios for further exploration (Scenarios A-H) in Stage 2, summarised on the next page in Table 5.2.

The Digital Realty starter network (referenced as Scenario A) encompasses the Spitalfields cluster, shown in Figure 5.1, and is driven by the waste heat recovered at the Digital Realty data centre. This scenario is a potential "starter" network for a larger network build-out. The CoLC only network (Scenario B) focuses on utilising waste heat recovered from the Bishopsgate office cooling cluster. This scenario investigates a network's performance relying only buildings within the CoLC for loads and waste heat recovery. Scenarios C – E represent the phased build-out of the ambitious NESQM network (referred to as the Demand-Driven Ambitious Supply option in Stage 1) and Scenarios F-H cover various levels of ambition for CBHSS networks.

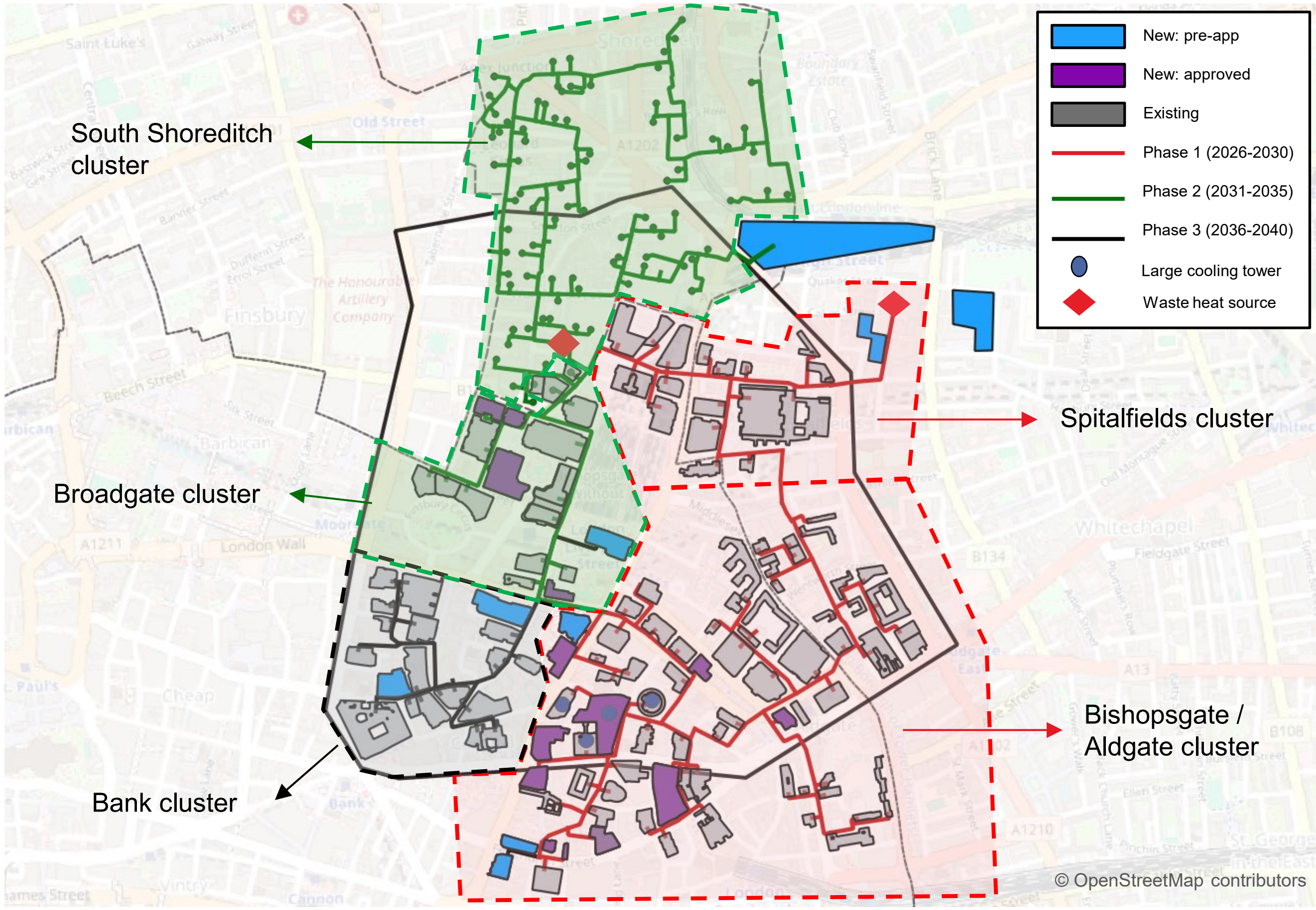

Figure 5.1: An Ambitious NESQM network broken down into phased clusters. Various combinations of these clusters are explored as scenarios in this study. The South Shoreditch cluster represents the South Shoreditch network option outlined in the Hackney heat network feasibility study and is explored as part of the CBHSS.

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5. Distribution assessment
Stage 2 explored 6 NESQM scenarios and 3 CBHSS scenarios

Ref	Study	Scenario	Spitalfields cluster	Bishopsgate/Aldgate cluster	Broadgate cluster	Bank cluster	South Shoreditch cluster	Annual heat demand (GWh/yr)	Peak (MW)
A	NESQM	Focus on data centre heat recovery	Connected	_	_	_	_	51	20
B	NESQM	Focus on office cooling heat recovery	_	Connected	_	_	_	136	96
C	NESQM	Ambitious NESQM network (Phase 1)	Connected	Connected	_	_	_	187	97
D	NESQM	Ambitious NESQM network (Phase 1 + Phase 2)	Connected	Connected	Connected	_	_	224	118
E	NESQM	Ambitious NESQM network (Phase 1 + Phase 2 + Phase 3)	Connected	Connected	Connected	Connected	_	269	137
F	NESQM	Conservative NESQM network	Connected	_	Connected	_	_	88	39
G	CBHSS	Conservative NESQM network with SS expansion	Connected	_	Connected	_	Connected	159	75
H	CBHSS	Ambitious NESQM network with SS expansion	Connected	Connected	Connected	_	Connected	296	155

Table 5.2: Overview of Stage 2 scenarios

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5. Distribution assessment
Integrated energy modelling informed the network design for all scenarios

Assumptions

Integrated energy modelling was performed to inform the network design for each scenario outlined above. This built on the dispatch modelling performed in Stage 1, with refined assumptions based on stakeholder engagement and additional technical analysis. All plant sizing was based on this hourly energy modelling.

Key assumptions include:

- Network flow/return temperature is assumed to be 65˚C/50˚C. The flow rate is based on an industry standard flow-rate for 4th generation heat networks, with the return rate determined by heat pump delta T limits indicated on manufacturers' datasheets.
- The heating plant operational strategy uses the following supply hierarchy driven by efficiency and availability to meet loads: DC waste heat -> Transformer waste heat -> Office cooling waste heat -> top-up ASHP. Electric boilers and gas boilers were excluded from the modelling in Stage 2, with ASHP chosen as the preferred peaking technology to align with decarbonisation efforts.
- During the peak load hours of the day, if waste heat cannot fully meet demand, any energy in tank TES is used to top-up supply before ASHPs are used. The TES is charged earlier in the day with any surplus waste heat. Surplus ASHP capacity is also used to charge the TES when there is an anticipated deficit of waste heat expected during the day's peak load. This enables more waste heat to be utilised and reduces ASHP requirements during peak hours over the year.
- TES sizing was performed to maximise usage of waste heat and minimise annual energy usage of top-up ASHP. TES was sized iteratively for each scenario, cumulatively increasing the TES capacity and assessing the impact on the proportion of annual available waste heat that could be utilised because of each TES capacity increase. The TES for each scenario was ultimately sized at the turning point where the increase in waste heat utilisation with increased TES size plateaus.
- For each cluster, each main EC is designed to meet 90% yearly heat load or to have a maximum indoor space requirements of 1,000 m^2, whichever is achieved first. The 1,000 m^2 main EC limitation was based on reasonable space expectations within the CoL. The installed capacity at the main EC is achieved through a mixture of temperature-boosting heat pumps, used to uplift low-grade waste heat where available, and additional ASHPs, where the waste heat HP output is insufficient.
- Any remaining heat load is assumed to be met by ASHP top-up in satellite energy centres. As such, satellite energy centres provide a top-up of local capacity and are modelled as contributing to the wider network in the dispatch modelling.
- As explained in Section 4, two categories of buildings were explored as satellite energy centre locations in this study – existing buildings older than 15 years old, with the potential for replacement of existing plant to ASHPs, and approved new developments, with planning permissions indicating the installation of ASHP. A full list of the potential sites to host as satellite EC has been identified, which should be further explored.
- Heat network primary losses is assumed to be 10%.
- Parasitic load such as pumping electricity consumption is assumed to be 3%.
- Time-varying CoP determined for ASHP was modelled based on ambient DryB temperature in London.
- Temperate-varying CoP determined for Waste heat HPs was modelled based on the low-grade waste heat temperature for each waste heat source.

The network designs for each scenario are described in subsequent pages. RIBA Stage 2 layout drawings were completed for the main energy centres for each scenario. These give an indication of the plant and space requirements for the main energy centres, which is summarised in Table 6.2.

ARUP

5. Distribution assessment
Network routing was refined from Stage 1 using NUAR data and a high-level constraints analysis

Network routing

Building on the Stage 1 network routing for each option, a further routing assessment was conducted using data from the National Underground Asset Register (NUAR) provided to Arup. This data offered insights into key underground infrastructure, including high-voltage and low-voltage cables, gas lines, water lines, and sewage mains. The network was then adjusted to avoid congested roads that might be unviable or costly.

The importance of the network crossing a main roadway at Commercial Street is highlighted, as it lies between NESQM and the identified heat sources (i.e., Digital Realty Data Centre), as well as potential Tower Hamlets loads. Additionally, the railway line that runs across Bishopsgate Goodsyard should be further explored if this site is to be taken forward as one of the main ECs.

A network sizing assessment was performed to estimate the overall length of pipework and the required diameter for the pipework to meet the anticipated load. A main trunk connecting each phase is sized as the largest pipework of the network to facilitate waste heat sharing. This main trunk branches into smaller pipes for each singular load connection. The main trunk is highlighted in Figure 5.2.

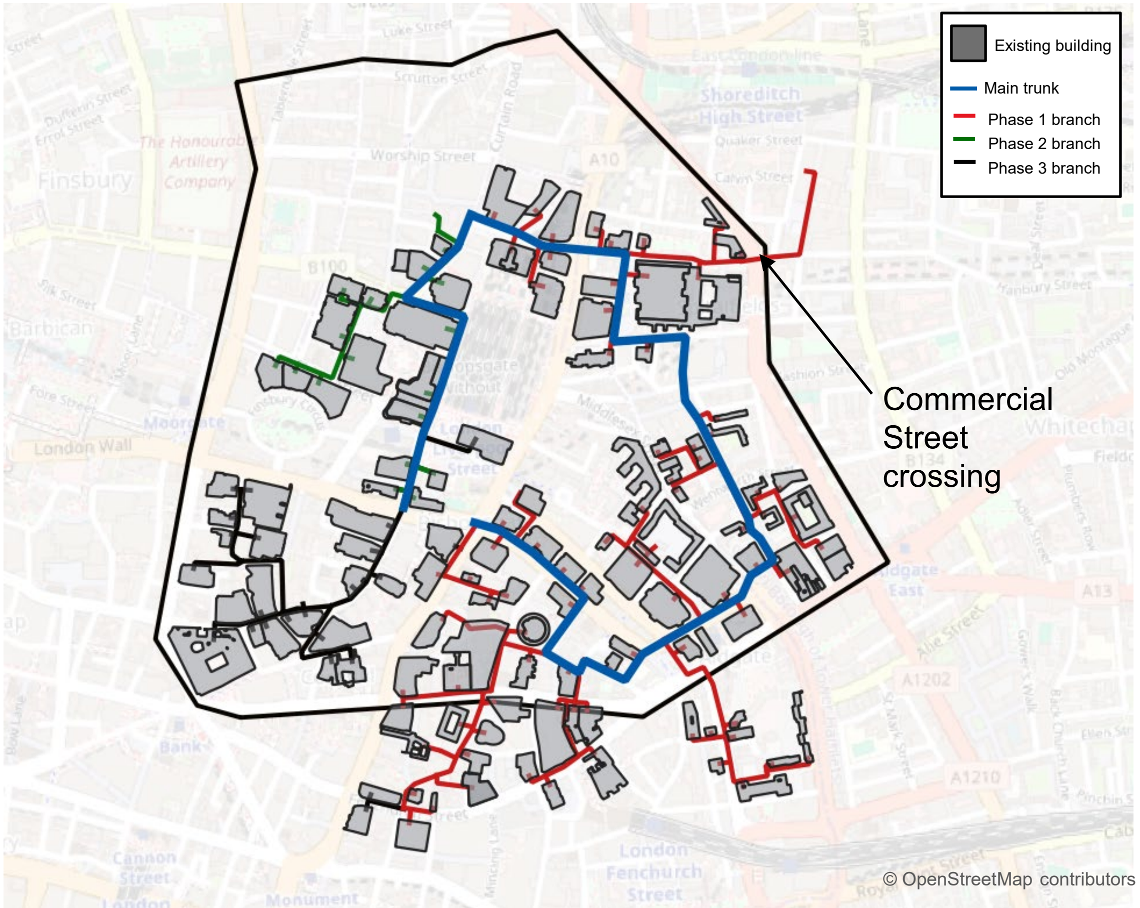

Figure 5.2: Proposed main pipework for the Ambitious NESQM network.

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6. Network options

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6. Network options

Connecting buildings in need of decarbonisation to adjacent low-carbon data centre recovered heat through a DHN

Scenario A: Focus on data centre heat recovery

Annual demand: 51 GWh/year
Peak demand: 20 MW
Network length: 2.4 km

Scenario A is driven by the waste heat availability at the Digital Realty data centre, as summarised in the engagement section above.

The majority of the identified potential customers for this cluster are existing buildings over 15 years old, with no proposed new developments identified. While a detailed building-level system analysis was not conducted as part of this study, it is assumed that these buildings may be seeking alternative sources for heat decarbonisation due to the age of the plant.

Based on the reasons outlined above, this scenario has the potential to have both sources and loads ready to connect. This network represents a potential 'starter' or first phase of a wider heat network in the NESQM, which could be constructed as early as 2026.

A centralised space to upgrade the waste heat to the required distribution temperature has not been identified and is expected to be further explored. This could be located either in one of the CoLC freeholds or in any future proposed development adjacent to the Data Centre. Indicative main energy centre requirements are outlined in Figure 6.1.

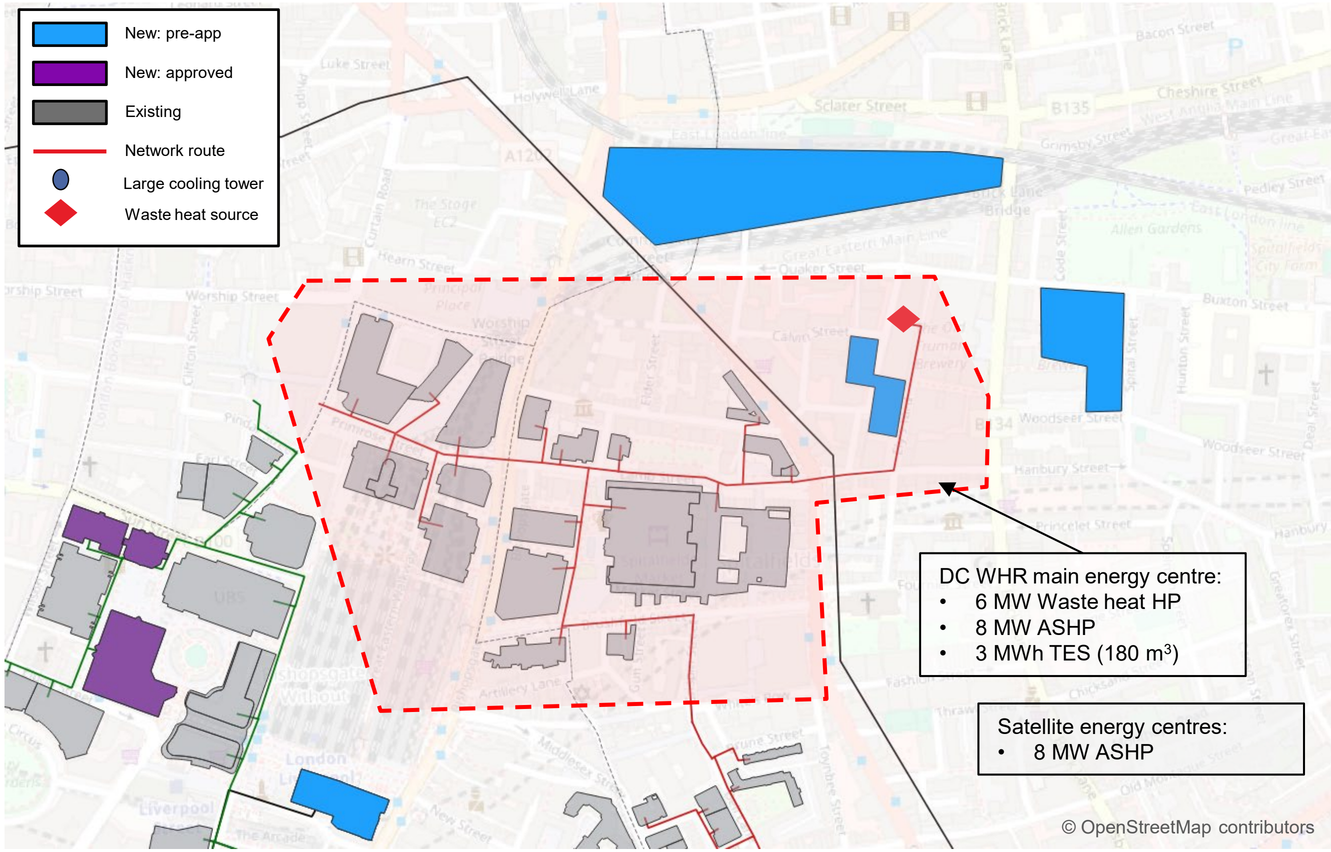

Figure 6.1: Digital Realty starter network design overview

Click here to go to comparison of all network scenarios

6. Network options
Utilising the significant waste heat available within NESQM to meet diverse heating demands in summer

Scenario B: Focus on office cooling heat recovery

Annual demand: 136 GWh/year
Peak demand: 96 MW
Network length: 5.6 km

Scenario B leverages the significant waste heat potential from the office building cooling systems within NESQM, building on the analysis developed during Stage 1. As the nature of waste heat is associated with cooling load, the summer hot water demand mainly from residential was considered as the main driver for the waste heat recovery capacity design.

1 Undershaft appears to be the most suitable location for the system upgrade and is assumed to be the main energy centre serving the equipment outlined in Figure 6.2. This assumption is based on the location of the cooling towers and its proximity to residential loads. It should be used as supporting evidence for future stakeholder engagement to gauge interest and availability in this area.

As mentioned in Section 3, to focus on developing heat network options in detail, Stage 2 scenarios like this one consider on-site recovery of heat from a few individual office buildings' existing cooling systems rather than the development of a cooling network. The option to develop a district cooling network should be revisited in the future.

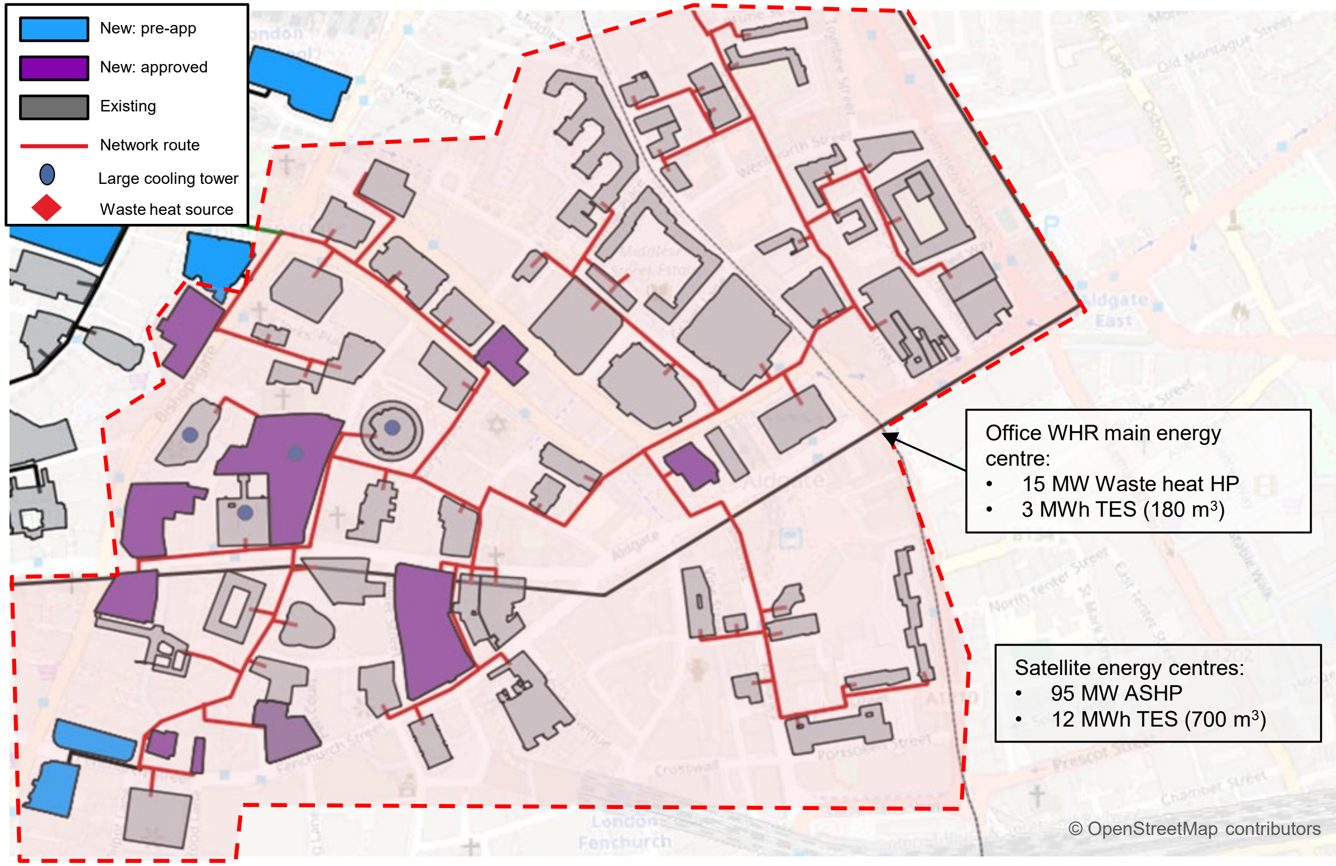

Figure 6.2: CoLC only network, focusing on office cooling waste heat recovery.

Click here to go to comparison of all network scenarios

6. Network options

Phasing is critical for creating an investible network, with further engagement required to build confidence

Scenario C-E: Ambitious NESQM network

Annual demand: 269 GWh/year
Peak demand: 137 MW
Network length: 13.1 km

Scenario C-E includes the clusters outlined in Scenarios A and B, with future expansion to the Broadgate and Bank clusters. These are phased build-out scenarios as detailed in Figure 6.3 and Table 6.1 below.

Scenario	Phase 1	Phase 2	Phase 3
Scenario C			
Scenario D			
Scenario E			

Table 6.1: Phased Ambitious NESQM network scenarios

These scenarios were developed to test a NESQM-scale network with dedicated clusters designed for multiple low-carbon source opportunities. Except for the Spitalfields cluster, which is solely driven by existing buildings, all other clusters include a mix of existing and new developments, contributing to the phased build-out assumption. The phasing strategy should be further explored in conjunction with building-level systems and the decarbonisation targets of building owners/tenants, which is currently based on building age and a high-level system compatibility assessment.

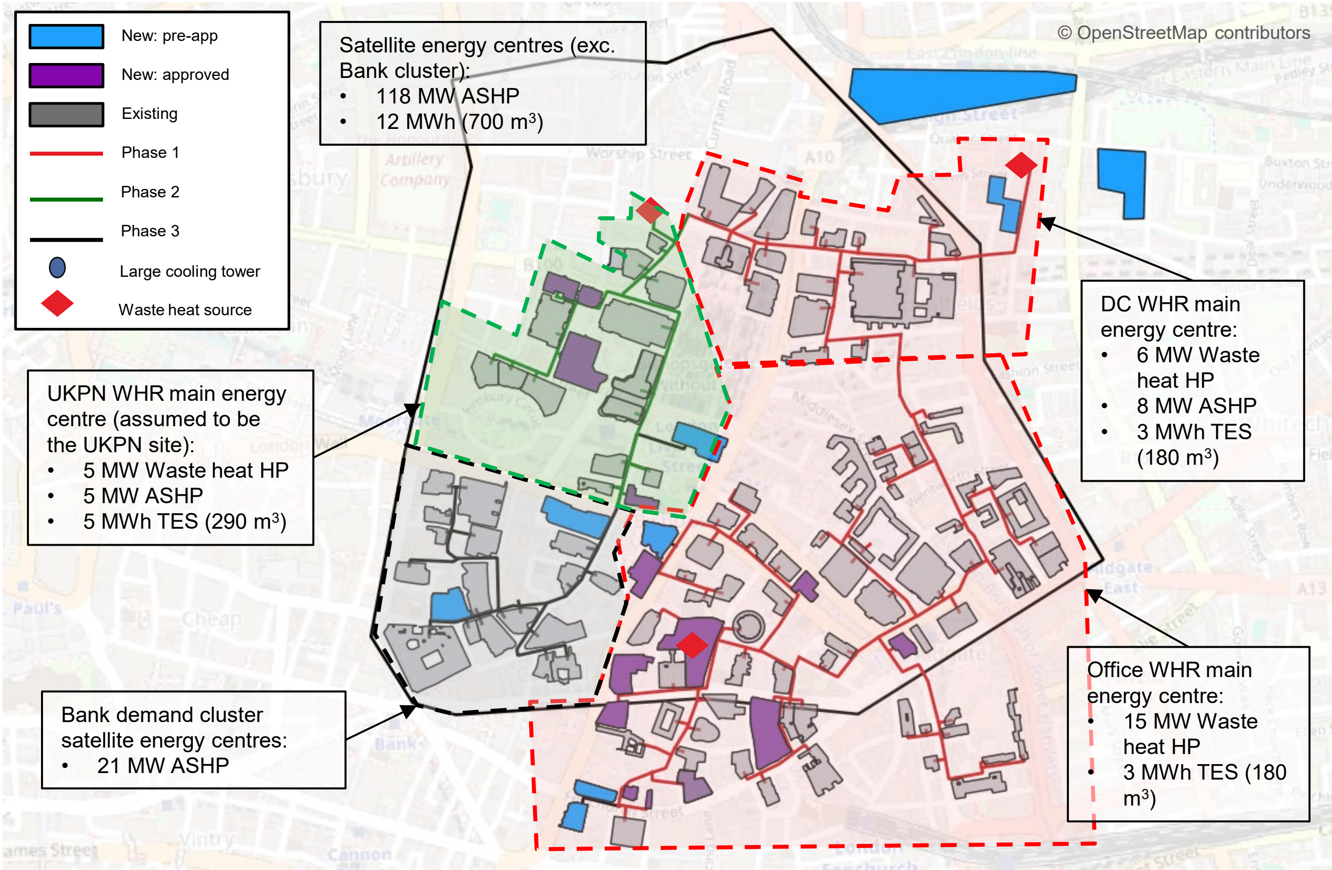

Figure 6.3: Full build-out of the Ambitious NESQM network.

Click here to go to comparison of all network scenarios

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6. Network options

A conservative NESQM network developed independently of office cooling heat recovery

Scenario F: Conservative NESQM network

Annual demand: 88 GWh/year
Peak demand: 39 MW
Network length: 5 km

This scenario represents a conservative NESQM network option, focusing on single large waste sources identified as priority heat sources in Stage 1 (e.g., transformers and data centre). It aims to explore the network performance independently of the office cooling system heat recovery progress, which is highly reliant on the private sector and is unlikely to be mandated under the proposed Heat Network Zoning regulation within the heat mandate policy.

This scenario is designed to accelerate the delivery of a low-carbon heat network. It could serve as a focal point for expanding the network to:

- Bishopsgate / Bank cluster: incorporating office cooling recovery, pending further engagement and confirmation with property owners/tenants.
- South Shoreditch cluster: seeking additional cross-boundary load and space for centralised ECs.

Should this network be adopted as the preferred solution, further engagement with UKPN should be initiated to ensure confidence in the heat supply availability and to explore the potential of the UKPN site serving as the central EC.

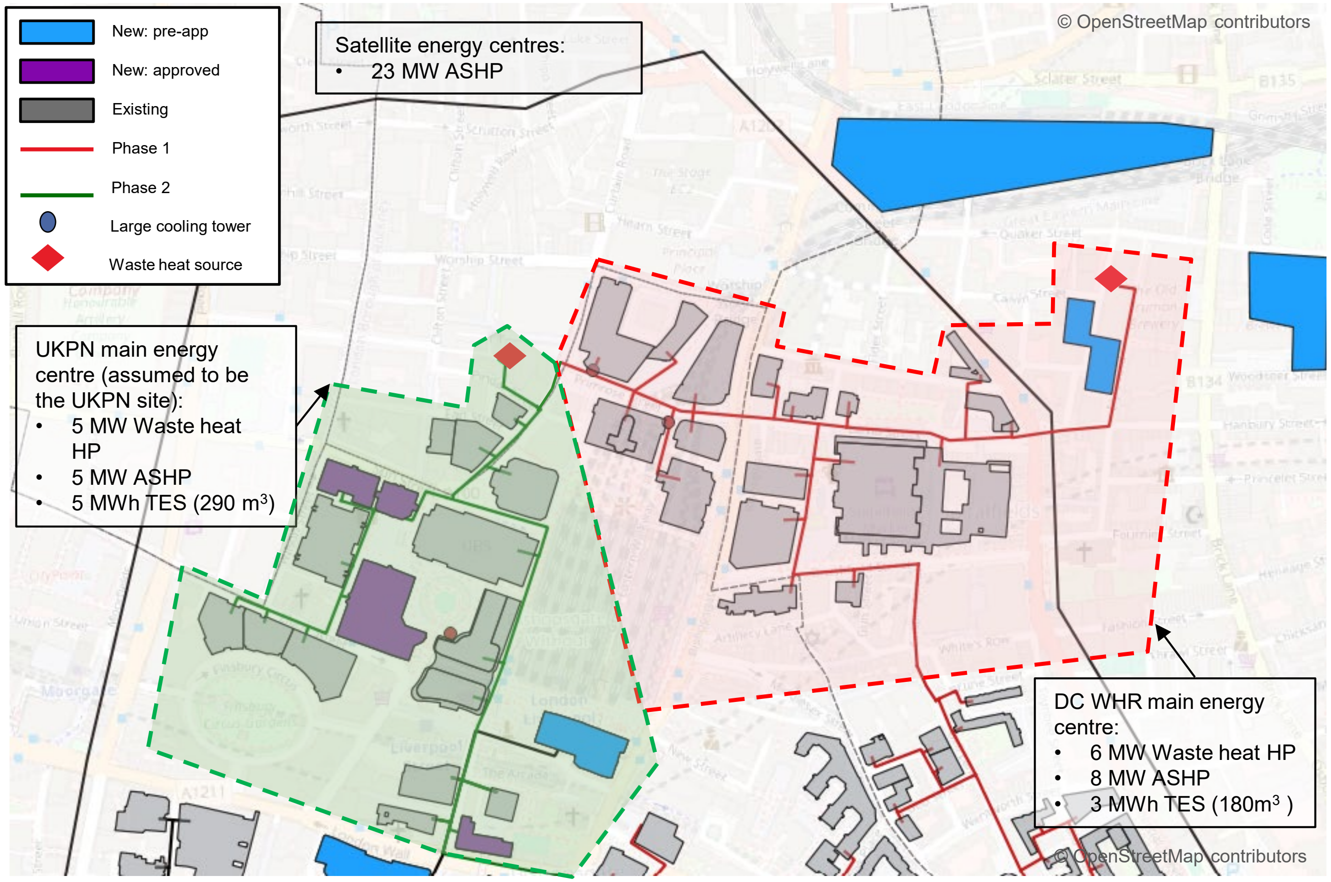

Figure 6.4: Full build-out of the Conservative NESQM network.

Click here to go to comparison of all network scenarios

6. Network options

The CBHSS can support the acceleration of the proposed integrated Hackney heat network

Scenario G: Conservative NESQM network with SS expansion

Annual demand: 159 GWh/year
Peak demand: 75 MW
Network length: 19 km

Scenario G builds on the South Shoreditch (SS) expansion in Scenario F, representing a cross-boundary network opportunity. This scenario was developed exploring the benefit of additional accessible potential space within the Hackney boundary: UKPN transformer site and the proposed Bishopsgate development (or any additional future proposed developments). Indicative EC requirements are outlined in Figure 6.5.

The Shoreditch feasibility study's final report and optioneering conclusions was not provided at the point of writing. From the output presentation delivered by BuroHappold, we understand that the SS network was considered a critical expansion to improve the commercial performance of the integrated Hackney-wide network expected to be constructed in 2036. In the CBHSS, it was assumed that the SS network programme could be accelerated by connecting to the NESQM network (i.e. 2031), depending on the feasibility of UKPN waste heat recovery.

The future connection scenario discussed how the network's technical and commercial performance could be optimised, which needs to be further explored, building on the final CBHSS and Hackney Feasibility Study.

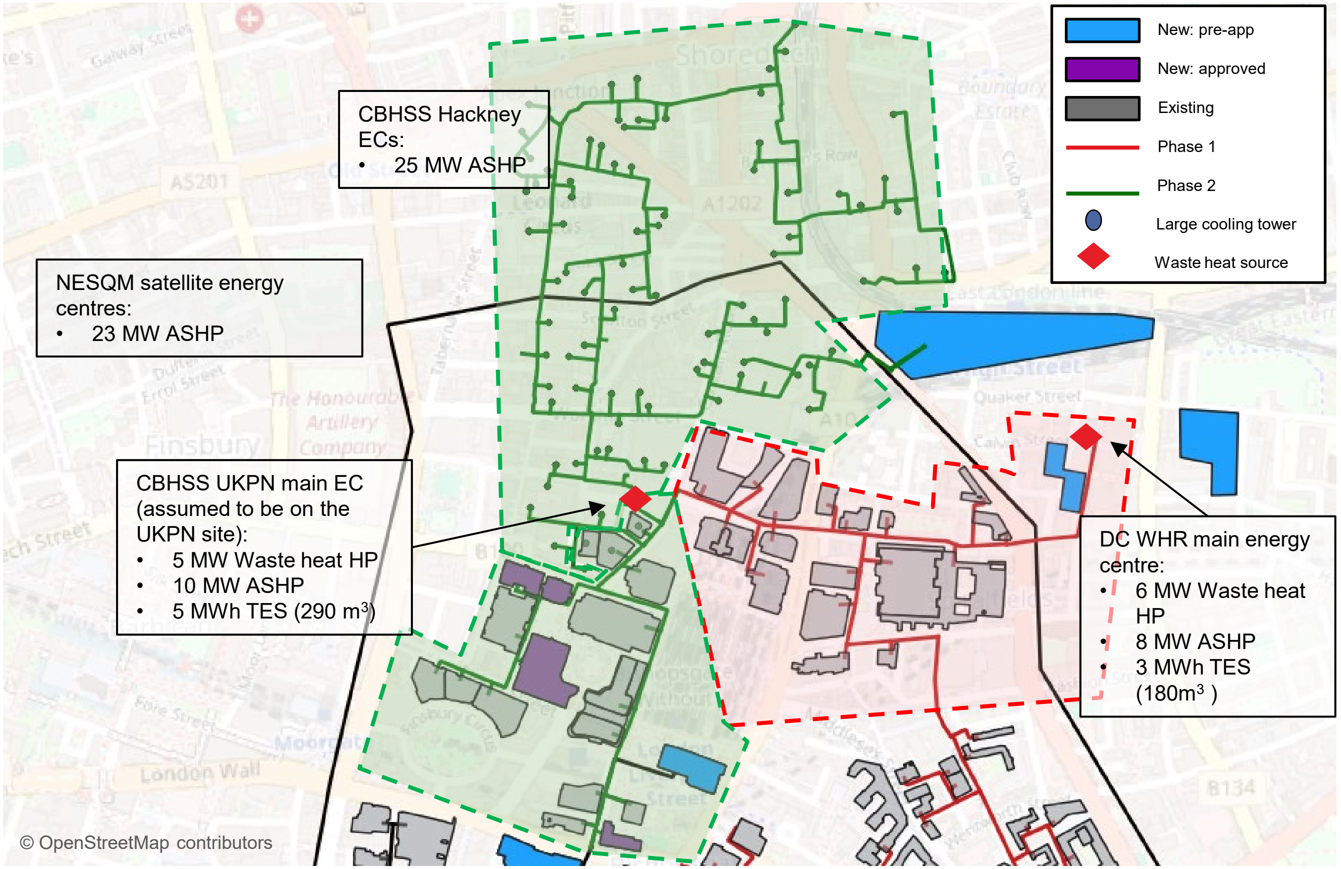

Figure 6.5: CBHS scenario, including no office cooling waste heat recovery.

Click here to go to comparison of all network scenarios

6. Network options

Potential to utilise an additional 6 GWh of heat from cooling systems through cross-boundary infrastructure

Scenario H: Ambitious NESQM network with SS expansion

Annual demand: 296 GWh/year
Peak demand: 155 MW
Network length: 25 km

This scenario represents the ambitious NESQM network expansion into Hackney. It aims to explore the synergy between the larger summer heat loads in the South Shoreditch cluster and the office cooling waste heat in the NESQM, which could improve overall network waste heat utilisation and system efficiency.

In this ambitious cross-boundary scenario, the waste heat from the office cooling system was increased from 15 MW (as in Scenario B) to 33 MW to incorporate the additional SS summer load outlined in the previous section. This modelling is developed using interim outputs provided by Buro Happold as part of the Hackney Feasibility Study, which should be collaboratively reviewed if this option is taken forward.

Modelling demonstrates that this extensive network could utilise 21 GWh of waste heat from the cooling system, with 6 GWh additional waste heat consumed by SS compared to Scenario D. This indicates the potential benefit of a cross-boundary heat network development.

Indicative space requirements for the main and satellite energy centres are outlined in Figure 6.6.

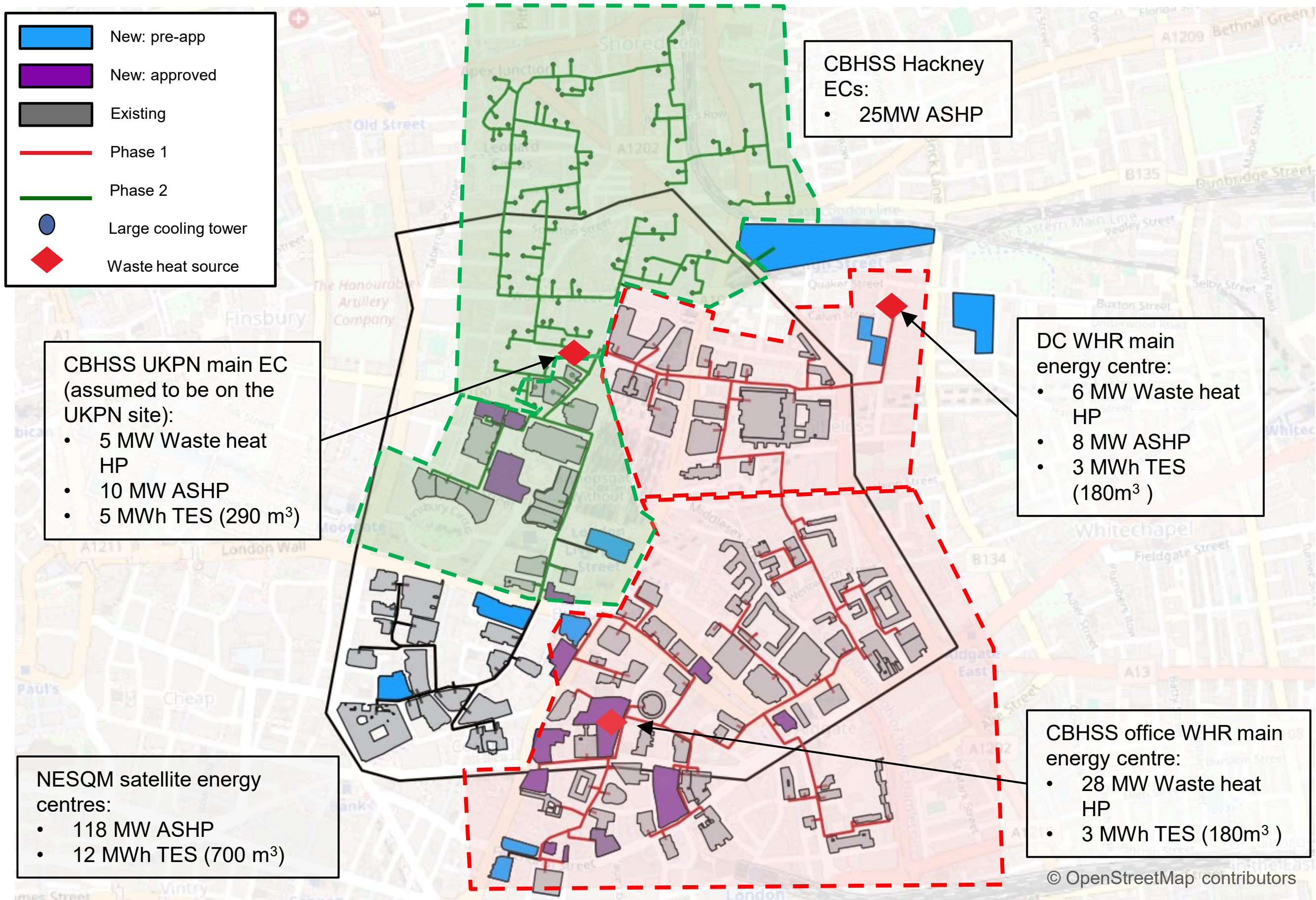

Figure 6.6: CBHS scenario, maximising office cooling waste heat recovery from the NESQM.

Click here to go to comparison of all network scenarios

6. Network options
Stage 2 network scenarios overview – 1/2

Ref	Scenario	Peak (MW)	DC WHR main EC Waste heat HP: 6 MW ASHP: 8 MW TES: 3 MWh Indoor space: 920 m^2 Outdoor space: 770 m^2	Office WHR main EC Waste heat HP: 15 MW ASHP: 0 MW TES: 3 MWh Indoor space: 810 m^2 Outdoor space: 0 m^2	UKPN main EC Waste heat HP: 5 MW ASHP: 5 MW TES: 5 MWh Indoor space: 1110 m^2 Outdoor space: 540 m^2	CBHSS office main EC Waste heat HP: 28 MW ASHP: 0 MW TES: 3 MWh Indoor space: 1120 m^2 Outdoor space: 0 m^2	CBHSS UKPN main EC Waste heat HP: 5 MW ASHP: 10 MW TES: 3 MWh Indoor space: 1100 m^2 Outdoor space: 970 m^2	Satellite energy centre/s *(Capacity housed in existing buildings > 15 years and/or approved new developments)**
A	Focus on data centre heat recovery	20	Included	-	-	-	-	ASHP: 8 MW TES: 0 MWh
B	Focus on office cooling heat recovery	96	-	Included	-	-	-	ASHP: 95 MW TES: 12 MWh
C	Ambitious NESQM network (Phase 1)	97	Included	Included	-	-	-	ASHP: 103 MW TES: 12 MWh
D	Ambitious NESQM network (Phase 1 + Phase 2)	118	Included	Included	Included	-	-	ASHP: 118 MW TES: 12 MWh
E	Ambitious NESQM network (Phase 1 + Phase 2 + Phase 3)	137	Included	Included	Included	-	-	ASHP: 139 MW TES: 12 MWh
F	Conservative NESQM network	39	Included	-	Included	-	-	ASHP: 23 MW TES: 0 MWh
G	Conservative NESQM network with SS expansion	75	Included	-	-	-	Included	ASHP: 48 MW TES: 0 MWh
H	Ambitious NESQM network with SS expansion	155	Included	-	-	Included	Included	ASHP: 143 MW TES: 12 MWh

Table 6.2: Overview of Stage 2 scenarios' energy centre requirements and phasing. Main energy centre space requirements outlined above relate to the plant requirements illustrated in previous slides and are based on RIBA Stage 2 drawings.

*Note that satellite EC capacities for each scenario are designed to provide resilience to the network through providing some redundant plant; some variation in the level of redundancy between scenarios exists due to the availability of different satellite EC sites in different areas of the NESQM

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6. Network options
Stage 2 network scenarios overview – 2/2

Ref	Scenario	Phasing	Network length (km)	Linear heat density (MWh/m)	Annual heat demand (GWh/yr)	Peak (MW)*
A	Focus on data centre heat recovery	2026-2030	2.4	21	51	20
B	Focus on office cooling heat recovery	2028-2030	6.5	21	136	96
C	Ambitious NESQM network (Phase 1)	2026-2030	8.9	21	187	97
D	Ambitious NESQM network (Phase 1 + Phase 2)	2031-2035	11.5	20	224	118
E	Ambitious NESQM network (Phase 1 + Phase 2 + Phase 3)	2036-2040	13.1	21	269	137
F	Conservative NESQM network	2031-2035	5	18	88	39
G	Conservative NESQM network with SS expansion	2031-2035	18	9	159	75
H	Ambitious NESQM network with SS expansion	2031-2035	25	12	296	155

Table 6.3: Summary of Stage 2 scenarios' phasing, network length, annual and peak demand.

*Note that peak loads shown are diversified; a diversity factor of 70% is used for Scenarios C-H, while a higher factor of 85% is used in Scenarios A and B to account for the majority of buildings in these scenarios being offices, with similar profiles and less diversity

6. Network options
Additional low-carbon sources required to meet the dense NESQM demand

Stage 2 scenarios supply breakdown

The data centre is assumed to have 24/7 stable waste heat profile due to the nature of its operation. **As a result, the integrated modelling results demonstrated a significant contribution from the data centre across all scenarios, with a marginal increase if the summer base load rises.** It is possible that the waste heat from the data centre can be fully utilised for the ambitious NESQM scenarios due to its significant base load.

Office cooling waste heat has a variable profile as shown in Figure 4.4, hence stable base load will have a higher impact on waste heat utilisation. A demand/supply optimisation assessment was conducted to ensure that cooling system waste heat capture is optimised to meet the desired adjacent loads and/or South Shoreditch residential loads; this ensured that heat exchangers and waste heat HPs are not oversized to capture significant volumes of waste heat that cannot be used. **The waste heat utilisation rate varies between 34% and 45%,** depending on the scenarios selected. This rate is not insignificant compared to the substantial heat demand, and it has the potential to increase if more residential load can be identified through future cross-boundary engagements.

The modelling outputs highlight the importance of additional low-carbon sources required to meet the dense NESQM demand and further lower the network carbon factors.

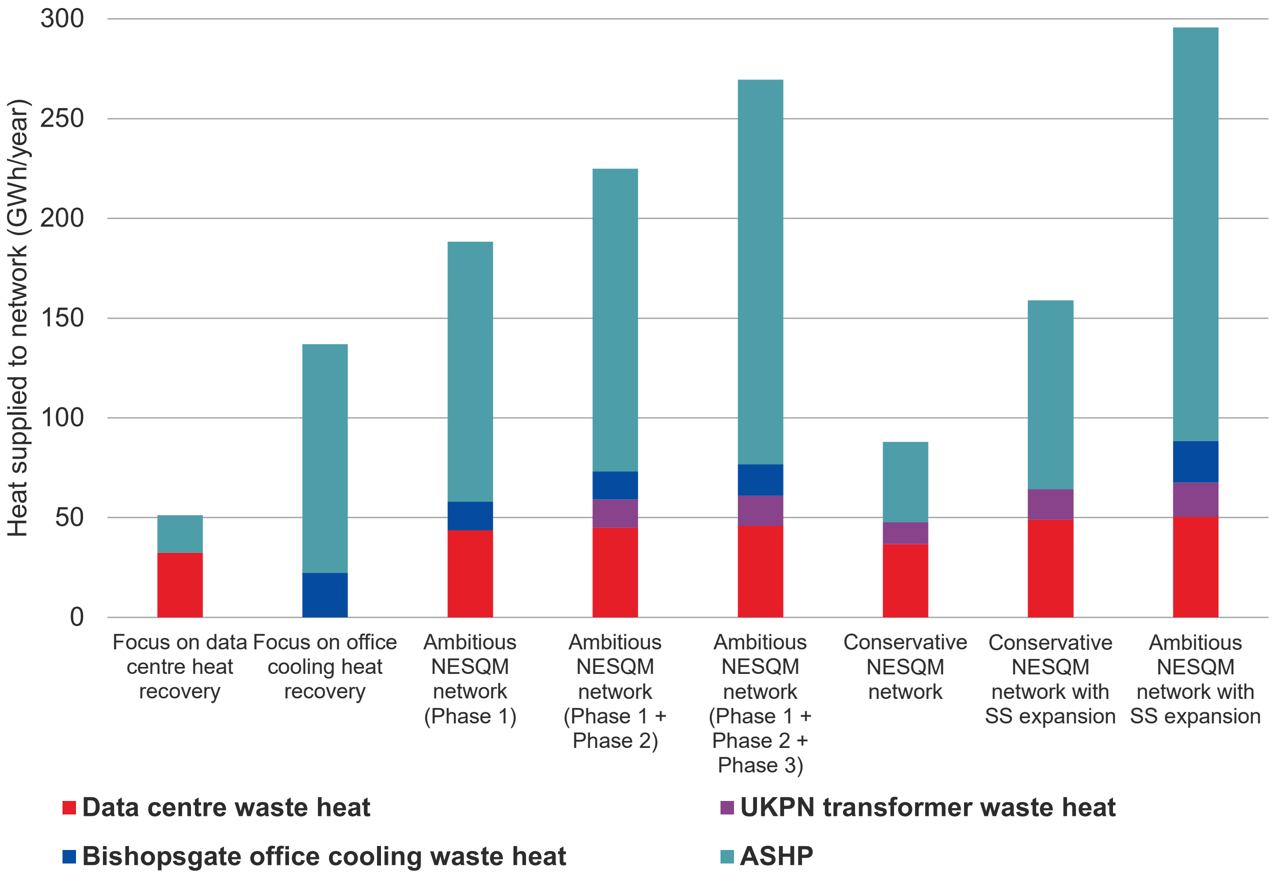

Figure 6.7: Summary of the split of annual supply to meeting demand for each scenario, including the proportion of the total waste heat source utilised in each scenario.

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6. Network options

The large deficit of waste heat supply in winter means that tank TES provides limited impact on waste heat utilisation

Stage 2 scenarios TES impact

As mentioned earlier in Section 5, the heating plant dispatch hierarchy used in the modelling sees tank TES used to store surplus waste heat. Spare ASHP capacity is also used to charge TES, when a deficit in waste heat supply compared to network demand in the peak hours of the day is anticipated. This reduces the amount of top-up ASHP dispatch required during peak hours.

The TES capacity for each scenario was sized based on incrementally increasing the TES capacity and assessing the impact of the amount of waste heat utilised and the reduced energy required from top-up plant over the year. The TES for each scenario was ultimately sized at the turning point where the increase in waste utilisation with increased TES capacity plateaus.

The results of this analysis showed limited impact of tank TES, with relatively small suggested TES capacities compared to the network loads. There are several reasons for this result:

- For the 8 months of the year containing the vast majority of the year's heat demand, the large amount of connected load and the scarcity of low carbon waste heat sources means that there is often no surplus waste heat available to store. Furthermore, when there is surplus waste heat available to store in the winter months, it is not significant compared to the scale of the network's load.
- As only tank TES was considered, during the summer months, when there is a significant volume of surplus waste heat available, this cannot be stored and used inter-seasonally to address waste heat deficits in the winter.
- The sizing strategy was based on optimising waste heat utilisation over the year to reduce annual ASHP dispatch requirements rather than to reduce ASHP installed capacity requirements.
- The use of time-of-use electricity tariffs or engagement in electricity system flexibility services were not considered in the modelling

Larger capacity thermal stores may be suggested for the networks if new TES sizing analysis is performed to minimise ASHP installed capacity requirements, or if the use of tank TES to respond to time-of-use tariffs and flexibility services is assessed.

7. Techno-economic modelling

7. Techno-economic modelling

The TEM was developed for all scenarios, using inputs developed across the Stage 1 and Stage 2 assessments

Techno-economic modelling methodology and assumptions (1/2)

The assessment outlined in the previous sections fed into the Techno-Economic Modelling (TEM) as inputs, providing a set of outputs that align with HNDU requirements. The following section details the TEM methodology and assumptions.

Counterfactual scenario

A counterfactual scenario was created to represent the heat loads supplied by the network. This scenario is defined as the most likely heat supply situation if a district heat network were not present. For this study, the counterfactual scenario involved using individual Air Source Heat Pumps (ASHP) in each building. This was evaluated as the most probable alternative decarbonised heating technology within the study area, considering policy and decarbonisation drivers across various sectors.

The costs and carbon performance of the counterfactual scenario were evaluated for comparative purposes. The carbon emissions are used as a baseline to calculate the carbon emissions reductions for each district heat network scheme relative to the counterfactual. The counterfactual costs also feed into the heat tariff structure, acting as a baseline for the development of the connection charge, the fixed heat charge, and the variable heat charge.

Interface boundary

The CAPEX cost boundary is outlined in Figure 7.1, for:

- Main Energy Centre and Satellite Energy Centre
- Waste heat source interface
- Customer building interfaces

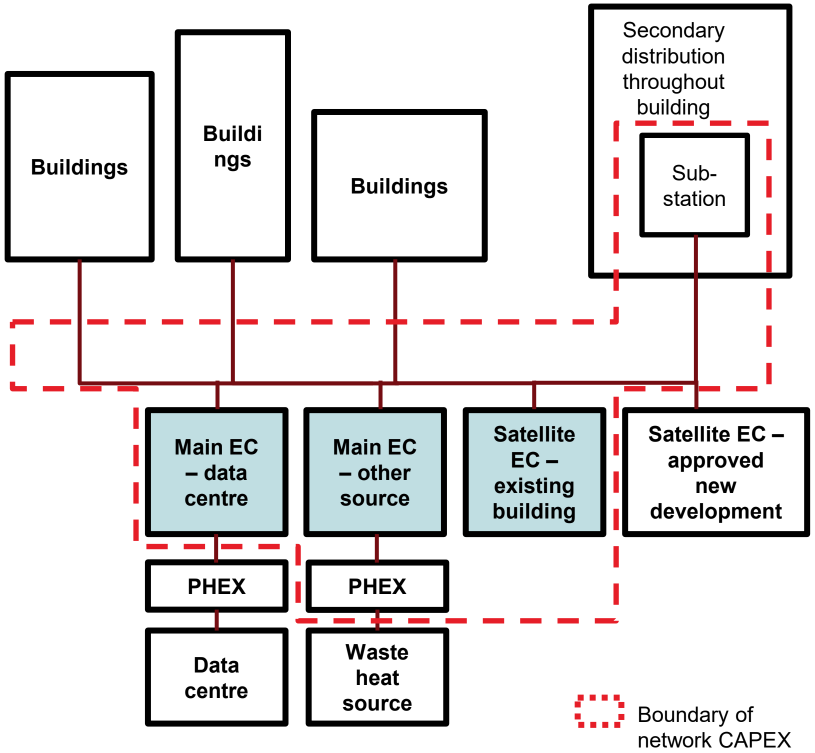

Figure 7.1: CAPEX split at building interface

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7. Techno-economic modelling

Scenarios evaluated achieve IRRs between 5-7% and offer carbon intensities below 100gCO_2e/kWh

Cost and Carbon discussion

Financial performance

Click here to go to comparison all CAPEX results

As shown in Figure 7.3, the plant costs and pipework costs contribute most to the CAPEX for majority of the scenarios as expected. Due to space constraints, the costs allocated to the development of the main and satellite ECs were assumed to cover fit-out and leasing, without the expectation of constructing new ECs.

The cost and carbon results from the techno-economic modelling are summarised in Table 7.1. Due to the high heating density of the area, positive Internal Rates of Return (IRRs) ranging from 5.3% to 7.3% were expected without the need for external funding. These IRRs exceed the typical local authority hurdle rate but fall short of the requirements for private sector investments such as energy service companies (ESCo).

The sensitivity analysis on CAPEX illustrates the potential for capital funding to edge the IRR for a number of these scenarios within the 12% range.

Adding the Bishopsgate office cooling cluster boosts the economic performance of scenarios compared to those without it. This is clear through the comparison Scenario A and C and Scenario G and H, where the IRR increases from 7.0% to 7.3% and 5.3% to 7.0%, respectively. This is the cumulative impact of additional, large loads contributing to revenue and more waste heat provided from office cooling reducing the need for ASHP top-up. These benefits counteract the additional plant and network CAPEX required.

The scenarios including the UKPN transformer waste heat recovery achieve marginally lower economic metrics than those without. This is because the higher amount of waste heat provided does not mitigate the additional plant costs and use of ASHP for top-up necessitated by the addition of more heat loads.

Carbon performance

All networks achieved a carbon intensity in the range of 63 gCO_2/kWh to 86 gCO_2/kWh in the first year of operation, with all networks carbon intensities dropping below 80 gCO_2/kWh by 2027. This falls well within the Green Heat Network Fund's (GHNF) 100gCO_2/kWh threshold. The 40-year average carbon intensities ranged from 8-11 gCO2/kWh, driven primarily by the decarbonisation of the grid. Figure 7.2 overleaf shows the carbon intensities of selected network scenarios over the project lifetime.

In general, scenarios facilitating a higher consumption of waste heat as shown in Figure 6.7 avoid more carbon relative to the counterfactual. This emphasises the importance of maximising waste heat utilisation when considering a network's carbon performance.

Adding the UKPN transformer cluster boosts the carbon performance of scenarios compared to those without it, as illustrated from the comparison of the carbon intensity of Scenarios A and F and Scenarios C and D. In both instances, the addition of the waste heat recovered from the UKPN transformer reduces the 40-year average carbon intensity from 10 gCO_2/kWh to 8 gCO_2/kWh and 11 gCO_2/kWh to 10 gCO_2/kWh, respectively.

From the NESQM scenarios, Scenario E (the Ambitious NESQM network Phase 1 + Phase 2 + Phase 3) avoids the most tonnes of carbon with 29,000 tCO_2 avoided over 40-years. However, this scenario performs worse economically than the Ambitious NESQM network Phase 1 + Phase 2.

Scenario H, the most ambitious CBHSS scenario has the highest utilisation of waste heat 88 GWh or 75% of the total available waste heat as a result of the maximisation of office cooling waste heat recovery and the integration of the SS cluster. Consequently, of the CBHSS scenarios, Scenario H achieves the highest total avoided carbon of 29,000 tCO_2, equalling the carbon avoided in Scenario E.

Click here to go to comparison all TEM results

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7. Techno-economic modelling

The carbon intensity of heat for all network scenarios reduces over time as electricity supply decarbonises

Carbon performance

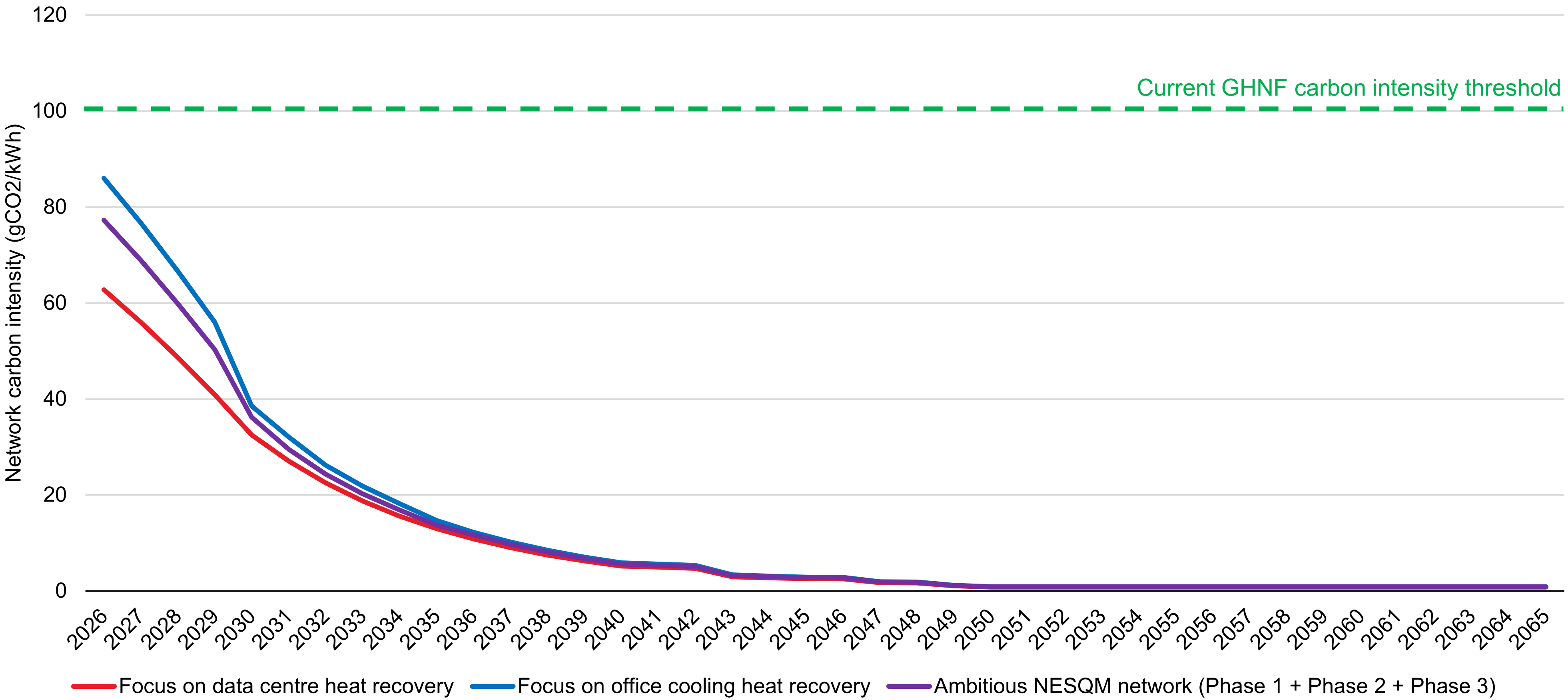

Figure 7.2: Carbon intensity of selected network options over lifetime

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7. Techno-economic modelling

Plant costs make up most CAPEX in the NESQM scenarios; pipework costs dominate for CBHSS scenarios

CAPEX

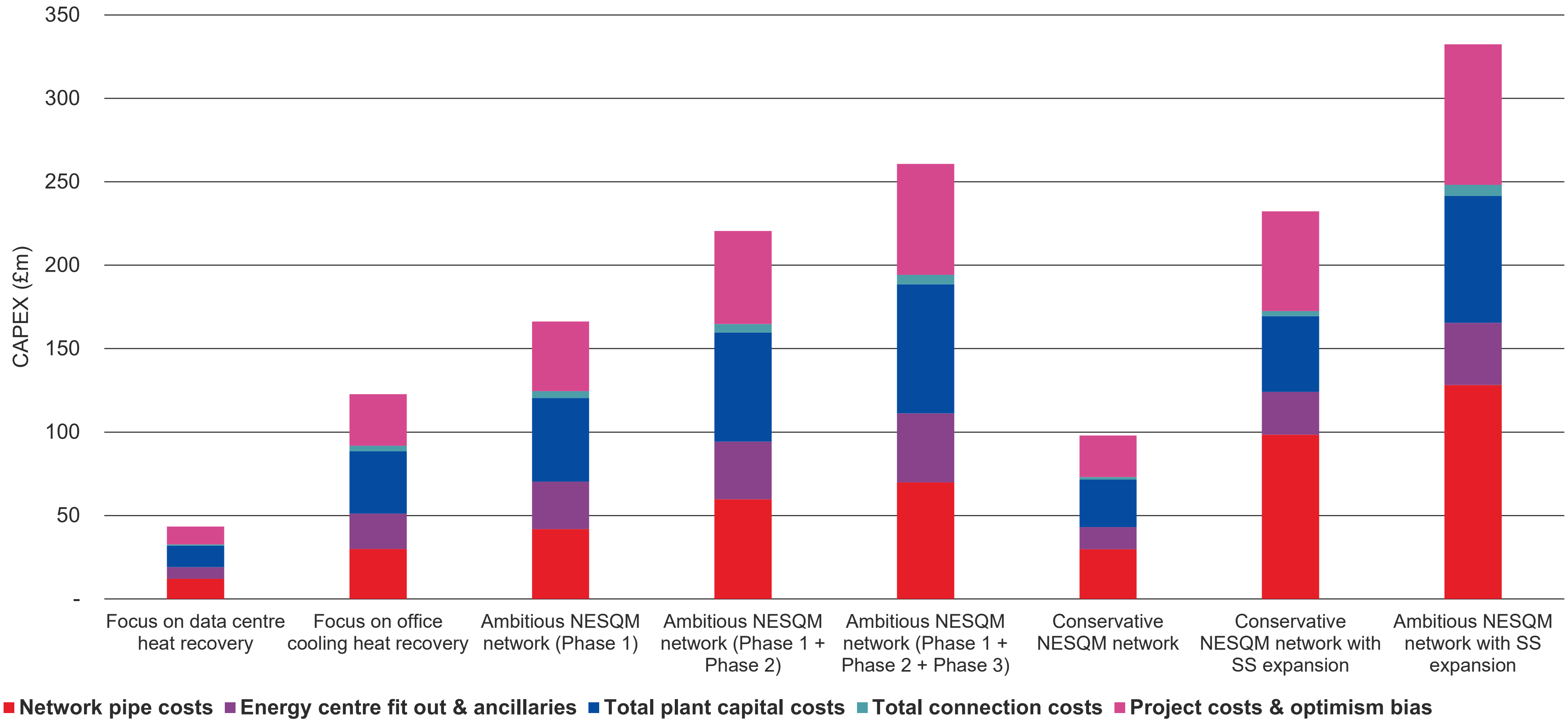

Table 7.3: CAPEX breakdown for each scenario.

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7. Techno-economic modelling
All scenarios have positive NPV's and IRR's ranging from 5-7%

Summary of TEM results

Metric	Unit	A	B	C	D	E	F	G	H
Scenario	**Name**	**Focus on data centre heat recovery**	**Focus on office cooling heat recovery**	**Ambitious NESQM network (Phase 1)**	**Ambitious NESQM network (Phase 1 + Phase 2)**	**Ambitious NESQM network (Phase 1 + Phase 2 + Phase 3)**	**Conservative NESQM network**	**Conservative NESQM network with SS expansion**	**Ambitious NESQM network with SS expansion**
CAPEX	**£m**	44	132	177	227	265	95	214	323
IRR	**%**	7.07%	7.12%	7.29%	7.08%	6.88%	6.35%	5.33%	6.97%
NPV	**£m**	12	37	51	58	59	17	30	91
LCoH	**£/kWh**	0.09	0.120	0.110	0.110	0.110	0.110	0.12	0.12
1st year carbon intensity	**gCO_2/ kWh**	63	86	77	77	77	63	63	79
40-year average carbon intensity	**gCO_2/ kWh**	10	11	11	10	9	8	9	9
Total Avoided Carbon	**tCO_2**	10,000	13,000	25,000	28,000	29,000	13,000	17,000	29,000

Table 7.1: Cost and carbon results from techno-economic modelling for each scenario.

7. Techno-economic modelling
Greater base load improves waste heat usage and carbon performance, but the economic impact remains minimal.

Sensitivity Analysis

This section outlines the sensitivity analysis for a selection of key scenarios as a reference. Figure 7.4 illustrates the impact of a CAPEX variation of +/- 30%, for the Digital Realty starter network (Scenario A). The NPV and IRR remains positive despite the additional CAPEX, although both values drop. A - 30% change in CAPEX elevates the IRR to 13%, which is within the standard ESCo range of viability.

In Figure 7.5, a +/-50% increase in residential demand (i.e. 4GWh increase in residential demand or 3% increase in overall demand) is depicted for the NESQM Ambitious Phase 2 scenario (Scenario D). This adjustment explores the effects of elevating the yearly base load, along with the subsequent rise in waste heat consumption, on the network's economic performance. As illustrated in Figure 7.5, increasing the base load leads to slightly higher overall waste heat consumption, thereby enhancing the network's carbon performance.

However, the economic performance is only slightly affected, showing a marginal decline in both NPV and IRR with increased residential demand. This occurs because, while more waste heat is used, additional output from ASHPs is also necessary to meet the demand, leading to a net increase in electricity consumption. This indicates that while greater base load improves waste heat usage and carbon performance, the economic impact remains minimal.

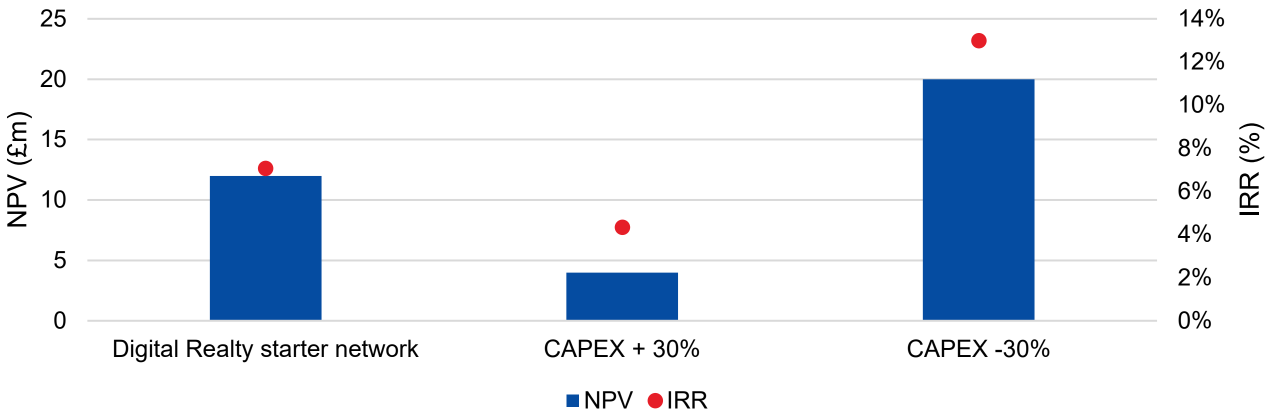

Figure 7.4: CAPEX sensitivity analysis results, for the Digital Realty starter network (Scenario A).

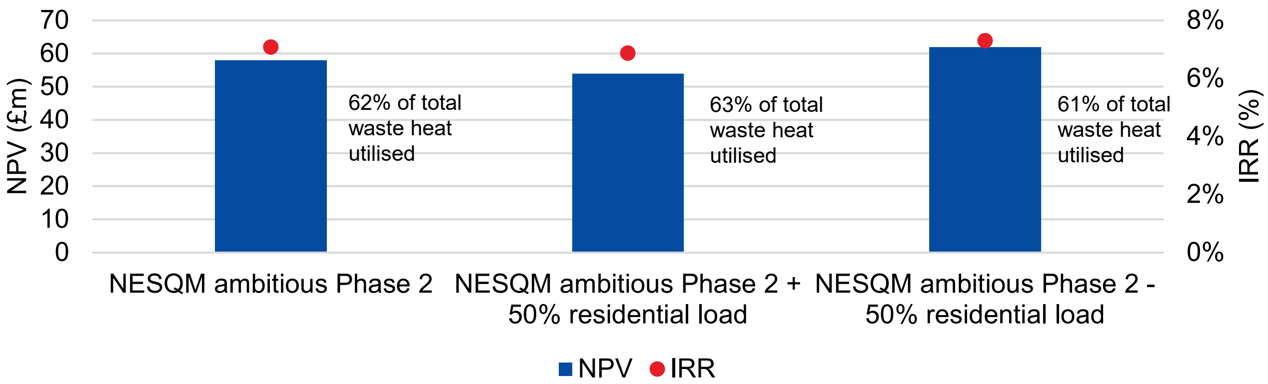

Figure 7.5: Residential base load sensitivity analysis results, for the NESQM Ambitious network Phase 2 (Scenario D).

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7. Techno-economic modelling

The Digital Realty starter network is a priority; promoting decarbonisation while performing well economically

Strategic conclusions

All the modelled networks performed well economically, achieving positive IRRs in the range of 5% - 7%. In addition, all modelled networks carbon intensity were below the GHNF threshold of 100gCO_2/kWh. As such, prioritisation of network options is based on strategic considerations rather than solely economic or carbon metrics.

The Digital Realty starter network has been identified as a technically and economically viable network, which is readily available to be taken for further investigation and progression as an immediate next step.

This network achieves an IRR of 7% and an NPV of £12m, with the IRR potentially jumping to 13% with capital funding support as shown in the CAPEX sensitivity analysis in this section. Integrating decarbonised waste heat sources is also key in initial stages of network development as the grid decarbonises, so it is strategically important to integrate viable waste heat sources into the network as soon as possible.

Digital Realty are the most progressed waste heat source in terms of engagement and technical readiness from the three priority waste heat sources. There are several favourable pre-application sites available as potential EC locations, namely Bishopsgate Goodsyard and the Truman Development. Spitalfields market and offices is a site relatively nearby the Digital Realty site, which is a CoLC freehold site and presents an attractive option for additional exploration.

The Bishopsgate office cooling cluster is key to the favourable economic performance of the Ambitious NESQM network Phase 2 scenario, which achieves the highest IRR from all scenarios of 7.3%. In addition, the CBHSS scenario performs better in terms of IRR and avoided carbon when the office cooling cluster is included, with the IRR increasing from 5.3% to 7%.

From a CBHSS perspective, connecting with South Shoreditch including only Digital Realty data centre and the UKPN transformer waste heat sources, excluding the Bishopsgate office cooling cluster, achieves the lowest economic performance across all scenarios of 5%. Even with capital funding, the IRR remains less than 12%. As such, the Bishopsgate office cooling cluster is key to the most optimal CBHSS scenario and facilitating connection with South Shoreditch.

This indicates **waste heat recovery from the Bishopsgate office cooling cluster in the NESQM is strategically pivotal in developing more ambitious, decarbonised networks both in the NESQM and considering optimal CBHSS with South Shoreditch**. There is significant uncertainty around the viability of the office waste cooling recovery and further technical investigation and stakeholder engagement is required. This should be a priority action before additional strategic decisions around the direction of travel are formulated.

While the scenarios including the UKPN transformer cluster achieve marginally lower economic metrics than those without, the waste heat provided by the transformer improves the carbon performance. As engagement with UKPN on the specific waste heat recovery scheme outlined in this report has been limited, although the concept design has been validated by UKPN in reference to another transformer waste heat recovery project, **furthering engagement with UKPN is key to maximising the waste heat in the network and furthering the aim of decarbonisation.**

8. Commercial considerations

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8. Commercial considerations
Several well understood Heat Purchase methodologies are commonly utilised

Heat Purchase Options - methodologies

The purchase price of heat is generally determined using one of three broad methodologies, with examples of these methodologies being used in the UK and Europe. Nuances to these methodologies tend to be specific to the contractual or technical requirements of the network. The complexity of the relevant heat supply agreement (HSA) will differ dependent on which methodology is chosen and can reflect key components such as the price review mechanisms, indexation, break points and termination and minimum service standards.

In addition to these three methodologies, free heat provision is also an option. Whilst less common for commercially focused networks, free heat provision tends to be employed on smaller privately run networks (with heat sharing between buildings) or, increasingly, where the benefits are non-commercial (e.g., sustainability) or where sharing of heat avoids cooling costs (e.g., data centres).

These four broad methodologies are set out opposite, with commentary on some of the variations that might be seen. The commercial and regulatory risks associated with them are then discussed on the next page.

Name	Description
Cost Plus reasonable profit margin	This is the methodology used on 'typical' heat networks where heat is generated and supplied from a central source e.g., a CHP / energy centre. The price of heat is based on the underlying costs for the producer (this can be capex and opex) plus a reasonable degree of profit. Underlying costs are indexed to appropriate mechanisms (i.e., CPI/RPI/RPIx/Labour Indexes) or shared annually on an open book basis. The methodology and terms will be set out in the agreement e.g. concession agreement or HSA.
Competitive discount to alternative sources of heat	This provides a percentage reduction or capping of the heat price vs. the cost of procuring the heat from alternative technologies. Future price indexation is generally linked to the evolution in the alternative price of heat. The alternative price of heat has historically been either the forward natural gas or wholesale electricity prices. However, it is increasingly being linked to the low carbon alternative e.g., heat pumps.
Regulated price of heat	A Regulatory Price Control mechanism which determines the price of heat, with a regular review being undertaken by a third party (usually the regulatory body) to ensure the price is appropriate. This is typically seen on large regulated networks such as electricity and gas, where prices are fixed in advance according to specific charging methodologies.
Free sharing of heat	In this instance, the benefits of sharing heat are non-commercial. These include sustainability outcomes achieved for organisations or balancing of heat loads / sources on the network. This can also be attractive to those who have high cooling requirements and can therefore avoid these costs (e.g., data centres).

Table 8.1: Typical heat purchase methodologies

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8. Commercial considerations
Some methodologies are based on ensuring set returns or ensuring alignment with alternative technologies.

Heat Purchase Options – risks and considerations 1/2

Name	Commercial considerations	Regulatory considerations
Cost Plus reasonable profit mechanism	• Independent heat providers (e.g., where heat is not their primary service) are unlikely to know how heat should be priced and therefore would require guidance / support to ensure consistency. Pricing risk, for example, will need to be understood by the provider. • Alternatively, a specific methodology for heat purchase could be established to ensure consistent pricing across the network (as seen in some Swedish networks). • Engagement with multiple heat sources (as opposed to a centralised source/energy centre) will require multiple HSAs and management of these (this applies to all options below).	• The introduction of regulation may lead to a fixed purchase price being set which must be agreed with Ofgem. This is typically seen on large regulated infrastructure (electricity and gas) for the purchase of some services. Most services are procured competitively. • Longer term, alignment/benchmarking between different networks might be considered for the purchase of heat (at least within a zone), although this is unlikely to be a consideration in the short term. This is mentioned in the government Zoning consultation. • Denmark operates a 'Cost Plus' regulatory regime. Germany is also similar but is a fully merchant market and has received some criticism due to significant differences in pricing between networks.
Competitive discount to alternative sources of heat	• The frequency of review against the alternative should allow for fair pricing but also stability in pricing for end users of the network. The frequency of review should not be an administrative burden. • By discounting to / aligning with another heating technology, there is a disconnect between the actual cost of heat and what it is being bought for. This is unlikely to be an issue where waste heat is being purchased. Where heat is being actively generated, however, protection mechanisms will need to be in place in the HSAs to ensure the heat generation is economically viable. • Different prices and commercial arrangements might be required if purchasing heating / cooling.	• Ofgem like costs to be transparent and reflect the actual cost of providing the service. Long term alignment with an alternative heat source might not be attractive to a regulator, especially if the cost of that alternative is likely to change in the medium – long term (e.g. heat pump costs decreasing). • With the introduction of heat zoning, there is potential for a common methodology to be established, at least within a zone. This is unlikely in the short term though. The heat zoning consultation does discuss ensuring the cost of heat is lower than the alternative to make it attractive for connection. • An example of this type of pricing methodology (and regulation) is Norway which has both a mandatory regulatory framework and cannot be more than the alternative heat source (generally gas).

Table 8.2: Commercial and regulatory risks associated with the Heat Purchase Options (1/2)

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8. Commercial considerations

Other methodologies ensure a ‘fair’ or low price for customers or allow for other benefits (recycling of heat).

Heat Purchase Options – risks and considerations 2/2

Name	Commercial considerations	Regulatory considerations
Regulated price of heat	• If a regulated price for heat purchase was established, consideration will have to made on how this impacts the economics of a project on a case-by-case basis as there may be less ability to change pricing. Where waste heat is being provided this is less likely to be an issue. • Regulation is likely to require licences, which may have additional stipulation that have to be met, on top of how heat purchase is undertaken. Too much administrative burden could put heat providers off, especially if they wanted to provide free / waste heat. • Pricing ‘caps’ can sometimes mean heat is higher than it would have been, as the cap is used as a target rather than a ceiling.	• A regulated heat purchase price is likely to also come with service standards and deliverables. These will need to be written into any HSA. • Mechanisms like the Energy Price Cap may, in future, apply to heat networks if they became regulated. The heat purchase price would have to feed into any such cap. • An example of this type of pricing methodology (and regulation) is the Netherlands which has ‘Price Cap’ regulation incorporating both fixed and consumption-based charges.
Free sharing of heat	• Where heat is being provided for free to a network, service levels will have to be clearly stated in the HAS, especially if the heat source is a baseload provider and key to network operation. • Additionally, there will be consideration to who funds, builds and owns connection assets at the boundary, as well as operational and maintenance responsibilities, if the heat provider isn’t being compensated for provision of heat. Generally the HSA/agreement will just set out responsibilities for ownership and operation, and the heat network operator might be required to cover any expenses faced by the heat provider. • Whilst a consideration for all options, the heat profile will need to be understood up front, or there be an agreement for flexible heat provision, as there is no financial incentive to provide heat in this scenario. This will ensure consistency.	• The regulator is likely to want to understand the party responsible for ensuring there is sufficient heat available (or back up) for end customers, especially if they are vulnerable customers, and if there is no financial payment for providing the heat. This is likely to require clear service levels and KPIs. • With the introduction of Zoning, where heat sources over a certain level might be required to connect, there is a strong incentive for providers of heat to connect to a heating network. These users might not want to have an ongoing role, however, if it is outside of their day-to-day business model. • Stakeholders interested in providing waste heat might have a different business profile to other heat providers e.g., local authorities rather than businesses.

Table 8.2: Commercial and regulatory risks associated with the Heat Purchase Options (2/2)

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8. Commercial considerations

Examples of Heat Purchase agreements

Open Call for Heat (Stockholm)

Stockholm Exergi uses an 'Open District Heating' approach where companies with excess heat can connect to their network, with a number of contracts to facilitate this.

Under the 'Open Call' contract, heat delivery conditions are set by the district heating network.

The supplier must provide heat when requested and there is a guarantee that it will always be required when outdoor temperatures are 10°C or less.

Renumeration consists of fixed monthly compensation and a variable energy renumeration for the heat supplied.

Suited to businesses that have a reliable heat surplus where generation is evenly distributed throughout the day and year e.g., data centres.

Open Spot Heating (Stockholm)

Heat delivery conditions are set by the supplier, and they are not constrained to deliver heat at a specific outdoor temperature / time frame.

This is suitable for businesses with a variable heat surplus. Compensation is dependent on the supply temperature to the network according to bands:

1. **68 – 103°C** delivery temperature required into feedline and based on the temperature that is guaranteed to end customers.
2. **68 – 80°C**, delivered to DH feedline and based on the location and size of the heat supply.
3. **At least 3°C** higher than the incoming return temperature with delivery into the return line of the district heating network.

Not-for-profit (Dublin Example)

Amazon Web Services (AWS) Dublin is providing waste heat from their data centres into the Tallaght District Heating Scheme.

Waste heat from their data centres will supply heat to the network and connected public, commercial and residential buildings. The heat will cover 100% of heat demand during normal operation.

The scheme will operate as Ireland's first not-for-profit utility and will be managed by South Dublin County Council. AWS will provide the heat for free.

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8. Commercial considerations

Heat Sharing

We investigated how heat could be shared across the local authority (LA) boundary, and whether the heat surplus will match the load across the boundary. This section discusses options for heat sharing across the local authority boundary in general terms, describing some of the key high-level considerations of doing so.

Based on current analysis, we have found:

1. The most likely heat sharing scenario is within-day sharing of heat.
2. Sharing of excess heat is likely to occur during the evening period for use in heating and hot water.
3. There is likely to be a seasonal impact of potential heat sharing, with more heat being available during the summer period, and reduced sharing during the winter period.

On the following pages we discuss two scenarios:

- heat is provided for free
- heat is sold across the LA boundary, as indicated opposite.

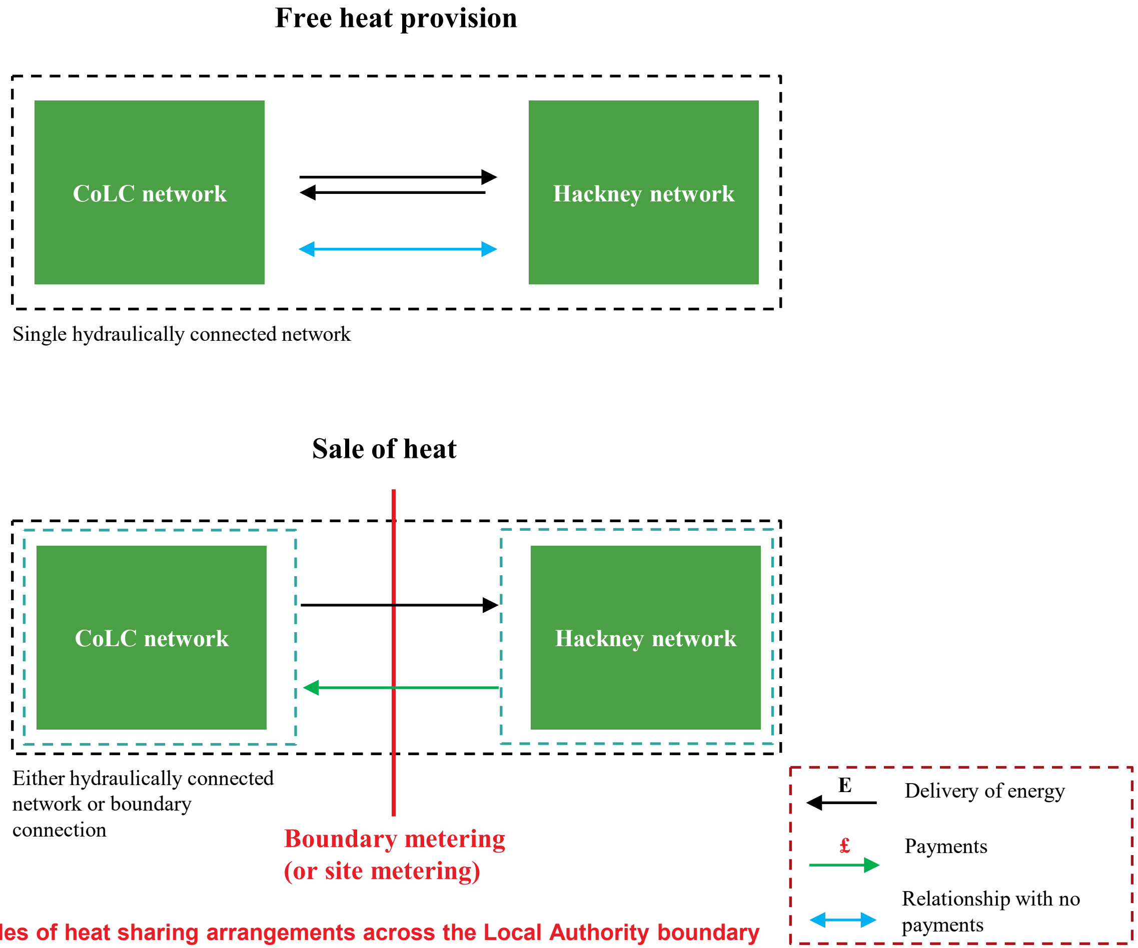

Figure 8.1: Examples of heat sharing arrangements across the Local Authority boundary

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8. Commercial considerations

Potential business models

In the following pages some example business models are demonstrated, with the key market actors / stakeholders set out, including their roles in the potential business models.

The first two business models presented (options A and B) are based on heat sharing across a network boundary, building on the examples on the previous slides, and are 'generic' in nature but with application to the future CoLC network. The final business model is an updated versions of these, taking into account stakeholder feedback gained in Stage 2 of the project.

Wehave also set out some key regulatory and commercial risks associated with these types of business models. These should be seen as a 'live list' which will be updated as the thinking on specific options develops. This is followed by a high-level discussion of the preferred business models that have been put forward in the governments 2023 'Proposals for heat network zoning' consultation.

8. Commercial considerations

Option A - Sale of heat across the boundary, separate networks

This delivery / business model represents a scenario where there is separation between the two LA networks, both physically, and commercially.

The commercial objective of this business model is to sell 'waste' heat across the LA boundary, with Hackney then selling this onto their network users or using for their own buildings (e.g. leisure centres).

Key characteristics

- Separate network funding and development by both CoLC (or its network developer) and Hackney.
- Generate revenues which can be passed onto sellers of waste heat that are connected to the network, as well as for the operator of the networks.
- This option allows for, and recognises the fact, that the two LAs might have a different desire to own the network i.e., CoLC do not want to, but Hackney likely will.
- Separation of different elements of the supply chain; heat generation, asset ownership, O&M etc.
- This option, due to its separation in ownership and hydraulic link, may fit better with any future zoning approach (yet to be seen as the policy develops). The separation might align with the Zoning Coordinator roles but might cause confusion where heat sources are 'required to connect'.

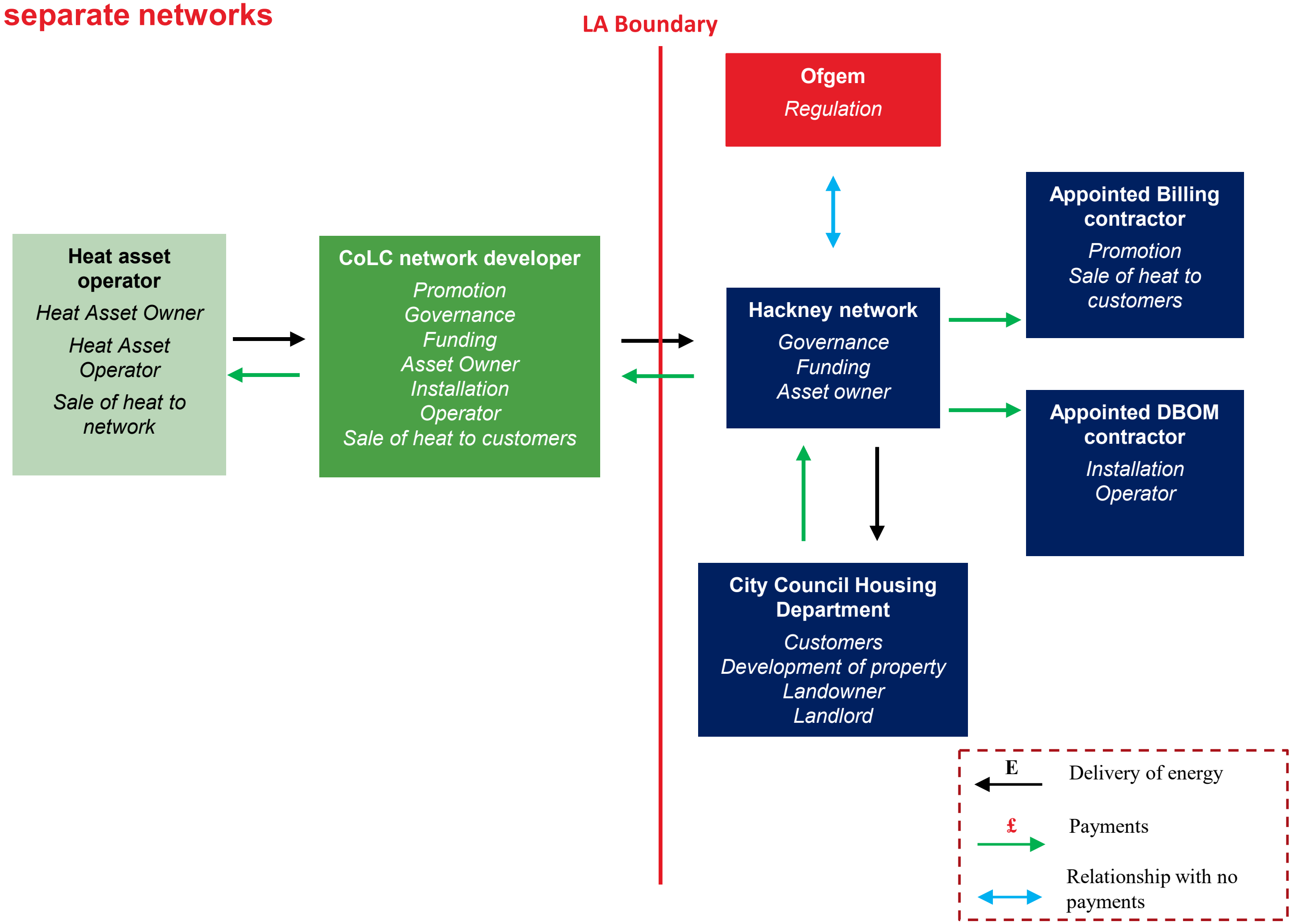

Figure 8.2: Responsible parties for the sale of heat across a LA boundary

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8. Commercial considerations

Option A - Sale of heat across the boundary, separate networks

Risk category	Potential risk	Mitigation
Commercial	Sale of heat is likely to require higher service standards to be in place, with a commitment to provide heat on demand when required. Additional baseload heat sources might be required to provide this.	Install additional base load heat sources, which come with additional cost, or have a contractual 'baseline' of heat delivery volumes that is low enough to ensure it can be met based on heat modelling.
Commercial	Multiple stakeholders across the two networks will add complication for commercial contracts / arrangements (compared to a single heat source).	Concession arrangements / contractual arrangements will have to be very specific on where responsibility lies for the different elements of heat delivery.
Commercial	The purchase of waste heat, and its transfer across the network boundary to Hackney is likely to add cost, and therefore increase the price of heat to Hackney end customers (compared to CoLC customers).	This is hard to avoid and will be within the end cost of heat. Subsidisation could occur, however, this is unlikely to be sustainable.
Commercial	Billing, and cost, across the two networks is likely to be different. This will also be impacted by how the network is funded and how much of this is passed onto the end network users.	Despite separation of the networks, there is potential for billing to be done on a fixed price of heat across both networks.
Regulatory	Hackney will not be in control of heat quality and generation and will have a significant reliance on the network developer / owner on the CoLC side of the connection.	Baseline deliverables and KPIs will have to be established and agreed between relevant stakeholders. Back up may be required.
Regulatory	With the introduction of regulation, there may be additional complexity in having two connected but separate networks, which might have separate licences, especially if different Zoning Coordinators.	This should be monitored as regulation develops. Complex arrangements are seen on the gas and electricity networks which can provide precedent.
Regulatory	Pricing might be different on both sides of the network connection boundary which could lead to customer dissatisfaction or difficulty if benchmarking is undertaken (Zoning consultation suggests national benchmarking).	Unify pricing across the networks, or provide transparent tariff build ups for the different network components / additions. This is likely to be a requirement as part of Zoning regardless.

Table 8.7: Risk register for option A

8. Commercial considerations

Option B - Heat sharing to allow network balancing, continuous network

This delivery / business model represents a scenario where heat is shared across the network across a continuously hydraulically connected network, with a single network owner and operator. Due to this, the network owner/operator would be required to have a relationship with both CoL and Hackney.

Heat will be shared in order to utilise any waste heat that is provided to the network and will reflect the differences in demand patterns between CoL and Hackney i.e., the CoL is expected to have a high heat demand during the working day, but a reduced demand in the evenings and overnight. This allows Hackney to utilise waste heat for heating and hot water during this time when the CoL might not need it.

For this model, it is assumed that all heat is provided to the network for free and that it is 'waste heat' e.g., from data centres or substations. This avoids the transfer of money to these users but will still require contractual arrangements to be in place to account for network operation requirements and to set out key responsibilities etc.

An assumption in this scenario is that contractual requirements, and the requirements to provide heat by waste sources, is likely to be less stringent to account for a lack of payment.

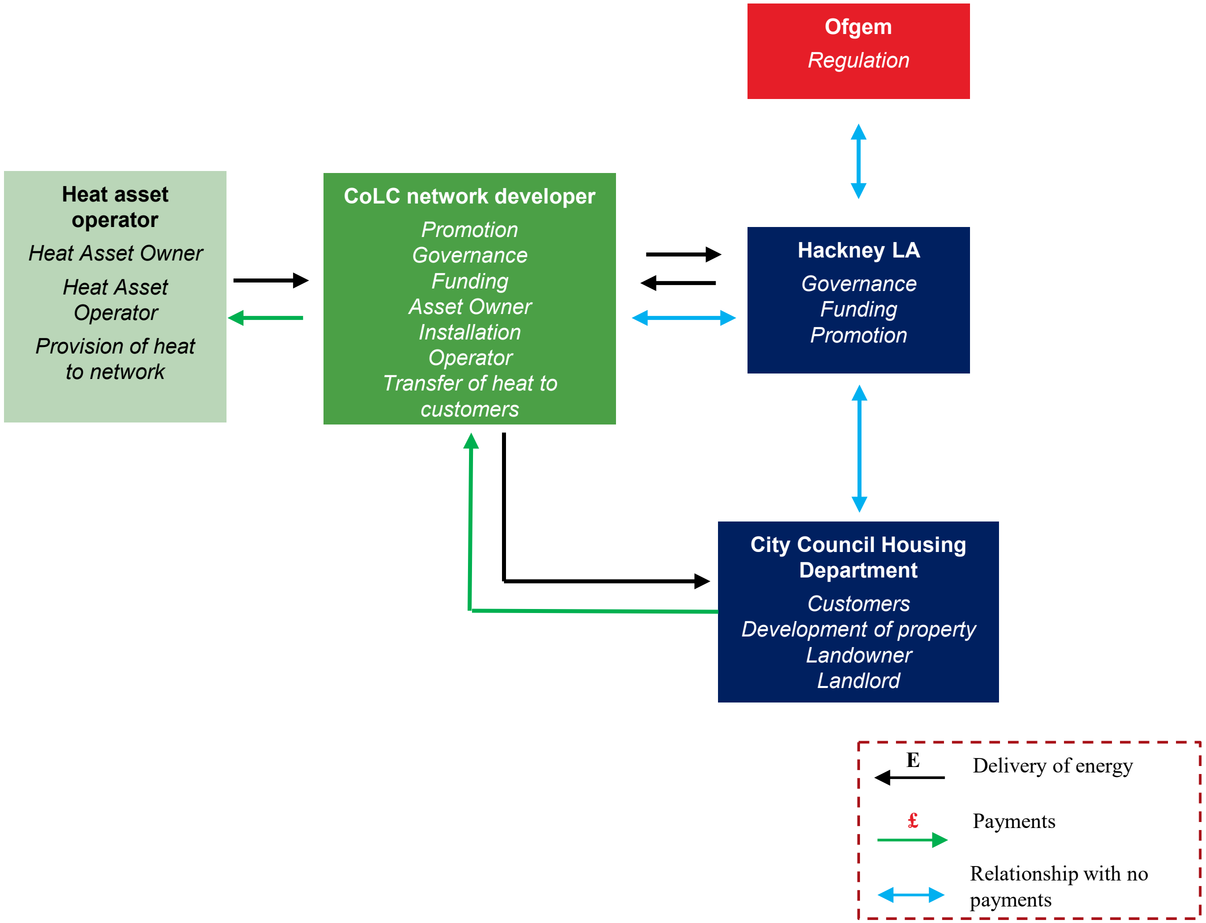

Figure 8.3: Responsible parties heat sharing across the LA boundary

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5. 8. Commercial considerations considerations

Option B - Heat sharing to allow network balancing, continuous network

Risk category	Potential risk	Mitigation
Commercial	CoLC developer would have to engage with customers across the LA boundary contractually and have visibility of their requirements.	Engagement could be through Hackney LA only to reduce the number of stakeholders / contracts, with Hackney then responsible for further engagement.
Commercial	Despite heat being provided for free, there will still be costs associated with building and operating the network, as well as delivery. How will the network owner / operator be reimbursed for these costs? Will some customers be charged to recover this?	Likely to require investment by Hackney LA. This could then be recovered through grant funding or pass through charges to some network users / based on the 'avoided cost of heating', or through simple standing charges.
Commercial	Hackney, the CoLC and the network owner/operator will have to agree on service standards and customer performance levels. KPIs are likely to be less stringent if heat being provided for free.	Contractual arrangements will have to mirror what can technically be delivered through heat sharing to manage expectation. This will have to be updated relatively frequently based on changes to the network.
Commercial	What are the commercial interfaces across the network and how will a CoLC developer interact with potential customers on the Hackney network?	As per the first point above, a single contractual body (e.g., Hackney LA) would simplify the requirement to interact, with Hackney LA taking onward responsibilities.
Regulatory	With the introduction of Zoning and regulation, consideration may be needed for a network with multiple LA input, especially if the LAs are chosen as the 'Zone Coordinator'.	Monitor the development of the Zoning consultations.
Regulatory	What happens in the event of a dispute, especially with the involvement of multiple LA's / stakeholders? Who is responsible?	Monitor future regulatory arrangements. Specific contractual arrangements will be required that clearly set out the key responsibilities of stakeholders involved. Ofgem may provide a way forward for this.
Regulatory	What will the heat delivery expectation be across the boundary and how will heating be 'topped up' if insufficient volumes are provided?	Likely to be best managed at the point of demand (e.g., back up boilers) which would add cost, or through a separate energy centre on the Hackney side of the boundary for efficiencies of scale.

Table 8.8: Risk register for option B

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8. Commercial considerations

Option C – Continuous network across LA boundary, two network owners

This delivery / business model represents a scenario where there a developer is able to build a network that crosses the LA boundary, servicing Hackney customers (e.g., into South Shoreditch). This is an extension to Option B, as there are two distinct networks (in terms of ownership) but still cross over the LA boundary.

The commercial objective of this business model is to facilitate the sharing of heat across the LA boundary whilst, maximising the development potential of a CoLC network, and for the benefits of a larger scale network to be shared with Hackney.

Key characteristics

- Continuous network and development by a private developer in CoLC and Hackney in the north of their LA.
- Sharing of elements of certain parts supply chain (ECs, waste heat) to drive efficiencies on the network but separation of others (pipelines, O&M contracts, network charging areas/customers).
- Consideration would have to be given to the different priorities of the heat network owners (i.e., CoLC developer and Hackney) to ensurea degree of alignment.

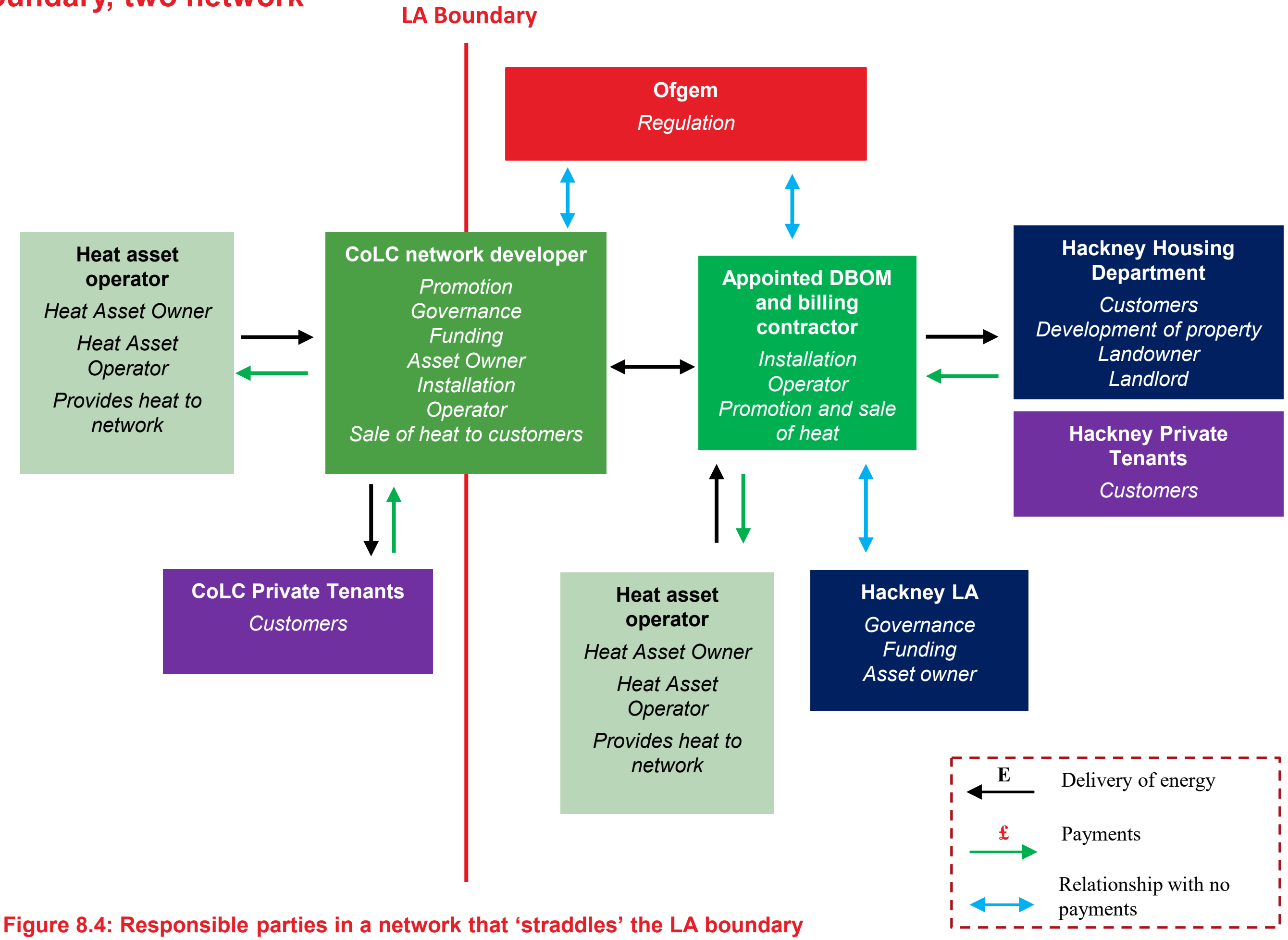

Figure 8.4: Responsible parties in a network that 'straddles' the LA boundary

5. 8. Commercial considerations considerations

Option C - Continuous network across LA boundary, two network owners

Risk category	Potential risk	Mitigation
Commercial	Expectation from Hackney is that this type of network arrangement allows cheaper tariffs and benefits for its LA network users.	Consideration will have to be given to what the benefits of this network can provide to Hackney tenants and whether these can be non-financial (i.e., the heat sharing) which in turn allows for reduced tariffs for some network users.
Commercial	Difference in pricing for different users of the network. Hackney are also setting lower tariffs than what might be expected on the CoL network (i.e., using a gas counterfactual rather than ASHP).	Not considered to be a material risk – this is already seen in other regulated utilities and discussed in the zoning consultations (price caps). Could agree tariff bandings in the Heads of Terms / contracts which could be aligned across the two LAs.
Commercial	There is a requirement for significant capex outlay to develop a large cross LA network. Need to consider the feasibility and timing of a single operator being responsible for this.	A clear roadmap will be required to how the network can be developed with clear phasing or the development of ‘mini-networks’ that later join up. There might be a requirement for CoLC to play a coordinating or financial role in this.
Commercial	Need to consider how heat sales are transferred between the different network operators if sharing key supply chain elements (e.g., EC locations and running generation plant for a ‘total network’ benefit).	Potential to use more metering to understand generation volumes and heat flow with reconciliation between the networks on a monthly / quarterly or annual basis.
Regulatory	The current zoning regulations are relatively inflexible on where a zone is and how a network might be developed in that zone. Hackney and Tower Hamlets not currently in the AZP zone.	Engage with DESNZ to ensure that the zoning limits and boundaries are more flexible, and that cross LA developments are captured in the proposed business models.
Regulatory	Mis-alignment in the planning policies and ‘requirement to connect’ either side of the LA boundaries. If there isn’t alignment, the viability of the larger network might be reduced as well as it being harder to ensure large heat loads connect.	Engage with DESNZ and LA planning teams to ensure there are sufficient incentives, and requirements, for certain building types to connect to a heat network.

Table 8.9: Risk register for option C

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8. Commercial considerations

Zoning Consultation – business models

The table opposite sets out the four ‘preferred options’ that are being considered by the government for Heat Network Zoning. It sets out the key roles that would be taken forward by the network developers, LA, ‘Zoning Coordinator’ (yet to be fully defined), Ofgem and the government.

These delivery models are still in development, and as such, are likely to change or are open to influence. It is worth considering how each of the separate models might impact the delivery of and development of the CoLC future heat network, as well as the commercial and regulatory risks that the deliver models might raise.

These considerations are set out in the table on the next page. It should be noted that this is not an exhaustive list.

Roles	‘Authorisation and Consent (Proactive)’	‘Local Authority Joint Venture (LA JV)’	‘Time Limited’ Concession	‘Evergreen’ Concession
Developer	Applies to a Zone Coordinator (ZC) to deliver and operate networks within a defined Zone Delivery Area. Developers will need to agree conditions proposed by the ZC.	Applies for a JV with LA to deliver and operate an entire Zone Deliver Area. Agrees share of control with LA in the JV (based on level of investment etc). Will need to agree conditions proposed by LA and ZC.	Similar to the LA JV however the developer has to agree to handover assets to the ZC after a defined period of time.	Similar to the LA JV but developer has a primary share in the JV and retains assets indefinitely. A special purpose vehicles is used rather than a JV, with the LA holding a special share and Developer being principle shareholder.
Local Authority (LA)	Little defined involvement but likely to work closely with the ZC (if not assigned ZC role) and may influence conditions.	Enters JV with winning developer, agrees share of control, and may propose conditions.	Like the LA JV but after handover of assets may be required to enter a new delivery model.	Similar to the LA JV however the LA takes a secondary share with a less involved oversight role.
	Oversees planning and development rights that will also influence delivery.			
Zone Coordinator (ZC)	Assigns winning developers to deliver and operate networks within the Zone Delivery Area and proposes conditions.	Assigns winning developer to enter JV with LA and proposing conditions.	Like LA JV but will take over assets following the designed period of time and will likely initiate a follow-on delivery model.	Like LA JV.
	Power to overrule if delivery model not meeting objectives.			
Ofgem	Authorises developers who may then apply for rights or to joint venture with LAs for delivery and operation of networks.			
DESNZ	Power to overrule if delivery model not meeting objectives.			

Table 8.10: Current ‘preferred’ options put forward in the governments Zoning Consultation

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8. Commercial considerations

Zoning Consultation – commercial or regulatory risks

Risk category	Risk and mitigations
Regulatory	The consultation suggests that aggregation of zones may occur if they are too small. Whilst this could be attractive to developers, the timing of when and how this occurs is important to ensure the development of the 'smaller' networks is still attractive to developers or that aggregation won't disrupt / hinder development.
Regulatory	Depending on the business model taken forward for Zoning, there could be a significant role for local authorities as a 'Zone Coordinator' or similar. This will have to be balanced with other responsibilities and in the context of wider project work (including the cross-boundary project etc).
Commercial / regulatory	One of the proposed roles is for a 'Zone Coordinator', with this being the Local Authority in some preferred business models. If a network is developed between CoLC and Hackney then each Zone Coordinator might have different priorities or approaches that have the potential to conflict. Good communication will be key to ensure alignment. It would also need to be considered whether CoLC want to take on this role given the fact they have expressed a desire for more of a developer led approach.
Commercial / regulatory	The wider framework on heat network zoning, and the wider regulatory framework, will have a positive impact if heat networks are given the same rights as similar utilities (easements, access, planning, installation rights etc). The timing of *when* this comes in though is still uncertain given Ofgem are likely to be playing 'catch up' with many new responsibilities.
Commercial	If there is a 'requirement to connect' for certain heat sources, of a specified size, then there is a possibility that they may want to connect to the larger 'zones' if it was more cost effective / commercially attractive. As such development of the CoLC network and any wider zoning considerations should be taken together.
Commercial	In order for Zone Coordinators to cover their costs, 'Zone Coordinator consent fees' may be charged to heat network operators and developers. Whilst these costs can be passed through to end users if heat is being purchased/sold, if free heat is being shared, then consideration will need to be given as to who these fees are passed onto or whether they are 'waived'.
Commercial	For any heat sharing across a network / LA boundary, consideration will have to be given to the types of concession / business model used in each zone as there could be misalignment in the types of concession models and their time limits e.g. evergreen vs time limited. Additionally, SPVs (as proposed in the 'evergreen' concession) could add complexity.
Commercial	There are likely to be controls on the connection costs for buildings, as well as transparency in pricing for all consumers. This could cause tension if heat is being provided for free in some areas and not others, and alignment is likely to be required across zones in the future (or at least benchmarking).
Commercial	Certain buildings are likely to be required to connect, and if not exempt, would then have to pay standing and connection charges. Consideration will have to be given as to whether this might disincentivise people from providing heat for free and how the rules can be used to prevent perverse impacts.
Commercial	Heat Source Pricing – the consultation proposes that this will be negotiated based on the marginal cost of heat (cost it is produced at) and the counterfactual for the heat network develop. If a heat source mechanism/methodology is introduced, it might decrease the likelihood of free heat sharing as providers would want the commercial upside.

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9. Next steps

9. Next steps

The Digital Realty starter network is readily available for further development and implementation

Summary and NESQM next steps

Summary

This report presented technical and commercial findings for both the NESQM and CBHSS.

Throughout the study, effective stakeholder engagement was conducted, supported by City of London Corporation and delivery partners E.ON and Hackney Council.

The main outcomes from the stakeholder engagement in Stage 1 was: improving data confidence, learning the spatial availabilities for potential energy centres, gathering heat source availabilities and understanding the network connection appetite from heat supply and/or heat customer perspectives.

In Stage 2, the stakeholder engagement activities focused on validating the potential energy centre locations through a prioritisation process. In addition, stakeholder engagement was key to refining the waste heat source technical assumptions and developing waste heat recovery configurations.

We developed hourly dispatch models for both studies to assess the optimised energy supply scenarios and how extra benefits through CBHSS. The results from this modelling exercise informed network design for various scenarios. RIBA Stage 2 energy centre concept designs were also created for the energy centre options.

Techno-economic modelling was performed for each network scenario to assess the cost and carbon performance.

Based on the outcomes of this study, the following next steps are proposed.

In the context of upcoming zoning regulations, and using the findings of this study, AZP, and the CoL LAEP, **a CoLC Heat Network Strategy should be developed** to provide a vision and align efforts on heat network development in the Square Mile.

NESQM

The Digital Realty starter network should be progressed as a priority. To progress this opportunity, it is recommended to:

- Continue engagement with Digital Realty to finalise technical and commercial arrangement.
- Locate energy centres, by engaging with priority EC locations Bishopsgate Goodsyards (through the GLA) and the Truman Development (focusing on Block A), and initiating engagement with CoLC-owned freehold site, Spitalfields market and offices.
- Identify key satellite energy centres from the list of buildings.

Investigation of office cooling waste heat recovery should be explored as a key strategic opportunity. To progress this opportunity, it is recommended to:

- Engage with identified large office buildings (1 Undershaft, 122 Leadenhall, 22 Bishopsgate and 30 St Mary Axe), specifically on the topic of heat recovery from cooling systems
- Investigate technical feasibility of office cooling heat recovery via an ambient loop
- Engage with 1 Undershaft on the potential to act as a main energy centre for this cluster.

Investigation of UKPN transformer waste heat recovery should be further advanced, as this is a technical proven initiative explored by UKPN in other locations. To progress this opportunity, it is recommended to:

- Engage another team in UKPN on the potential for heat recovery at the Finsbury Market substation cluster
- Explore the technical feasibility of hosting an EC at the Finsbury Market substation site

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9. Next steps
Continue collaboration with Hackney to ensure strategic alignment; Tower Hamlets' is a key future opportunity

CBHSS next steps

The following actions are recommended to progress the CBHSS.

Continue collaboration with Hackney to ensure strategic alignment between the NESQM and Shoreditch network development

- Key levers to consider in Hackney engagement includes EC locations in Shoreditch High Street and potential interconnection of the NESQM and South Shoreditch networks.
- This engagement is key as both feasibility studies consider the Digital Realty data centre as a source.

Tower Hamlets' high residential demand and significant data centre capacity make the borough a key opportunity for future cross-boundary heat sharing collaboration.

- There are 40 communally heated council estates identified in Tower Hamlets, presenting the opportunity for integrating additional residential loads into the network options.
- In addition to Digital Realty, there are various data centres situated in Tower Hamlets, with significant projected growth. The Isle of Dogs LAEP anticipated 500MW growth in data centre capacity in the area. The potential exists for further exploration of data centre WHR if the CBHSS boundary is extended to consider Tower Hamlets.

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