Public Document Pack

Policy and Resources Committee

Date: **THURSDAY, 21 SEPTEMBER 2023**

Time: **1.45 pm**

Venue: **COMMITTEE ROOMS, 2ND FLOOR, WEST WING, GUILDHALL**

8. **CITY OF LONDON - LOCAL AREA ENERGY PLAN (LAEP)**

For Decision
(Pages 3 - 130)

Ian Thomas CBE
Town Clerk and Chief Executive

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ARUP

City of London Corporation

City of London Local Area Energy Plan

July 2023

Agenda Item 8

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Executive summary

In 2020 the City of London Corporation published its Climate Action Strategy that detailed its commitments to reach net zero carbon emissions within its own operations by 2027, and net zero across the Square Mile and the City Corporation's supply chain by 2040.

This Local Area Energy Plan for the City of London sets out the details of what the future energy system would look like in the Square Mile, combining robust technical analysis with stakeholder engagement to develop priority action areas that should be focussed on by the City Corporation and wider stakeholders within the City, as summarised in Figure 0.1

The following technical analysis has been carried out:

- Baselining current demand and infrastructure for provision of heat, cooling, power and transport.
- Estimations of future energy demands, accounting for climate change, building energy efficiency improvements and the effects of new development
- Modelling of key decarbonisation scenarios including heat pumps, heat networks and waste heat, renewable energy generation, transport electrification and the future role of hydrogen
- Carbon emissions and energy pathways analysis and high level costing.

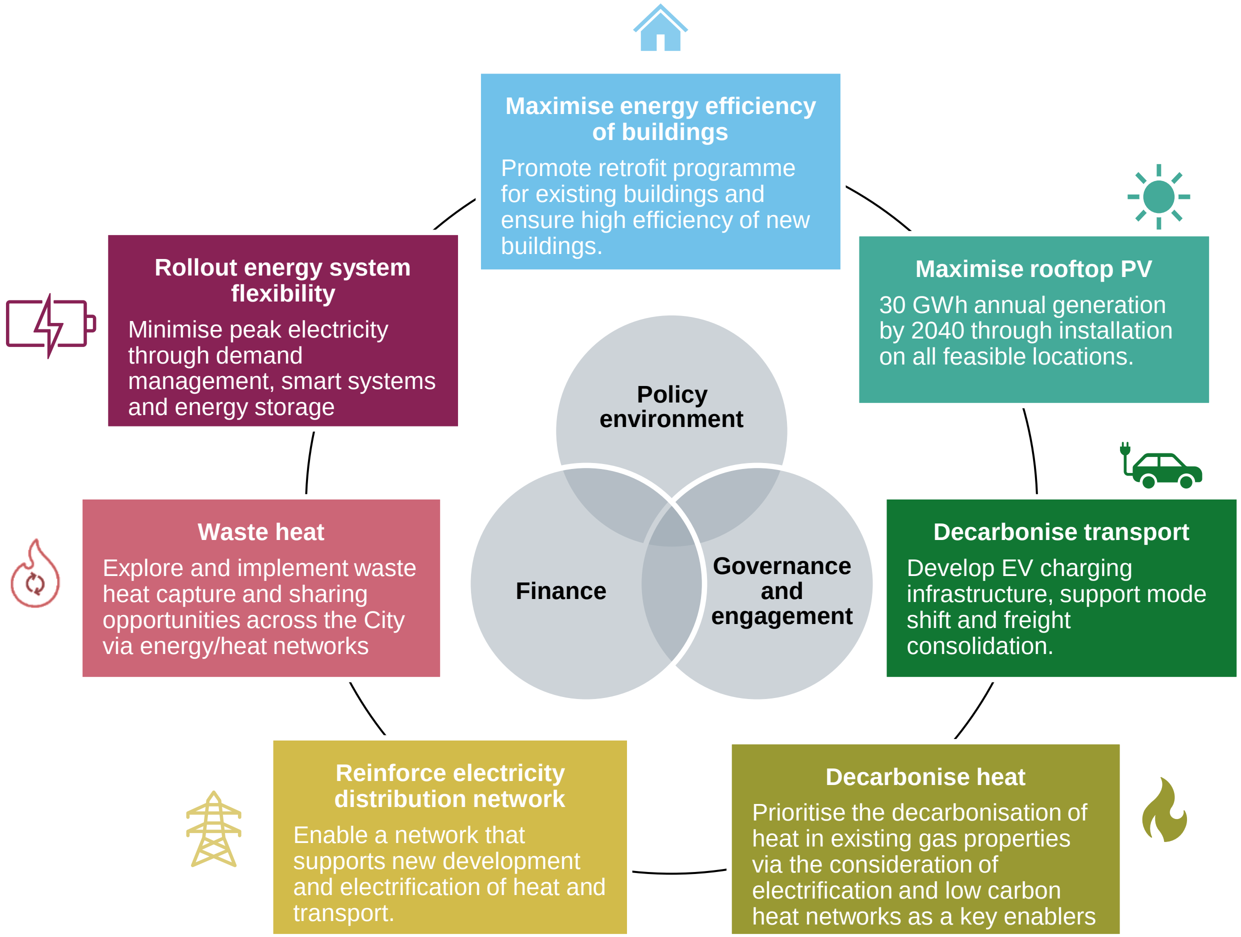

Figure 0.1: The City of London LAEP priority intervention areas.

Executive summary

Emissions pathways

An examination of the current energy consumption and associated emissions across the City has produced the definition of an energy baseline, from which this study builds upon. Future energy demands have then been projected out to 2040 accounting for the development of new buildings, retrofit of existing buildings and future transport projections and associated decarbonisation. Variations in these inputs were combined with energy system components to test future energy scenarios and pathways:

- **High Energy Demand -** tests the potential maximum system demand and resulting electricity grid capacity/upgrades.
- **Low Energy Demand -** tests the synergies of both centralised (heat networks) and decentralised (building-level) heat pump deployment.
- **Green Growth -** tests an 'ideal' low carbon future demand scenario regarding new development and efficient energy consumption reduction via considerable retrofit of the existing building stock. Within green growth, three pathways are analysed:
  - Individual building – decentralised electrification of heat on a building-by-building basis
  - Heat Network – maximum heat network deployment
  - Hydrogen – conversion of the current gas grid to low carbon hydrogen

Figure 0.2 displays this series of future pathways that demonstrate how the City's carbon emissions could change between now and 2040. The business as usual curve shows the current trajectory, whilst the green growth curves reduce emissions through deeper building energy efficiency improvement, and deeper electrification, hydrogen or heat network rollout, representing the scale of the opportunity to reduce carbon. The 2040 carbon emissions for the 5 optimised scenario pathways can be seen in further detail in table 0.1 overleaf.

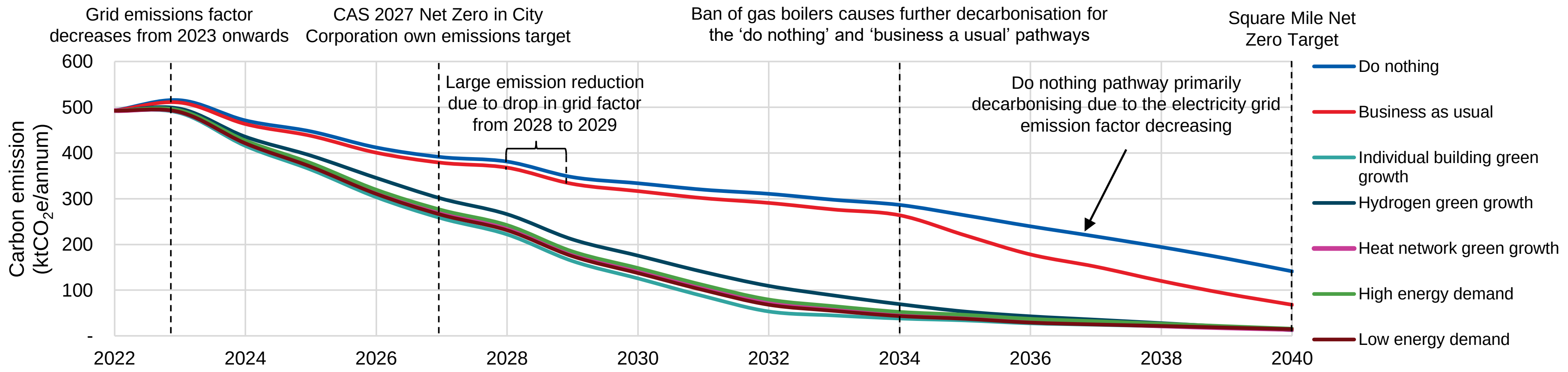

Figure 0.2: The City of London projected annual carbon emissions based of energy transition pathways.

Executive summary

Recommended pathway

Figure 0.3 displays the modelled cumulative emissions of each pathway from 2022 to both 2027 and 2040. This indicates that the lowest cumulative carbon emissions are associated with the individual building green growth pathway. The low energy demand scenario is associated with a lower level of building development and hence is not reflective of the City Corporation's ambition regarding growth – it is therefore not included within the recommend future pathway.

In addition to the analysis undertaken for energy, carbon and infrastructure of the future energy system a **multi-criteria assessment** has been used to identify and compare other criteria that are important to the City and the City Corporation. This resulted in a **recommended pathway** which is a blend of the heat network and individual building green growth pathways. Hydrogen was discounted due to the lack of credible plans to supply hydrogen into the City within the timeframes required.

It is expected that the level of heat network deployment will be driven by up-coming Heat Network Zoning policy, currently under development by DESNZ. The City is already participating in the Advanced Zoning Pilot.

Where buildings are not mandated to connect, it is recommended that individual heat pumps are used to decarbonise heat. Office buildings should also participate in wider City heat networks where possible as heat suppliers, sharing rejected thermal energy from their cooling systems.

Due to the quantum of office buildings present, there may also be opportunities for the area to become a net heat exporter, where heat rejected is supplied into surrounding areas like Islington, where residential heat demands are higher.

Table 0.1: Final annual 2040 emissions for 5 optimised pathways.

Pathway	2040 emissions (ktCO2e)
High energy demand	16.02
Low energy demand	14.64
Individual building green growth	14.15
Heat network green growth	14.01
Hydrogen green growth	12.64

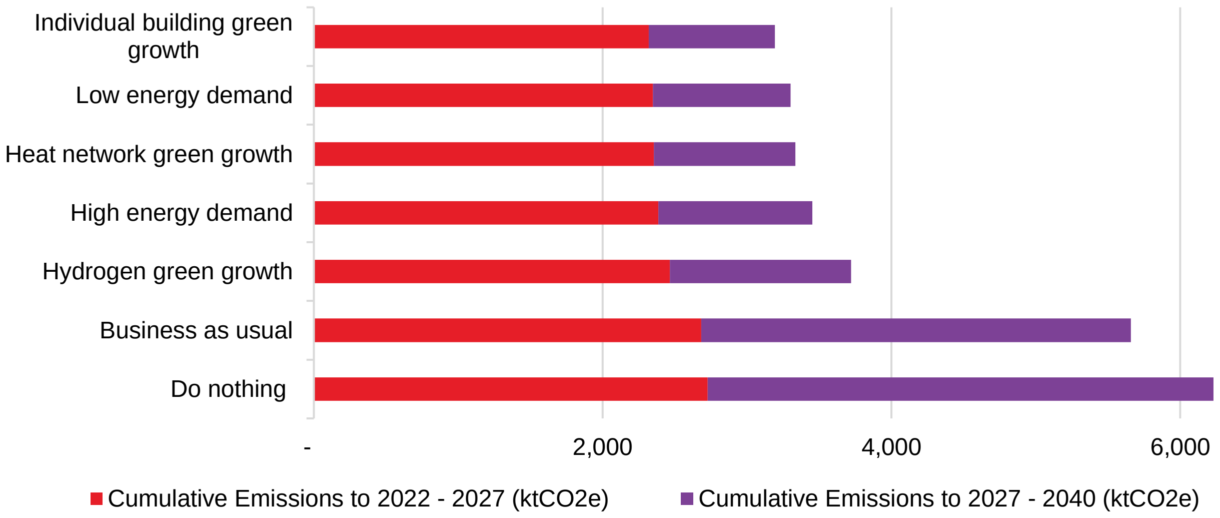

Figure 0.3: Cumulative emissions for the energy system pathways.

Executive summary

Actions, governance, monitoring and review

A significant aspect of developing this plan was undertaken through engaging with the following local and wider energy system stakeholders:

- City of London Corporation departments such as climate, energy, transport and planning.
- Utilities and ESCos: UKPN, Cadent, E.On
- The four City of London Business Improvement Districts
- The City Property Association
- Other energy stakeholders like Ofgem and TfL

This engagement process has been utilised to both collate and verify data used within the modelling, and enable the development of actions for both the City Corporation and wider stakeholders, which accompany the recommended pathway.

Meeting the Green Growth trajectories is highly dependent on a number of factors outside of the City Corporation's control, or at least heavily reliant on action from others, such as delivering significant energy efficiency improvements in commercial buildings, grid reinforcement at scale, heat network deployment, maximising solar generation and capturing waste heat. The City Corporation will play a key role in enabling and influencing others to ensure this plan and the recommended actions are undertaken.

This LAEP and it's implementation is to be governed under the Square Mile workstream of the Climate Action Strategy, within which two new management posts are proposed:

- Project & Partnerships – additional resource to support the delivery of the LAEP
- Investment & Delivery – role to aid in the development of financing and delivery mechanism for LAEP-related actions

These posts represent the initial steps towards creating a Net Zero Delivery Unit (NZDU), a defined group responsible for facilitating the LAEP implementation. The NZDU should set up and facilitate a City of London LAEP Steering Group, that includes third parties like the BIDs, CPA, utilities like UKPN and E.ON, and major land owners .

To support the delivery of the actions defined within this LAEP the following additional initiatives are recommended:

1. **Establishment of a London LAEP committee.** To include key parties from the wider stakeholder group including the NZDU, equivalent groups from neighbouring boroughs, representatives from the GLA, TfL, UKPN and Cadent.
2. **Sustainable City Charter.** A business-led group to support the decarbonisation of commercial buildings.
3. **Procurement of a strategic energy partner.** To unlock opportunities regarding the scaling and implementation of some of the actions.

Monitoring and review

The City Corporation should identify a set of indicators against which to measure progress in meeting the LAEP objectives, summarising these in an Annual Monitoring Report. This should include establishing specific indicators and monitoring frameworks to measure progress towards objectives, such as monitoring building decarbonisation / retrofit, or the rollout of flexibility in the City. This would provide supporting evidence of progress alongside policy specific indicators to understand how the measures are supporting the City Corporation's climate change targets.

Progress and actions should be reviewed and revised on a 3- to 5-yearly basis. This process should also ensure that additional information and studies undertaken in neighbouring boroughs are considered and integrated into future plans as cross-LAEP collaboration will help to accelerate shared goals of areas and authorities.

1. Introduction
Overview

Introduction and 'What is a LAEP?'

The City of London occupies a roughly one square mile area within the heart of Greater London, as shown in Figure 1.1. It is governed by the City of London Corporation, which is responsible for providing local government services within the area and beyond its borders through private, public and voluntary sector responsibilities. In 2020, the City Corporation committed to reaching net zero carbon emissions within its own operations by 2027, and net zero emissions within the Square Mile (i.e. the area of the City) and the City Corporation's supply chain by 2040, as part of its Climate Action Strategy[1].

The Square Mile is a historic centre, as well as a key financial and commercial district within the UK and globally. It is the home to over 8,000 residents, has over 500,000 people commuting to work there daily and over 10 million annual visitors[2], making it a unique area with specific challenges in reaching Net Zero.

To help set the actions to meet the 2040 net zero target, the City Corporation commissioned Arup to produce a Local Area Energy Plan (LAEP). The LAEP outlines a targeted action plan for the decarbonisation of the whole energy system, whilst accounting for external factors like policy and climate changes, expected development within the area, and an anticipated shift in how people move around.

What is a LAEP?

A LAEP is a plan which takes account of the whole energy system in a local area, accounting for the needs of the area and its multitude of stakeholders, underpinned by rigorous and data-led technical analysis. The LAEP process results in action recommendations for multiple actors, including local and national government, energy and utility providers, regulators, commercial tenants and residents.

The whole energy system approach includes the consideration of heat, cooling, electricity, transport, buildings, energy system flexibility, storage and generation. The plan sets out a vision for a zero-carbon energy system to decarbonise an area cost effectively, and the associated infrastructure, policy and programmes which will be needed to realise this plan. The route map outlines short, medium and long term actions for the local area, developed through a credible approach to engagement, governance and delivery.

Throughout this report, the City of London area is referred to as the City or the Square Mile, and the City of London Corporation is referred to as the City Corporation.

Figure 1.1: The City of London (red) within Greater London.

1. Introduction
Context

Socio-economic context of City of London

The City Corporation's history

The City is the oldest and most historic part of London, and today stands as the leading international financial and business centre. The City Corporation's administration and governance is unique among local government units: it is headed by the Lord Mayor of London; the Court of Common Council is the main decision-making body and it has an independent police force. It holds an independent and non-party political voice and convening power which enables it to promote the interests of people and organisations across London.

The role of the City Corporation goes beyond that of a normal local authority and extends past the boundaries of the Square Mile to support a diverse and sustainable London, within a globally successful UK. The City Corporation also holds responsibilities across the private, public and voluntary sectors. This includes:

- More than 11,000 acres of green spaces, including Hampstead Heath and Epping Forest
- Billingsgate, Smithfield and New Spitalfields wholesale food markets
- The Heathrow Animal Reception Centre
- Housing across London
- A range of schools and academies
- London's Port Health Authority

Demographic Baseline

Population: The population of the City in 2021 was ~8,600 residents, growing 12.5% from the previous year. The population density is ~3,000 people per km^2, which is below the London average of 5,600 people per km^2. The City's low population density is largely due to the fact that there are almost 60 times more daily commuters than residents, which results in a relatively low volume of domestic properties compared to non-domestic. The city also welcomes 10 million annual visitors.

Deprivation: Based on the 2019 Indices of Multiple Deprivation (IMD), a measure of the relative deprivation of an area, the City is a relatively affluent area – it ranks within the top 40% least deprived local authorities in England and is the sixth least deprived in Greater London[3]. None of the City's Lower Super Output Areas are considered to be in the 20% of the most deprived in England. Less than 5% of households are in fuel poverty[4].

Housing: 10% of the buildings with the City are domestic, mainly apartments. The main residential estate in the Barbican was developed between 1965 and 1976. Two thirds of the buildings were built in the 1970s and 1980s, as the city developed its iconic skyscraper office buildings and rebuilt following World War II.

1. Introduction
Context

City of London policy context

The City Corporation's Climate Action Strategy (CAS) was released in 2020[1]. It sets out how the City Corporation will reach its net zero targets whilst building resilience and championing sustainable growth up to 2040. Within the CAS the City Corporation commits to:

- Achieve net zero carbon emissions for its own operations by 2027
- Achieve net zero carbon emissions across its investments and supply chain by 2040
- Support achieving net zero for the Square Mile by 2040
- Invest £68 million over 2020-2026 to support these goals

Some of the actions for the City Corporation identified to support the CAS included transforming the energy efficiency of buildings through the best available technologies, maximising the use of renewable energy sources and educating the workforce on net zero. For the Square Mile, this involved developing a Climate Action Fund and a Square Mile renewable energy strategy.

City of London Transport Strategy was published in 2019 by the City Corporation and sets out proposals to decarbonise the City's streets[5]. One proposal is to ensure that 90% of motor vehicles entering the Square Mile are zero emission capable by 2030, through the introduction of Zero Emission Zones and the installation of additional Electric Vehicle (EV) rapid charge points. The City Corporation will also request that within the City all buses are hydrogen or electric by 2030 and encourage businesses to use non-motor vehicle alternatives, such as cargo bikes, through preferential pricing. City Corporation vehicles and those of contractors will also be required to be a zero emission fleet.

EV charging was explored within the report 'EV Infrastructure Forecasts 2025' by the Energy Saving Trust and later by the City Corporation in 2020[6]. The research report gave recommendations on installing 26 rapid chargers and 65 standard chargers by 2025 to support the Square Mile reaching its zero emission transport goals.

Within the decarbonisation of housing, the Housing Net Zero Action Plan in 2021 by the City Corporation and Etude describes the actions needed to achieve the City's 2027 and 2040 net zero emission targets for housing[7]. This includes stopping the use of gas in the City Corporation's housing stock, installing hot water storage, roof insulation and as much roof PV as possible by 2026, with location priorities given for each action. Similar actions were identified for the rest of the housing in the Square Mile, with an aim of completing retrofit by 2032. The plan was released alongside the Retrofit London Housing Action Plan which looks widely at London boroughs[8] .

1. Introduction
Context

Greater London Policy Context

Greater London is governed by the Mayor of London and the Greater London Authority (GLA). As the City of London sits within Greater London, it is additionally under the influence of wider London policy as well as governance from the City Corporation.

Within Greater London, the London Plan sets out the framework for the future development of London[9]. The plan, published by the GLA in 2021, includes significant actions and targets focused on addressing the climate emergency. Some key outputs of the plan include:

- The development of an energy hierarchy that prioritises reducing use and increasing efficiency before relying on renewables and offsetting, as shown in Figure 1.2.
    - The ‘Be clean’ aspect focusses on heating infrastructure and the requirement to exploit local energy resources. Heat networks are identified to as a key heating solution that enables the use of secondary or waste heat and therefore are a prioritised within the design and development of buildings.
- The strategic target of 80% of all trips in London to be made by foot, cycling or public transport by 2041.
- The action to identify Heat Network Priority Areas within which new developments must be able to facilitate a future connection to a heat network.

The GLA also published a London Solar Action Plan in 2018 that sets the target of 1GW of installed solar capacity in London by 2030 and 2GW by 2050[10].

Element Energy authored Analysis of a Net Zero 2030 Target for Greater London, a report on pathways for London to reach net zero by 2030, in January 2022[11]. The report includes:

- Targets for a 37% reduction in heat demand of domestic buildings and a 39% reduction in non-domestic buildings by 2030 compared to 2020,
- The suggested policy of the retrofit of 26,500 buildings a year and financial incentives.
- The aim that these actions will lead to reaching a target of 60% of domestic heat demand being met by low carbon systems by 2030.
- Within transport, a target for a 27% reduction in car travel by 2030.

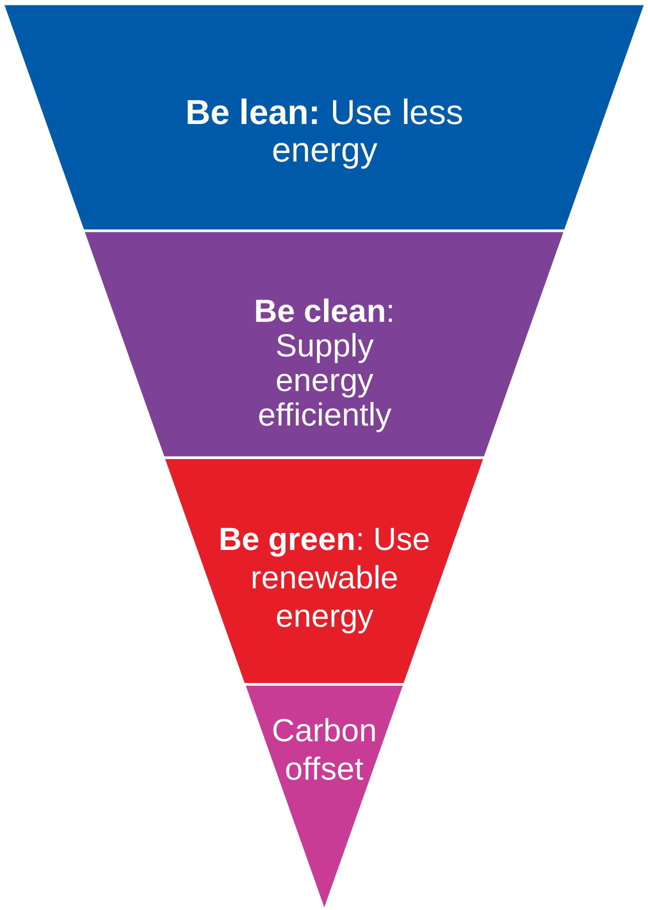

Figure 1.2: The London Plan energy hierarchy (Source: Greater London Authority).

1. Introduction
Context

National Policy Context

The UK government has published key strategies to reduce carbon emissions since it pledged in 2019 to net zero carbon by 2050, as an update to the Climate Change Act. This also involved the creation of the UK Committee on Climate Change (CCC). The main policies and strategies that come out of this have been considered in the preparation of this LAEP where relevant and are detailed below.

The Net Zero Strategy[12], released in October 2021, details policies and spending to meet the net zero pledge. The report sets the target of fully decarbonising the UK power system by 2035 which is expected to involve using new flexible storage methods. Within the heat and buildings sector, the sale of new gas boilers will be banned by 2035 and the government will push for the installation of low carbon heating. By 2037, there is a target to reduce the emissions of public sector buildings by 75%. Within the transport sector the main policy update was the ban of petrol and diesel cars after 2030 and the pledge that all vehicles are zero emission capable by 2035 as well as funding allocated to support this.

The UK Heat and Buildings Strategy[13] was also published in October 2021 which outlines the strategy for the decarbonisation of the country's domestic, public, industrial and commercial buildings. It describes decarbonising heat through electrification or using hydrogen gas, as well as the importance of energy efficiency and flexibility of buildings. A government decision on the use of hydrogen for domestic applications was deferred until 2026.

Decarbonising Transport[14], published in July 2021, outlines the plan to decarbonise the UK's entire transport system. The strategy includes actions to facilitate the development of the charging infrastructure that will be needed to support the electrification of transport, with the commitment that public transport is zero-emission by 2050. The strategy also plans to promote active transport, especially in urban areas where there is a target that 50% of journeys are met by cycling or walking by 2030.

The Energy Security Bill was introduced to Parliament on 6 July 2022. There is also a focus on accelerating the growth of low carbon technologies including:

- Introducing a regulatory framework for heat networks and powers to enable heat network zoning in England
- Scaling up heat pump manufacture
- Incentivising the use of low carbon fuels in transport
- Enabling the delivery of a large village scale hydrogen heating trial by 2025.

The UK Hydrogen Strategy, published in 2021, announces the decision on hydrogen used for heating in 2026 alongside targets for use within transport and industry and production targets for blue and green hydrogen. Blue hydrogen is produced using steam methane reformation with carbon capture and storage technology to ensure it remains a low carbon gas. Green hydrogen is produced using electrolysis powered by renewably generated electricity. The minimum carbon emissions at production for each class of hydrogen for the fuel to be classed as low carbon are outlined in the Low Carbon Hydrogen Standard.

Figure 1.3: National Policy Documents.

1. Introduction
Methodology overview

Stakeholder engagement

We engaged with stakeholders across the City Corporation's various teams as well as the Business Improvements Districts, the City Property Association and other organisations across the energy sector to gather relevant data and establish plans, objectives and priorities. This engagement was ongoing throughout the project to allow it to inform and influence at all key stages as the plan developed.

Relevant stakeholders were identified jointly with the City Corporation and the project team. These stakeholders were engaged with to enable a better understanding of their current roles and responsibilities; existing decarbonisation targets and their objectives regarding the development of the LAEP. Specific stakeholders provided data regarding energy demand or supply and associated energy infrastructure.

To define priorities, various stakeholder engagement sessions were undertaken throughout the project. These ranged from one-on-one sessions aimed at gathering information and understanding future plans, to collaborative workshops where wider discussions were held to identify common constraints and collaboration opportunities, and to review develop potential actions.

Notable engagement sessions include:

Assumptions Workshop – Held with wider City Corporation stakeholders, with representatives from Planning, Transport and Energy teams to discuss and finalise the assumptions implemented within the modelling aspects of this work.

City Properties Association (CPA) Workshop – CPA members were introduced to the LAEP, discussion was held on specific net zero plans and perspectives, and how the LAEP can be developed to reflect their ambitions and level of influence.

Business Improvements District (BIDs) Strategic Partnership Meeting - Introduction of the LAEP to the BIDs and other City Corporation members, and discussion around how its implementation can be supported and facilitated by these groups.

Delivery Action Workshop – Stakeholders from across a variety of bodies and companies came to Guildhall to brainstorm and discuss the possible LAEP actions, how they can be delivered and who they might be assigned to.

Throughout the project, biweekly, wider update calls were used to inform the City Corporation project team on progress, as well as to help track concurrent workstreams that may affect or overlap with the LAEP outputs.

The following slide provides an overview of the specific stakeholders that were identified alongside a brief description of their main action areas specifically regarding the City and this LAEP.

1. Introduction
Methodology overview

Stakeholder engagement

The following stakeholders were identified as key actors associated with the City and this LAEP, and hence will be vital in the successful delivery of the actions defined.

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Stakeholder	Role	Action areas
Department for Energy Security & Net Zero	Department for Energy Security and Net Zero	DESNZ plays a role across all action areas
Engaged for LAEP ✓ Cadent – Your Gas Network	Gas network operator	Heat decarbonisation Transport decarbonisation
Engaged for LAEP ✓ UK Power Networks	Power distribution network operator	Electricity network Flexibility Heat / transport decarb
Engaged for LAEP ✓ ofgem	Government regulator for energy markets	Electricity network Flexibility Heat/transport decarb
Engaged for LAEP ✓ City of London	Planning policy, Climate Action Strategy, Transport etc	LAEP delivery Planning policy Funding
Engaged for LAEP ✓ Business Improvement Districts	Place shaping Representing local business ambitions	Funding / investment
Engaged for LAEP ✓ e·on	Operator of Citigen heat network	Heat decarbonisation
Engaged for LAEP ✓ Greater London Authority	Greater London's governance body; powers over planning	The GLA plays a role across all action areas
Engaged for LAEP ✓ Transport for London	Transport operator	Transport decarb Waste heat offtake Building energy efficiency
Engaged for LAEP ✓ CPA City Property Association	Represents building owners/operators	Retrofit and energy efficiency Flexibility

Figure 1.4: Key stakeholders identified throughout the LAEP process.

1. Introduction
Methodology overview

Technical approach

The technical approach taken has involved the following steps across the heating, cooling, power and transport aspects of the energy system:

1. Data collection and transformation
2. Energy system baselining, including existing infrastructure and demands
3. Future energy demands assessment including the effects of future development, building retrofit and changes to the way people move around
4. Scenarios modelling to look at how future demand could be met by various low carbon technologies
5. Pathway modelling to show what would need to be done to achieve targets

This analysis and the stakeholder engagement enabled development of a list of priority interventions and actions for the area. The interventions were developed in a delivery action roadmap, detailing the short-, medium- and long-term actions which the City Corporation can focus on. This roadmap also shows how other stakeholders may own actions or can inform and support the transition.

A summary of the demand and supply analysis is shown in Table 1.1, and a detailed description of the methodology used can be found in Appendix A.

Table 1.1: List of modelled sectors and the associated analysis undertaken as part of this project.

Modelled Sector	Demand analysis	Supply analysis
Heating	Individual building level modelling of heat demand and consumption, including consideration of building fabric, building retrofit potential and the impact that future climate change and new development may have on heat demand.	Existing gas infrastructure, electrification of heating, hydrogen for heating and the opportunity for heat networks – both through expansion of the existing Citigen heat network and development of new networks. The heat network analysis considered a review and mapping of potential waste heat sources. Contribution of thermal energy storage
Electricity	Individual building level modelling of electricity demand and consumption. Future demand analysis includes consideration of electrification of heat and the effects of retrofitting energy efficiency measures and climate change. Consideration of electricity flexibility technologies and their impact on demand peak reduction.	A review of the system's current primary substation capacities and their interconnection, to understand the impact of energy demand changes and any upgrades which could be needed. Renewable power generation potential, e.g. rooftop solar Contribution of battery storage technologies
Cooling	Individual building level modelling of cooling demand and consumption. Future scenarios included consideration of the impact of the future climate on cooling.	How heat rejected from cooling plant could be used as a means of supplying heat
Transport	Current transport related energy demands and how this will change in future when accounting for mode shift, and a reduction in freight and heavy goods vehicles in line with the City Corporation's ambitions to reduce traffic.	Electrification of vehicles and the future requirement for EV charging stations, as well as how charging infrastructure can contribute to electricity system flexibility via vehicle to grid or smart charging technologies.

1. Introduction
Methodology overview

Modelling Zones

The City of London comprises 25 geographical wards and has seven ‘Key Areas of Change’ (KAOC) identified within the Draft City Plan 2040[15]. These KAOC have been identified due to the significant change they will experience in the coming years as the Plan is implemented and as areas with potential for opportunities that may require specific thought and policy focus.

For the purposes of the Local Area Energy Plan modelling, the area was split into 11 zones based on the Primary substation feeding areas covered by the UKPN (the District Network Operator within the area) electricity substations. This helped reflect the impacts decarbonisation actions could have on the power system. The results and recommendations for each zone include relative influence from their overlap with the KAOCs, and represent an overlap of multiple wards.

Two additional substations zones lie on the border of the City of London and are shared by its neighbouring boroughs. As the majority of the area of these substations lie outside of the City of London they have not been included in the analysis. Their areas within the City have instead been included in the calculations for the next nearest substation. Information on the zone names, substations and grid supply points is detailed within Appendix B.

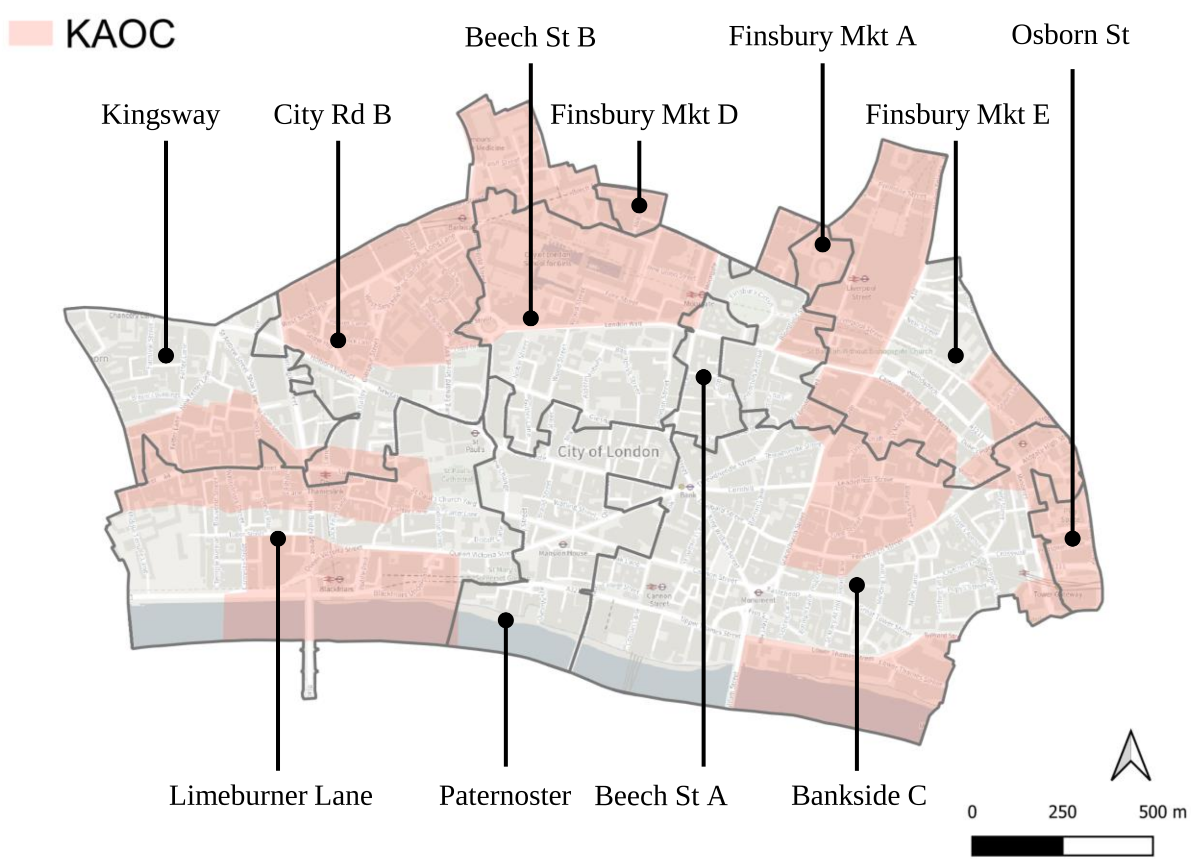

Figure 1.5: 11 modelled zones across the City.

1. Introduction
Methodology overview

Digital practices

Data collection

In order to build an understanding of the current energy system within the City, baseline data was collected from a range of sources. These helped to inform the input dataset for the subsequent system modelling. Most notably this process included gathering information from:

- City Corporation – buildings portfolio metered data, previous studies, plans, targets
- UKPN
- OS Mastermap
- Energy Performance of Buildings Register
- E.ON/Citigen
- Cadent

Data cleaning and processing

Information and data received relating to the City's energy system including building demand data; energy generation/supply technologies; existing and planned infrastructure; and physical constraints were checked, cleaned to remove irrelevant or incorrect data points and processed to a centralised filing structure.

Assumptions

To develop an understanding of the future energy demands of the City, a number of assumptions were applied to the raw data, such as future demand benchmarks per building typology, growth projections and future climate projections (using a future weather file – CIBSE London_TRY_2050Medium50).

A workshop was held with colleagues from the City Corporation to discuss assumptions that were to be incorporated within the model. This included choice of assumptions, their origin and how they were being used.

Transformation

Once the data had been pre-processed at the most granular level available (e.g. building by building level), it was structured and aggregated to a series of zonal scale datasets for model ingestion. Proceeding the transformation process included a Quality Assurance (QA) process to identify and mitigate the propagation of errors through the modelling stages.

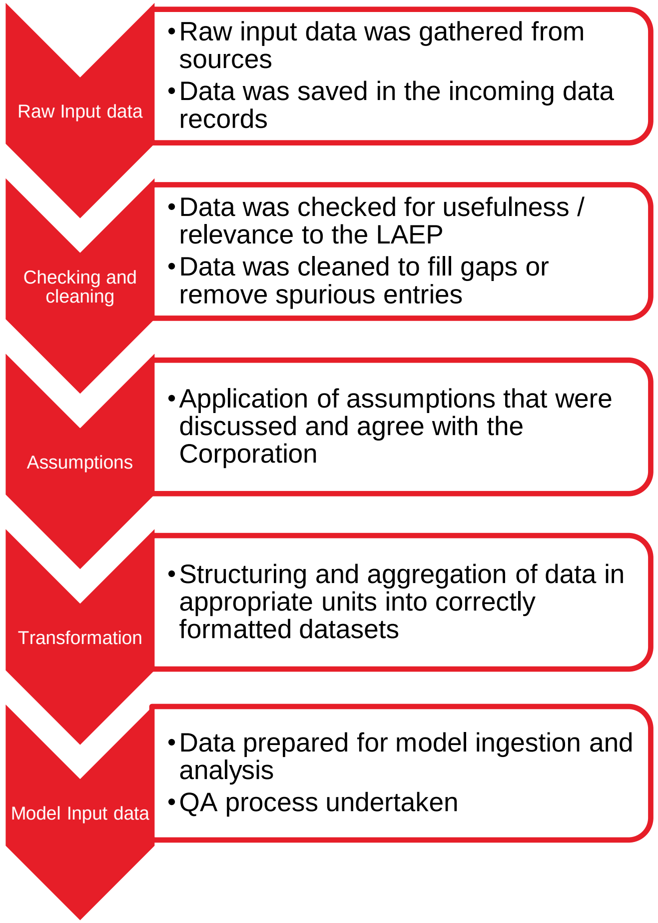

Figure 1.6: Data transformation process.

1. Introduction
City of London Local Area Energy Plan report structure

Plan contents and structure

This LAEP presents a potential vision for a net zero local energy system in the City of London, with a route map to getting there, including a set of actions for the City Corporation, recognising the role of other key actors in government, the energy sector and across the Square Mile.

This plan is structured into the sections shown in Figure 1.7. This follows the methodology of work, starting with identification and understanding of the current energy systems across the City; developing what the future system could look like; the resultant energy pathway; and the route map and actions required to get there.

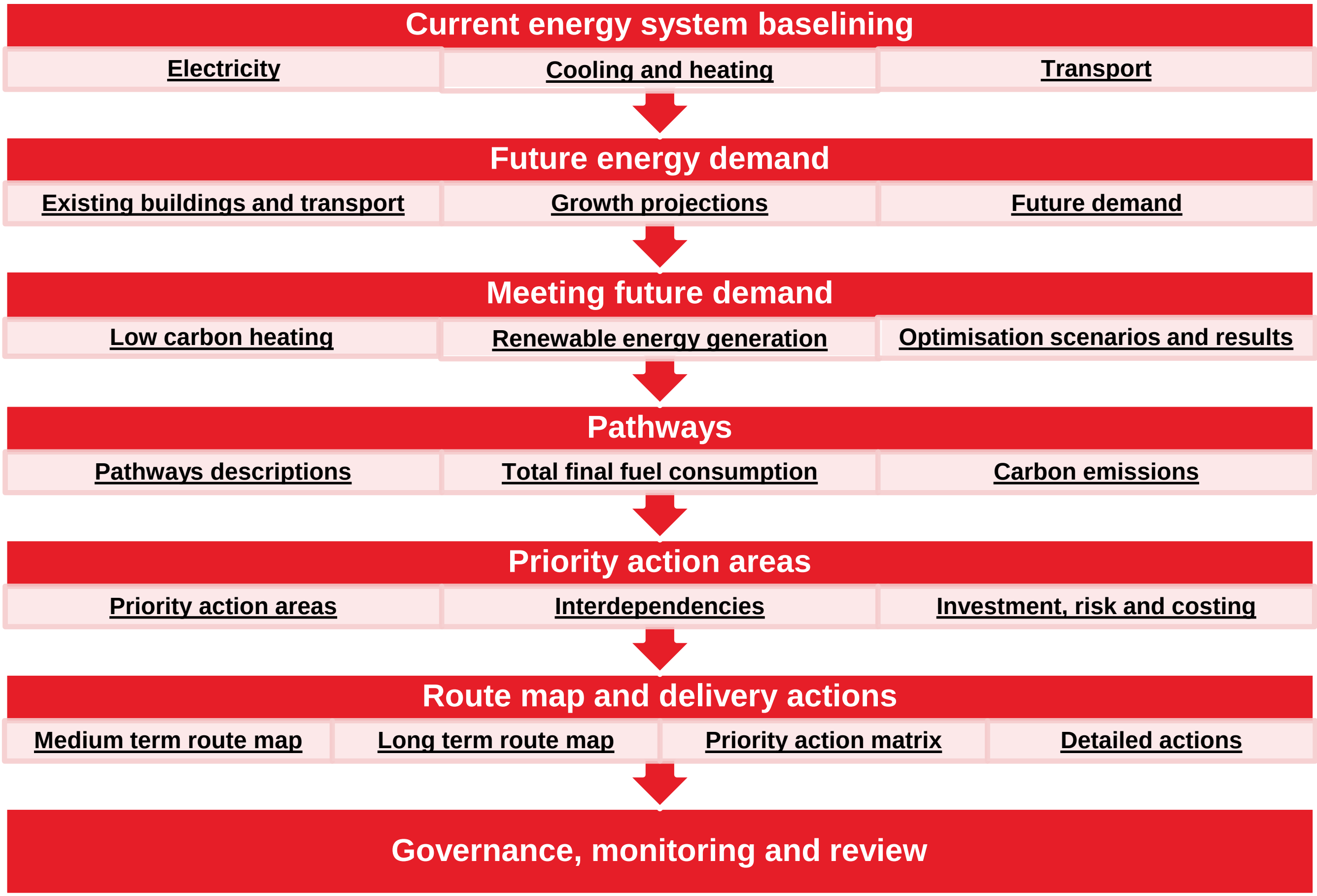

Figure 1.7: LAEP report structure.

2. Current energy system baselining
Introduction

Section overview

This section of the report details our findings in relation to baselining the current energy system, i.e. the existing demand for energy in the City and the infrastructure there to serve it. It is split into the following sections:

- Electricity
- Energy Networks
- Heat
- Transport

Within each of the four sections, the existing infrastructure is described, as well as the existing demand for that energy vector/system.

Cooling demands of buildings are captured within the electricity sections, as that thermal energy demand is typically derived electrically (with the exception of absorption chillers that use heat to generate cooling). The heating and cooling loads provided by Citigen are included on page 22.

In order to estimate the current heat and electricity consumption of buildings in the City, we used data on individual building floor space, use typology and, where possible, building fabric to model the annual consumption. Where available, we collected actual building data from key stakeholders and used this in preference to modelled values. Industry recognised benchmarks have been applied to model the demands and the usage profiles over a typical year and on an hourly basis, based on the current climate.

Figure 2.1: St Paul's Cathedral located on Ludgate Hill within the City.

2. Current energy system baselining
Electricity

Electricity infrastructure

Network infrastructure

The City of London electricity distribution network is operated by UK Power Networks (UKPN) to deliver electricity to users in the area. The majority of the area is supplied by a single Grid Supply Point (GSP), City Road, which connects nine primary substations. However, the City also overlaps slightly with the GSP area of St Johns Wood to the north (supplying three primary substations) and New Cross 132kV to the east (supplying one primary substation). Two of the total 13 City primary substations are within the City's geographical boundary but supply ~1% of the feeding area and therefore were recommended by UKPN to be excluded from the study. The extended areas of the substation zones within this study are shown in Figure 2.2.

UKPN produces a Long Term Development Statement[17] which provides the latest view on available headroom across the network, recognising that these values are variable and not constrained by administrative boundaries, unlike the study. Multiple projects have occurred within the City of London recently to increase the available capacity to support the anticipated development and demand increase in future.

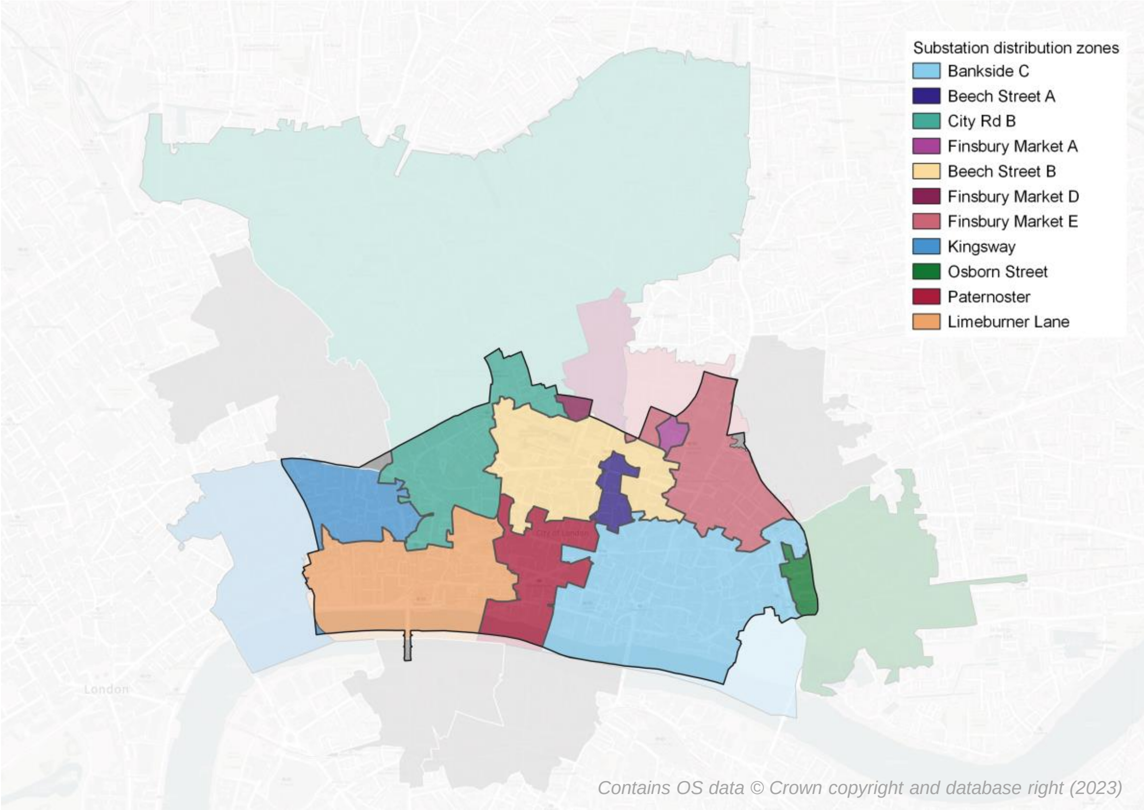

Figure 2.2: Map of substation zones and interface with City boundary.

2. Current energy system baselining
Electricity

Electricity infrastructure and key loads

33kV ring

In addition to the 11kV network of substations, there is a 33kV distribution network in the form of a ring. This was developed due to the increasing demand density and need for supply higher than 11kV. The ring is connected to the transmission network through the City Road and St Johns Wood GSPs. The ring supplies two primary substations in the City of London area (Back Hill B and Finsbury Market F) to provide increased resiliency between the two, by enabling them to share their firm capacity.

Future focus areas

UKPN recognises the extent of future growth and pressure on the network which will come with decarbonisation. Recently they designated a dedicated team to support Local Area Energy Plans, as they are recognised to be a key part of transitioning to a net zero energy system, and give UKPN the evidence they need to secure agreement from Ofgem for reinforcement. Areas of focus include EVs (increasing charging capacity, building new charge points and improved forecasting to predict pinch points); electrification of heat; and an increase in solar PV generation. The UKPN net zero team can be contacted at 'Your Local Net Zero Hub'.

Local renewable generation

As the City is a dense urban area in central London, its renewable generation capacity is limited to rooftop solar PV. The National Statistics Regional Renewable Statistics[17], produced for DESNZ, estimated that the City has 0.8MW of installed solar PV capacity as of 2021. There is 1.1MW of solar PV capacity on Blackfriars Bridge, however this has been excluded from this analysis as all generated power is used entirely by TfL for its own power needs. There are wider GLA plans to increase rooftop solar PV across London, to 1GW installed capacity by 2030 and 2GW by 2050.

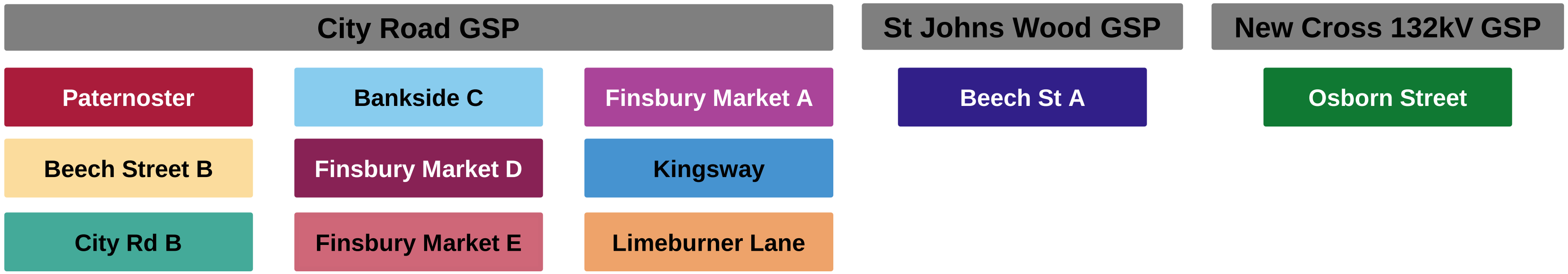

Figure 2.3: 11 modelled zones and their associated grid supply points.

2. Current energy system baselining
Electricity

Electricity and cooling consumption

Current electricity consumption

Annual building electricity consumption in the City is approximately 1,590 GWh/annum; this does not include transport or non-building energy uses such as construction machinery or street lighting. Similarly to heating, office buildings comprise the majority of the total electricity consumption (50%), followed by retail (28%), with residential consumption making up just 1%. The City's cooling consumption is 3% of the total electricity consumption, which is explored further in the subsequent cooling section on this page.

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Electricity consumption follows a similar geographical distribution to heating, with the highest energy use around Liverpool Street, see Figure 2.5. Again, this is likely to reflect the density of high rise buildings in this area.

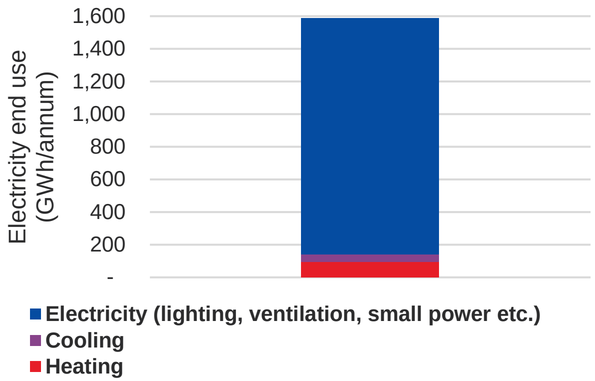

Figure 2.4: Electricity end use (GWh/annum).

Current cooling consumption

Cooling is provided to the City's buildings via refrigerant based systems. These systems utilise electricity to reject unwanted heat from within buildings to maintain internal environments for both occupants and equipment. The current requirement amounts to approximately 259 GWh/annum of cooling demand. Distribution of consumption is similar to that of electricity and heat, with the highest values around Liverpool Street as shown in Figure 2.6 which reflects the relatively higher density of office buildings. Within the City, office buildings make up ~50% of total cooling demand.

Modelling of the cooling consumption of the buildings was based on industry recognised assumptions based on the building use typology. The City has a large number of buildings with significant computer server demand due to the financial services in the area. Buildings with these systems require a higher amount of cooling. Data on the number of buildings with this demand, or their energy requirement for this cooling is limited and it was not possible to fully model it across the City. This should be considered when reviewing the cooling consumption, which is likely to be underestimated.

The waste heat rejected from cooling plant could in principle be captured and used to reduce building heating demand. This is discussed further in Section 4.

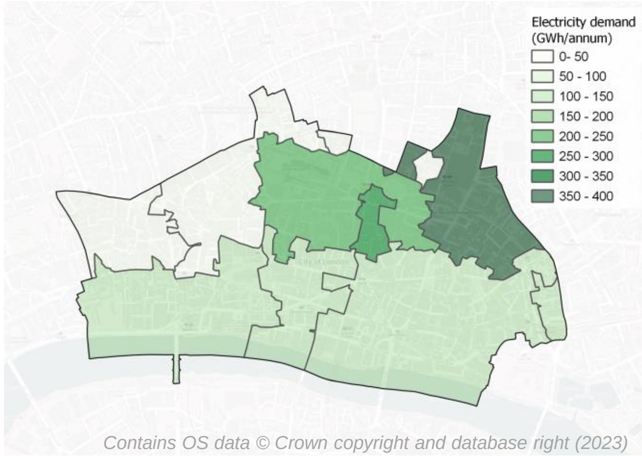

Figure 2.5: Baseline annual electricity consumption per zone.

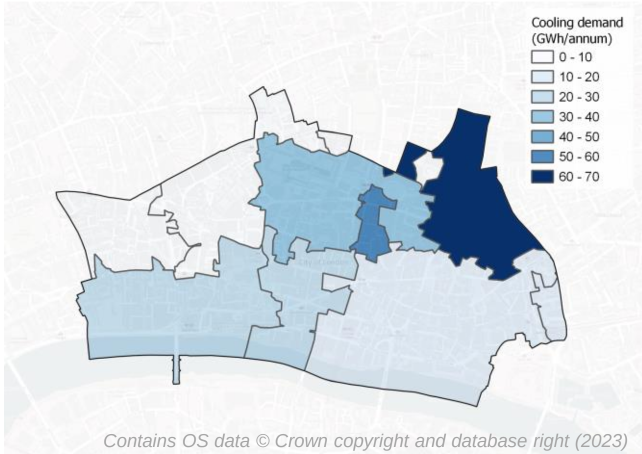

Figure 2.6: Baseline annual cooling consumption per zone.

2. Current energy system baselining
Energy networks

Network infrastructure

Existing energy networks

The City of London has one main energy network, Citigen (the ESCo), which is owned and operated as a subsidiary of E.On. The network lies in the north of the area, with the Energy Centre itself located on Charterhouse Street; which forms the Boundary between the City and in the London borough of Islington. The network was constructed in the early 1990s and the City Corporation provides some of the key anchor loads: Guildhall, the Barbican Arts Centre, Smithfield markets, Guildhall School of Music and Drama, the Museum of London and Bastian House. The network provides both heating and cooling across its 11km pipeline and has a tri-generation system which comprises a gas (Combined Heat and Power (CHP) and boilers) and electrically (Electric Chillers and Ground Source Heat Pump) based energy centre close to Smithfield. The system delivers around 40GWh of heating, 7GWh of cooling and 36GWh of electricity.

Citigen and the City Corporation have an ongoing co-operation agreement to work together to develop and expand the system. Previous expansion and decarbonisation plans have explored upgrading the existing energy centre or incorporating new low carbon heat sources like ground source heat (boreholes), the River Thames, the Underground and building waste heat recovered from cooling plant. The scheme has since installed 4MW of ground source heat pumps via three 200m deep boreholes to access aquifer water, and captures waste heat from both the CHP and the electric chiller plant to improve the generation efficiency. The heat pumps supply 9GWh of heating and 4GWh of cooling.

Further studies have been carried out to explore a Southern expansion of the scheme with integration of additional low carbon heat to connect buildings extending south of the scheme towards the river Thames such as St Pauls and the Old Bailey, and there are ambitions to run this as a low/ambient temperature network. Securing this development may rely on support through the potential future Heat Network Zoning, The City of London is currently being used as a study case for future role out of the zoning regulations, via involvement in the Advanced Zoning delivery Programme.

Figure 2.7: Citigen network energy centre plant – heat pump.

Figure 2.8: Citigen network energy centre plant above the ground source heat borehole.

2. Current energy system baselining
Heating

Heating infrastructure

Gas network and hydrogen

The City's gas network is operated by Cadent and currently serves ~ 90% of properties across the area. Figure 2.9 shows the proportion of heat demand currently met by gas, split across the 11 modelled zones. In a net zero future, the heat demand met by natural gas today will need to be met in the future through either electrification or the use of low carbon hydrogen. It should be noted that natural gas is also used within the City for cooking and non-heating loads. The heat demand not met by gas is primarily through the use of electricity currently, either with direct electric heaters or heat pumps, the remaining demand is met by biomass or oil – though this is significantly lower.

The UK Government's decision on hydrogen for heating is expected in 2026, currently there is considerable uncertainty regarding the future direction of energy policy and the exact role hydrogen will have to play. Cadent is focussed on enabling the transition from natural gas to other fuel sources as national emissions ambitions and targets develop. Cadent's primary focus is therefore on the role of hydrogen as a possible energy vector within the future energy system. Cadent has a detailed understanding of the existing infrastructure within the City and the associated transition requirements that are required to support the transition.

The Irons Mains Replacement Programme developed by Ofgem and the Health and Safety Executive has been running since 2002 and is focused on switching old aging iron gas mains with hydrogen ready piping. Within the City, Cadent has currently replaced 92% of the low-pressure network to piping that is fit to distribute natural gas, and hydrogen in the future, if it were available (there is still significant uncertainty regarding its the future availability and affordability). This helps to mitigate a significant barrier to hydrogen deployment as infrastructure works on network replacement and routing has already been completed.

Beyond gas grid conversion, the Maritime Hydrogen Highway project is a development programme looking at the feasibility of establishing a national hydrogen network with the River Thames used as a transportation route, facilitating the landing and distribution of hydrogen to inland port terminals.

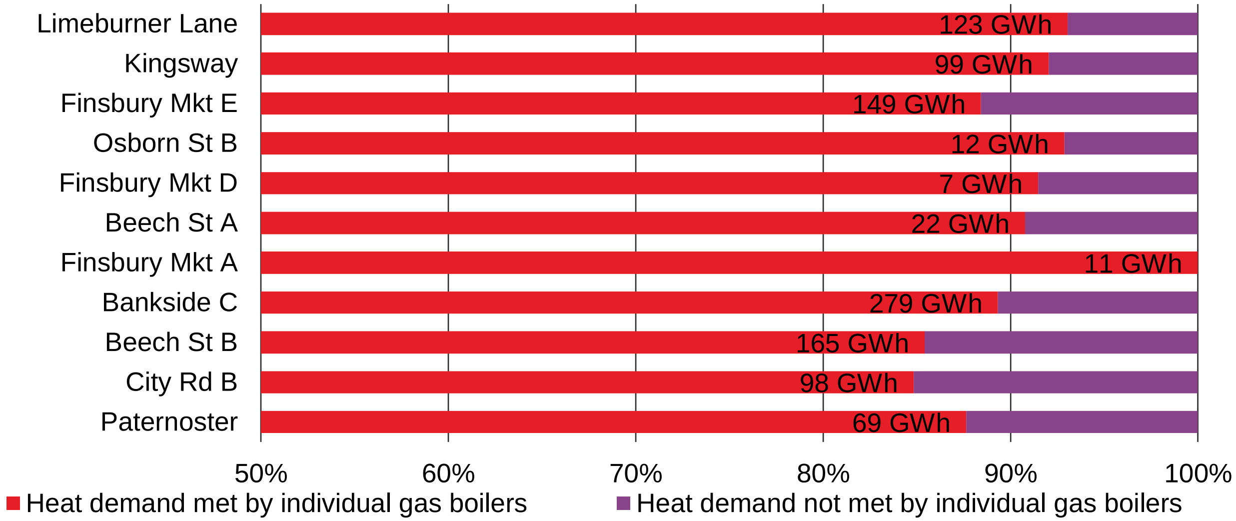

Figure 2.9: Building heat demand met by individual gas boilers vs other heat sources split by modelled zone.

2. Current energy system baselining
Heating

Baseline heat consumption

Annual heating consumption in the City is approximately 1,150 GWh/annum. This consumption represents space heating and hot water for buildings and is mainly provided through gas boilers (88%), a small amount from gas CHP through the Citigen heat network (4%), electric heating (8%) and a small contribution from oil and biomass boilers (<1%). This is shown in Figure 2.10.

A very small amount (2%) of the heating consumption is from residential properties, as the majority of the buildings in the area are commercial offices (64%) and retail (22%), the remaining 10% is from other commercial buildings.

As shown in Figure 2.11 the highest density of heat demand is in the north east of the City, around Liverpool Street station where there are a significant number of high rise buildings, particularly offices and retail. There is also a notable heat density in the central north area, around the Barbican and Guildhall.

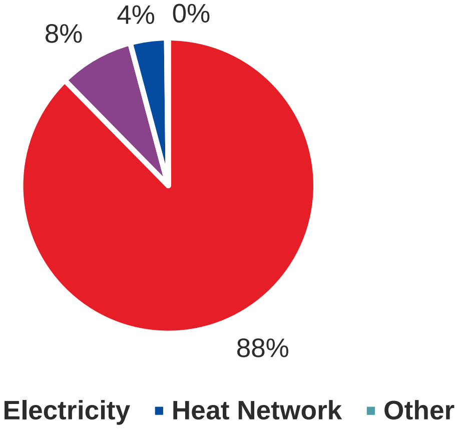

Figure 2.10: Share of heating consumption in the City by fuel source.

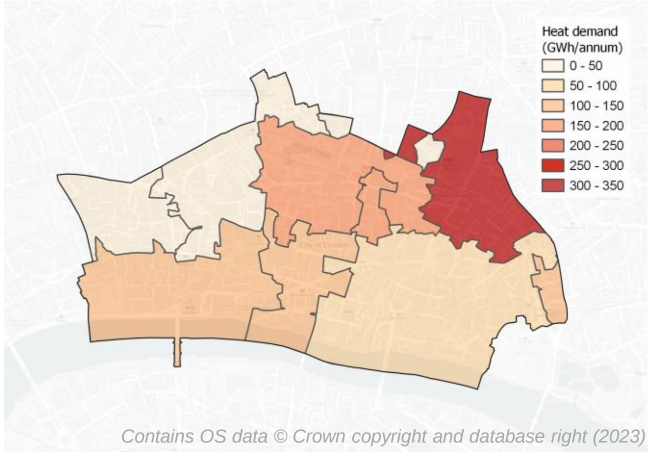

Figure 2.11: Baseline annual heat consumption per zone.

2. Current energy system baselining
Transport

Transport infrastructure

As previously mentioned in the Policy context section (page 8), the City Corporation published a transport plan in 2019[5], outlining projected development and priorities for transport in the City. This plan has served a basis from which this LAEP and the model inputs used have been based upon.

Baseline transport demand values follow the same calculation method used in the CAS[1], which is based on traffic surveys capturing the miles travelled by each subset of vehicles. This is then used to estimate the total fuel (petrol, diesel or electricity) used within the City's boundaries.

Public and active transport

TfL has rated the City to have a public transport accessibility rating of six, the highest possible score. The area hosts six mainline railway stations, 12 underground and DLR stations, a high density of bus services and the recent development of the Elizabeth Line. 93% of travel to the city is public, with a mix of 84% bus, 5% walking and 4% cycling. Cyclists make up a quarter of traffic through the area, and can increase to 50% during rush hour periods. This is partially supported by the two cycle superhighways and one quiet way which exist in the area.

The rail and bus-based transport assets contribute to a significant amount of energy consumption in the area. However, TfL has its own energy supply and distribution infrastructure for London Underground, and busses refuel outside the area. As such, energy demand linked to public transportation is not considered for this LAEP.

Road Network

The City of London is entirely covered by the London Congestion Charge Zone and Ultra Low Emission Zone. It contains several miles of TfL's Transport for London Road Network. Reduction of traffic, increase in safety and reduction of air pollution are high on the City Corporation's priorities.

Between 1999 and 2017, the level of traffic in the City has halved, with the greatest reduction from cars and taxis – likely influenced by the focus on improving public transport and cycle networks. The City Corporation have an ambition to further reduce the volume of motor traffic by 25% by 2030, with the most significant reductions across private cars and private hire vehicles and specifically freight and delivery traffic by 15%. The plan includes actions around development of charging mechanisms for road users; review of the Congestion Charge; promotion of ridesharing and reduction in empty taxis.

EV infrastructure

As of 2019, the City had 18 chargers between 3 and 50kW which are publicly accessible. There are a further 14 rapid charge sites within half a mile of the boundary of the borough, which help to support its current EV demand. The Energy Saving Trust carried out an Electric Vehicle Infrastructure Forecast study to estimate the demand for EVs and necessary charging through to 2025[6]. This recommended the roll out of 26 rapid chargers and 65 standard chargers across the area, which the City Corporation declared in its EV Action Plan in 2020.

2. Current energy system baselining
Transport

Transport demands

Based on 2019 road traffic composition data, collected as part of the London Energy and Greenhouse Gas Inventory (LEGGI)[18], approximately 122 million miles are driven by vehicles in the City per year. As shown in Figure 2.12, the majority of this mileage is from cars (59%) followed by Light Commercial Vehicles and buses which each make up 16% of mileage.

Vehicle mileage is currently split between diesel (89%), petrol (11%) and electricity (0.3%), showing that significant changes are needed to make the transition to low emission vehicles. Cars, including taxis and private taxis, are the largest consumer across all of the fuel types, as shown in Figure 2.13. LGVs and HGVs make up a significant proportion of diesel (16% and 14% of total diesel consumption respectively) despite HGVs only making up 2% of total miles travelled within the city. This is due to their intensive fuel consumption. Recent transport studies show that numbers of HGVs in the City have reduced since 2017 but this has been slightly offset by an increase in LGVs. LGVs make up 12% of energy consumption for transport which presents an opportunity for low and zero carbon freight if the required infrastructure is put in place.

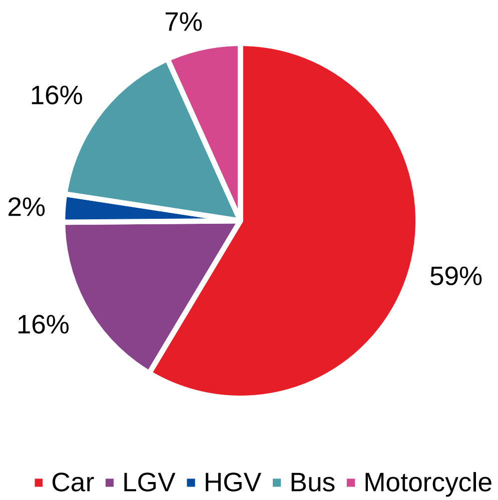

Figure 2.12: Share of road transport miles driven by vehicle type, from LEGGI data[16].

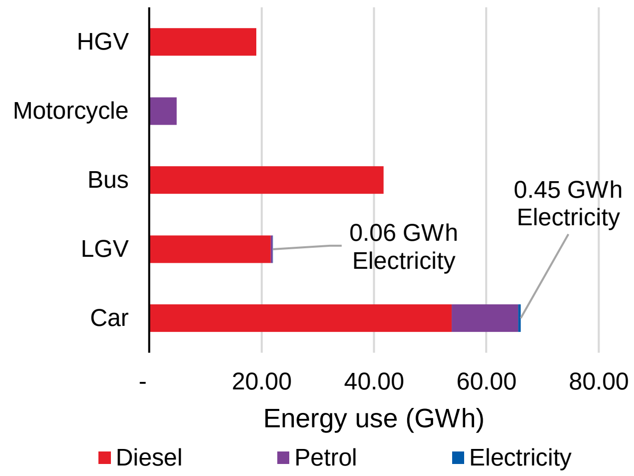

Figure 2.13: Energy use across different vehicle types.

2. Current energy system baselining
Aggregated baseline characterisation

2022 modelled energy system

The City's current energy system is mostly separated into three areas with limited overlap: electricity, heating and transport. The split between electricity and heating is relatively even, which could be attributed to the low residential density and high volume of non-domestic, office based buildings in the area. The heating is met mainly by natural gas in the form of boilers and a small amount by biomass, oil, heat pumps and direct electric heating. Figure 2.14 presents the relatively small heat and electricity contribution from the Citigen heat network, which is also largely gas powered through boilers and CHP.

The grid is relied upon for electricity, with only a small amount of distributed energy across the City in the form of rooftop solar PV. This provides the electricity demand for the buildings as well as a small amount of cooling.

Transport demands are mainly from internal combustion engines relying on fossil fuel (petrol/diesel as a primary energy source), however there is a small number of EVs.

A major focus for this area is the transition away from the reliance on gas, which will be addressed in subsequent sections.

The Sankey in Figure 2.14 is intended to visualise the flow of energy from 'import' into the City's boundary, to meeting the final discrete types of demand. Two energy types that are present in the baseline system but not represented within this visual include:

- Secondary heat – energy within the air, water or ground that can be harnessed and elevated to a useful temperature using a heat pump. The resulting heat helps to meet building thermal demands.
- Waste heat – waste thermal energy from a number of different source types (for example building cooling plant, London Underground ventilation shafts and data centres) that is currently rejected into the atmosphere. The opportunity to recover and utilise this is explored in further sections.

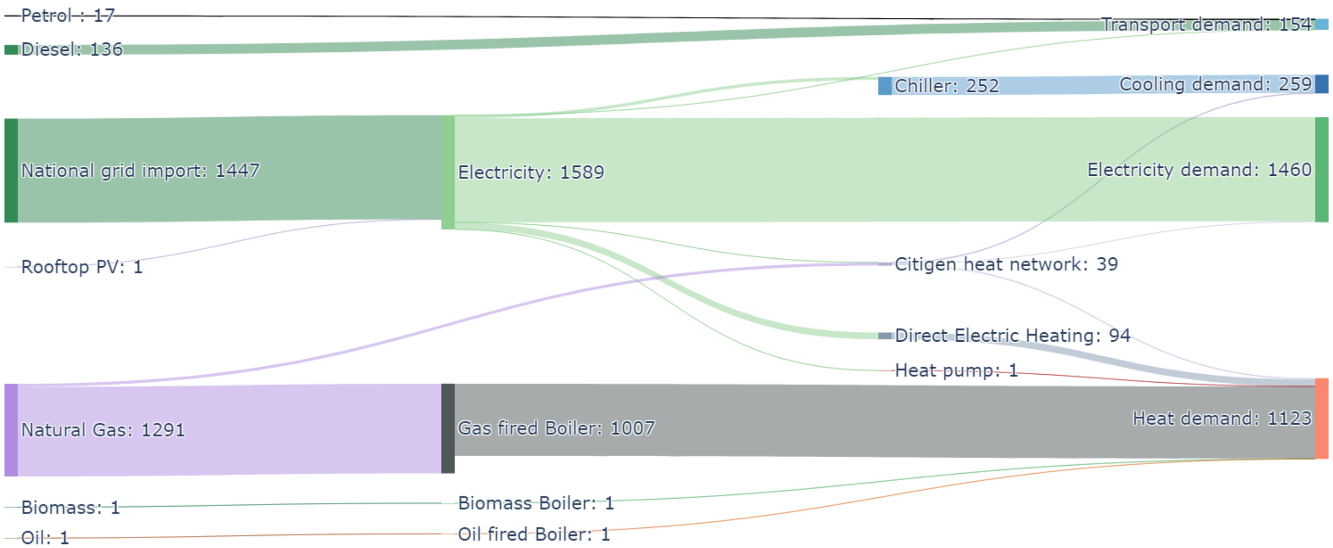

Figure 2.14: Sankey diagram of energy flows in the City in 2022 (GWh/year).

3. Future energy demand
Introduction

Section overview

This section of the report details our findings in relation to the future energy demands modelled within the City. It covers the following areas:

- Existing buildings future energy demand projections
- Transport future energy demand projections
- Growth projections
- Future demand cases
- Future demand in the City

Building upon the baselining work, the future demand of existing buildings and transport is projected out to 2040, accounting for strategic and retrofit interventions.

The expected growth and new development within the City is accounted for and combined within the existing building projections to create a complete estimated future demand dataset. This is then pulled together to understand the different future demand cases in the City and identify the changes from the baseline characterised in the previous section.

Figure 3.1: The City skyline viewed from across the Thames.

3. Future energy demand
Existing buildings and transport

Future energy demand projections for existing buildings and transport

Future energy demand projections for existing buildings

The future energy demands of the City will be heavily influenced by the retrofit interventions that have been developed and modelled within the existing building stock, new developments (addressed in the following pages) and the future climate.

We developed a set of retrofit interventions spanning across three main areas:

- Building automation and management systems e.g. installation of meters and sub-meters, calibration of temperature set points, lighting controls
- Building services interventions e.g. recommissioning of building services, inclusion of heat recovery systems, replacement of ventilation plant
- Building fabric interventions e.g. optimisation of free cooling and fabric upgrades

These were mapped against the appropriate building archetypes where they could be implemented and then classified into either shallow or deep regarding their impact on overall energy performance of the buildings. Further detail on these interventions, the mapping and classification can be found in Appendix C.

Following on from the baseline energy consumption analysis, the steps detailed in the modelling methodology section in Appendix A describe the components used to model the future annual energy demand estimates in 2040.

A climate change adjusted weather file was used to inform the future demand modelling of existing buildings. This accounts for future projected variations to weather patterns including an increase in average external ambient temperatures.

Future energy demand projections for transport

The estimations for future transport demand were modelled around the anticipated increase of electric vehicles. As the City's rail systems are powered by TfL's and Network Rail's respective private energy networks, and public busses do not currently refuel within the City, these were excluded from the analysis.

The projection of future electric vehicle demand has been based on the likely energy to be consumed through charging within the City boundaries. Unlike the baseline assessment, it is not based on the mileage travelled within the City and therefore the two cannot be directly compared. One of the outcomes of the LAEP is to determine the impact of electrification on the local electricity infrastructure and the additional demand on the primary substations. Therefore it was decided that understanding the quantity of energy required for charging (but not necessarily used for driving) within the City's boundaries was more important.

The projection for EV charging was built from the City of London's infrastructure analysis up to 2025, and further projections were applied to general EV growth across public and private chargers beyond this. This was combined with assumptions on charger types (70% rapid and 30% standard) and their usage rates to estimate the annual energy consumption for EV charging. Due to the low density of domestic buildings in the City, it was estimated that private home charging would only make up 25% of demand.

A consistent approach to the future transport demands and mode shift was applied across each of the scenarios.

3. Future energy demand
Growth and development projections

Future growth projections

The City Plan 2040[15] sets out the development plans of the Square Mile alongside the City Corporation's vision and strategy. The Spatial Strategy provides the projected growth split over four land use types: Offices, Retailing, Housing and Hotels, with office space continuing to be the most prominent land use within the Square Mile.

As described in Section 1 the City Plan defines seven distinct 'Key Areas of Change' (KAOC) within which it is expected significant change will occur regarding future development. These areas have also been defined to provide a strategic context for new developments and funding bids. Figure 3.2 maps the KAOC across the Square Mile. The City Plan also provides an indicative distribution of development across these KAOC, providing the basis from which the modelling of growth and development undertaken within this work package has been focussed.

The City Corporation provided two development schedules regarding proposed development within the City. 'Development Schedule 1'[19] provides data on planned Housing and Hotel developments, including size (floorspace/no. units/ rooms) and location, and was used to spatially map known developments coming forward across the City. Future office developments were taken from a more recent 'Development Schedule 2'[20] - this schedule represented proposed office schemes at various stages of design/development including some from pre-application stage at the time of monitoring.

The data of planned developments obtained from these development schedules was combined with the growth targets defined within the City Plan to develop an understanding of the future building development and specific locations where possible.

It was agreed that the office development was to be solely based upon the development schedule defined, superseding the targets stated within the City Plan. The remainder of the growth targets associated with housing, hotels and retail (i.e. not accounted for within the development schedules) were then allocated to each KAOC, as per the indicative distribution figures mentioned above. Table D.1 in Appendix D details this breakdown.

Where the specific locations of new developments were known (data obtained from either development schedule), the existing buildings that were to be demolished and replaced were removed from the citywide dataset to mitigate the double counting of buildings/developments.

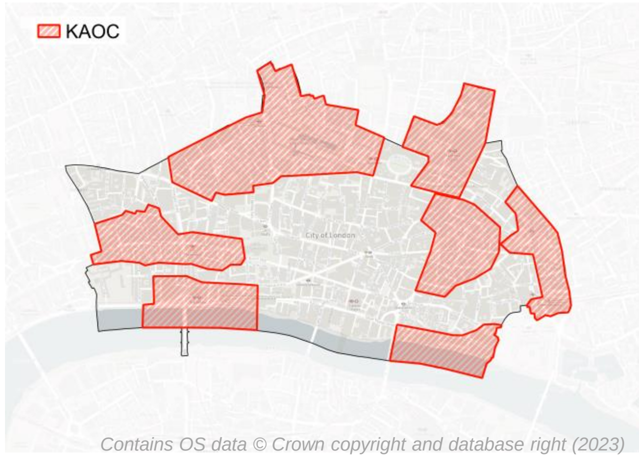

Figure 3.2: Key areas of change (KAOC) in the City.

3. Future energy demand
Growth and development projections

Future growth projections

The model considers two levels of future development: low growth and high growth. These were agreed with the City Corporation and are intended to reflect and test potential future scenarios regarding new building construction and their associated demand for energy.

The growth scenarios are as follows:

- High growth: construction of all buildings identified within the development schedules alongside meeting the target floorspace defined within the City Plan out to 2040.
- Low growth: construction of all buildings defined with the development schedules, and 65% of the remaining target floorspace defined within the City Plan out to 2040.

Figure 3.3 shows the cumulative percentage increase in floorspace increase due to new developments across the city for both future development scenarios. Across both scenarios, there is accelerated growth to 2030 before the rate of growth becomes more steady. Figure 3.4 shows the distribution of this growth according to building typology.

Each growth scenario and the associated floorspace values were geospatially mapped according to the development distribution in Table D.1, Appendix D.

By superimposing the 11 optimisation modelling zones, this development data was then aggregated aligning with these zones to provide an indication of the amount and type of new development per zone. It was agreed with the City Corporation's Planning team that the distribution of future development within the Smithfield and Barbican KAOC would be significantly weighted to the west of the Barbican Estate due to physical limitations of further development in that area.

Figures 3.5 and 3.6 on page 32, show the distribution of this floorspace across the 11 modelled zones within the City.

The future demands of these new developments were calculated using a range of benchmarks that reflect future target energy usage, whilst also accounting for the performance gap between the design ambitions and actually operation of building usage. This process, and the values used, is described in Appendix A on page 106.

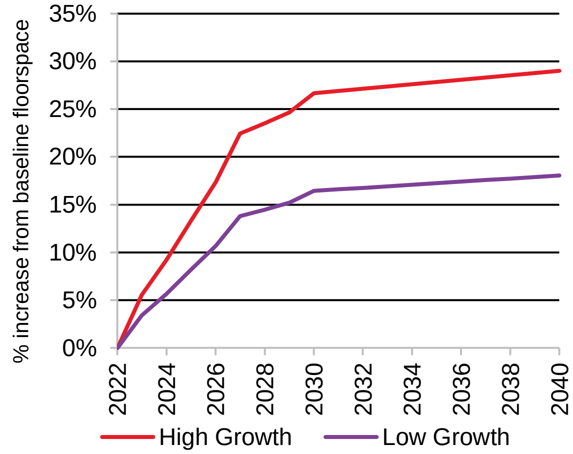

Figure 3.3: Cumulative % increase in City floorspace from new developments, against 2022 baseline

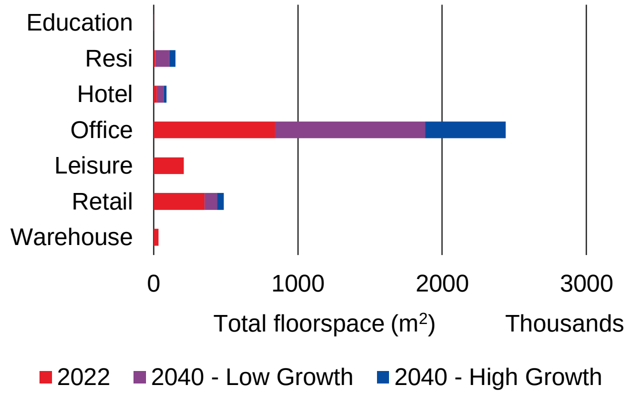

Figure 3.4: Total floorspace by typology.

3. Future energy demand
Growth and development projections

Future growth scenario maps

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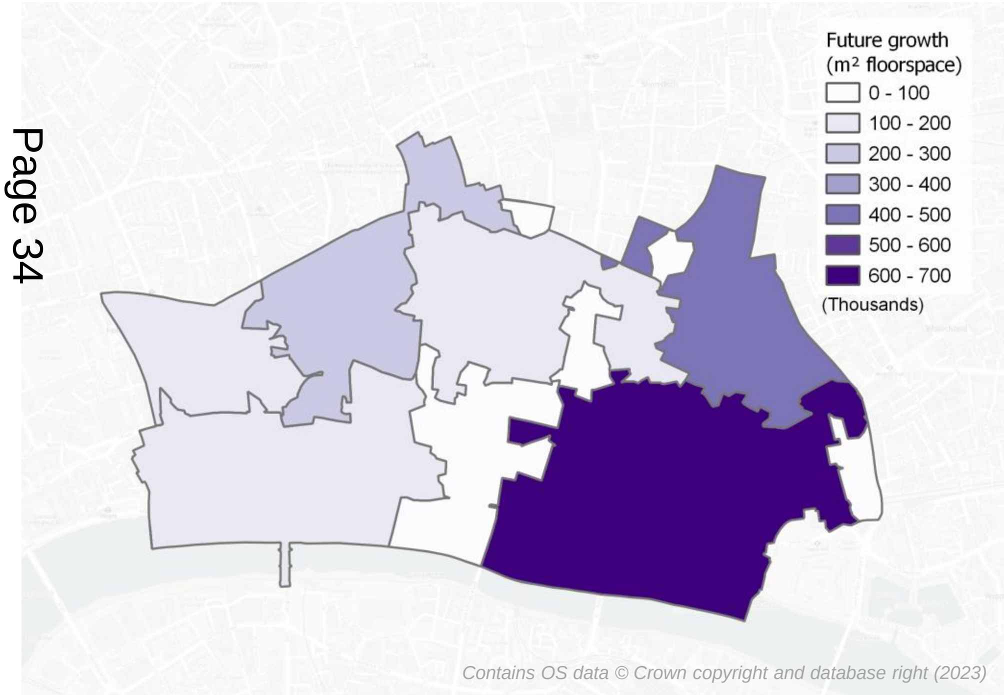

Figure 3.5: High Growth – distribution of future development floorspace across modelled zones.

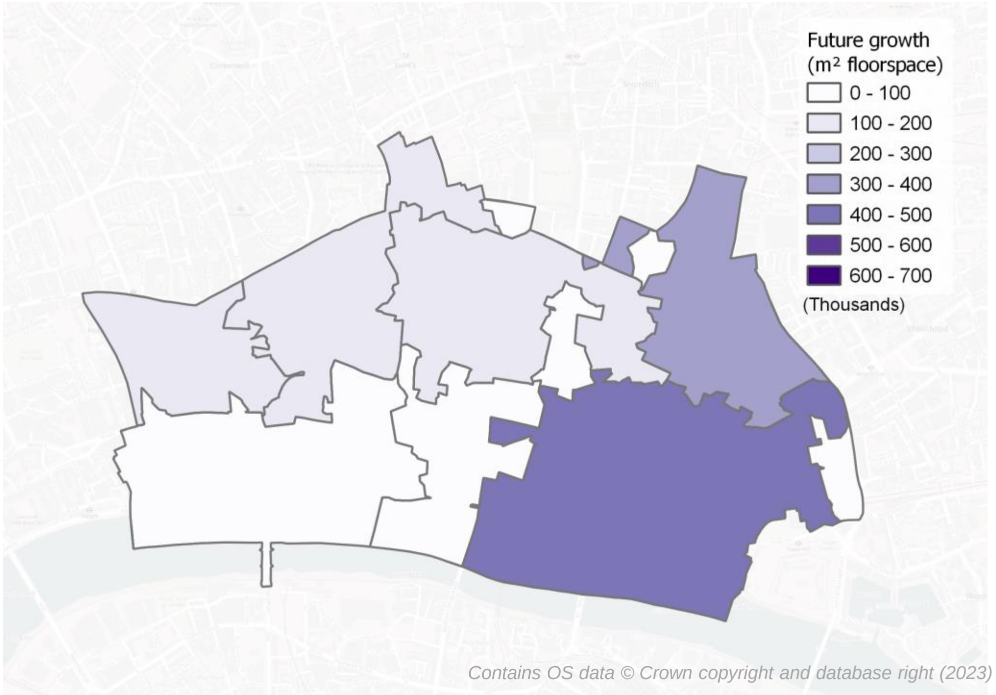

Figure 3.6: Low Growth – distribution of future development floorspace across modelled zones.

3. Future energy demand
Aggregated future demand: all scenarios

Future demand cases

Considering the effects of changing transport demands, deploying different levels of retrofit rollout, and delivering different levels of growth, there are a number of possible future energy demand cases which have been calculated and are shown in Table 3.1.

These cases are defined by two demand 'levers': the level of building retrofit modelled applied to the existing stock and the scale of future development. Table 3.1 shows these three future demand cases, the levers that have been applied to each and the effects this has on future demand. Future demand scenarios also take into account future transport demands and climate change projected weather files which are expected to raise cooling and reduce heating in future.

Consistent trends can be seen across all three demand cases and the annual demand breakdowns - heat and power demands are reduced, whilst cooling demand increases. The comparison between High energy demand and Green Growth shows the difference between level of retrofit. Deeper retrofit interventions increase the heating and power savings, but reduce the savings in cooling demand (due to greater building insulation). The future risks around overheating should be factored into decisions around retrofit interventions.

Figure 3.7 overleaf details the future energy demands (GWh/annum) associated with each modelled zone, and the relative modelled reduction in those demands against the 2022 baseline. Aggregated values are shown in Table 3.1.

The maps at the bottom of Figure 3.7 signify the relative % changes in demand compared to the 2022 baseline demands in each zone.

Paternoster shows the least reduction in heating, largest increase in cooling and a slight increase in electricity demand. This is because of the relatively lower opportunity for building retrofit in the area, compared to others.

Power demand does not include electricity used for heating and cooling, and in Paternoster it increases slightly due to the new development projected there.

Table 3.1: Baseline and future energy demand cases including heat, cooling and power.

Energy demand case	Baseline	High energy demand	Low energy demand	Green Growth
Units	-	GWh (% against baseline)	GWh (% against baseline)	GWh (% against baseline)
Year	2022	2040	2040	2040
Retrofit Level	-	Shallow	Deep	Deep
Future Growth	-	High	Low	High
Heat Demand	1160	760 (-35%)	340 (-70%)	360 (-70%)
Cooling Demand	260	275 (+5%)	330 (+25%)	335 (+30%)
Power Demand	1450	1150 (-20%)	1045 (-30%)	1,100 (-25%)

3. Future energy demand
Aggregated future demand: Green Growth scenario

Future demand

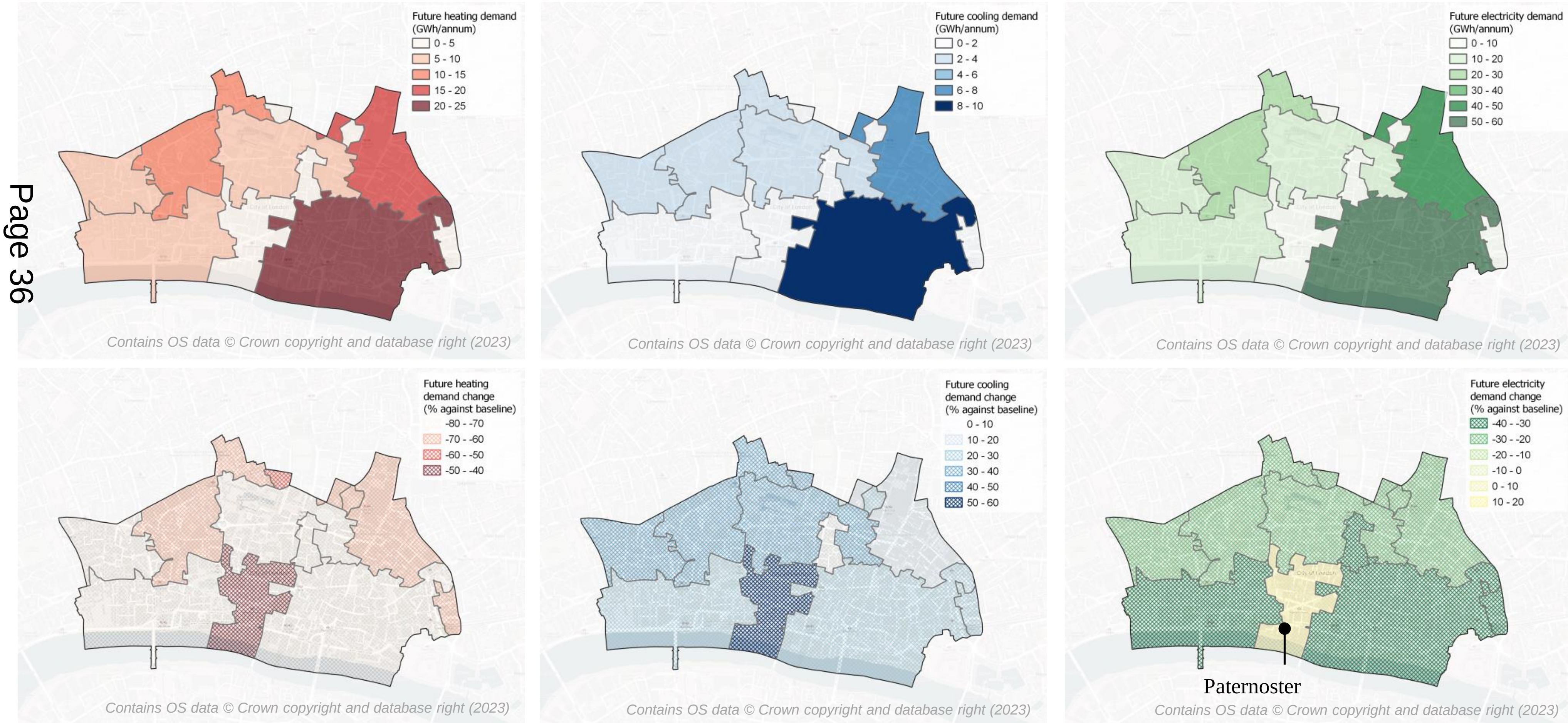

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Figure 3.7: Top – Future demands associated with 2040 Green Growth demand case scenario, Bottom – Relative change in demand of 2040 Green Growth demand case scenario against the 2022 baseline demands, L to R: heating demand, cooling demand, electricity demand.

4. Meeting future demand
Introduction

Section overview

This section describes how the future demand cases defined in section 3 could be met by a number of energy system scenarios. The section is split into the following sections:

- Low carbon heating – opportunities identified regarding waste heat and renewable generation across the City
- Renewable energy generation – assessment of local power generation via rooftop PV deployment
- Optimisation scenarios overview – table detailing the optimisation scenarios definition
- Optimisation modelling results – Sankey diagrams providing a breakdown of energy sources and vectors per scenario that most optimally meet the projected demand, followed by analysis of the energy generation and consumption and impact on the grid.

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Five optimisation scenarios, described in more detail on page 43, were developed from the three future demand cases and agreed with the City Corporation. These scenarios are intended to represent and test the energy systems' build-up and characteristics:

- High energy demand – high growth of future buildings coupled with shallow retrofit, electrification and heat network deployment
- Low energy demand – low growth of future buildings coupled with deep retrofit, electrification & heat network deployment
- Individual Building Green Growth – seen as the preferred demand scenario of the City Corporation – high growth of future buildings with deep retrofit measures on existing building stock, building level electrification of heat
- Heat Network Green Growth– as per the Green Growth demand case with the addition of Heat Networks serving as the predominant heat supply technology served by heat pumps
- Hydrogen Green Growth– as per the Green Growth demand case, with Hydrogen supplying the majority of heating to buildings

The system configurations tested within these five optimisation scenarios will impact the ultimate demands of the energy system within the City e.g. electrification of heat will increase the overall demand for electricity and reduce the demand for gas.

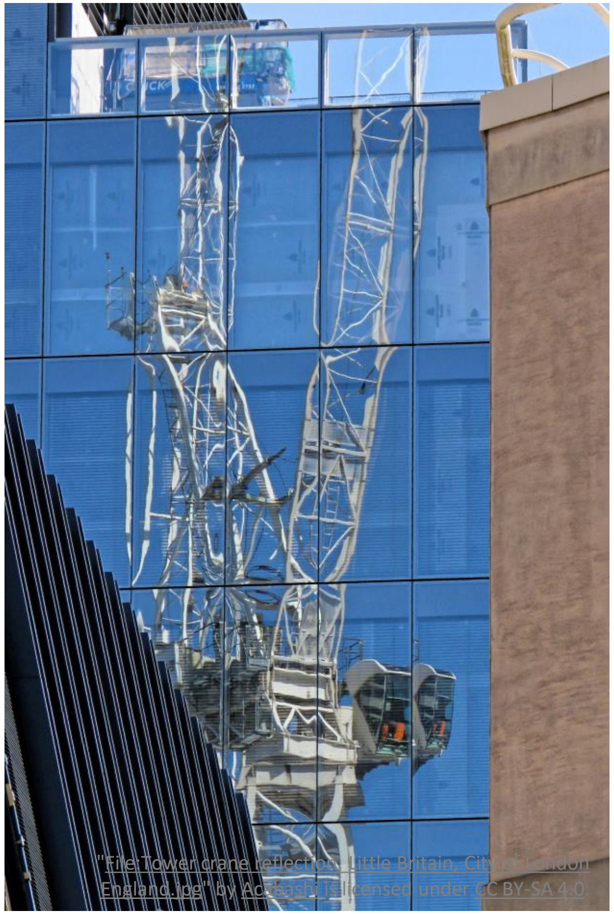

Figure 4.1: Construction in the City.

4. Meeting future demand
Low carbon cooling and heating

Future technologies

Heating

In line with the UK Net Zero Strategy, heat demand that is currently met by natural gas will need to met by an alternative low carbon energy vector in the future. It is widely accepted that the two primary choices for achieving this transition are electricity and hydrogen.

Electricity in the UK is already considered a low carbon source of energy, and its carbon content is expected to fall a further 90% by 2040 as more renewable power generation is brought online.

The model assumes these projections are correct (assumed emissions factors for grid electricity are detailed on page 55), but there is a risk the energy transition will be slower than projected. More details on this risk can be found on page 70.

Natural gas used for catering has been assumed negligible so is not included.

The technologies proposed to meet future heating demand are varied within the scenarios presented in page 43 and 44. Air, water and ground source **heat pumps** (ASHP, WSHP and GSHP) capture heat from the environment, achieving efficiencies of around 2 - 4 (seasonal coefficient of performance, the amount of useful heat out for a unit of electricity used). ASHPs are the least costly and can be installed on a property by property basis, or can be used to supply heat into an area-wide network (like Citigen). Fan and coil evaporators are used to collect the heat, but have large space demands and need access to fresh air. Within a block of flats or offices there may not be the physical space for each unit to install an individual ASHP.

Heat pumps are suggested over **direct electric boilers** due to their much higher efficiencies and reduced peak power draw (which infers additional power infrastructure). Modelling has found that when paired with thermal storage this is sufficient to meet peak loads to support this.

An alternative potential fuel for heating is **hydrogen**. It is assumed that if the UK gas grid is fully converted hydrogen, this would be the primary source of heat in the City. “Blue” hydrogen is produced from natural gas (where carbon is emitted, but would be captured and stored) and is not considered a long term solution due to its fossil fuel reliance. “Green” hydrogen is created from water using electrolysis, but is much more energy intensive and therefore would require significant new renewable power generation. Right now there is very little hydrogen use in London, but Cadent have plans to supply it into the city via their Capital Hydrogen project.

In a future hydrogen scenario, hydrogen is likely to provide low carbon heat via either individual hydrogen gas boilers on a property by property basis (similar to the current set up in many buildings) or as the input for heat networks to take advantage of the associated improvements in efficiency. It is unlikely that the City will have any hydrogen production within its boundary so it is assumed in this LAEP and the associated modelling that all hydrogen is imported (via pipes or potentially via shipping on the Thames).

Heat networks get around the space issues of heat pumps by centralising plant in an energy centre, and enable the use of various heat source types. Heat is generated and distributed to nearby buildings with water. In the heat network analysis, green heat networks are assumed, i.e. their heat sources are low carbon, for example renewably sourced heat pumps, waste heat or hydrogen. Heat networks are explored further in the following pages.

Cooling

As the UK’s summers increasingly get hotter due to climate change, there will be an increased need for cooling in buildings. This will require chillers to be installed or the use of reversible ASHPs, which can be used to provide cooling as well as heating. Both technologies are powered by electricity and so are reliant on either renewable generation or the emissions factors of grid electricity. Cooling also represents an opportunity for ambient temperature heat networks, where rejected heat can be captured easily and shared with nearby buildings during periods of concurrent heating and cooling demand on the networks.

4. Meeting future demand
Low carbon cooling and heating

Waste/renewable heat source opportunities

The utilisation of waste or renewable heat sources across the city could be vital in ensuring the successful decarbonisation of heating. Such heat could be captured by a range of applications, from building-level systems to recover and reuse waste heat, to network-scale capture, storage and sharing of heat between buildings.

Analysis of potential waste/renewable heat opportunities was based upon a desktop study of published data and previous studies, alongside undertaking benchmark-based calculations. Areas of potential waste heat recovery/renewable energy sources (including ambient air and water for heat pumps) that have been identified within the City include the following:

- Buildings with servers (this study has focussed on buildings with larger waste heat opportunities from servers/equipment loads – page 36 provides further detail on building heat rejection within the City)
- CHPs e.g. Citigen, St Barts Hospital
- TfL vent shafts
- UKPN electricity substations
- Sewers and subterranean rivers e.g. River Fleet
- River Thames*
- London Aquifer*

* (assessment not included within this study)

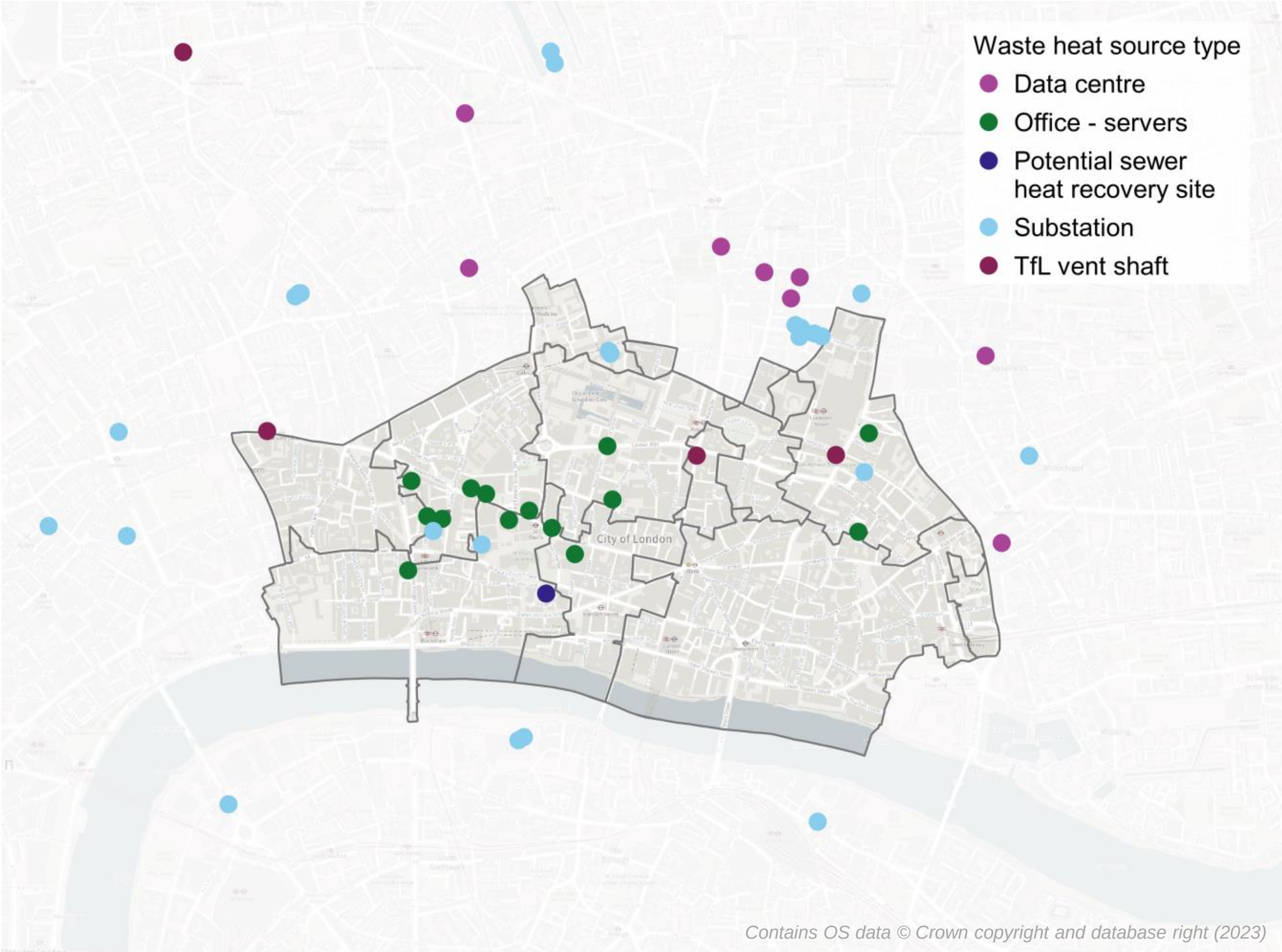

Figure 4.2: Map of potential waste heat sources.

4. Meeting future demand
Low carbon cooling and heating

Waste/renewable heat source opportunities

Each of the identified heat sources carries particular challenges and uncertainties which will affect their practicable yield. Detailed individual assessments of sources and potential uses will be needed to verify the heat potential.

The potential waste heat available, calculated from the sources identified, totals to ~38 GWh/annum (representing ~10% of the total future building heat demand in the green growth scenario). The zonal breakdown of this future heat demand within the City boundary is shown in Figure 4.3.

The London Aquifer opportunity has not been included within this value: although a large resource with a year round temperature of ~14DegC, the chalk aquifer is fractured and therefore yield is very location specific with high level of risk associated until drilling and testing takes place. Detailed site specific analysis is required to produce meaningful resource estimates. Further detail on these sources identified is included in Appendix E.

Further potential waste heat sources (including a number of data centres) have been identified within neighbouring boroughs beyond the City's boundary, and are shown in Figure 4.2 on page 37.

Exploration of the opportunities that these may provide should be a priority action of the City Corporation, the GLA and the associated boroughs.

In the future modelled scenarios electricity demand is seen to increase across the city, this results in an increase in the available waste heat from the substations serving these zones by approximately 60% on average.

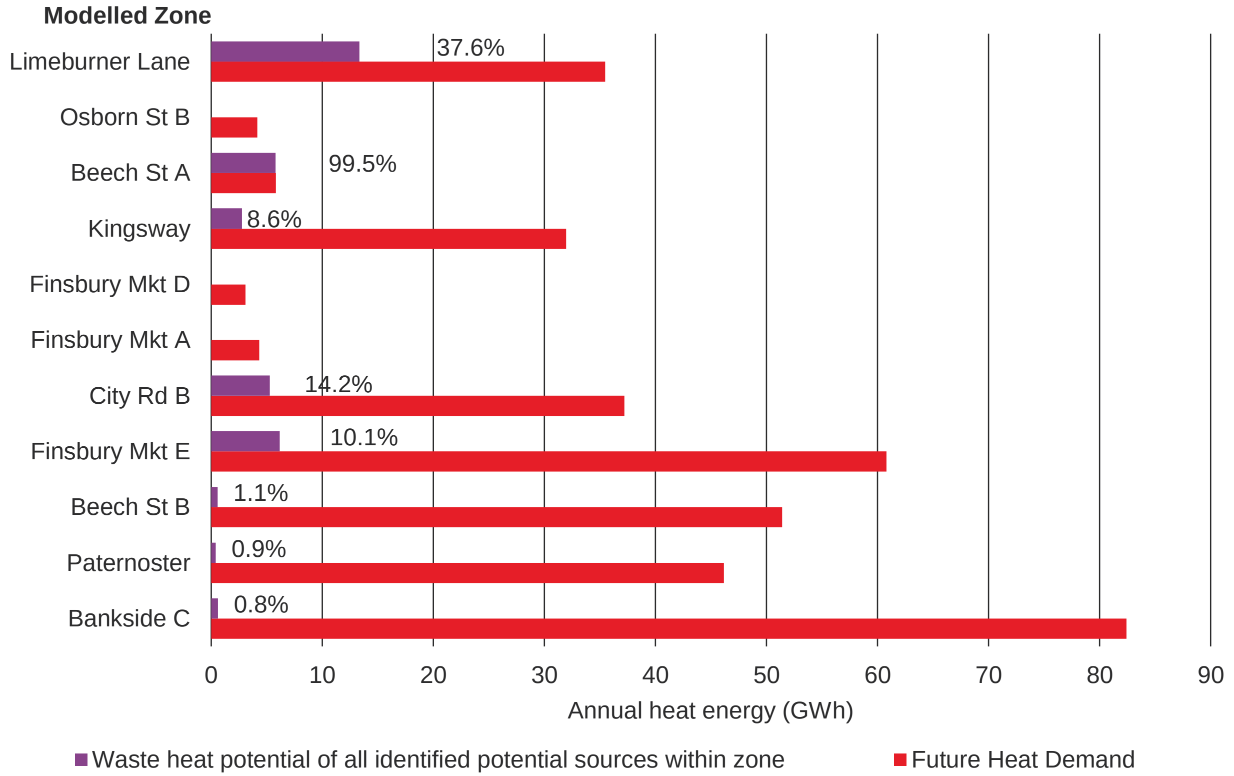

Figure 4.3: Total identified potential waste heat opportunity within each zone compared to total future heat demand (from the green growth scenario), the percentage signifies the ratio between waste heat potential per zone and the future heat demand of that zone.

4. Meeting future demand
Low carbon cooling and heating

Cooling heat recovery opportunities

Cooling/heat rejection opportunities

Page 34 highlights the magnitude of the cooling load associated with comfort in buildings across the City, for each future demand case. The rejected heat associated with cooling provides an additional opportunity to recover and re-use thermal energy, beyond the larger scale sources.

As mentioned on page 37 – recovering heat and reusing it within that same building is cheaper and much easier to implement, however this will not allow for much heat recovery during the summer, when offices have low energy demands but high rates of heat rejection.

Aggregating multiple buildings and typologies improves the opportunity for utilising this waste heat further, due to the diversity of usage and higher likelihood of seeing concurrent demands for heating and cooling on the same network. A high proportion (~65%) of the City buildings are commercial offices with similar demand profiles for heating and cooling, i.e. they do not lend themselves collectively to thermal energy sharing. Export of heat from offices in the City during the summer, to residential/non-commercial buildings in neighbouring boroughs may present a bigger opportunity, but is not straightforward to achieve. The installation of heat capture equipment to existing buildings alongside a suitable distribution network for the recovered heat will require significant investment but will be key in unlocking the full waste heat potential of the City and beyond.

Table 4.1 provides a breakdown considering the future building cooling load across all buildings within the City and the associated estimation of potential usable waste heat that could be recovered across the year, using the assumptions detailed in Table 4.2. This estimate of potential heat supply waste heat value of 280 GWh (potential usable heat uplifted by heat pump sCOP), representing ~70% of the estimated future heat demand within the City, is intended to demonstrate the magnitude of opportunity, and can be used as a basis of further investigation alongside steering energy strategies of new developments. Inter-seasonal thermal energy storage may be needed to realise the full extent of this potential, such as sub-surface heat storage.

Table 4.1: Potential cooling system waste heat recovery across the city.

Metric	Value
Green Growth total building heating load	360GWh
Green Growth total building cooling load	330GWh
Total rejected heat	410GWh
Total potential usable waste heat	100GWh
Total potential heat supply to meet demands	280GWh

Table 4.2: Assumptions used for heat rejection recovery.

Assumptions	Value
Chiller Energy Efficiency Ratio (EER)	4
Air source heat pump (ASHP) seasonal coefficient of performance (sCOP)	2.8
Heat recovered per chiller	50%
Available chillers to access	50%

4. Meeting future demand
Low carbon cooling and heating

Heat networks and zoning

As mentioned on page 22, the UK government is currently developing policy regarding heat network zones and planning to implement this in 2025[21]. The purpose of the policy is to define and designate zones across England and where heat networks can provide the lowest cost low carbon solution for decarbonising heating within a specific area. The intention of zoning is to unlock the full potential of heat networks within the UK and increase the proportion of heat delivered by heat networks from its current figure of 2% up to potentially 18% by 2050. This 18% value is an average across the UK, it is likely that in dense urban areas such as the City, this proportion will be significantly higher.

By designating zones, common risks perceived to be associated with network development including security of demand, scaling opportunities and ownership models are mitigated. Zone designation following types of buildings will be mandated to connect to heat networks

Low carbon heat sources are a central focal point of the policy and future network development. Opportunities to utilise waste heat will be integral to enabling the deployment of low carbon networks, alongside using other renewable sources e.g. geothermal, river/water etc.

The implementation of this policy will have a significant impact regarding future heat provision within zoned areas across England. Areas (if not all) of the City will likely be located within a designated zone, therefore the future direction may well be more focussed on heat networks as the primary means of supplying heating. The costs of network deployment will be considered within the zoning definition and the higher relative cost of network routing within the City, when compared to other areas across the UK, may impact the size and shape of zones defined in the area.

Heat Network Zoning policy is currently being further developed with a number of ongoing projects (e.g. Heat Network Zoning Pilot Project, City Decarbonisation Delivery Programme and Advanced Zoning Programme – the last of which the City is currently involved in) feeding into the scheme and , testing . As part of these projects, zone implementation, governance structures and resource requirements are being tested and developed.

Notably, the role of Local Zoning Coordinator (LZC) is intended to be undertaken by local government/authority with support from a central national body. This role will involve overseeing the zoning process including being responsible for carrying out the zoning methodology; data collection; stakeholder engagement; zone designation and delivery model assignment; monitoring of heat network development and reporting on performances.

Although the specifics of resource are still being established – it is likely that the City Corporation will have a role to play, whether that is as a LZC, or supporting a wider coordinator role.

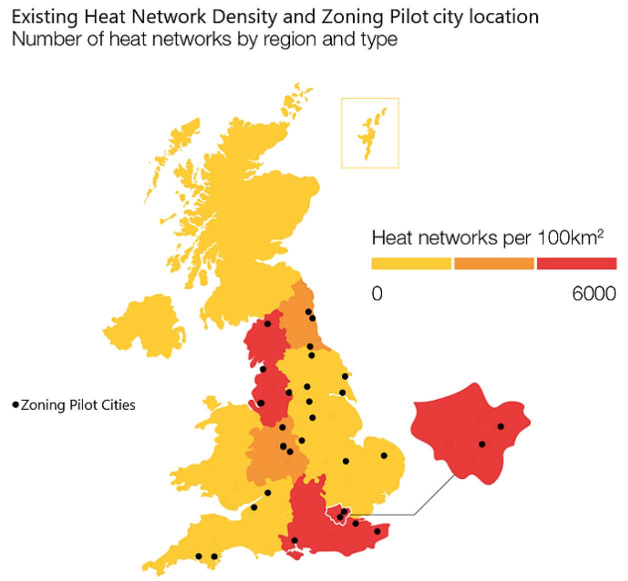

Figure 4.4: UK Map showing current heat network deployment and the 28 cities within the Pilot Project[19].

4. Meeting future demand
Low carbon cooling and heating

Heat network opportunities

Across the five optimisation scenarios described in Table 4.4 on page 44, two different heat network scenarios were tested: *conservative* heat networks with shallow retrofit to be used in the 'High Demand' scenario and *optimistic* heat networks with deep retrofit to be used in the 'Low Demand' and 'Green Growth' scenarios.

The results of the analysis are shown in Figure 4.5 and Table 4.3, and demonstrate significant potential for low carbon heat networks to meet the City's future heat demand, compared with a current 4% share of heat demand.

The implementation of Heat Network Zoning Policy in 2025 would have a significant impact on the amount of buildings that would be considered for heat network connection. Under the current Policy development and wording 30% - 60% (depending on future demand scenario, with the lower values associated to a future demand where deep retrofit is applied, and the higher value associated with shallow retrofit) of the buildings within the City could be mandated to connect to heat networks. This could materially change the clusters identified within this analysis.

Alongside future considerations of Heat Network Zoning Policy, the identification of heat network connection opportunities beyond the City's boundary will promote efficient network design and enable the utilisation of waste/shared heat between groups of buildings. Engagement with existing projects including the Bunhill network in Islington and the Westminster LAEP will help to ascertain and define the cross boundary network prospects. For example, the City of London could supply excess heat from cooling into areas like Islington where there is more residential heating demand.

Within the analysis undertaken in this study, it is assumed that future heat networks will use heat pumps and waste heat capture (where available) as their energy input. Detailed studies into the availability of potential sources following on from that detailed in pages 37 and 38 will enable suitable energy centre locations to be identified that will be needed to develop the future heat networks.

Table 4.3: Potential heat network results.

Potential heat network scenario	Heat supplied (GWh)	Heat supplied (% of total heat)	Buildings connected (% of total no.)
Optimistic	250	75%	29%
Conservative	230	34%	12%

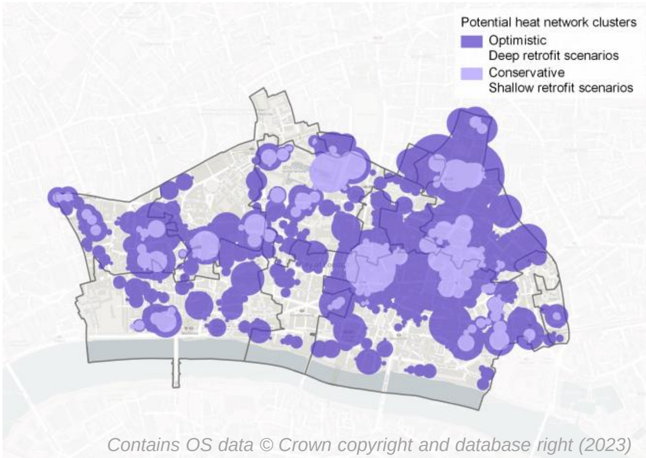

Figure 4.5: Optimistic and conservative potential heat network clusters.

4. Meeting future demand
Renewable energy generation

Energy Generation

Due to the location and nature of the City, renewable energy generation technology options are quite limited. The primary feasible opportunity for local energy generation comes from rooftop Solar Photovoltaic (PV) panels and is included within the optimisation modelling. The current rooftop PV capacity (detailed on page 20) was implemented within the model as the minimum rooftop PV capacity available for the future modelled scenarios.

An assessment of the maximum potential for rooftop PV installations was undertaken on a building-by-building basis using the building dataset built from Ordinance Survey, EPC and Valuation Office Authority (VOA) data to develop an understanding of all buildings within the City.

The following parameters were included within this analysis to produce a estimation of the maximum rooftop PV capacity that could be deployed across the City.

- Rooftop area (m²) – projected from ground floor area
- Roof azimuth (degrees) – clockwise direction from North for optimum panel alignment (i.e. East: 90˚ , South: 180˚, West: 270˚)
- Roof area deduction (%) – proportion of available area for PV installation
- Panel tilt (deg) – optimal slope of panel
- Panel array gap (m) – Spacing between panel arrays to prevent self-shading
- Available panel area (m²) – area for panel after applying parameters/limitations
- Panel capacity (kW) – total capacity of panels

A local annual solar irradiance weather file was then applied to the aggregated panel areas calculate the total potential annual generation.

The model does not currently include the shading of neighbouring buildings, and therefore may result in an overestimate of the feasible annual generation.

Figure 4.6 displays the aggregated zonal PV capacity across the City, showing where the opportunities lie for rooftop PV deployment.

There is an additional potential opportunity to install rooftop PV on Canon Street Bridge. Our indicative study suggested that if a roof was installed over the bridge there may be the potential to generate over 500 MWh of electricity per year. The bridge is technically outside of the City's boundary and the installation of solar panels and a roof on Canon Street will involve negotiation with TfL, so this assessment was not assumed to be available to be used within the City in this report. It was noted that the neighbouring zone, Paternoster, is found to be the most constrained in 2040 (see Figure 4.13) however the renewable generation from Canon Street Bridge would only alleviate this by less than 0.5%.

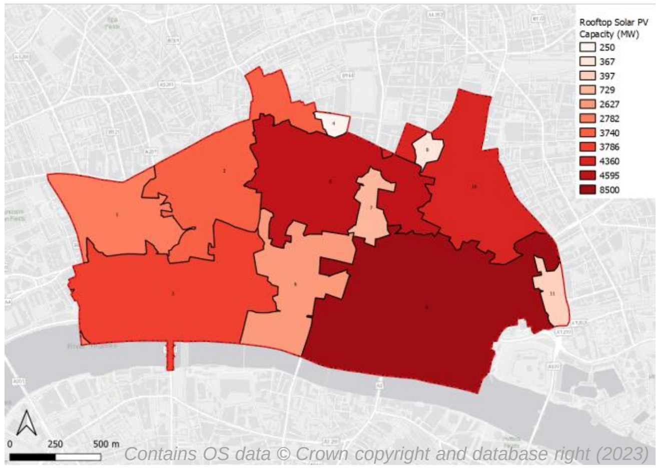

Figure 4.6: Zonal distribution of maximum rooftop PV capacity.

4. Meeting future demand
Optimisation modelling scenarios

Optimisation scenarios

Five optimisation scenarios were defined and modelled to test the possible future energy systems within the City. These are not intended to signify single solutions that are adopted within the City, they are designed to test certain parameters and characteristics of the energy system. The actual future energy system will likely consist of a mixture of the technologies and cases tested. The scenarios are based on the future demand cases detailed in Table 3.1, with additional variation in the green growth scenarios to explore different possible heating technologies: heat networks and hydrogen. An overview of each of the scenarios is provided below:

- **High Energy Demand**

Based upon the *high energy demand* future demand case - high development projections with shallow retrofit interventions applied to building stock. Heat networks are implemented where heat density is particularly high. Tests the potential maximum system demand and resulting electricity grid capacity/upgrades.

- **Low Energy Demand**

Based upon the *low energy demand* future demand case - low development projections with deep retrofit applied to building stock. Heat networks are implemented where heat density is relatively high i.e. using the optimistic heat network scenario metrics and therefore yielding more/larger heat networks than the high energy demand scenario. This tests the synergies of both centralised (heat networks) and decentralised (building-level) heat pump deployment.

- **Individual Building Green Growth**

Based upon the *green growth* future demand case - high development projections with deep retrofit interventions applied to building stock. Heat is predominantly provided by decentralised building-level heat pumps. This scenario tests the City Corporation's preferred future demand case (regarding new development and retrofit) alongside the electrification of heat and transport.

- **Heat Network Green Growth**

Based upon the *green growth* future demand case - high development projections with deep retrofit interventions applied to building stock. The majority of heat is provided by network solutions - within which centralised heat pumps will likely be the main source of heat, utilising renewable (ambient air and water) and waste heat (heat rejection from buildings/processes) sources.

- **Hydrogen Green Growth**

Based upon the *green growth* future demand case - high development projections with deep retrofit interventions applied to building stock. This scenario explores the potential impacts of the UK Government's decision in 2026 for the use of hydrogen for heating. This assumes that the current gas grid is converted to distribute hydrogen to all buildings that it is currently connected to, enabling the majority of heat across the City to be provided by hydrogen-ready gas boilers. Other technologies including hydrogen fuel cell CHPs have not been tested within this, however could play a significant role if hydrogen becomes a predominate energy vector . Heat networks are omitted to enable comparison of their benefit with the Individual Building Green Growth.

4. Meeting future demand
Optimisation modelling scenarios

Optimisation scenarios

Table 4.4 below summarises the energy systems across each of the five optimisation scenarios. The energy flows for each optimisation scenario are then shown in the Sankey diagrams, Figures 4.7 to 4.11 on pages 45 to 49. The Sankey diagrams show how a mix of energy sources can meet that scenario's demand case and are annotated to show the key differences between each scenario, this is then summarised further in Table 4.5. Each Sankey represents the potential future energy system for the City and demonstrates the technologies and supply needed to meet heating, cooling, power and transport demands in 2040, note that chiller loads include coolth met by heat pumps. The left hand side of each Sankey represents anything being imported into the City (in the state it is imported in), for example grid electricity or imported low carbon hydrogen, or generated within the City, for example rooftop PV. The right hand side represents the future demand. Across all scenarios the future transport demand was not varied, the values used were based on the Corporation's targets for vehicle use and mode shift.

Table 4.4: Optimisation scenario energy system definitions

Scenario	High Energy Demand	Low Energy Demand	Individual Building Green Growth	Heat Network Green Growth	Hydrogen Green Growth
System characteristic	Electrification of heat & heat network deployment	Electrification of heat & heat network deployment	Decentralised electrification of heat	Maximise heat networks, electrify remaining heat	Hydrogen grid conversion
Building retrofit	Shallow	Deep	Deep	Deep	Deep
Planned development growth	High	Low	High	High	High
Heat networks (see page 41)	Yes - Conservative	Yes - Optimistic	No	Yes - Optimistic	No
Hydrogen gas grid conversion	No	No	No	No	Yes
Flexibility – Demand Side Management and Storage	Yes	Yes	Yes	Yes	Yes

4. Meeting future demand
Optimisation modelling results: High energy demand scenario

~ 460GWh/year of total energy demand decrease from baseline

Majority of electricity imported from the grid

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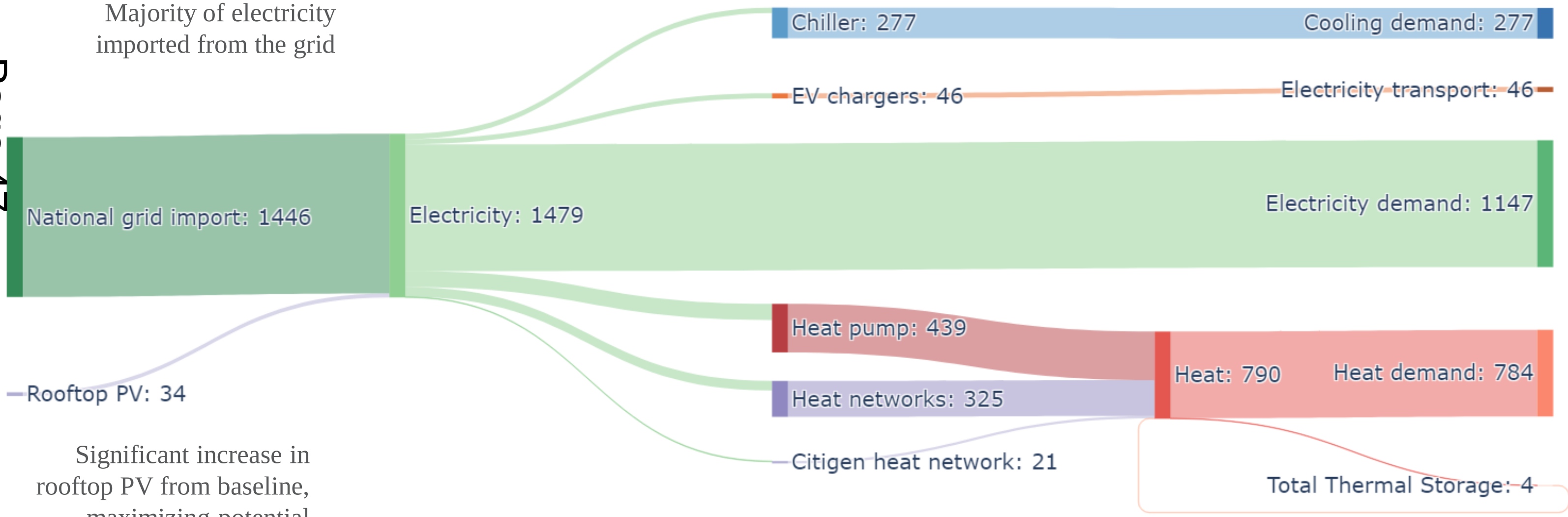

Significant increase in rooftop PV from baseline, maximizing potential deployment

~20GWh increase cooling demand due to high development and shallow retrofit measures implemented

Electrification of transport with total demand reduction

~300GWh Electricity demand decrease

~380GWh heat demand decreased via the through implementation of shallow retrofit

Heat demand met through heat pumps and heat networks

Thermal storage deployed as key flexibility mechanism

Supporting text highlights differences from the baseline; text in red highlights the distinctive features of this scenario

Figure 4.7: 2040 energy flows in the high energy demand scenario (GWh/year)

4. Meeting future demand
Optimisation modelling results: Low energy demand scenario

~ 960GWh/year of total energy demand decrease from baseline

~ 240GWh/year of national grid imports decrease from baseline

Majority of electricity imported from the grid

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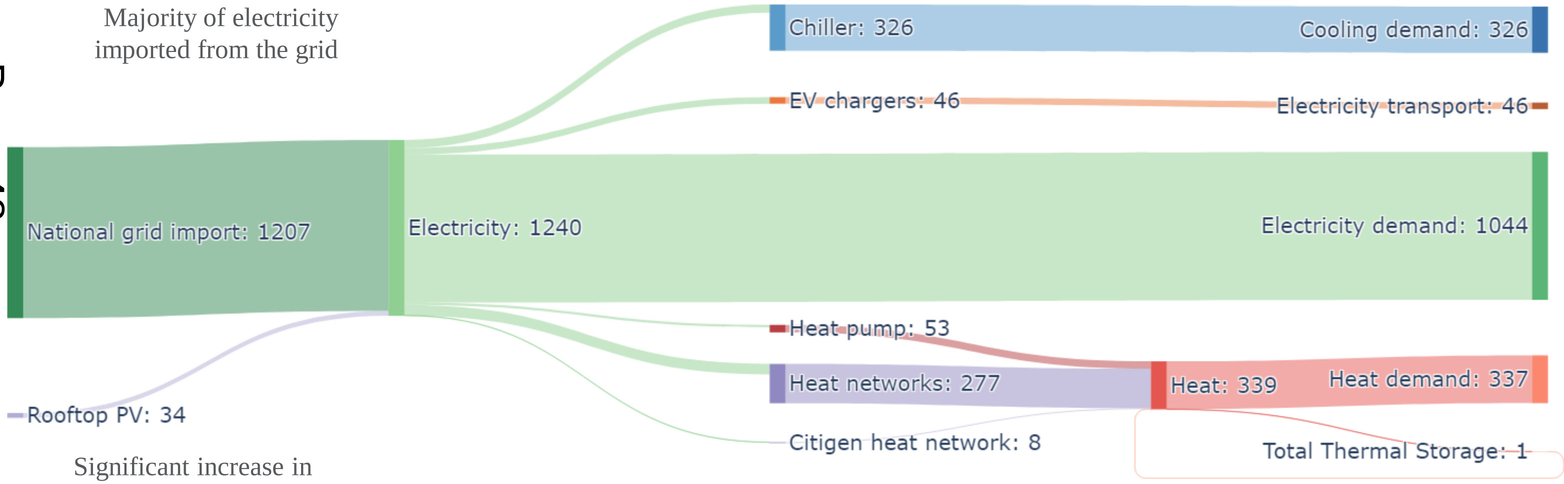


Significant increase in rooftop PV from baseline, maximizing potential deployment

~70GWh increase cooling demand due to low development and deep retrofit measures implemented

Electrification of transport with total demand reduction

~400GWh Electricity demand decrease

~820GWh heat demand decreased via the through implementation of deep retrofit and low growth

Heat demand predominantly met through heat networks

Thermal storage deployed as key flexibility mechanism

Supporting text highlights differences from the baseline; text in red highlights the distinctive features of this scenario

Figure 4.8: 2040 energy flows in the low energy demand scenario (GWh/year)

4. Meeting future demand
Optimisation modelling results: Individual Building Green Growth scenario

~ 160GWh/year of national grid imports decrease from baseline

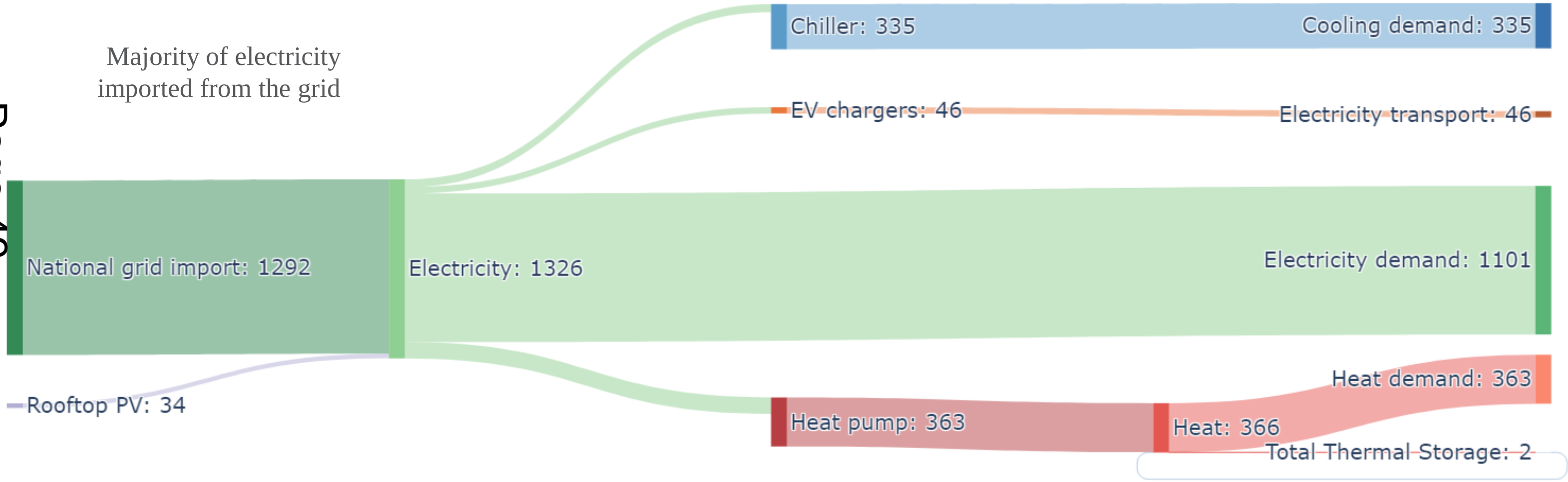
~ 870GWh/year of total energy demand decrease from baseline

~80GWh increase cooling demand due to high development growth and deep retrofit measures implemented

Majority of electricity imported from the grid

Electrification of transport with total demand reduction

Page 49



~340GWh Electricity demand decrease

~800GWh heat demand decreased via the through implementation of deep retrofit

Heat demand met entirely through heat pumps

Significant increase in rooftop PV from baseline, maximizing potential deployment

Thermal storage deployed as key flexibility mechanism

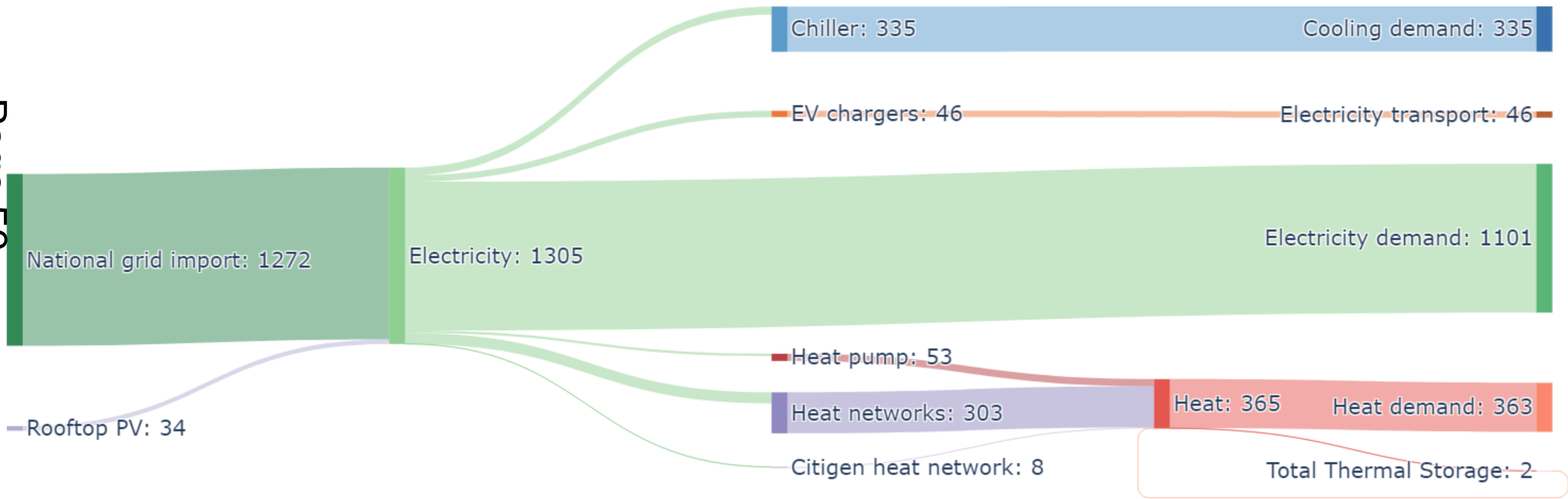
Supporting text highlights differences from the baseline; text in red highlights the distinctive features of this scenario

Figure 4.9: 2040 energy flows in the Individual Building Green Growth scenario (GWh/year)

4. Meeting future demand
Optimisation modelling results: Heat Network Green Growth scenario

~ 180GWh/year of national grid imports decrease from baseline

Page 50



Heat demand predominantly met through heat networks – these will be supplied by centralised heat pumps

Text in red highlights the distinctive features of this scenario when compared to the baseline

Text in **bold** highlights the distinctive features of this scenario when compared to the Green growth scenario

Figure 4.10: 2040 energy flows in the Heat Network Green Growth scenario (GWh/year)

4. Meeting future demand
Optimisation modelling results: Hydrogen Green Growth scenario

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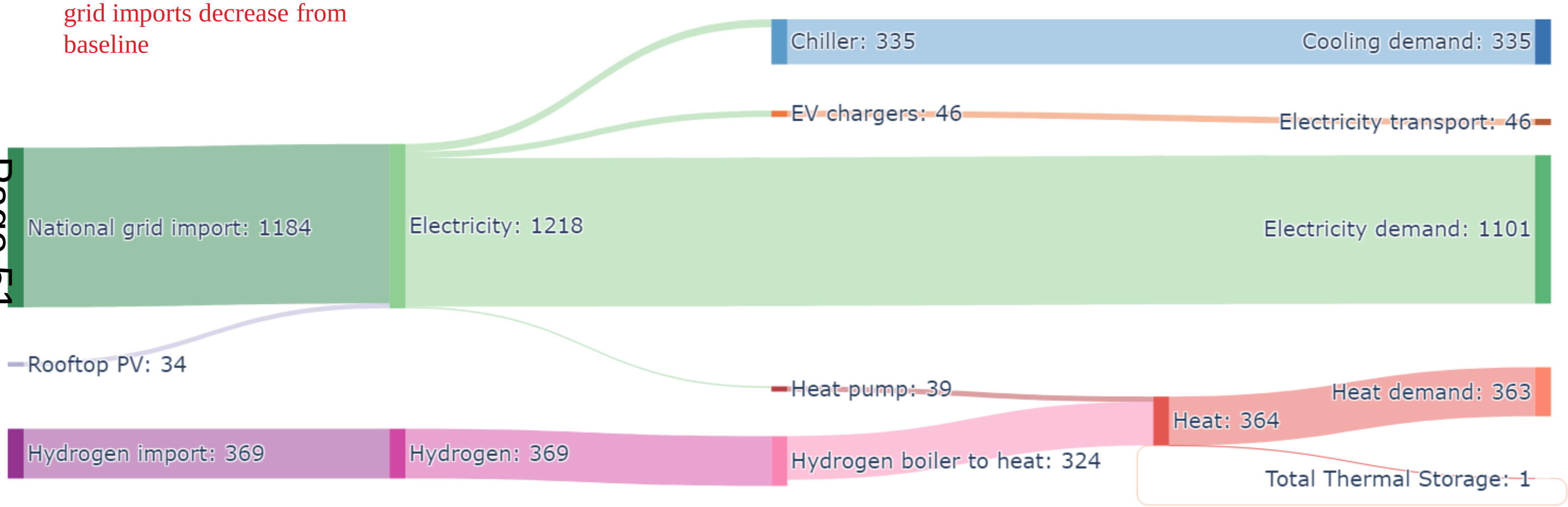
~ 260GWh/year of national grid imports decrease from baseline



Heat demand predominantly met through hydrogen boilers

Low Carbon Hydrogen import as primary energy source for heating

Text in red highlights the distinctive features of this scenario when compared to the baseline

Text in **bold** highlights the distinctive features of this scenario when compared to the Green growth scenario

Figure 4.11: 2040 energy flows in the Hydrogen Green Growth scenario (GWh/year)

4. Meeting future demand
Optimisation modelling results: All scenarios

Future Scenarios

In order to reach net zero by 2040 and the interim emission reduction targets, significant changes to the energy system across the whole of the City are required. Across all scenarios a reduction in overall demand is achieved via the retrofit of buildings alongside development of energy efficient new buildings. Despite this, the transition away from fossil fuel-based heating and transport to lower carbon technologies via electrification or the use of hydrogen is required. Table 4.5 highlights some of the key changes identified via running the five optimisation scenarios when compared to the current baseline system

Table 4.5: Key changes to the 2040 scenarios compared to the 2022 baseline

Change	High energy demand	Low energy demand	Individual Building Green Growth	Heat Network Green Growth	Hydrogen Green Grown
Demand – Heat	Least reduction due to impact of shallow retrofit	Largest reduction due to implementation of deep retrofit and lower building growth	Significant reduction due to deep retrofit and development of energy efficient buildings	As Green Growth	As Green Growth
Demand – Cooling	Least increase due to impact of shallow retrofit	Significant increase due to impact of heat focussed retrofit interventions	Largest increase due to impact of heat focussed retrofit interventions and high building growth	As Green Growth	As Green Growth
Demand – Power	Least increase due to impact of shallow retrofit	Largest reduction due to implementation of deep retrofit and lower building growth	Significant reduction due to deep retrofit and development of energy efficient buildings	As Green Growth	As Green Growth
Demand - Transport	Reduction achieved via mode shift	Reduction achieved via mode shift	Reduction achieved via mode shift	As Green Growth	As Green Growth
Heat Generation	60% heat delivery via HNs likely supplied via heat pump(s)	80% heat delivery via HNs likely supplied via heat pump(s)	Heat solely delivered via ASHPs at a building by building level	75% heat delivery via HNs likely supplied via heat pump(s)	90% heat delivered via hydrogen (inc. any HNs converted to H_2)
Transport fuel	Full electrification of transport system	Full electrification of transport system	Full electrification of transport system	As Green Growth	As Green Growth
Local power generation	Maximum deployment of rooftop PV ~40x current installed capacity	Maximum deployment of rooftop PV ~40x current installed capacity	Maximum deployment of rooftop PV ~40x current installed capacity	As Green Growth	As Green Growth

4. Meeting future demand

Optimisation modelling results: Electricity generation and consumption

Monthly generation and consumption

Figure 4.12 shows the optimised generation and dispatch of electricity to meet demand for the Individual Building Green Growth scenario. As discussed on page 42, there is relatively limited potential for local generation across the City beyond rooftop PV. Throughout the year the generation achieved via full deployment of rooftop PV accounts for ~3% of the total electricity demand. In contrast, the current 15-year Solar PPA (Power Purchase Agreement) that the City Corporation have entered for their associated energy usage will provide ~54GWh/annum, equivalent to ~4% of the total City consumption. The vast majority of electricity is sourced from outside the City's boundary via grid-supplied energy due to the constraint of the lack of space within the City, the procurement of a larger or extended PPA is explored in Section 7. Electricity consumption for transport and buildings is relatively consistent throughout the year. The electrical consumption for heating is greatest in the winter months, where flexibility technologies such as thermal storage are deployed to minimise peaks and reduce loads on the electrical distribution network.

The combination of future climate predictions (increase in ambient temperatures resulting in higher building cooling demands), development growth, heat focussed retrofit interventions and the electrification of transport and heating all put strain on the existing electrical infrastructure within the City.

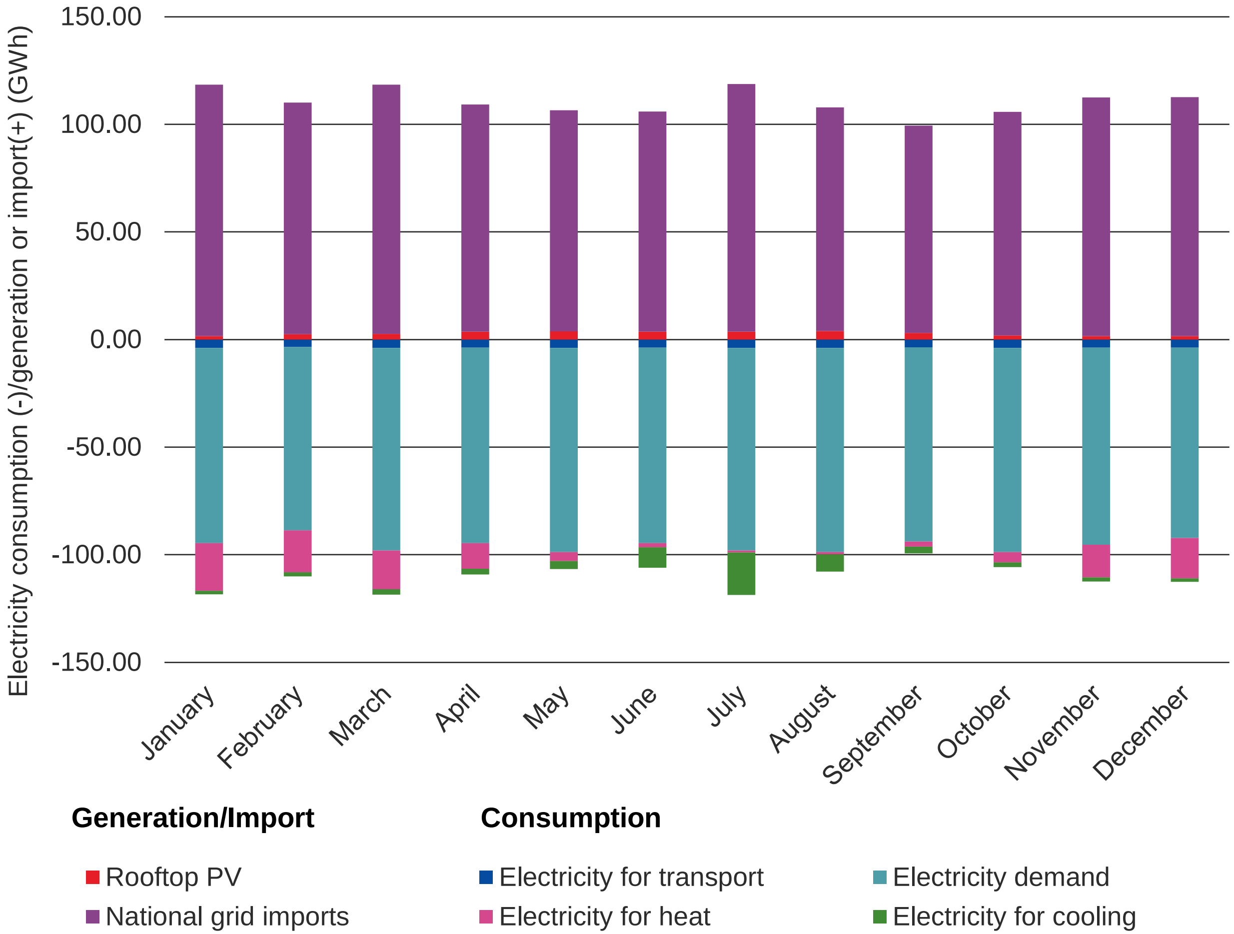


Figure 4.12: Monthly generation and dispatch of electricity in the modelled 2040 Green Growth scenario

4. Meeting future demand
Optimisation modelling results: Electricity generation and consumption

Future grid capacity constraints

The geospatial mapping undertaken as part of the optimisation modelling process has enabled the identification of where primary substation capacity constraints may be most prevalent in the future, and indicates where infrastructure upgrade planning should be focussed.

Figure 4.13 identifies the 11 zones modelled and where future capacity constraints may occur, the following ratings have been applied regarding percentage capacity increase required compared to current infrastructure: None/Low: c.0% , Medium: 0 – 25% High: >100% (the ratings provided are representative of all future scenarios tested). There is significant uncertainty in the assumptions made and further detailed analysis will be required to ascertain the extent of infrastructure upgrades likely to be required. Paternoster has been identified within UKPNs demand RAG assessment[22] as higher risk (the only zone within the City that has been classified as 'Amber - 5% - 20% capacity available', with the rest of the zones 'Green - over 20% capacity available') regarding the available demand. This is reflected in the future upgrade requirement identified within this model: Paternoster is the most constrained/likely to need the highest relative infrastructure upgrade requirements across all zones, with both Bankside C and Kingsway also deemed to have insufficient current capacity to cater for future demands.

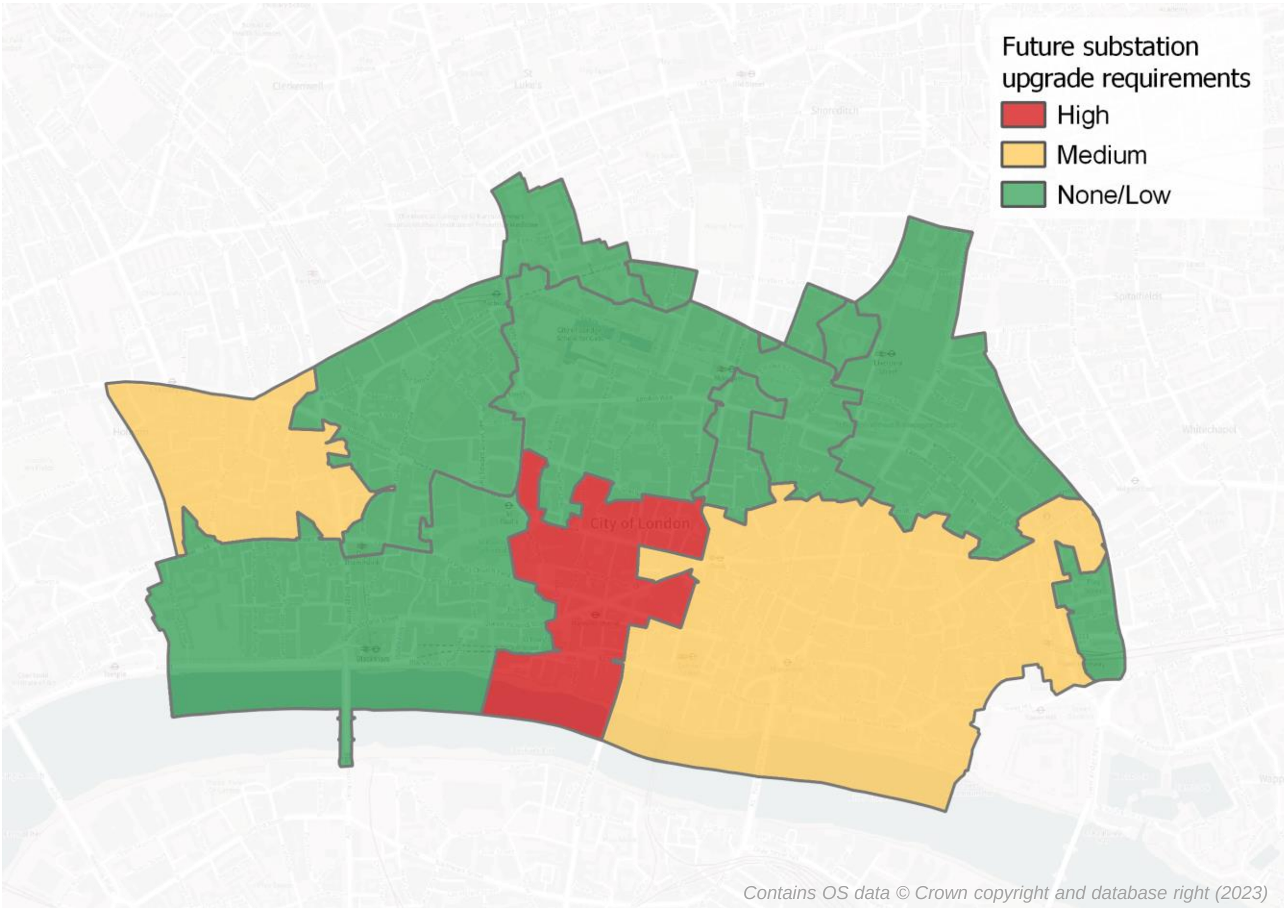


Figure 4.13: Map of modelled future primary substation upgrade rating from the optimisation analysis undertaken within this study

5. Energy transition pathways
Introduction

Energy transition pathways

We developed a series of pathways to show the rate at which the energy system change impacts on the ability to meet the City Corporation's net zero targets. These pathways have been prepared using assumptions for the rate of demand increase as described already, and potential technology deployment rates based on existing policies, targets, and trends.

Page 55

In addition to the pathways specific to the five optimisation scenarios that have been developed, we have included two counterfactual pathways: Do Nothing and Business as usual (BaU) intended to represent different energy transition aspects and timescales.

This section outlines the different pathways and technology deployment curves, and shows how the City Corporation can meet targets.

Figure 5.1: The City skyline at night

5. Energy transition pathways
Pathways

Do Nothing and Business as Usual pathways description

Table 5.1 breaks down the assumptions made for the deployment of technologies and change in demand across the different pathways. This is broken down in further detail in Appendix F. For all pathways, the same grid emission factors have been used as discussed on page 55.

The '**do nothing**' pathway is included to show what the City's carbon emissions would look like if no further action to decarbonise, beyond national policy and targets is taken. Within the 'do nothing' scenario, it was assumed that all existing technologies remain at a constant capacity unless there is a change to national regulation. The changes in heating, cooling and electricity demand are due to changes in climate and new developments being built in the high growth scenario. Transport demand is assumed to be consistent.

'**Business as usual**' represents a scenario in which the City's current plans and policies are carried out, including the actions detailed within the Climate Action Strategy (CAS)[1]. Offsetting is not included within emission calculations in the LAEP. 'Business as usual' incorporates changes in demand based on the high growth scenario and the rollout of retrofit in accordance with existing national, Greater London and City Corporation specific plans. Rollout of heat pumps, decarbonisation of Citigen and increase in EV market share happen in line with existing commitments (e.g. in the UK Net Zero Strategy[12]).

Table 5.1: How the Do nothing and Business as usual pathways differ from the Optimised scenarios.

Technology	'Do nothing'	'Business as usual'	Optimised scenarios
Heat	32% decrease due to climate change	59% decrease due to retrofit rollout and climate change	See page 34
Electricity	0.3% increase due to climate change	1.1% decrease due to retrofit rollout and climate change	See page 34
Cooling	61% increase due to climate change	46% increase due to retrofit rollout and climate change	See page 34
Transport	No change	Transport Strategy aligned	Transport Strategy aligned
Growth scenario	High	High	High and low
Retrofit rollout	None	Shallow, only rolled where a heat pump will be installed	Varying shallow/deep
Heat pump	In line with national 2028 targets, increase from 2035 to replace 50% of gas boilers scrapped	In line with national 2028 targets with an increase from 2035 to replace gas boilers scrapped	Linear increase from now until 100% deployment in 2032
Hydrogen boilers	None	None	In hydrogen scenario, assume hydrogen roll out from 2026
Heat networks	No new networks	No new networks	Accelerated by Heat Network Zoning
Citigen decarbonisation	No further decarbonisation	In line with current City Corporation strategy	In line with current plans, accelerated from 2027 to 2040
Solar PPA	As existing 15 year agreement	As existing 15 year agreement	Length of PPA agreement extended to 2040
Rooftop PV	No additional rooftop PV	Linear increase to 2040	As per London Solar Plan
EVs	Increase from 2035 due to petrol, diesel and hybrid ban	Increase from 2035 due to petrol, diesel and hybrid ban	Aligned to charger rollout based on ESC forecasts

5. Energy transition pathways
Pathways

Energy consumption pathways

The energy consumption pathways show the direct impact of actions on the City's energy consumption. The carbon emission pathways are then created by applying the respective emission factors to then show the impact these changes have in meeting the City's net zero target, and the influence of the emissions factor of the fuels used. Across all pathways, the same grid emissions factors were assumed based on the Future Energy Scenario 2022: Leading the way electricity CO_2 intensity (excluding negative emissions from bioenergy with carbon capture and storage (BECCS)) by National Grid[23].

Primarily, the reduction in consumption shown in the 'do nothing' and 'business as usual' scenarios up to 2034, as shown in Figure 5.3 and Figure 5.4, respectively show the reduction that is occurring due to changes in the climate reducing the need for heating, the development of new highly efficient buildings, and the deployment heat pumps replacing gas boilers (albeit a relatively small proportion in these scenarios). A national ban on new gas boilers from 2034 causes the reduction in gas consumption to occur at a faster rate, as boilers are replaced by electric heating technologies with improved efficiencies. Within the 'do nothing' this is assumed to be a mix of direct electric heating and air source heat pumps, whereas within 'business as usual' this is expected to be majority heat pump installation. This, alongside some retrofit deployment and accelerated boiler replacement accelerates the decline in fuel consumption within the business as usual pathway.

It can also be seen in Figure 5.2 that the final energy consumption in the green growth and green growth with heat networks scenarios is similar to the low demand scenario. This indicates that the City can achieve ambitious levels of development sustainably through the use of efficient, low carbon technologies.

The City Corporation's targets to reach net zero emissions in their own assets by 2027 are built into the 'business as usual' scenario by ensuring it is in line with the proportional reduction in emissions; however, compared to the energy consumed within the rest of the city, it can be seen on Figure 5.2 that it does not cause a significant decrease in total energy consumption. The City's reductions due to offsetting have not been included within the LAEP emission pathways.

In contrast, within the five optimised scenarios, as shown in Figure 5.2, the majority of the reduction in energy consumption occurs before 2032. This early reduction in gas, petrol and diesel fuel consumption leads to the optimised scenarios having almost 50% less cumulative emissions compared to the 'do nothing' and 'business as usual' scenarios (shown in red on Figures 5.3-5.6). This has the additional advantage of better air quality, reduced environmental effect and potentially reduced energy costs, benefitting the local economy. The individual building green growth and hydrogen green growth are shown as comparison to 'do nothing' and 'business as usual' in Figures 5.3 and 5.4. The decreased efficiency of hydrogen as a heating fuel in comparison to heat pumps leads to the higher total fuel consumption for the green growth with hydrogen scenario. The electricity consumed in 2040 across all four figures on page 57 appears fairly consistent because by 2040 the majority of electricity consumed is for uses other than heating, as shown in Figure G.1 in Appendix G.

It should be noted that this reflects only the energy consumed with the City, and ignores any primary energy consumed in order to produce the fuels (for example hydrogen production requires significant input energy). However, the emissions factors used to calculate the carbon emissions from the fuels consumed do account for emissions associated with the production and distribution processes. For hydrogen, the emissions factor used varied with time. It was assumed that there was an initial blend of low carbon hydrogen and natural gas in the grid, with this reaching 100% hydrogen by 2040, and that the hydrogen imported would always meet the UK 'low carbon' hydrogen standard. See Appendix F for the assumed hydrogen blend build out.

5. Energy transition pathways
Pathways

Total energy consumption

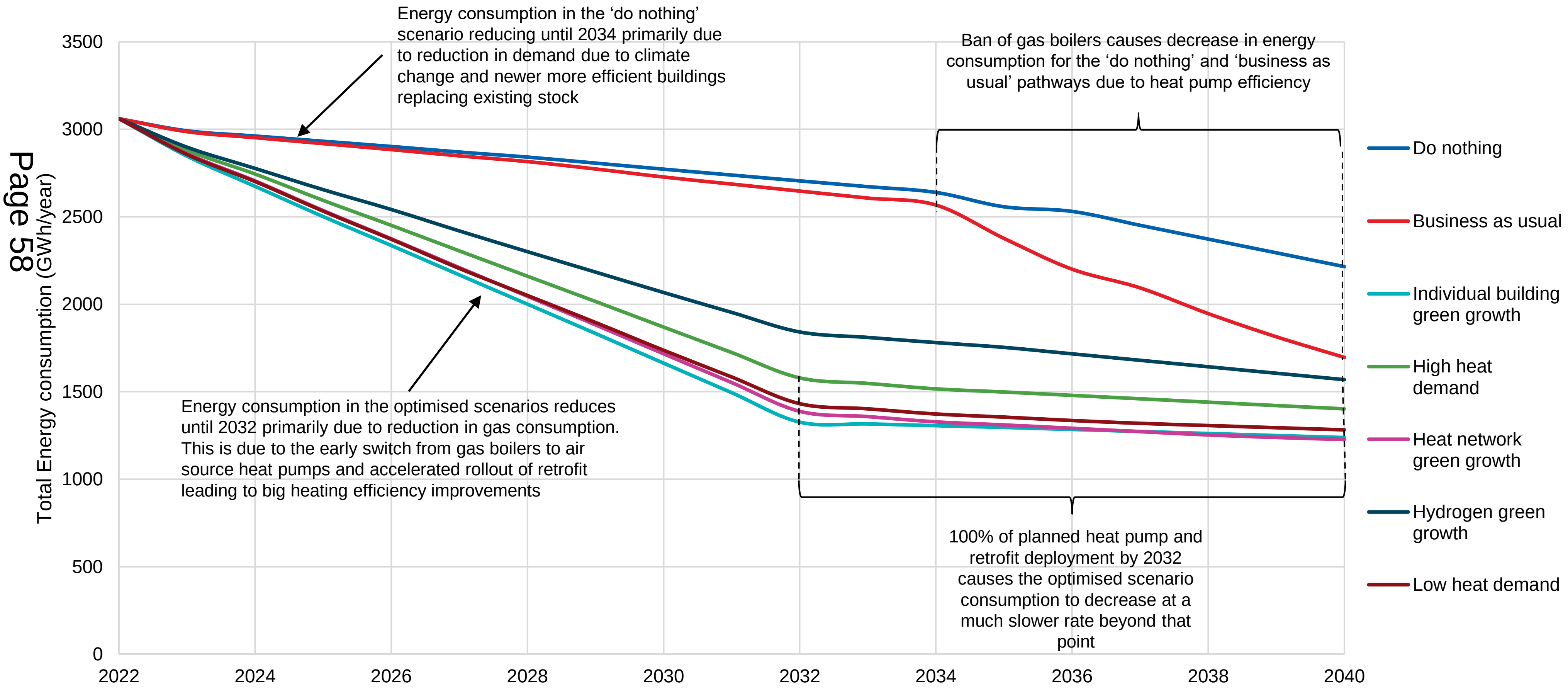


Figure 5.2: Total energy consumption for different pathways

5. Energy transition pathways
Pathways: Energy consumptions and cumulative emissions

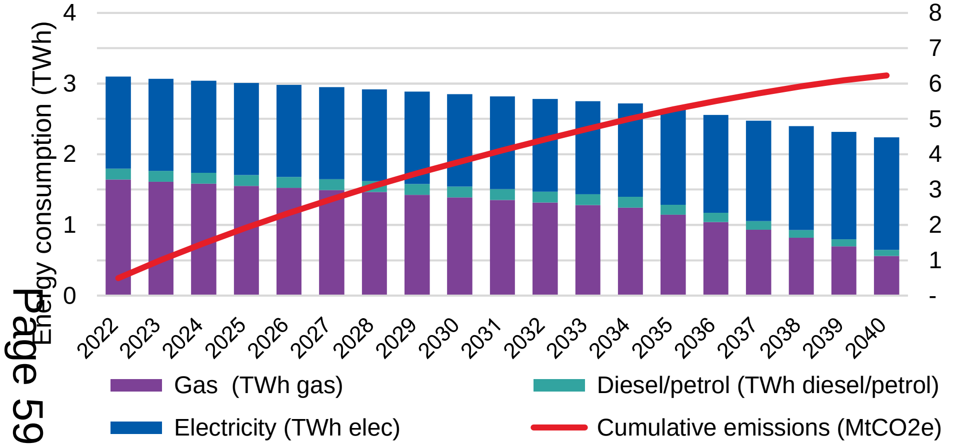


Figure 5.3: Energy consumption and total cumulative emissions for 'do nothing' scenario

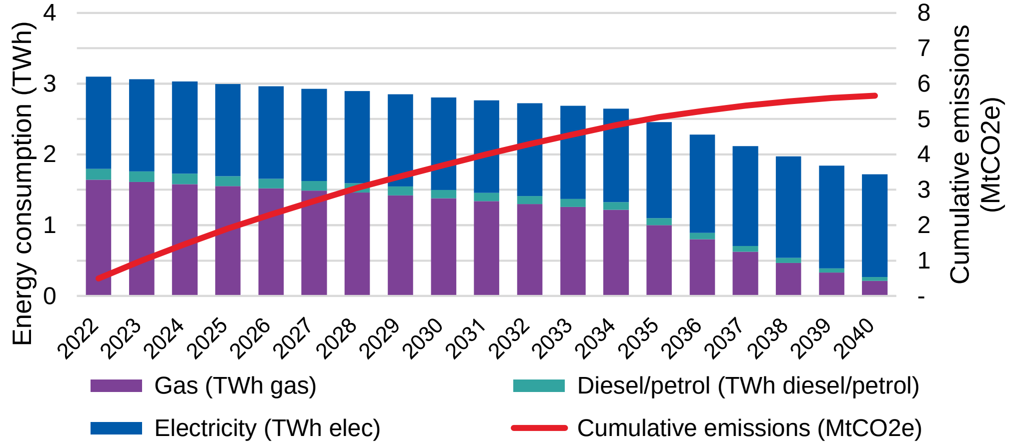


Figure 5.4: Energy consumption and total cumulative emissions for 'business as usual' scenario

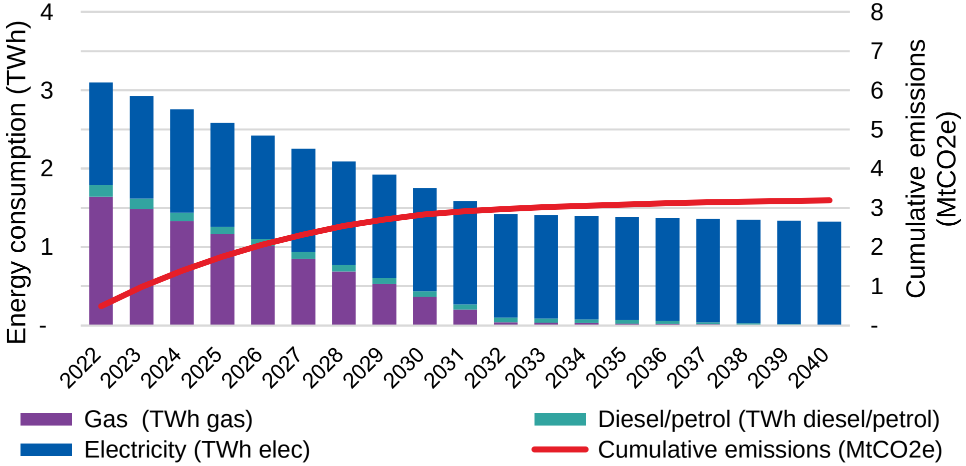


Figure 5.5: Energy consumption and total cumulative emissions for ' individual building green growth' scenario

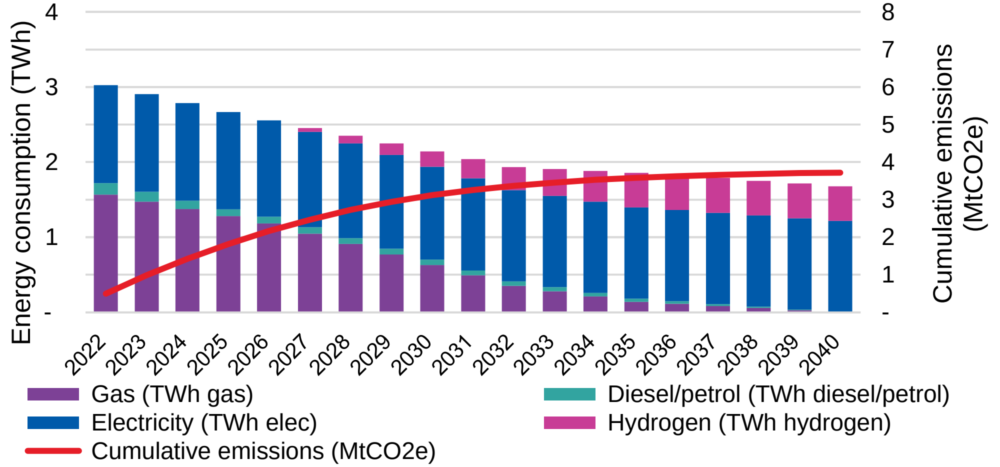


Figure 5.6: Energy consumption and total cumulative emissions for 'hydrogen green growth' scenario

5. Energy transition pathways
Pathways

Carbon emissions pathways

Carbon emission pathways

The carbon emission pathways have been developed to show how the City's energy emissions could change between 2022 and 2040 for each of the five modelled scenarios as well as the 'do nothing' and 'business as usual' scenarios for comparison. These are shown in Figure 5.8.

The baseline 2022 carbon emissions for the energy demands within scope for this study were estimated to be around 490 $ktCO_2e$. Within the 'do nothing' scenario, these emissions are estimated to drop by 70%. This is primarily due to the reduction in the emission factor of the grid, which within the UK is forecast to reduce by 90% by 2040 compared to 2022 and the fact that electricity makes up around 50% of the City's energy consumption (see Figure 5.3). This shows that even without further action emissions will decrease, but meeting net zero requires more action. As discussed on page 55 and shown in Figures 5.3-5.6 on page 57, there are also higher cumulative emissions associated with this scenario which will lead to a more negative impact.

The 'business as usual' pathway presents the potential carbon emissions reduction to 2040 if the City follows all of their existing plans, as well as London and national policy. The divergence between the 'do nothing' and 'business as usual' pathways to 2027 is due to the implementation of the actions laid out in the climate action strategy to reach net zero emissions across the City Corporation's own assets.

By 2040, it can be seen in Figure 5.8 that based on current policies and planned actions, the 'business as usual' pathway, there is still further decarbonisation that can be implemented, as shown across the optimised scenarios. The 'business as usual' and 'do nothing' scenarios currently heavily rely on the decarbonisation of the grid without first reducing consumption. This has the potential to lead to overloading the grid if upgrades and supply cannot keep up with the increased demand. Current City plans are fairly in line with national plans, showing that more can and should be done by the city to avoid having to rely on high levels of offsetting.

The optimised scenarios pathways all end at similar residual emissions by 2040 ranging from 'high energy demand' at around $16kTCO_2e$ to 'hydrogen green growth' at around 13 kTCO2e. These final residual emissions are so similar because in each scenario the model has optimised against lowest carbon. Furthermore, since the electricity carbon factor is projected to be so low in 2040, only minor differences in emissions are seen between scenarios. This is broken down in further detail in Appendix G. The residual emissions are from the import of grid electricity and the associated emission factor used for the grid (further detail on the emissions factors used are included in Appendix F). It should be noted that if BECCS is included, the emissions in the optimised scenarios are negative by 2040.

The grey area in Figure 5.7 shows the emissions gap between the 'business as usual' and green growth scenario. This gap represents the emission reduction opportunity. The scale to which this gap is closed and potential emissions are avoided, by improving on the current 'business as usual' trajectory, is dependent on the implementation of the delivery actions detailed on pages 78 - 95.

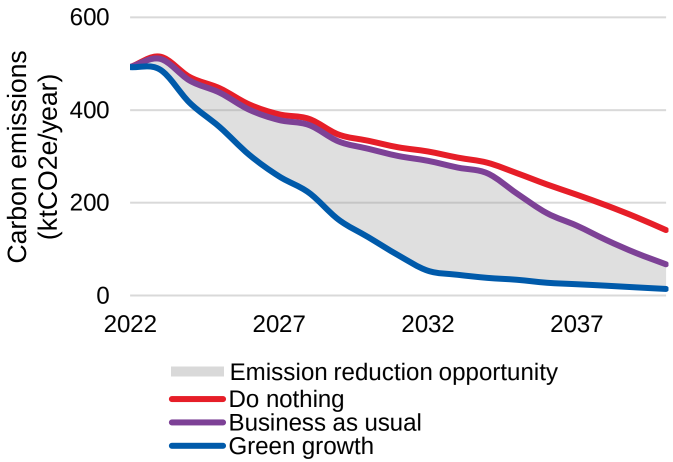


Figure 5.7: Emissions gap between Business as Usual and the Future Green Growth Scenario.

5. Energy transition pathways
Pathways

Carbon emissions

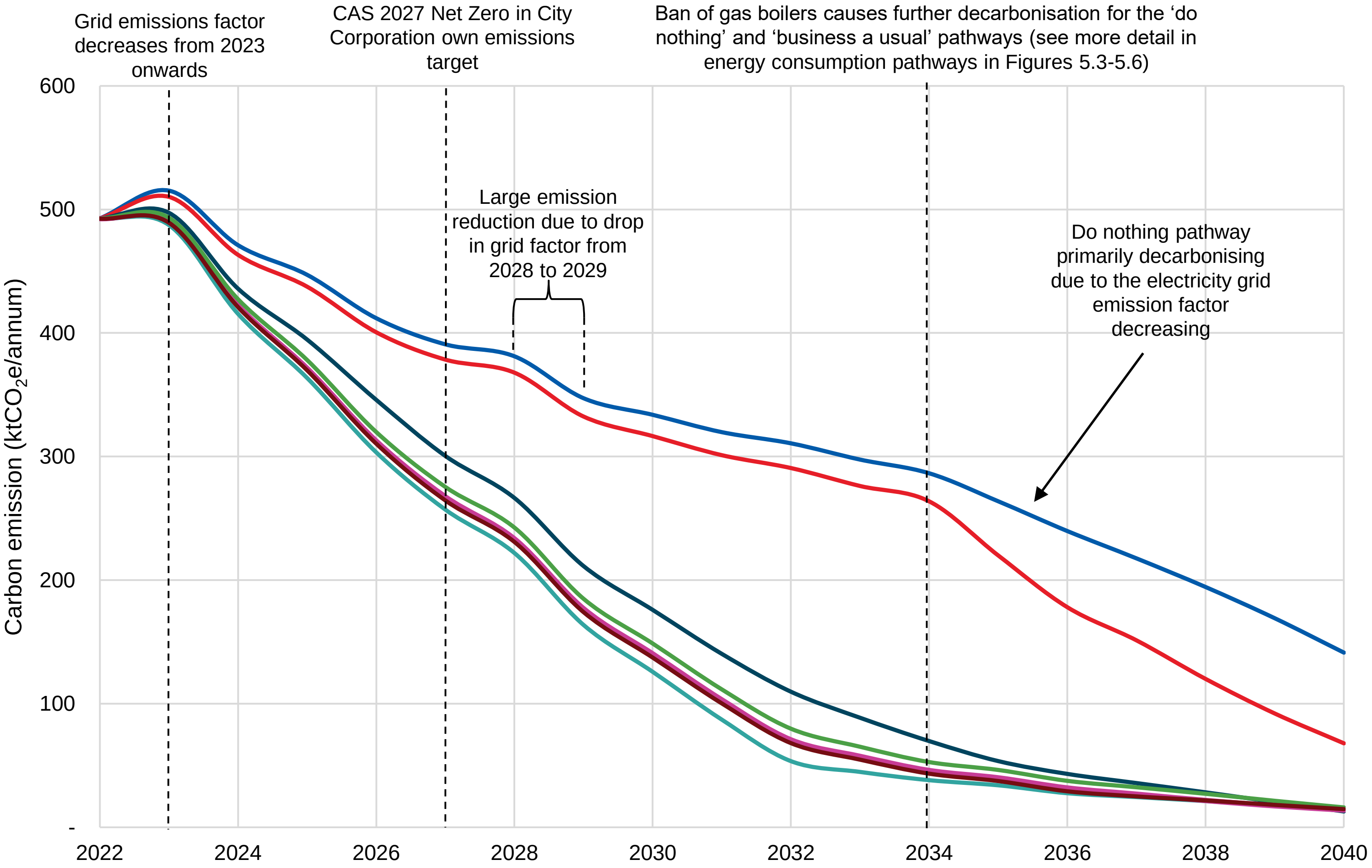


Figure 5.8: Projected annual carbon emissions based of energy transition pathways.

Pathway	2040 emissions (ktCO2e)
High energy demand	16.02
Low energy demand	14.64
Individual building green growth	14.15
Heat network green growth	14.01
Hydrogen green growth	12.64

Table 5.2: Projected annual carbon emissions for the optimised scenarios.

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5. Energy transition pathways
Future energy system mix

Multi-Criteria Analysis, Low Carbon Technologies & Recommended Pathway

Multi-Criteria Analysis

Multi-Criteria Analysis (MCA) was undertaken to assess the potential future energy system scenarios. This helps to inform a recommended pathway that should be taken forward as a basis for the whole energy system within the City. Four overarching criteria themes have been defined that encompass the City Corporation's wider ambition beyond the carbon focussed analytical modelling undertaken for the scenarios:

- Achieves CAS net zero targets
- Benefits to society
- Affordability
- Deliverability

The three Green Growth scenarios (Individual Building Green Growth, Heat Network Green Growth, Hydrogen Green Growth) have been scored against 18 criteria that reflect the aims of this LAEP, CAS and wider Corporation ambitions. Inclusion of a 'Business as Usual' (BaU) pathway, introduced on page 54, has also been included as a point of reference against these scenarios. The scores allocated against each criteria reflect the descriptions stated in Table 5.3.

Recommended Pathway

The recommended pathway is a blended version of the optimised scenarios. From the results of the MCA, this pathway incorporates a mix of individual building green growth and heat network green growth, recognising that the final technologies rolled out for decarbonisation, especially for heating, will be selected depending on a building or area's suitability. This will integrate the efficiency benefits of heat networks, supported by Heat Network Zoning Policy, whilst incorporating individual heat pumps where they are the more cost effective option. Using this blended approach will limit the criteria that Heat Networks Green Growth scored lower on, including minimising disruption and new infrastructure needed by selecting individual heat pumps on a building level where it is the more appropriate technology.

The blend will also capitalise on the benefits of heat networks identified in the MCA, including putting less stress on the grid by reducing overall energy consumption and increasing the opportunity to utilise waste heat and heat sharing. The heat network clusters identified on page 41 show the areas of high heat density which can be the starting point and priority areas for further analysis.

Low Carbon Technologies

Figure 5.9 on page 62 shows the expected future capacity required for each modelled zone of low carbon technologies/ including: heat networks (served by centralised heat pumps), individual building ASHPs, EV chargers and rooftop PV. These values stated reflect the system and technology capacities associated with the Heat Networks Green Growth Scenario, they are intended to reflect the magnitude of capacity needed to meet net zero for the recommended pathway in 2040.

Table 5.3: MCA of a BaU and Green Growth scenarios

Score	Description
3	Criterion well fulfilled
2	Criterion mostly fulfilled
1	Criterion somewhat fulfilled
FAIL	Criterion not fulfilled

5. Energy transition pathways
Future energy system mix

Multi-Criteria Analysis & Proposed Scenario

Table 5.4: MCA of a Business as Usual and Green Growth scenarios.

Criteria Theme	No.	Criteria	Business as Usual	Individual Building Green Growth	Heat Network Green Growth	Hydrogen Green Growth
Achieves CAS net zero targets	1	Minimises 2030 corporation residual emissions to offset	1	3	3	2
	2	Minimises 2040 residual emissions to offset	FAIL	3	3	2
	3	Minimises cumulative 2022-2040 emissions	FAIL	3	3	1
	4	Reduces overall primary energy consumption and increases energy efficiency	FAIL	2	3	1
Benefits to society	5	Minimises disruption in businesses and homes caused by interventions	2	1	1	2
	6	Creates local investment and new local green jobs	1	2	3	1
	7	Improves the local environment	FAIL	3	3	2
	8	Lowers system operating costs, lowering long term energy costs for businesses and residents	FAIL	2	3	1
	9	Helps make the City's buildings, public spaces and infrastructure climate resilient	1	2	3	2
Affordability	10	Minimises capital costs for delivery	2	1	1	1
	11	Minimises impact on the viability of new developments	1	3	3	2
	12	Current availability of investment for low carbon technologies	1	2	2	FAIL
Deliverability	13	Minimises new local City infrastructure and reduces disruption to the public realm	2	2	1	3
	14	Maximises energy security and long term system resilience	1	2	2	2
	15	Maximises the Corporation’s level of influence to support delivery	1	1	2	FAIL
	16	Supported by current and emerging regulatory environment	1	3	3	1
	17	Technological readiness and leverage of local heat sources	2	2	3	FAIL
	18	Positions the City as an innovation test bed	FAIL	2	3	3
TOTAL:			16	**39**	**45**	26

5. Energy transition pathways
Future energy system mix

Low Carbon Technologies

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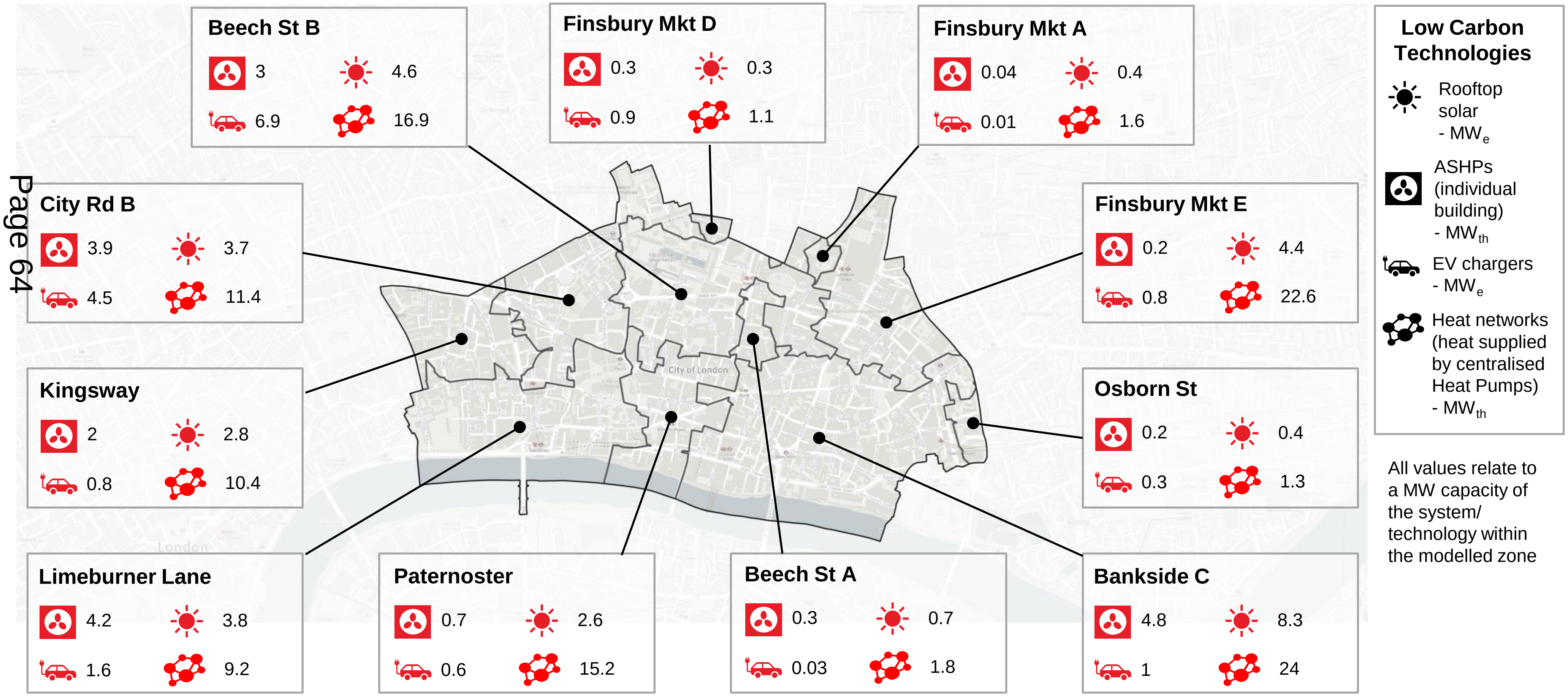

Figure 5.9: Low carbon technologies per zone – reflective of the Heat Network Green Growth Scenario.

5. Energy transition pathways
Future energy system mix

Integrated energy system vision

Figure 5.10 is intended to display the relationship between the core energy system components, shown within the sankeys on pages 45 - 49, and the energy use (and recovery) opportunities that will be key in the future system within the City*. The sankey identifies the following:

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- Ambient energy (air, water or ground) that is utilised as an input to the low temperature heat networks, alongside power demands of heat pump conditioning equipment.
- Heat rejection and the potential to recycle waste heat that can then serve as a heat source for heat pumps providing heat to buildings across the City. This recovery can be done both on a local scale i.e. within building using heat recovery units, and at a neighbourhood scale via heat networks. The heat recovered from buildings, assets and processes will be used as a heat source from which centralised high efficiency heat pumps serve the networked buildings.

* Transport demand and associated energy has been omitted from this Sankey to enable simplification of visual shown

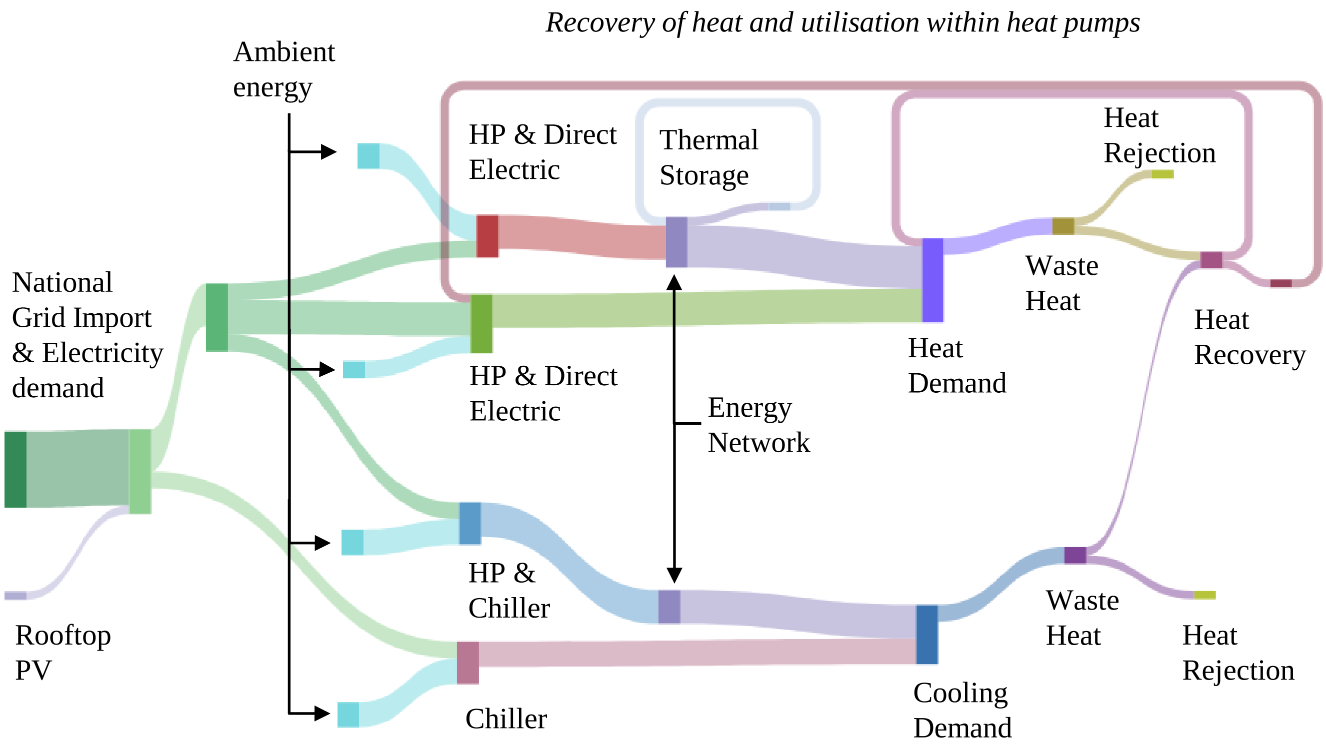

Figure 5.10: System Sankey including

6. Priority intervention areas
Introduction

Section overview

This chapter sets out the priority intervention areas identified within the LAEP and is split into the following sections:

- A detailed overview of the 6 priority intervention areas and their interdependencies
- The level of investment required for each area
- Uncertainty risk analysis
- Costing considerations

The optimisation modelling presented on the preceding pages shows the change that will be necessary to deliver a net zero energy system in the City. Across all modelled scenarios, the least cost pathway to net zero will involve significant investment and profound changes to how energy is used. However, due to the interdependencies between pathways and interventions, it is inherently difficult to estimate the costs of the different scenarios.

The priority intervention areas to deliver this change are set out in Figure 6.1. Delivery of the wider objectives of the plan will need to be supported by the right governance and engagement, policy environment and financing solutions. The main interdependencies and interactions between the priority intervention areas are shown on page 68. This highlights the importance of a whole system approach with a coordinated programme of delivery to meet the City's net zero carbon target by 2040.

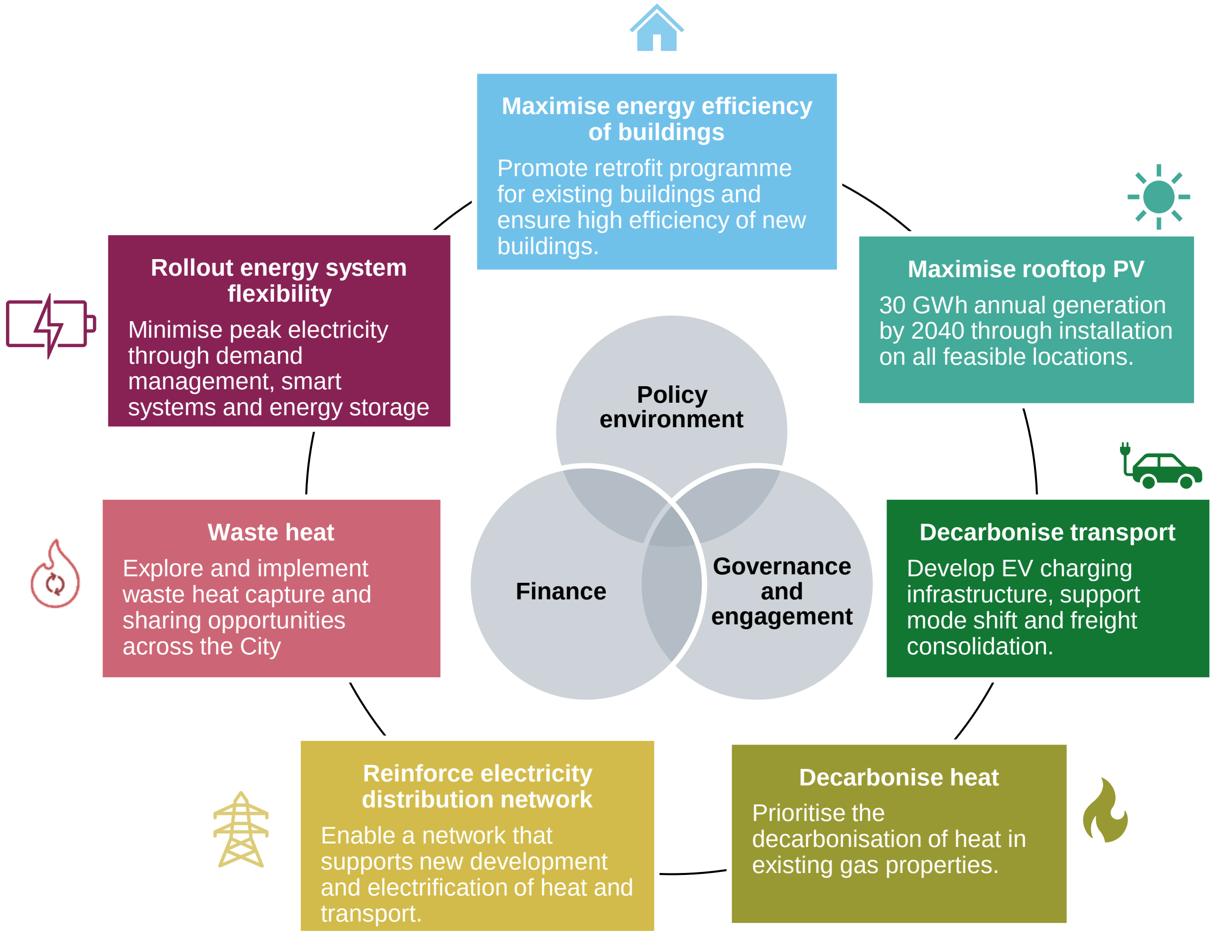

Figure 6.1: Priority intervention areas in the City

6. Priority intervention areas
Priority intervention areas

Energy efficiency of buildings and rooftop PV

Energy efficiency of buildings

Reducing energy demand of buildings through improved energy efficiency minimises the need for potential electricity network reinforcement; decreases the associated energy bills, which in turn will help support businesses and residents in the face of rising energy costs; and when done at City scale will significantly contribute to the net zero targets.

Due to the building typology splits in the City, the predominant focus of both existing and new developments is on commercial/office spaces which favour certain types of energy efficiency and building retrofit measures. Efficiency improvements can be made with both:

- Passive measures - building fabric upgrade including insulation and air tightness, high performance glazing, solar control devices/shading (where feasible)
- Active measures – high efficiency system and plant replacement, smart meters, optimised building controls systems and energy recovery systems

Further policy should be put in place to ensure new developments in the City meet stringent requirements for energy demand, supply, and reporting. All developments should be encouraged to be designed to meet certification schemes including NABERS certification, as well as planning policy to require a minimum BREEAM rating of 'Excellent' (with an aim for 'Outstanding') for new major developments. This includes the use of highly efficient building fabric (which also minimises overheating); high efficiency lighting, ventilation, and appliances; and efficient operation of the buildings themselves.

As outlined as an action within the CAS, there is a need to roll out a programme for energy efficiency retrofit in the City Corporation's own building stock, the City Corporation Housing Estates, and other City Corporation non-domestic buildings (e.g. schools. Through community engagement, government incentives and planning measures, building owners will also need to be encouraged and supported to carry out efficiency upgrades. Existing properties with low EPC ratings and where retrofit is more cost effective should be prioritised.

Rooftop PV

The City's dense, urban context means that opportunities for local low-carbon energy generation are limited. However, the technical analysis and optimisation modelling undertaken for this plan communicates that there are still benefits of maximising the deployment of rooftop PV in the area, which will support in delivering low-cost, zero-carbon energy to residents and businesses. Other opportunities for Building Integrated PV (BiPV) including external wall PV, Solar tiles, Solar Glass and Solar Shading should also be assessed in detail and implemented if proved to be viable.

This plan recommends that the City Corporation should aim to deploy rooftop PV on all feasible City Corporation assets, to be delivered alongside energy efficiency retrofits, and encourage uptake among building owners and developers through education and engagement. The maximum utilisation of rooftop PV in all modelled scenarios points toward the requirement for widespread deployment to all feasible locations.

By 2040, at least 30MW of rooftop PV should be deployed across the City's buildings, resulting in ~34GWh of local electricity generated annually.

6. Priority intervention areas
Priority intervention areas

Transport and heat decarbonisation

Transport decarbonisation

As road transport becomes increasingly electrified, a significant rollout of electric vehicle charging infrastructure will be needed to ensure the needs of residents and vehicles are met. This will include installation of public chargers located at workplaces and destinations and encouraging others with off street parking and loading bays to install rapid charge points. The City Corporation have a detailed transport strategy which covers all forms of transport, as well as an EV infrastructure forecast which extends to 2025. These focus on the voices of residents and workers within the City to make it safer, prioritise pedestrians and active transport whilst also providing cleaner and lower carbon streets.

The modelling carried out for this plan supports the electrification of transport, and thus the scaling up of public and private EV charging infrastructure within the City. By 2040, there should be a total of 3MW of standard EV charging infrastructure installed and 14MW of rapid EV chargers installed within the Square Mile. This includes the installation of chargepoints across City Corporation assets, as well as advocating and supporting local businesses with installation, to enable private sector rollout.

Alongside electrification, this plan supports the City Corporation's ambitions to reduce motor vehicle traffic by 25% by 2030. This will minimise charging demand within the City, as well as reduce congestion, making the area more accessible to active travelling such as cycling and walking. This includes expanding and developing the identified plans to reduce freight and last-mile delivery logistics within the City through consolidation services and last-mile hubs.

Heat Decarbonisation

The majority of the current building stock within the City of London is heated by natural gas boilers, which will need to transition to a low carbon heat source by 2040 in order to meet the City's net zero ambitions.

The City's dense building stock and concentrated demands makes it an area that is well suited to heat network development, which has been explored through the technical analysis and modelling carried out as part of this plan. This plan recommends that the City Corporation should explore the potential for heat network development opportunities within the City. This includes the expansion and decarbonisation of existing heat networks in the area, waste heat offtake opportunities, and enabling existing and new developments to connect to future networks.

For buildings where a future connection to a heat network is deemed to be infeasible or unlikely, alternative low carbon heat sources will need to be explored, such as heat pumps or hydrogen boilers. Heat pumps will have a role to play in the future energy system irrespective of the other systems/vectors i.e. heat networks and hydrogen. Therefore implementation of heat pumps within buildings which are likely to not be connected to a heat network or served by a hydrogen grid provides a no regrets route to decarbonisation.

There is potential for heat decarbonisation through the use of renewable heat sources available in the City, such as the air ground and water. This included the use of air source heat pumps and the Thames.

6. Priority intervention areas
Priority intervention areas

Waste heat, electrical infrastructure and flexibility

Waste heat

Capturing and utilising heat which is produced as a by-product from other processes is an effective and efficient method of providing low carbon heating to buildings directly or via heat networks. This can be via building scale energy centres or larger network scale energy centres as a source for heat pumps. The latter has the additional advantage of allowing the buildings that otherwise would not have access to a waste heat opportunity due to location to benefit from it whilst also providing efficiency improvements of large scale waste heat capture. Even compared to air source heat pumps, which are commonly proposed to replace gas boilers, waste heat sources can offer a reduction on electricity demand as the heat they produce is normally at a higher initial temperature and therefore requires less energy to be 'boosted'.

In dense, urban areas such as the City, waste heat is often readily available from a range of sources such as building cooling plant and London Underground ventilation shafts. The location, temperature and quantity of potential heat from these sources should be mapped in parallel to any heat network studies. Waste heat from cooling in particular is of interest to the City which has a large proportion of non-domestic buildings such as offices and businesses with servers which require constant cooling. Opportunities to share this heat across the area boundary with neighbouring boroughs should also be explored.

It is recommended that the Local Plan is updated to mandate new developments with a waste heat source to be enabled for heat offtake. This could also be encouraged through development of a waste heat pilot study to present the financial and carbon benefits to the asset owner.

Electrical infrastructure

Electrical infrastructure network upgrades are a priority intervention to allow new local renewable assets to connect to the electricity grid, as well as meeting the increased electricity demand due to growth and a shift to electrified transport and heat. This plan recommends that the City Corporation continues to engage and coordinate with UKPN to understand the implication of growth and electrification on the electricity infrastructure in the area, and to work collaboratively to deliver additional capacity where required.

Energy system flexibility

To minimise the need for further grid infrastructure, and to deliver a resilient energy system to businesses and residents, this plan recommends that the City Corporation will need to support the uptake of flexibility technologies. These include demand side response and smart appliances, thermal/battery storage and vehicle-to-grid, alongside more. The City Corporation should look to embed flexibility technologies in their own assets, condition developers to design flexibility solutions into new buildings, and encourage energy stakeholders and local businesses to participate in flexibility pilots such as testing smart appliances and time of use tariffs (TOUTs) which can become replicable use cases for delivering flexibility.

6. Priority intervention areas
Priority intervention areas

Interdependencies across priority intervention areas

There are numerous interdependencies and interactions between the priority intervention areas, as shown in Figure 6.2. This highlights the importance of a whole system approach with a coordinated programme of delivery to meet the net zero carbon target by 2040.

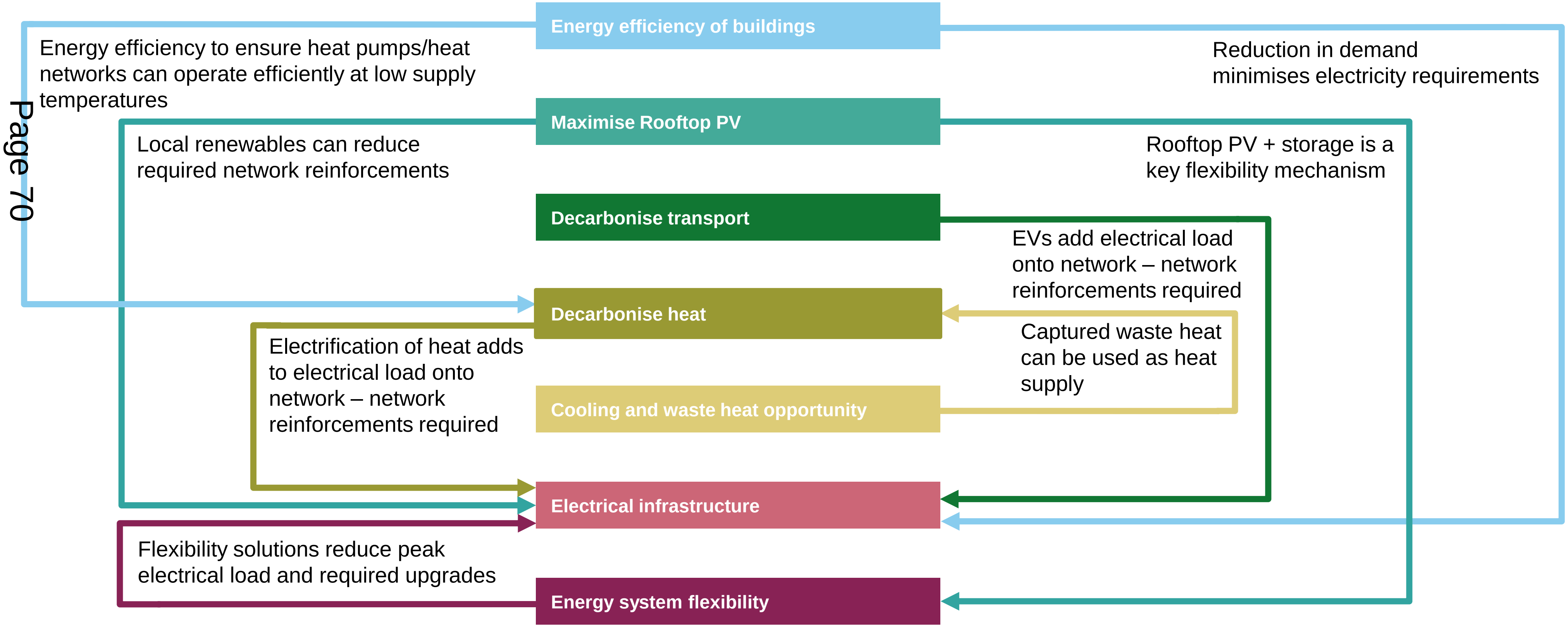

Figure 6.2: Key interdependencies across priority interventions areas

6. Priority intervention areas
Investment required

Indicative investment

To deliver this LAEP and reach net zero by 2040 in line with the City Corporation's targets, high levels of investment will be required. Table 6.1 shows the indicative capital expenditure (CAPEX) required for the green growth scenario. There will be some variation for the other optimised scenarios, especially in decarbonising heat where the technology used is varied.

Currently, the CAPEX needed for electrical infrastructure upgrades is not clear. The costs of reinforcement will depend on the extent of the upgrades needed which requires more detailed analysis, particularly at the lower voltage level. Similarly, the opportunity to extract waste heat is highly dependent on where the heat is being rejected – since this is largely unknown, the costs cannot be developed. Within energy system flexibility there will be additional capital costs to enable and rollout demand side management (DSM) and demand side response (DSR), however this requires more detailed analysis to quantify.

Some intervention areas also have an associated change in operating expenditure (OPEX) from current values. For example, the decarbonisation of heat will change operational costs for consumers, with increased efficiency of buildings potentially reducing this cost. The impact of uncertainties and risks on the final costs of the future energy system are explored further in table 6.2 on page 70.

Funding will be a key enabler for the delivery of the LAEP, suitable funding mechanisms need to be sourced. This is addressed in the enabling actions and governance sections.

Table 6.1: Indicative investment requirements associated with the green growth scenario energy system

	Indicative CAPEX (£m)	Basis for CAPEX estimate	Party responsible for securing CAPEX
1. Energy efficiency of buildings*	1,000-2,900*	Shallow-deep retrofit scenario	City Corporation, housing and property associations, commercial building/land owners, residents
2. Maximise rooftop PV	30	Rooftop PV installation	City Corporation, housing and property associations, public, building owners, renewable energy providers
3. Decarbonise transport	20	EV charger installation	City Corporation, public
4. Decarbonise heat	170 (HPs) Key uncertainty (heat networks)	Heat pump installation Heat networks where feasible	Building owners and tenants (with the City Corporation and government help)
7. Cooling and waste heat opportunity	Key uncertainty	-	City Corporation, housing and property associations, public, building owners, heat network provider
5. Electrical infrastructure	Key uncertainty	Grid reinforcement	UKPN, Developers
6. Energy system flexibility	3 (storage), Key uncertainty (DSM/DSR)	Thermal storage installation, DSM/DSR rollout not included	Building owners and tenants, developers, energy providers
Total	1,200 - 3,100 +	-	-

* This figure is a high level estimate, and depends on what supposed interventions are applicable to buildings in the area, which would be subject to further study and feasibility assessment on a building / estate level.

6. Priority intervention areas
Uncertainty risk analysis

Table 6.2: Future energy system uncertainties and risks. Arrows represent the direction of change expected: ↑ = increase, ↓ = decrease, ? = unclear.

Uncertainty	CO_2 emissions	CAPEX	OPEX	Other notes
Lower uptake / rollout of retrofits	↑	↓	↑	Higher consumer bills and more CAPEX spent on deploying heat pumps, likely to result in poor consumer perception.
Lower uptake / rollout of standalone heat pumps	↑	↓	?	More chance of hydrogen/ heat network scenario. OPEX changes would depend on future costs of electricity, gas and hydrogen.
Lower uptake / rollout of demand side management	↑	↑	↑	Less resilient energy system and higher energy infrastructure costs. Greater cost to consumers.
Lower Heat Network deployment	↑	↑	?	Delays to Heat Network Zoning Policy implementation may have knock-on effects to decarbonisation especially where waste heat sources are being implemented within the network development.
Lower uptake of EVs	↑	↓	?	OPEX changes would depend on future costs of diesel/petrol and electricity.
Higher uptake of hydrogen	↓	?	↑	Achieved through investment to deliver hydrogen to London. Higher uptake of hydrogen could facilitate a faster transition to net zero, with less pressure on the power network.
Lower uptake of hydrogen	↑	?	↑	Availability, pending UK government decision in 2026, or affordability could lead to lower uptake of hydrogen in a hydrogen scenario, leading to higher operating costs.
Slower decarbonisation of the national electricity grid	↑	?	↑	Decarbonisation of the grid occurs slower than projected leading to higher overall carbon emissions from all electricity based technologies
Increased grid electricity prices	?	?	↑	Might slow down electrification, higher chance of hydrogen scenario. Likely to drive more demand side management in area which would mean carbon emissions and infrastructure investments needed would reduce.
Reduced gas prices	↑	↓	↓	Less customers switch to heat pumps, more chance of hydrogen scenario.
Increased CAPEX for electrical reinforcement	↑	↑	↑	Could slow down electrification, with impact on overall carbon emissions.
More extreme weather	?	↑	↑	More extreme cold days mean higher heat pump capacities would be required. More hot summer days could lead to increased cooling, with increase in OPEX. Overall emissions remain similar if annual average temperatures vary as predicted.

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6. Priority intervention areas
Costing considerations

Figure 6.3 shows that high levels of investment are needed to reduce carbon emissions within the City. The ‘do nothing’ and ‘business as usual’ pathways have the least cost associated with them as they do not require significant capital investment in new technologies. However, they lead to greater residual carbon emissions, greater cumulative emissions and potentially higher operational costs for the end user due to reliance on less efficient technologies. The move away from gas imports towards UK produced renewable electricity as a fuel source also provides increased energy security for the future as local supplies are used up. Within the ‘business as usual’ pathway, to still meet net zero targets the City will have significantly more carbon offsetting will be needed, leading to higher costs.

Within the cost estimates, there is a high level of uncertainty for both the capital costs of new technologies and how these will change as they penetrate the market further as well as their operational costs which will depend on future costs of the electricity grid, gas and hydrogen imports. As a result, the costs included in this report have been calculated from high level assumptions and further modelling and refinement will be needed to understand the costs associated with the future energy system.

It is likely that the future energy system of the City will involve a combination of a number of the factors tested within the optimisation scenarios presented. A more detailed analysis of the interventions would be needed to understand the full system cost and provide a more precise prediction. Some of the additional factors that should be considered are listed below:

- The magnitude of power infrastructure upgrades (and associated costs) needed for the grid to meet electrification requirements, particularly at the lower voltage levels and secondary substations
- Heat network routing analysis, heat sources identification and materials costs
- The development of hydrogen distribution infrastructure and gas network conversion
- Existing technology decommissioning costs
- The effect of road disruption and installation costs of new technologies – known to be a considerable cost within the City
- Workforce considerations
- The timescales intervention infrastructure is likely to be delivered for the area (e.g. for hydrogen)
- The extent to which costs are expected to be borne by building owners. Including: heat supply, retrofit and flexibility measures; avenues for grant funding of such measures

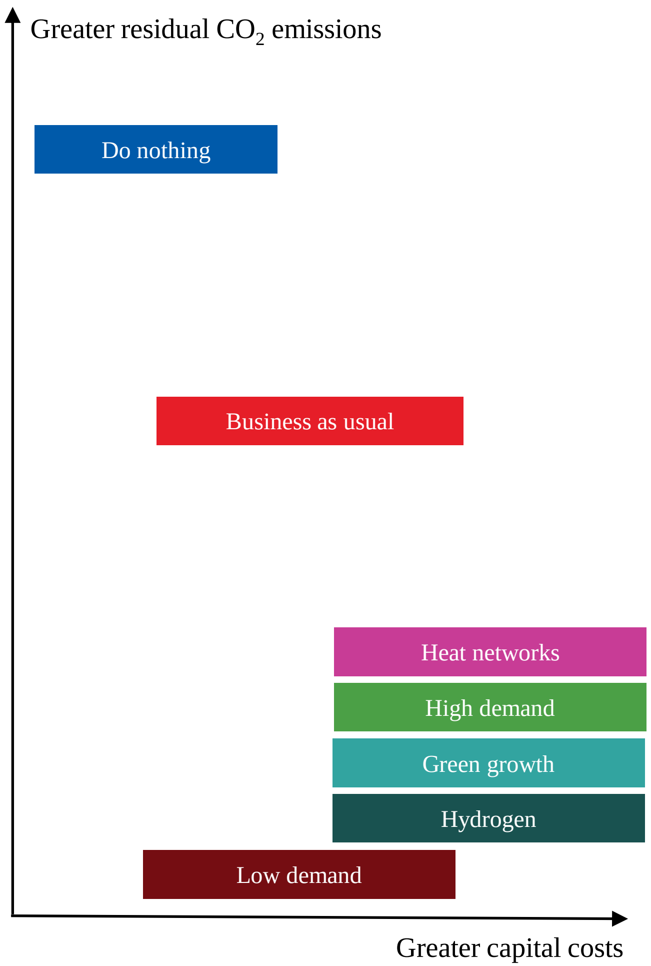


Figure 6.3: Optimised scenarios against capital cost and carbon emissions

7. Route map and proposed actions
Introduction

Section overview

This section sets out a number of specific actions within each of the seven intervention areas, alongside high level route maps to set these actions out over time. An action priority matrix has been created to identify the actions that are high priority (higher effort but higher impact) and quick wins (lower effort and higher impact) to aid action prioritisation.

Actions are described in further detail from page 78, with the action owners, other stakeholders involved and resource commitments from the City Corporation detailed. It is likely there will be a need for additional third party resources as well.

The route maps provide a focused view of actions that will be taken in the coming decade, while also showing key milestones on the decarbonisation trajectory to 2040. Each intervention requires four key elements to be successful:

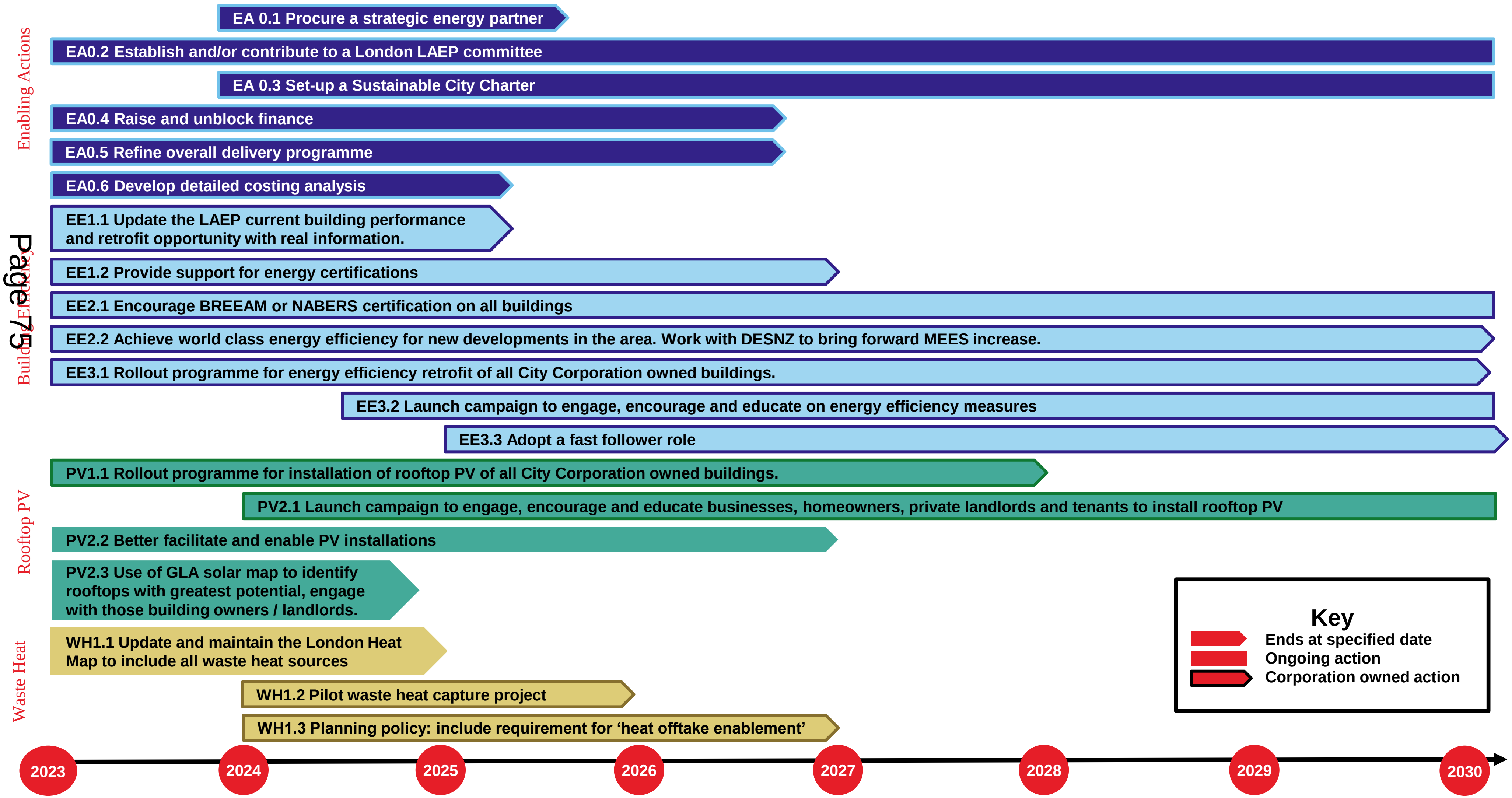
1. Mobilising finance
2. Strong and consistent policy framework
3. Delivery owners
4. Local engagement

The role that the City Corporation can play for each intervention will vary. Some intervention areas will call for direct action from the City Corporation in the material delivery of programmes, while other interventions will require the City Corporation to act more as a facilitator for market driven change. Although the exact form of the decarbonised energy system in 2040 is uncertain, there are actions that can be taken now to maintain the ability to meet the 2040 and interim targets.

Figure 7.1: Looking down Cannon Street

7. Route map and proposed actions

Medium term route map



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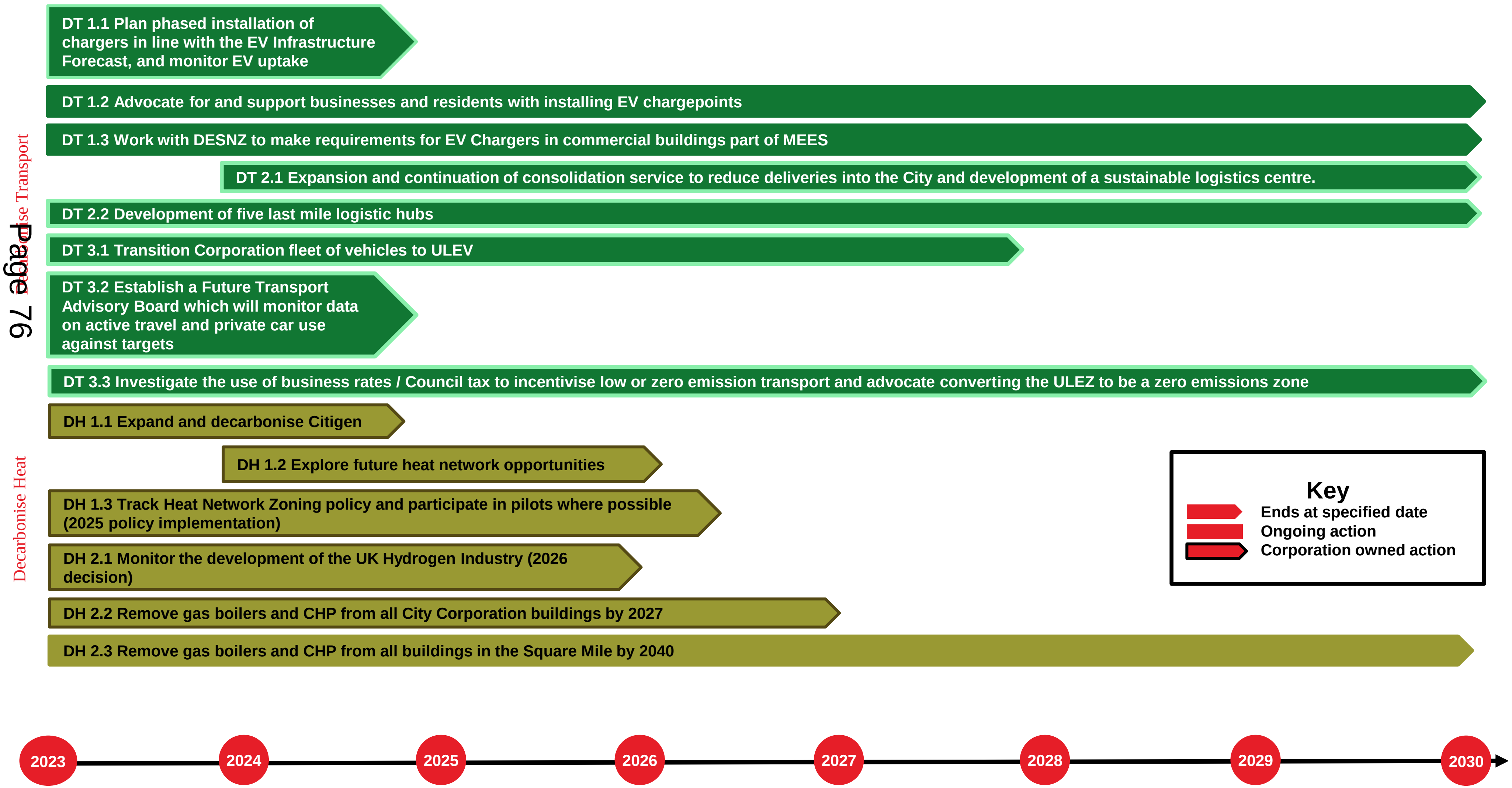
7. Route map and proposed actions
Medium term route map



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7. Route map and proposed actions
Medium term route map

Key
- Ends at specified date
- Ongoing action
- Corporation owned action

Electrical Infrastructure

- EI 1.1 Establish a bilateral City Corporation and UKPN group
- EI 1.2 Investigate pooling of buildings together and securing multi-offtake PPA.
- EI 1.3 Track heat electrification applications against projections
- EI 1.4 Prioritise connections where renewable generation is proposed, to stimulate growth in solar
- EI 1.5 Facilitate and/or reduce costs of sleeving arrangements
- EI 1.6 Extend the City Corporation multi-offtake PPA

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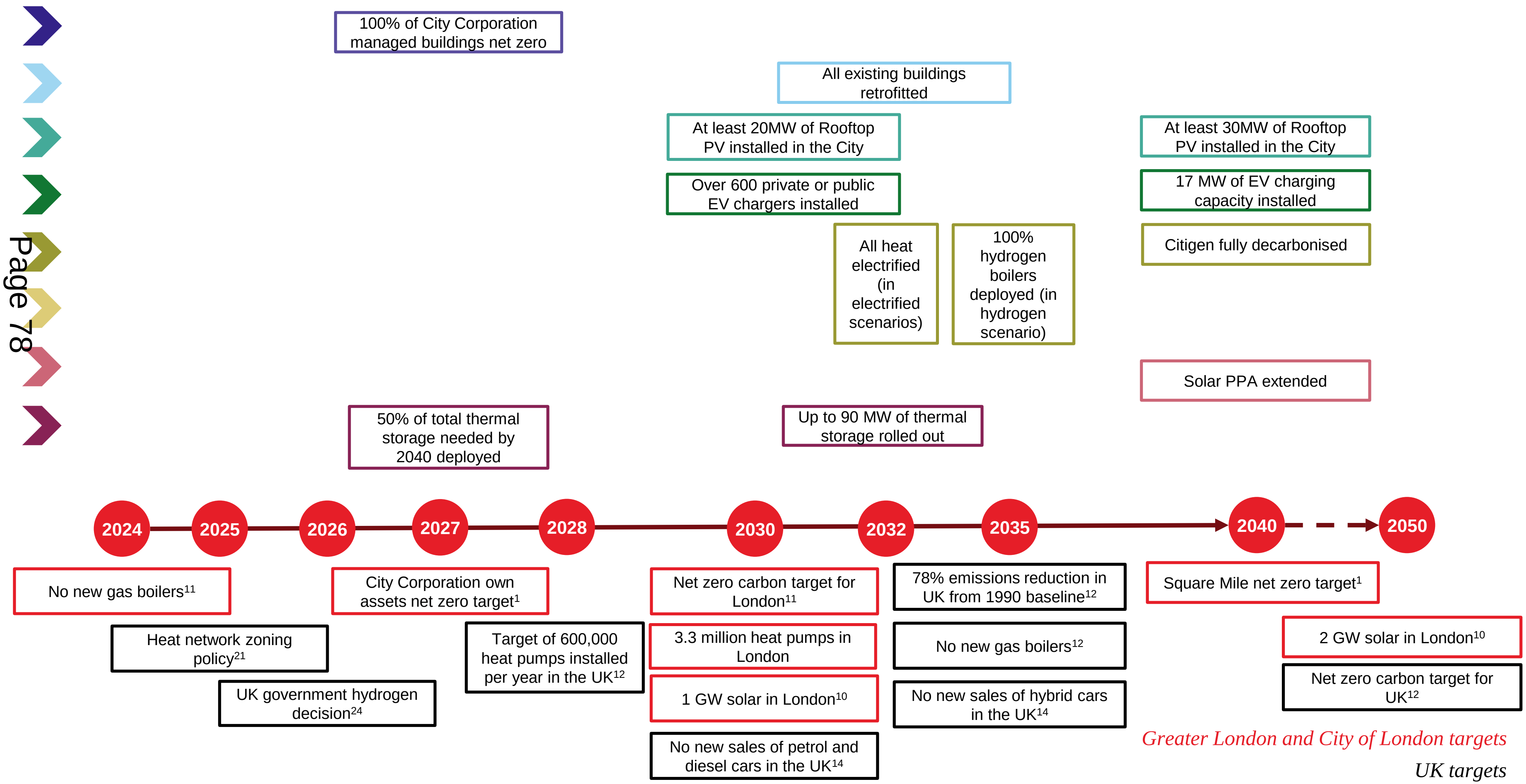
Flexibility

- FL 1.1 Engagement with existing GLA studies into flexibility and its future role in London
- FL 1.2 Improve transparency and accessibility to flexibility data
- FL 1.3 Educate and communicate with owners/occupiers on flex and benefits via City Corporation resource
- FL 2.1 Switch City Corporation buildings to time of use tariffs / carbon flex initiatives
- FL 2.2 Condition developers to design in flexibility solutions where relevant
- FL 2.3 Lobby to generate flexibility policy
- FL 2.4 Create or engage in pilot study
- FL 2.5 Direct Citigen expansion and/or heat network development towards areas of power capacity constraints

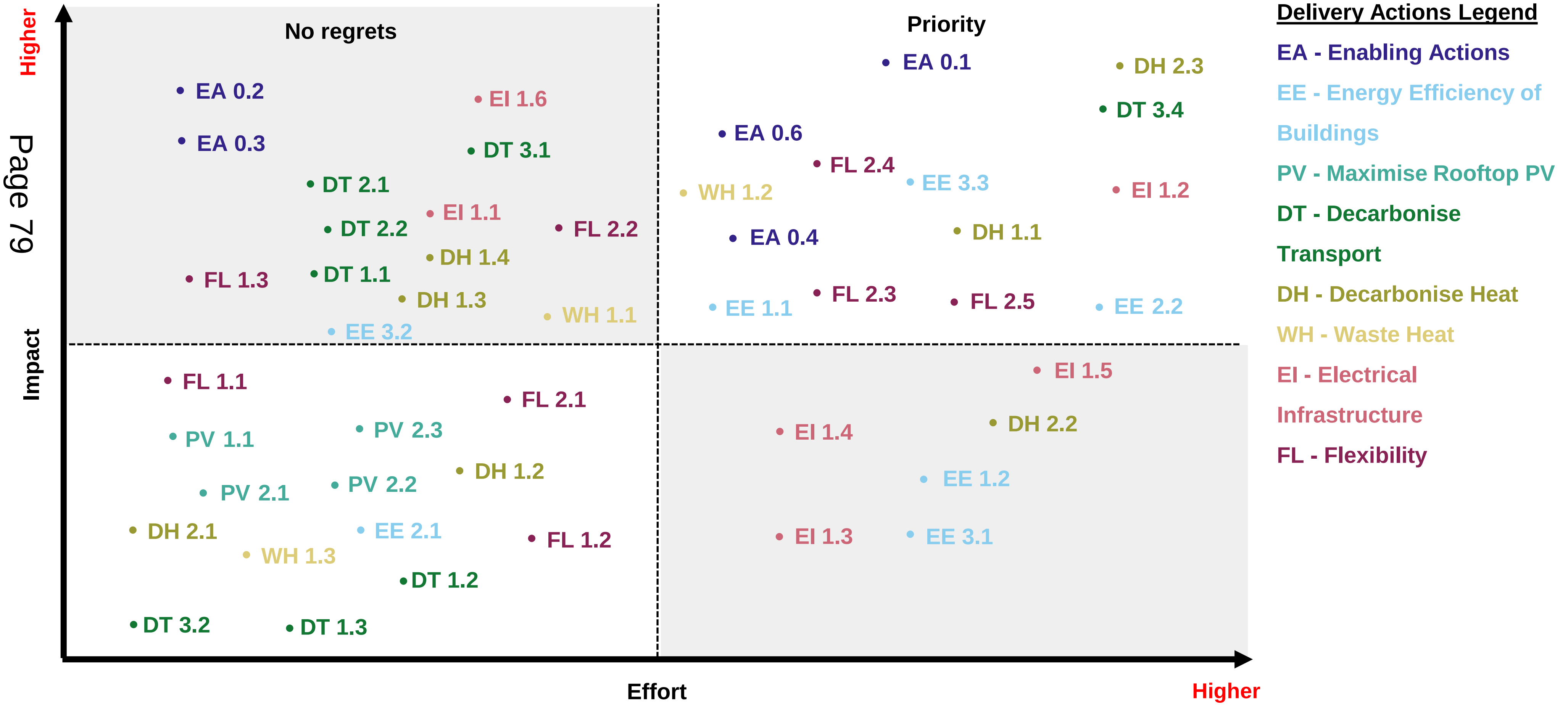
2023 — 2024 — 2025 — 2026 — 2027 — 2028 — 2029 — 2030

7. Route map and proposed actions
Long-term route map and high level targets



7. Route map and proposed actions
Action priority matrix

The actions were ranked based on how much effort would be required by the action owner and other stakeholders involved to implement the action and how much impact the action would have in reaching net zero in the square mile, relative to the other actions presented. The result is the action priority matrix below which identifies high priority and quick win actions.



7. Route map and proposed actions
Delivery actions

Enabling actions

EA 0.1 Procure a strategic energy partner

The City Corporation should investigate how the procurement of a partner (or partners), to jointly establish a Special Purpose Vehicle (SPV), could help them to deliver, operate and maintain energy projects throughout the LAEP area.

The scope of strategic partnership(s) could include:

- Assessing the potential for and driving forward identified district energy networks, including delivery and operation. This would need heat network zoning policy intervention, currently under development by DESNZ. The policy development is exploring possible delivery options – which may include concession agreements and/or exclusivity arrangements.
- A concession agreement allowing the Partner to have first refusal on projects which roll out solar PV, energy efficiency retrofit, and heat pump conversion across City Corporation buildings, (could be through heat/solar as a service to the City Corporation, or the City Corporation could pay the partner to deliver the services). Note that the Corporation already has an ESCO partner, Vital Energi, procured through the GLAs Refit framework to undertake building retrofit works; future procurement should account for this.
- Rolling out EV charging across City Corporation buildings and on streets
- Coordinating other energy activities (e.g. DSR pilots, smart grid infrastructure etc)

This approach is being taken by various councils in the UK, including Bristol, Newcastle and Coventry.

The strategic energy partner(s) would bring funds and expertise, while the City Corporation would exclusively procure the partner for energy projects. There is great potential for heat networks, rollout of rooftop PV and deep retrofit in homes in the area; wide strategic scope would be difficult for the City Corporation to deliver alone. Note it may not be appropriate to have the same partner undertaking all workstreams noted here.

This action could be enabled by undertaking soft market testing, understanding the appetite internally and development of heat network zoning policy.

Action owner: City of London Corporation

Other stakeholders: ESCos, DESNZ, Building owners, Operators, Developers

City Corporation resource commitment: 1 FTE

EA 0.2 Establish and/or contribute to a London LAEP committee

This entity could include members from the GLA, London Boroughs, key stakeholders and businesses who want to contribute to London's Net Zero targets. It could explore how members can collaborate and influence government to deliver policy and regulatory changes. It could include identification of investment opportunities or manage engagement programmes for significant areas of change like energy efficiency and behaviour change. It could be used to track and monitor plans, help foster ownership of actions and highlight areas for resource sharing. Identification of existing groups should be undertaken to see whether their mandates could be expanded to meet these needs.

Joined up action across stakeholders is key to delivering LAEPs. Members may be incentivised to attend from a Corporate Responsibility perspective. Where an organisation contributes to carbon reduction initiatives, emissions savings could be shared.

Action owner: City of London Corporation, GLA, London Boroughs, energy system stakeholders.

Other stakeholders: London Boroughs, GLA, UKPN, Cadent, Ofgem etc

City Corporation resource commitment: 0.2 FTEs

7. Route map and proposed actions
Delivery actions

Enabling actions

EA 0.3 Set up a Sustainable City Charter

The Charter recently launched by the City of Westminster includes eight commitments focused on commercial and institutional buildings, covering areas including energy, procurement, deliveries, waste and collaboration. Organisations participating in the Charter will provide annual updates on their progress in implementing these commitments and on their energy consumption.

A similar Sustainable City Charter is currently being explored by the City Corporation and could aim to build a strong business partnership on climate action across the city, encouraging businesses to lead and collaborate with the City Corporation on climate change and sustainability.

Action owner: City of London Corporation, BIDs, CPA

Other stakeholders: Local businesses

City Corporation resource commitment: 0.4 FTEs

EA 0.4 Raise and unblock finance

The City Corporation could develop a plan for funding arrangements to support the delivery of the LAEP actions it owns.

Private sector funding is difficult to raise, especially on decarbonisation projects that have longer payback periods. Incentive schemes like the Boiler Upgrade Scheme[25] go some way to support investment in things like heat pumps, and there are community schemes which could support rooftop PV and heat pump delivery. This will need to be supported by monitoring programmes to ensure understanding of the benefits of these schemes.

This action could be enabled by work being undertaken through the Climate Action Fund, Net Zero Delivery Unit and the Square Mile 2040 Partnership.

Action owner: City of London Corporation

Other stakeholders: DESNZ, GLA, CPA

City Corporation resource commitment: 0.2 FTEs

EA 0.5 Refine overall delivery programme

Continuous monitoring should be undertaken until 2045 to ensure targets are met. This will require continuous refinement and management of the delivery programme, following the whole systems approach so that initiatives are not siloed. This could potentially be delivered in collaboration with the strategic energy partner outlined in Action EA 0.1

A coordinated delivery programme to ensure that available funding arrangements are utilised in the most appropriate ways, and that the interdependencies are considered.

Action owner: City of London Corporation

Other stakeholders: all LAEP stakeholders

City Corporation resource commitment: 0.1 FTEs

7. Route map and proposed actions
Delivery actions

Enabling actions

EA 0.6 Develop detailed costing analysis

Further development of the current cost modelling will be critical to ensure all costs associated with the future energy system are considered. This should include an economic and financial analysis of whole life system costs accounting for the CAPEX, OPEX and REPEX of system components. This analysis will help to identify the level of investment needed and where that investment may come from – enabling the development of an economic case that can be presented to appropriate parties. Costing should focus particularly around the decarbonisation of heat and transport.

Action owner: City of London Corporation

Other stakeholders: all LAEP stakeholders

City Corporation resource commitment: 1 FTEs (plus consultants)

7. Route map and proposed actions
Delivery actions

Energy efficiency of buildings: stream 1 – identifying current ratings of buildings

EE 1.1 Update the LAEP current building performance and retrofit opportunity with real information.

Use the Sustainable City Charter to update where possible the LAEP dataset and profile of the current building performance and retrofit opportunity. This would require buildings / businesses / members to submit information about current energy demand and any future projections based on retrofit surveys / plans. Through this the City Corporation can update its information on energy demand and reduction potential as modelled in the LAEP.

This can also help to identify which buildings could be eligible for funding and could support engaging the building owners and managers to plan their retrofit pathway. It will also help to bring building owners together, has potential to improve data sharing and energy metering.

Action owner: City of London Corporation, Sustainable City Charter members

Other stakeholders: BIDs, CPA, building owners/tenants

City Corporation resource commitment: covered under EA 0.3

EE 1.2 Provide support for energy certifications.

The City Corporation could engage directly with building owners and landlords to encourage or support them in gaining updated energy certifications such as BREEAM and NABERS (or other operational performance certification). This could be awareness building or technical support and would help develop better understanding around energy use and retrofit options within the Square Mile buildings.

Action owner: City of London Corporation, Sustainable City Charter

Other stakeholders: BIDs, CPA, building owners/tenants

City Corporation resource commitment: 0.1 FTEs

7. Route map and proposed actions

Delivery actions

Energy efficiency of buildings: stream 2 – implement policy for new developments

EE 2.1 Encourage BREEAM or NABERS certification on all new buildings.

The City Corporation could encourage all new building developments to obtain a certain NABERS certification to support a higher standard of building performance and energy efficiency moving forwards, further increasing the requirements of current policy which requires BREEAM 'Excellent' as a minimum with 'Outstanding' as the aim. This would need enforcement from the City Corporation planning authority, but could be delivered via the new Local Plan.

Action owner: City of London Corporation

Other stakeholders: Developers

City Corporation resource commitments: 0.5FTE to set up, 0.2 FTEs to enforce

EE 2.2 Achieve world class energy efficiency for new developments in the area. Work with DESNZ to bring forward MEES increase.

As the City Corporation updates their Local Plan, they could work on policies that help them to ensure that developments in the area meet stringent requirements for energy demand, supply and reporting. This may include policies on the type of calculations which they expect to see in Energy Statements, who they expect to see Energy Statements from, and how they expect energy demand to be reported post completion. The Corporation are advised to engage with DESNZ to encourage the MEES standard of a minimum EPC C to be brought forwards from 2030.

This would also keep tenant energy costs down, improve local air quality and reduce the risk of overheating.

High energy efficiency is hard to achieve in tall buildings, and the City may need to recognise that any policies which are adopted that may reduce building heights need to be balanced off against housing targets. Making it harder for developers to obtain planning permission may reduce planning applications and slow growth.

Action owner: City of London Corporation planning team

Other stakeholders: Developers, housing associations, building owners/operators, commercial tenants.

City Corporation resource commitment: Likely to be covered under New Local Plan development, c. 0.2 FTE

7. Route map and proposed actions
Delivery actions

Energy efficiency of buildings: stream 3 – implement retrofit of existing buildings

EE 3.1 Rollout programme for energy efficiency retrofit of all City Corporation owned buildings.

Measures include roof and wall insulation, improving building air tightness, glazing replacement and more. Much of this is already happening and is in line with the CAS net zero target of 2030 for Corporation owned assets. Buildings with poor energy efficiency performance and gas/resistance heating should be prioritised for retrofit so that low carbon technologies, energy efficiency improvements and smart controls can be rolled out in tandem. The City Corporation should start with an exercise to undertake strategic decarbonisation planning across their building stock. Where funding is available for local authorities to rollout to buildings outside the City Corporation's control (e.g. the Home Upgrade Grant), the scope of the programme may be extended to support or influence these buildings.

Potential enabling funds include the Mayor’s Energy Efficiency Fund, Public Sector Decarbonisation Scheme, the Retrofit Accelerator.

Action owner: City of London Corporation, CPA, with possible strategic energy partner

Other stakeholders: Retrofit companies, residents, fund managers, DESNZ, GLA.

City Corporation resource commitment: 2 FTE

EE 3.2 Launch campaign to engage, encourage and educate on energy efficiency measures.

Target leafletting in areas where current EPC ratings are low. Engage with CPA and BIDs to access commercial building landlords and other property owners directly, focusing initially on small power reduction and controls interventions within commercial offices.

Engagement with existing schemes like the GLA’s Low Carbon Accelerator may facilitate this action.

Action owner: City of London Corporation, BIDs, CPA, residents, local businesses

Other stakeholders: Private landlords, tenants, homeowners, housing associations, Community Energy London, NGOs.

City Corporation resource commitment: 0.5 FTE

EE 3.3 Adopt a retrofit fast follower role

Identifying replicable interventions that have been implemented on similar building stock across the UK and applying these across City building stock will capitalise on ‘easy wins’ and accelerate their decarbonisation. This may be more relevant to heritage buildings. Additionally the City Corporation could quickly identify national retrofit initiatives and ensure timely participation in new schemes as they come forward.

Action owner: City of London Corporation

Other stakeholders: Community Energy London, DESNZ, building owner / operators

City Corporation resource commitment: varying between 0.1 - 1 FTE

7. Route map and proposed actions
Delivery actions

Maximise rooftop PV

PV 1.1 Rollout programme for installation of rooftop PV of all City Corporation owned buildings.

Where possible, this should align with other implementation of other retrofit measures described in the Building Energy Efficiency priority to save costs and streamline engagement.

Unlocks further demand-side flexibility potential and aligns with GLA’s wider targets to increase rooftop solar PV generation across the whole of Greater London to 1GW installed capacity by 2030 and 2GW by 2050. Also aligns with the CAS aims to maximise the use of renewable energy sources across City Corporation operational buildings. Enabling funding sources include the Mayor's Energy Efficiency Fund.

Action owner: City Corporation with possible strategic energy partner

Other stakeholders: UKPN, PV installation companies, residents.

City Corporation resource commitment: 0.1 FTE

PV 2.1 Launch campaign to encourage and educate businesses, homeowners, private landlords, and tenants (where applicable) to install rooftop PV.

Identify installers and local businesses with capacity and skills to offer the relevant services and champion them. Refer landlords and residents to key enablers (e.g. ECO4, Solar Together London). Unlocks further demand-side flexibility potential and aligns with GLA’s wider targets to increase rooftop solar PV generation across the whole of Greater London to 1GW installed capacity by 2030 and 2GW by 2050.

Engaging with the SolarTogether initiative could facilitate this action.

Action owner: City Corporation with possible strategic energy partner

Other stakeholders: Private landlords; Tenants; Homeowners; Housing associations; BIDs; CPA; Businesses; PR/marketing consultants

City Corporation resource commitment: 0.2 FTE

PV 2.2 Better facilitate and enable PV installations

Ofgem, UKPN and DESNZ could work together to create a process to speed up or prioritise applications for PV grid connections. This would help increase uptake of PV. This action would need alignment with GLA to standardise the approach across London and the UK.

Action owner: Ofgem, DESNZ

Other stakeholders: UKPN, Private landlords; Homeowners; Housing associations; BIDs; CPA; Businesses.

City Corporation resource commitment: none from City Corporation

PV 2.3 Use of GLA solar map to identify rooftops with greatest potential, engage with those building owners / landlords.

Prioritise the buildings with the most potential for installation and highest potential capacity to maximise the amount of solar PV installed and encourage those building owners to employ the technology, therefore maximising the generation capacity.

Action owner: BIDs

Other stakeholders: Private landlords; Homeowners; Housing associations; BIDs; CPA; Businesses.

City Corporation resource commitment: none from City Corporation

7. Route map and proposed actions
Delivery actions

Decarbonise transport: stream 1 – install EV infrastructure

DT 1.1 Create a delivery plan for phased installation of chargers, in line with the EV Infrastructure Forecast and Transport Strategy, and monitor EV uptake.

Widespread planning of future transport infrastructure, including collaboration with the GLA and other local authorities to consider opportunity for strategically placed charging. Creation of a programme for installation. Include consideration of innovative technologies e.g. solar shading infrastructure to have urban heat island and solar flex / feed co-benefits. Start with City Corporation sites with installations capable of smart charging.

Action owner: City of London Corporation and possible strategic energy partner

Other stakeholders: City Corporation transport planning, neighbouring boroughs, UKPN

City Corporation resource commitment: 0.25 FTEs

DT 1.2 Advocate for and support businesses and residents with installing EV chargepoints.

Consider how funding can help deliver or financially incentivise installation of private EV chargers, identify areas where smart charging hubs can be located and engage with the private sector and support in finding the most viable route to market for delivery.

During this early phase of the EV market, the economic case for charging hubs can be difficult to prove. Since this action relies on private sector investment, some public sector support may be required in order to improve the business case.

Action owner: BIDs, CPA

Other stakeholders: City of London Corporation and possible strategic energy partner, GLA, EV chargepoint suppliers and private sector, neighbouring boroughs, UKPN

City Corporation resource commitment: none from City Corporation

DT 1.3 Work with DESNZ to make requirements for EV Chargers in commercial buildings part of MEES

Advocate for all buildings to be required to have EV charging facilities in order to meet the MEES requirements for 2030. This is a wider recommendation not specific to the City Corporation.

Action owner: GLA, DESNZ

Other stakeholders: BIDs and CPA, building owners, UKPN

City Corporation resource commitment: none from City Corporation

7. Route map and proposed actions
Delivery actions

Decarbonise transport: stream 2 – freight consolidation

DT 2.1 Expansion and continuation of consolidation service to reduce deliveries into the City and development of a sustainable logistics centre.

Development of plans to implement an area-based approach to managing freight and servicing by creating a consolidation centre which redistributes deliveries to make fewer and fuller vehicles. Freight vehicles could then also transport waste and recycling out of the City by returning it to the logistics centre.

This action aligns with the City Corporation's transport strategy to reduce the number of freight vehicles in the City and to reduce daily motorised vehicles by 30% by 2040.

Action owner: City of London Corporation, partner hauliers

Other stakeholders: BIDs, local businesses

City Corporation resource commitment: Varying, average 2FTEs

DT 2.2 Development of five last mile logistic hubs.
The City Corporation is aiming for more deliveries to be made by cargo cycles, foot and small EVs which could be partially achieved through setting up last mile logistics hubs within City Corporation assets. This has been started, with two hubs to have been delivered by 2022 and a further three by 2025.

Action owner: City of London Corporation

Other stakeholders: City Corporation supply chain, Delivery partners and operators

City Corporation resource commitment: 2FTEs

7. Route map and proposed actions
Delivery actions

Decarbonise transport: stream 3 – transition to EVs

DT 3.1 Transition City Corporation fleet of vehicles to zero emissions.

Vehicles belonging to the City Corporation will need to meet the standards to be set in the proposed zero emissions zones. Any contractor vehicles which operate within the City will also need to meet these standards.

This action is in line with the City Corporation's transport strategy for their own fleet, ambition for 90% of all vehicles entering the City to be zero emission capable by 2030 and to champion a zero-emission zone.

Action owner: City of London Corporation, City Police

Other stakeholders: TfL, CPA, UKPN

City Corporation resource commitment: 0.4FTEs

DT 3.2 Establish a Future Transport Advisory Board which will monitor data on active travel and private car use against targets.

This plan has been developed assuming that there is an overall 25% reduction in car mileage originating in the area by 2030, as people move towards active or public modes of travel. To meet this target, the City Corporation will need to monitor how the area performs against it between now and then. By setting up a Future Transport Advisory Board, this would facilitate such monitoring and provide a governance structure to help meet targets.

Action owner: City of London Corporation

Other stakeholders: Future Transport Advisory Board, TfL, Taxis

City Corporation resource commitment: 0.5FTEs

DT 3.3 Investigate the use of business rates / Council tax to incentivise low or zero emission transport and advocate converting the ULEZ to be a zero emissions zone.

The City Corporation is championing central London to become a Zero Emission Zone through access restrictions and charging. If this is not committed to within the next Mayor's election manifesto, the City Corporation will explore a City-wide zero emission zone with immediate clusters across the Barbican, Golden Lane estates and the City. They will also work with neighbouring boroughs.

Action owner: City of London Corporation

Other stakeholders: Mayor of London, neighbouring boroughs

City Corporation resource commitment: 0.1FTEs

7. Route map and proposed actions
Delivery actions

Decarbonise heat: stream 1 – expand and decarbonise heat networks

DH 1.1 Expand and decarbonise Citigen

Investigation into the feasibility of expansion and decarbonisation of Citigen is already underway (as part of the CAS) and will help E.On and the City Corporation understand surrounding heat demands (and potential future demands) as well as to map and engage with waste heat suppliers.

This could have the potential added benefit of reducing pressure on the electrical infrastructure. Potential enabling schemes include the Green Heat Network Fund; Heat Network Efficiency Scheme; HNDU; LEA Framework.

Action owner: City of London Corporation, E.ON/Citigen, possible strategic energy partner

Other stakeholders: Potential waste heat suppliers, UKPN, residents and businesses, Cadent.

City Corporation resource commitment: 0.5FTE

DH 1.2 Explore opportunities for further heat network development within the City and develop energy masterplans for new heat networks

In line with CAS actions, undertake feasibility studies, engage with the ESCo market and waste heat suppliers, explore other heat supply options e.g. the River Thames, subsurface opportunities, engage with developers to understand future demand. Identify potential energy centre locations for new networks. Include multi-offtake heat networks, local heat networks and City-wide ambient networks that bring in heat from a range of sources.

Action owner: City of London Corporation, possible strategic energy partner

Other stakeholders: ESCos, potential waste heat suppliers, UKPN, residents and businesses, Cadent, developers, BIDs, CPA.

City Corporation resource commitment: 0.5FTE

DH 1.3 Track and prepare for Heat Network Zoning policy and participate in pilots where possible

The City Corporation should track the development of the Heat Network Policy Framework, paying particular attention to the likely demands made of Local Authorities in designating zones, and planning ahead for potential resource commitments. In line with the CAS, this should also involve establishing a plan for the City's role to prepare for the upcoming regulations. Where Heat Network Zoning pilots would allow participation from the City Corporation then this should be pursued (like was done in applying to be part of the Advanced Zoning Pilot (AZP) scheme).

Action owner: City of London Corporation

Other stakeholders: ESCos, possible strategic energy partner in future

Resource commitment: 0.1FTE

7. Route map and proposed actions
Delivery actions

Decarbonise heat: stream 1 – expand and decarbonise heat networks

DH 1.4 Development of guidance and for new buildings

The City Corporation should develop guidance regarding heat network connection for new buildings, highlighting the upcoming Heat Network Zoning Policy and its likely impact on the City's buildings and infrastructure. This action should identify possible alterations of the planning process to support energy network integration within the City and devise appropriate enforcement procedures applicable to new buildings (aligning with the current policy wording related to mandated buildings connection). It should also focus on the connection of waste heat from office building cooling into future networks.

Action owner: City of London Corporation, possible strategic energy partner

Other stakeholders: Potential waste heat suppliers, UKPN, residents and businesses, Cadent.

City Corporation resource commitment: 0.5FTE

7. Route map and proposed actions
Delivery actions

Decarbonise heat: stream 2 – building level solutions

DH 2.1 Monitor the development of the UK Hydrogen industry

Although there are no plans for hydrogen pipelines to serve the City currently, this may change in the future. Any developments should be considered in tandem with engagement with neighbouring boroughs to understand alignment opportunities. This will be key up to 2026, when the national decision on hydrogen for heating in buildings will be made.

Action owner: City of London Corporation

Other stakeholders: Cadent

City Corporation resource commitment: 0.1FTE

DH 2.2 Remove gas boilers and CHP from all City Corporation buildings by 2027

Expand on existing CAS plans to decarbonise heat in City Corporation owned buildings by strategising, planning and implementing the replacement of all gas boilers with a low carbon solution in City Corporation buildings by 2027, if buildings will not connect to a heat network. Undertake feasibility of installing low carbon heat generation plant like heat pumps in all City Corporation buildings.

Action owner: City of London Corporation, CPA

Other stakeholders: UKPN, Cadent

City Corporation resource commitment: Varying between 0-1 FTEs

DH 2.3 Remove gas boilers and CHP from all buildings in the Square Mile by 2040

Strategise, plan and implement the replacement of all gas heat generation equipment in the Square Mile if buildings will not connect to a heat network. To facilitate this, building owners and operators shall need to undertake feasibility of installing alternative low carbon heat generation technologies. The City Corporation could investigate the power it has in making the requirement for a feasibility study mandatory.

Action owner: BIDs, local building owners, land owners, building operators, tenants.

Other stakeholders: UKPN, Cadent

City Corporation resource commitment: Varying between 0-1 FTEs

7. Route map and proposed actions
Delivery actions

Cooling and waste heat opportunity: stream 1 – explore opportunities

WH 1.1 Update and maintain the London Heat Map to include all waste heat sources

The London Heat Map has been developed to display information like heat demand, heat sources and heat networks in the capital. This has been used by developers, planners, LA stakeholders and heat network operators to identify opportunities for waste heat capture. Information within the map is out of date and needs updating. An up to date heat map will allow for easy identification of waste heat sources and assessment of the waste heat capture opportunity for heat network feasibility studies.

Action owner: GLA, London Boroughs

Other stakeholders: LAs/Boroughs, TfL, Thames Water, DNOs and other waste heat providers

City Corporation resource commitment: none from the City Corporation

WH 1.2 Pilot waste heat capture project

Identify and implement a flagship pilot opportunity for waste heat recovery and utilisation within the City (or connecting to adjacent areas). This may be done in conjunction with the AZP workstream that the City have been successful with and is currently undertaking, as suitable heat source identification is likely to form part of that.

Action owner: City Corporation, potential strategic energy partner

Other stakeholders: Neighbouring boroughs, asset owners

City Corporation resource commitment: 1 FTE during delivery

WH 1.3 Planning policy: include requirement for 'heat offtake enablement'.

Develop policy to mandate any buildings with large (threshold to be defined) heat rejection to provide the opportunity for the recovery and use of heat. This could be delivered via the new Local Plan or included in any update to the London Plan.

Action owner: City Corporation or the GLA

Other stakeholders: Developers, GLA

City Corporation resource commitment: <0.1FTE

7. Route map and proposed actions
Delivery actions

Electrical infrastructure

EI 1.1 Establish a bilateral City Corporation and UKPN group.

To develop strong ties and communication between the council and the DNO for continuous engagement. Aims of the group would include:

- Sharing of planning data (where possible) to improve UKPN forecasting and modelling in advance of RIIO-ED3 (2028-2033)
- Coordinating with planning team over delivery of new infrastructure
- Align modelling assumptions across different organisations

Working closely with UKPN will ensure that both organisations can make well informed choices about the timing of growth and planned infrastructure work.

Action owner: City of London Corporation, UKPN

Other stakeholders: Developers, National Grid, GLA.

City Corporation resource commitment: <0.1FTE

EI 1.2 Investigate pooling of buildings together and securing multi-offtake PPA.

By investigating this opportunity on a building-by-building (and grouped/pooled) basis alongside collaboration with corporate PPA providers, it can be ascertained as to whether savings (in both cost and carbon) can be made from procurement of a multi-offtake PPA.

The BIDs should engage with building owners in key high density areas (like around Liverpool Street) to test their appetite for participation in such a scheme, as well as undertaking soft market testing with generators to understand whether sufficient power could be sleeved to such ‘pools’ of buildings.

Pooling offtakers together help secure lower energy costs and make the offer more attractive for generators as they would have greater secured sales volume.

Action owner: City of London Corporation

Other stakeholders: BIDs, local businesses and building owners, CPA, Corporate PPA providers (e.g. Octopus Energy), UKPN

City Corporation resource commitment: 0.3 FTEs

EI 1.3 Track heat electrification (e.g. applications for new connections to serve heat pumps) against projections.

Active tracking of planned and potential future connections associated with electrified heat demand. This may involve providing the opportunity for this information to be easily documented / captured (e.g. within the connection application form). Ideally this information could be fed back to the City Corporation although it is recognised this would currently be in breach of data privacy regulations.

Action owner: UKPN

Other stakeholders: Ofgem, DESNZ, Building owners

City Corporation resource commitment: none

7. Route map and proposed actions
Delivery actions

Electrical infrastructure

EI 1.4 Prioritise connections where renewable generation is proposed, to stimulate growth in solar.

Introduce a 'scoring' system based on type of proposed connection, allowing for those linked with low carbon/renewable generation to be prioritised over others. This would incentivise those applying for a new connection to install additional generation capacity.

Action owner: Ofgem

Other stakeholders: UKPN, Developers, building owners, CPA, City Corporation

City Corporation resource commitment: none

EI 1.5 Facilitate and/or reduce costs of sleeving arrangements.

Sleeving is the process by which an electricity supplier manages the offtake from a generator, effectively delivering it to the buyer via existing infrastructure. Often the costs to sleeve power can be prohibitive to enabling Power Purchase Agreements (PPA) or decentralised energy projects like small scale solar. Ofgem could work with suppliers / regulate the market to reduce sleeving costs and stimulate the renewable power market, particularly for inner-city areas where the grid is often constrained.

Action owner: Ofgem

Other stakeholders: Elexcon and DCC

City Corporation resource commitment: none

EI 1.6 Extend the City Corporation PPA.

The City Corporation PPA came online in January 2023. If successful, it is recommended that the agreement is extended both in terms of volume (i.e. to cover any remaining City Corporation consumption following energy efficiency measures), and length (i.e. extending the existing solar PPA past its current 15-year plan).

Action owner: City Corporation

Other stakeholders: PPA Market, UKPN

City Corporation resource commitment: varying between 0 – 0.5 FTE

7. Route map and proposed actions
Delivery actions

Flexibility: stream 1 – understanding flexibility in the City

FL 1.1 Engagement with existing GLA studies into flexibility and its future role in London.

The Corporation is currently commencing an LEA funded study, as part of and alongside this there is an action to get familiar and engage with existing studies and pilots (e.g. FlexLondon and 24/7 Carbon-Free Energy score) and their possible applicability in the City. Assessment of opportunities for flexibility and flex technologies across the City off the back of studies' existing data and their identified use cases. Stakeholders such as building owners may be resistant to taking part if they don't know much about what flexibility entails or what the benefits are. The City Corporation, BIDs and CPA may need to help with this through promoting and sharing information about the benefits.

Action owner: City of London Corporation, BIDs, CPA

Other stakeholders: GLA, UKPN, aggregators

City Corporation resource commitment: 0.1 FTEs

FL 1.2 Improve transparency and accessibility to flexibility data, conduct asset flexibility suitability analysis.

Create a transparent database and log of: a register of existing flexibility assets; a database of future flex-suitable assets from analysis, and opportunities for flex use e.g. business models such as community energy, VPPs, energy as a service. Conduct an assessment of existing flex suitability. Improve the data transparency and accessibility to be able to map out flexibility development across the City and understand progress. This will enable planning of wider flexibility schemes and systems between different buildings and to provide aggregated flex services. Gaining data off building owners can be challenging, particularly if they have limited awareness of flexibility and its benefits. Analysing future flex suitability will require good transparency of data.

Action owner: City of London Corporation, BIDs, CPA, building owners/operators

Other stakeholders: UKPN, GLA

City Corporation resource commitment: 0.2 FTEs

FL 1.3 Educate and communicate owners/occupiers on flex and its benefits via a City Corporation resource.

Encouraging local buildings to trial flexibility measures such as TOUTs, DSR and smart appliances will create an evidence base for taking action in the future. It will also familiarise building residents and operators with the benefits of flexibility, help them save money on their energy bills and cut carbon emissions.

Action owner: City of London Corporation, BIDs, CPA

Other stakeholders: Building owners / operators, tenants, businesses.

City Corporation resource commitment: 0.1 FTEs

7. Route map and proposed actions

Delivery actions

Flexibility: stream 2 - trialling flexibility in the City

FL 2.1 Switch City Corporation buildings to time of use electricity tariffs / carbon flex initiatives where available.

Leading by example in council buildings will encourage others to install flexibility technologies that could relieve electricity network pressures and contribute to decarbonisation. The City Corporation is already investigating how this could be applied in the Guildhall and Barbican estates. Need to be careful that switching tariff does not lead to increased costs for the City Corporation; need to identify buildings with scope for flexibility to provide reduced costs.

To accompany installation of smart controls over the next few years.

Action owner: City of London Corporation

Other stakeholders: Energy suppliers, aggregators, UKPN

City Corporation resource commitment: 0.2 FTEs

FL 2.2 Condition developers to design in flexibility solutions where relevant.

The City Corporation should outline the importance of smart systems and energy storage in new developments by incorporating specific flexibility policies in the local plan. This might include a hierarchy of expected flexibility technologies, and requiring evidence of what is proposed by developers.

Action owner: City of London Corporation

Other stakeholders: Building developers

City Corporation resource commitment: <0.1 FTEs

FL 2.3 Lobbying to generate flexibility policy.

This could be an action taken on by the proposed London LAEP Committee, to promote instigation of specific policies on flexibility into Building Regulations and/or the London Plan.

Action owner: London LAEP Committee

Other stakeholders: UK Government, GLA, DEZNZ, NHBC

City Corporation resource commitment: covered under LAEP Committee action

FL 2.4 Create a flex pilot study or engage in an existing one.

Engage in existing flexibility initiatives such as pilots through the GLA, participatory flex services, or set up a new pilot study to futureproof buildings for flexibility and engage with building owners and occupiers to join. This will encourage area-wide engagement in flexibility through learnings and evidence base created by pilots.

Action owner: City of London Corporation, BIDs, CPA

Other stakeholders: GLA, energy suppliers, aggregators

City Corporation resource commitment: <0.1FTEs

FL 2.5 Direct Citigen expansion and/or heat network development towards areas of power capacity constraints

The use of heat networks – including thermal storage – can help reduce the overall grid capacity upgrade requirements as heat generation moves to more electrically derived sources. This can help relieve pressure in areas where the grid is particularly constrained and offer cheaper heat decarbonisation to end users / customers.

Action owner: E.ON, heat network operators, City Corporation

Other stakeholders: Heat customers, end users, UKPN

City Corporation resource commitment: <0.1FTEs

8. Governance, implementation, monitoring and review

The structures required to deliver the plan

Governance

The City Corporation is proposing that the LAEP will be governed under the Square Mile workstream of the Climate Action Strategy. Within the Square Mile workstream, two new management posts are proposed: Project & Partnerships and Investment & Delivery. The first would be extra resource to work on the LAEP and other projects, the second post is to develop financing and delivery mechanism for LAEP-related actions, as well as wider Square Mile initiatives. These are initial steps towards creating a Net Zero Delivery Unit (NZDU), responsible for facilitating the LAEP implementation.

This future City Corporation group will be vital to ensuring the ownership and continued delivery of actions specified both within the Square Mile workstream as well as other CAS workstreams.

It is envisaged that establishment of a London LAEP committee would oversee and govern the delivery of LAEP actions across London. The NZDU would sit on the committee, alongside equivalents from other boroughs, to ensure cross-borough collaboration and help achieve wider strategic London aims and objectives. The committee may also include key parties from the wider stakeholder groups including representatives from the GLA, TfL, UKPN and Cadent.

Implementation

The NZDU would be responsible for delivery and implementation of the plan. To help them in this, the NZDU could also set up and participate in a wider City of London LAEP Steering Group, that includes third parties like the BIDs, CPA, utilities like UKPN and E.ON, and major land owners.

Appetite for this group has been evident in the City BIDs Strategic Partnership meeting and with members of the CPA, and should be formalised as soon as possible. The steering group will promote the implementation of actions beyond the City Corporation, and could provide advice and inputs to ensure the outputs and outcomes of the LAEP are realised.

Beyond the steering group other enablers of this plan and the associated actions are the:

- **Sustainable City Charter.** This business-led group will support the decarbonisation of commercial buildings, and include building owners/operators in the area.
- **Procurement of a strategic energy partner(s).** This could unlock opportunities regarding the scaling and implementation of some of the actions that have been defined.

Monitoring and review

The City Corporation should identify a set of indicators against which to measure progress in meeting the LAEP objectives, summarising these in an Annual Monitoring Report. This should include establishing specific indicators and monitoring frameworks to measure progress towards objectives, such as monitoring building decarbonisation / retrofit, or the rollout of flexibility in the City. This would provide supporting evidence of progress alongside policy specific indicators to understand how the measures are supporting the City Corporation's climate change targets.

Although spanning out to 2040, this plan and the associated actions will need to be reviewed and revised on a 3- to 5-yearly basis. The revisions will be focussed on progress to date, developments of targets and ambitions, and the uptake of novel mechanisms and technologies that might assist in accelerated decarbonisation of the whole energy system. It is likely that similar LAEPs will be commissioned and completed in neighbouring areas, and hence cross-LAEP collaboration could become more pertinent and accessible in the future.

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Appendices

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Appendix A

Modelling methodology

A. Modelling methodology

Modelling Purpose

The optimisation model is designed to set and test the limitations and opportunities of the future energy system within the City of London. The relationships between the different energy vectors and possible components are dynamically modelled to obtain the possible energy system configuration. Each optimisation scenario is designed to test certain parameters and constraints specific to the City. The outputs of the various scenarios modelled are then compared and combined with our understanding of plan objectives and strategic opportunities to produce series of recommendations and actions that are detailed in Section 7.

Figure A.1 represents this process diagrammatically, detailing the optimisation task, comparison of results and liking with area specific objectives and development of the delivery actions and route map.

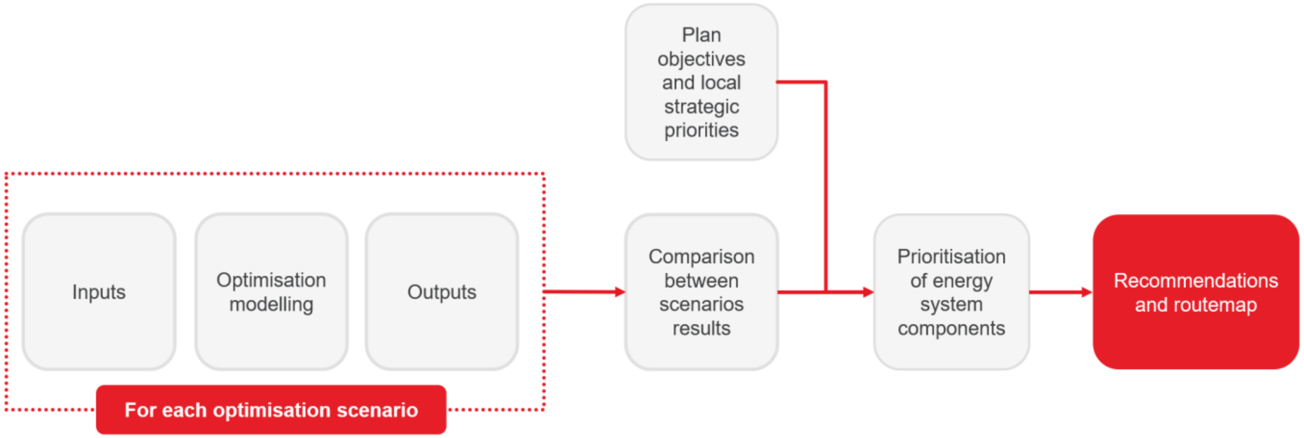

Figure A.1: A high-level overview of the role of scenario modelling in creating LAEP recommendations

A. Modelling methodology

Modelling methodology

Figure A.2 provides additional detail on the scenario optimisation aspect of the modelling process that was undertaken for each of the scenarios defined in section 4. The model was using an open-source linear optimisation package, with a database and python wrappers to ensure efficiency and to minimise errors.

For each modelled scenario, the inputs shown on the left were collected and fed into the model, which optimises technology mix and dispatch to meet all energy demand in each hour across the year 2040, within the specific constraints defined by the energy system. We set up the modelling to optimise for both cost and carbon, finding the most economical solutions to deliver the required carbon savings

The technologies that are included with the energy optimisation model are categorised in 5 main categories: supply, demand, conversion, transmission and storage.

Figure A.3 shows these categories, the associated technologies that were modelled for this LAEP and the relevant carriers (energy vectors). The technologies included are those that resulted from a shortlisting exercise undertaken with the City Corporation.

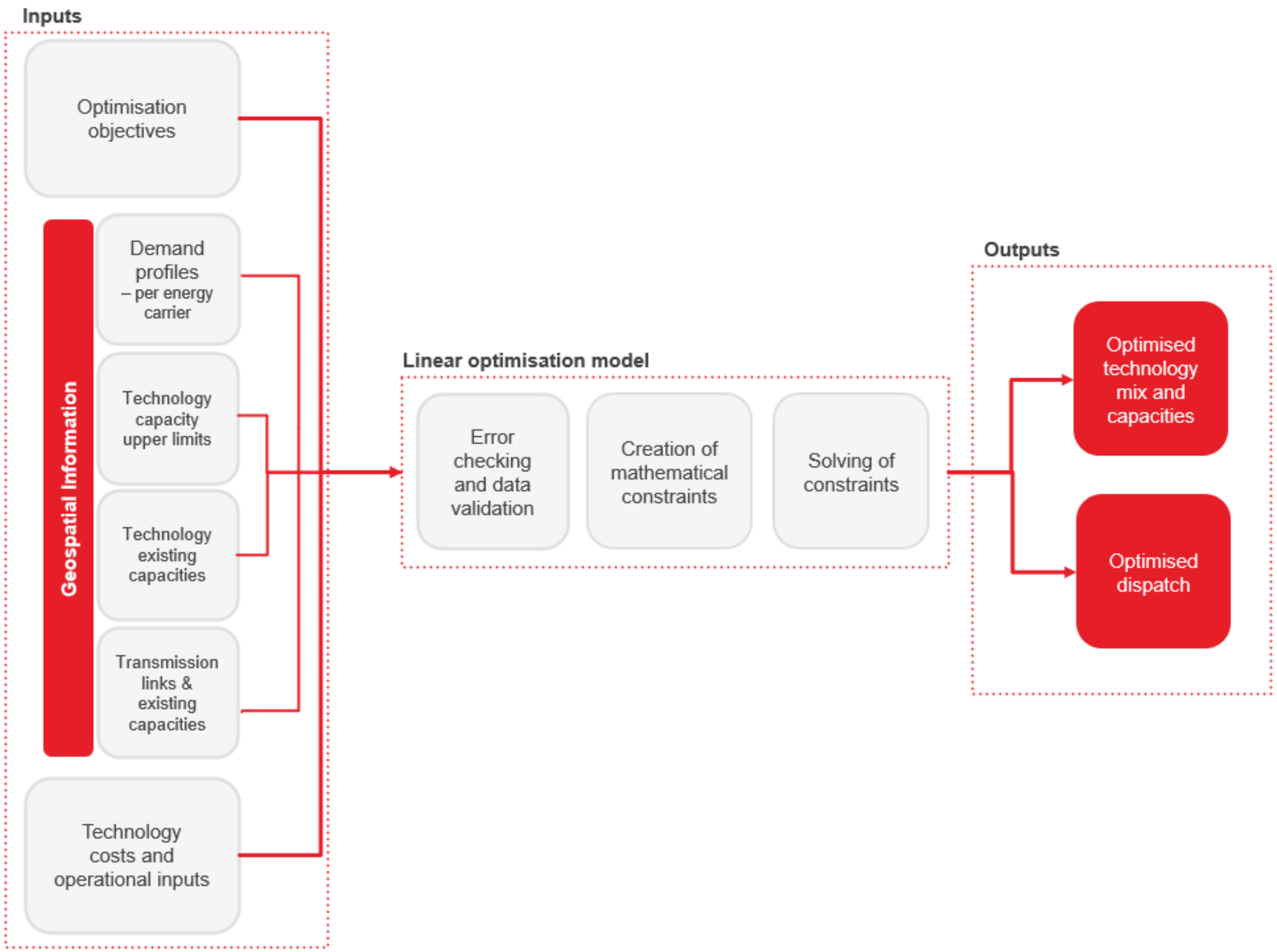

Figure A.2: Optimisation model overview including inputs and outputs

A. Modelling methodology

Technologies modelled

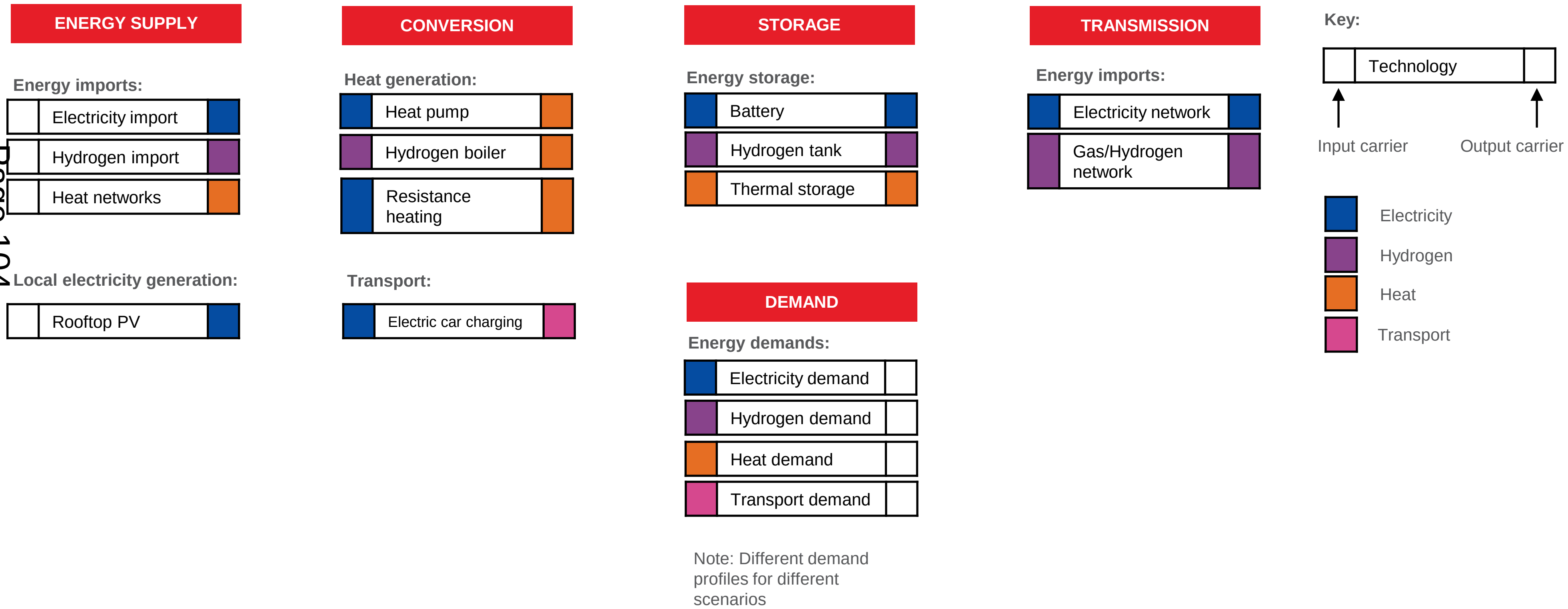

Figure A.3: Technologies included in optimisation modelling

A. Modelling methodology

Characterising technologies: constraints, costs and emissions

For each technology, key information defining costs, deployment and relationships with other technologies was collected. The key parameters collected are summarised in Table A.1. These parameters were then used in the linear optimisation approach to build up a representation of the entire energy system and optimise for a solution that minimises cost and operational carbon emissions. The results created by the model include choices on how to meet each demand.

Technology costs include:

- CAPEX = capital expenditure
- OPEX = operational expenditure

Alongside the baseline information collated on demands, existing energy assets and potential renewable locations and capacities, this information was loaded into a database. Automated Python scripting was used to handle this data and transform it into formatted model inputs in preparation for running the model. This approach was adopted to ensure efficiency and consistency, and minimised opportunities for manual errors.

There are challenges to projecting out many of the technological data parameters, and some will carry greater confidence than others. Novel technologies, for example, might have a wider spread of potential costs in 2040 depending on the source consulted. For quality assurance purposes, sources of costs and details of any data transformations taken to normalise all units were stored alongside their values in the database.

Table A.1: Technology data parameters applied within the optimisation model

Technology data parameters
Technology costs • CAPEX (£/kW capacity) • OPEX (£/kWh output)
Technology emissions • Operational carbon emissions (tCO_2e/kWh)
Technology essentials • Efficiencies where applicable (%) • Technology lifetime (years)
Technology constraints • Maximum technology capacity per substation distribution boundary, where applicable (kW) • Minimum renewable energy technology capacity per substation distribution boundary, from baseline assessment (kW) • Minimum connection capacities between modes for transmission technologies

A. Modelling methodology
Technology specific methodologies

Approach for heat

In modelling the five optimisation scenarios of the LAEP area's future energy system, three main heat sources were considered.

Heat pumps: Air source heat pumps, which convert electrical power and renewable heat to usable heat, have been modelled as a core source of heat as their deployment is not dependent on wider policy decisions, and easily replace gas boilers.

Heat networks: The UK Government's Heat Network Zoning Policy planned for implementation in 2025 will likely materially change the deployment of heat networks across the UK. Although still in development, the City is likely to be located within a policy zone due to the nature of high heat density and the potential for the integration of waste heat recovery as a source of energy for network development. The City has also been identified in the London Plan as a Heat Network Priority Area. Heat networks have been included within the analysis for three of the scenarios – this is further detailed within page 41.

Hydrogen for heating: The UK Government is due to make a decision on whether to allow up to 20% volumetric hydrogen blending in the GB gas distribution networks in 2023 and a decision on the role of hydrogen for heating in 2026, where hydrogen would be supplied through existing gas infrastructure to hydrogen boilers . The hydrogen scenario models what the energy system in the City might look like if the 2026 decision results in a conversion of the existing gas network to hydrogen.

Heat Networks

To model the potential heat network zones within the City, a spatial analysis approach was taken to find building clusters where connection to a heat network is potentially feasible. Using the heat demands provided in the SkenarioLabs data and the estimated linear heat density thresholds for the City, buffers around each building were drawn to identify overlaps. The size of the buffer was determined from the individual building heat demand divided by the associated scenario's linear heat density. These linear heat densities were calculated based on the cost per metre to install new heat network piping within the City and the cost of the waste heat source to be used, the final values are shown in Table A.2. These values were applied to the shallow and deep retrofit building demands respectively, excluding any buildings currently connected to Citigen, the City's existing heat network.

Clusters were then identified where building buffers overlapped spatially within GIS. To finalise the clusters, any buildings without a high enough heat demand to justify connection to a heat network (<73 MWh/year) were removed, as well as any clusters without a minimum of 3 buildings per cluster and at least one anchor load (with a heat demand >250 MWh/year). These finalised clusters provided the potential heat network zones. To feed into the optimisation model, the heat demand connected to a heat network per zone was needed. So the maximum percentage heat demand of each LAEP zone that could be connected to a heat network was calculated for each scenario based on the buildings that had been identified as economically beneficial to connect. This provided a high level estimate of heat network size and capacity for each scenario tested.

Table A.2: Linear heat density selection

Heat network scenario	Retrofit level	Linear heat density used (MWh/m/annum)
Optimistic	Shallow	13
Conservative	Deep	58

A. Modelling methodology
Technology specific methodologies

Energy demand profiling and system flexibility

Demand Profiling

Annual energy demand profiles were generated using a standard Arup hourly profiling tool. These profiles were adjusted for future climate change predictions and account for variations in building type, occupancy and energy use profiles across the year. The profiles were mapped and applied to each of the buildings' modelled heating, cooling and power demands to define the hourly variation in demands across the whole of the City. Grouping the buildings and associated demand profiles by LAEP zone then allowed for the identification of local demand peaks.

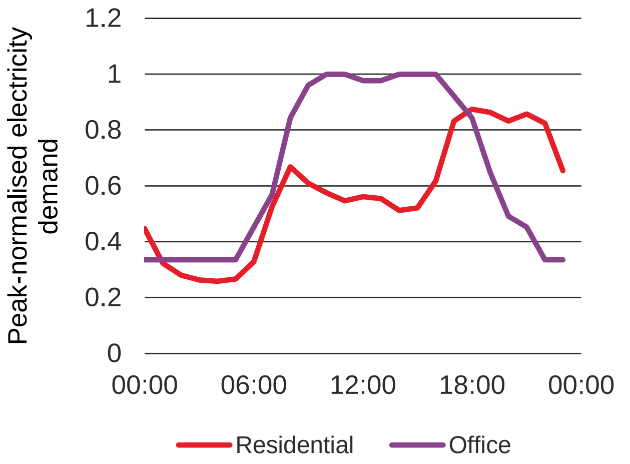

Figure A.4: Peak normalised electricity demand for residential and office buildings

Energy system flexibility

Energy system flexibility was identified as a key opportunity to effectively manage demand peaks across the City. Within the model, flexibility was integrated via two mechanisms: energy storage and demand side management.

Energy storage, either electrical via batteries, or thermal via hot water (with technologies including solid-state thermal storage becoming more commonplace) enables the improved use of energy within buildings via storing energy when the network is unconstrainted, and using it at a later time when the system is nearer/at capacity.

Demand side management (DSM) is based upon modifying the energy usage pattern to divert consumption during hours of significant constraint (e.g. carbon or cost) to those where the constraints are less significant. For the modelling undertaken within this study, both domestic and non-domestic DSM was considered and was modelled following the central scenario of the BEIS Energy System Flexibility Modelling Assumptions, detailed in table A.3.

Figure A.5 displays the impact of implementing DSM on an office electrical demand profile.

Table A.3: Flexibility demand shifting by building type

Building Type	% of half-hourly demand that can shift to different half hour	Note
Domestic	3	Demand can shift 4 hours ahead/behind of the peak hour
Non-domestic	10	Demand can shift 4 hours ahead/behind of the peak hour

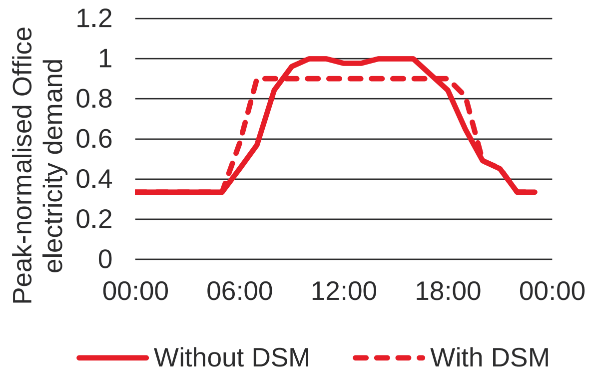

Figure A.5: Example electricity demand profiles over 24 hours, with and without modelling of demand-side management

A. Modelling methodology
Modelling growth and development projections

Future energy demand projections – new developments

Benchmark energy consumption assumptions were applied to the new development floorspace detailed on page 30. These were based upon the improved building performance and efficiencies of new builds and aligning with the stringent energy requirements set out in the New London Plan.

The recommendations made by the London Energy Transformation Initiative (LETI)[26] on Energy Usage Intensity (EUI) were used as a basis for the development of the benchmarks implemented. A comparison between a current energy benchmark for heating of non-domestic buildings using values taken from the Building Energy Efficiency Survey (BEES)[27] against the equivalent LETI values, representing future energy benchmarks, was made to calculate a percentage reduction in heating energy demand. This percentage reduction was then applied to the other non-domestic building typologies to produce future heat demand consumptions per square meter.

The domestic heating consumption benchmark used was based on the LETI 15kWh/m^2 space heating benchmark and 24kWh/m^2 for DHW (based on recent Arup residential projects). The electrical demand benchmark from NEED analysis of newbuilds in England and Wales was uplifted by 13% to account for elevator consumption on the basis that this facility is likely available in most residential properties located within multistorey buildings.

A 50% performance gap uplift was included to all future consumption benchmarks to account for the ‘energy performance gap’ – the difference between design/target energy consumption and actual building energy performance currently commonly seen within new developments. Table A.4 below details the benchmarks used and applied to the building typologies.

Table A.4 : Final demand benchmarks for the future building typologies

Building Typology	Heating (kWh/m^2 annum)	Cooling (kWh/m^2 annum)	Power (kWh/m^2 annum)
Office	38	13	80
Retail	91	30	185
Hotel	66	22	135
Housing	60	5	33

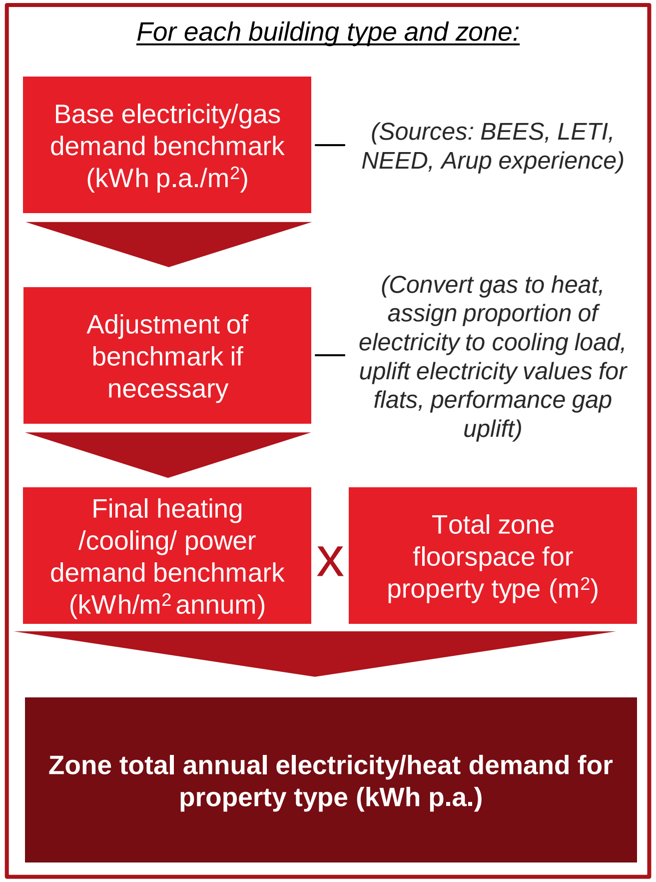

Figure A.6: Future demand projections modelling approach

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Appendix B

Modelling zones information

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B. Modelling zones information

Table B.1: Zones used within modelling, linked substations and associated information

Zone Name	primary_su	primary_si	Grid Supply Point	Bulk Supply point	Note
Kingsway	Kingsway 11kv	Kingsway 11kv	St Johns Wood	Direct	-
Limeburner Lane	Seacoal Lane 11kv	Seacoal Lane 11kv	City Road	Direct	-
City Rd B	City Rd	City Rd B 11kv	City Road	Direct	-
Finsbury Mkt D	Finsbury Mkt D 11kv	Finsbury Mkt D 11kv	City Road	Finsbury Market B 33kV	-
Beech St B	Beech Street B	Beech St B	City Road	Direct	-
Paternoster	Bankside C 11kv	Paternoster	City Road	Finsbury Market F 33kV	-
Beech St A	Leicester Sq 11kv	Beech St A	City Road	Finsbury Market F 33kV	-
Finsbury Mkt A	Finsbury Mkt A 11kv	Finsbury Mkt A 11kv	City Road	Finsbury Market A	-
Bankside C	Bankside C	Bankside C 11kv	City Road	Bankside C Total	-
Finsbury Mkt E	Bow 11kv	Finsbury Mkt E 11kv	City Road	Direct	-
Osborn St B	Osborn St	Osborn St	New Cross 132kV	Direct	-
-	Devonshire Square	Devonshire Square	City Road	Direct	Combined with Finsbury Mkt E
-	Back Hill A 11KV	Back Hill A 11KV	City Road	Direct	Combined with Kingsway

Appendix C

Retrofit intervention mapping and classification

C. Retrofit intervention mapping and classification

Tables C.1-C.3 display the retrofit interventions that were applied to the model. These were classified as either deep or shallow and assigned to the appropriate/feasible building archetypes.

Table C.1: Building automation/BMS retrofit interventions

Intervention	Shallow/ Deep	Residential	Office	Assembly building	Hotel	Industrial	Retail	School	Warehouse
Health check on controls and/or BMS	S	included	included	included	included	included	included	included	included
Install incoming utility (gas/elec/water) energy meters	S	included	included	included	included	included	included	included	included
Install system specific energy sub-meters (e.g. distribution board level)	S	included	included	included	included	included	included	included	included
Calibrate building temperature set points	S	included	included	included	included	included	included	included	included
Targeted energy consumption monitoring	S	included	included	included	included	included	included	included	included
Lighting controls (programmable, daylight/occupancy linked)	S	included	included	included	included	included	included	included	included
Building user guide production & training	S	included	included	included	included	included	included	included	included

C. Retrofit intervention mapping and classification

Table C.2: Building services retrofit interventions

Intervention	Shallow/ Deep	Residential	Office	Assembly building	Hotel	Industrial	Retail	School	Warehouse
Recommissioning of ventilation	S	included	included	included	included	included	included	included	included
Recommissioning of cooling systems	S	excluded	included	included	included	included	included	included	excluded
Replace ventilation units + heat recovery units	D	included	included	included	included	included	included	included	included
Incorporate VSDs to HVAC motors	S	excluded	included	included	included	included	included	excluded	excluded
Power factor correction	S	excluded	included	included	included	included	included	excluded	excluded
Check/repair ductwork leakage	S	included	included	included	included	included	included	included	excluded
Luminaire replacement (to LED's & high frequency ballasts)	S	included	included	included	included	included	included	included	included
Heat recovery from ventilation outflow	D	included	included	included	included	included	included	included	included
Renew heat distribution (if required e.g. due to lower temperature inflow with heat pumps)	D	included	included	included	included	included	included	included	included
Low flow sanitary appliances installation	S	included	included	included	included	excluded	excluded	included	excluded

C. Retrofit intervention mapping and classification

Table C.3: Building fabric retrofit interventions

Intervention	Shallow/ Deep	Residential	Office	Assembly building	Hotel	Industrial	Retail	School	Warehouse
Optimise free cooling	S	included	included	included	included	included	included	included	included
Consider internal spatial layouts to maximise daylight penetration and natural ventilation	D	excluded	included	included	excluded	excluded	included	excluded	excluded
Internal solar control devices (blinds)	S	included	included	included	included	excluded	included	included	excluded
Exposing of internal thermal mass (false ceiling removal)	D	excluded	included	included	included	excluded	included	excluded	excluded
External solar control devices (brie solei, light shelves, etc)	D	included	included	included	included	excluded	included	excluded	excluded
Replacement of/additional glazing	S	included	included	included	included	excluded	included	included	excluded
Replace windows (U-value & g-value)	D	included	included	included	included	excluded	included	included	excluded
Improve external wall insulation	D	included	included	included	included	included	included	included	included
Air tightness improvements *	S/D	included	included	included	included	included	included	included	included
Roof/loft insulation *	S/D	included	included	included	included	included	included	included	included
Mineral wool insulation below floor	D	included	excluded	excluded	excluded	excluded	excluded	excluded	excluded

* The *shallow* or *deep* classification for these specific interventions is dependent on the type of building – this was further assessed and defined within the model via further archetype definition

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Appendix D

New development distribution across the KAOC

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D. New development distribution across the KAOC

Table D.1: New development distribution.

Land use type	Retail	Retail	Retail	Hotels	Hotels	Hotels	Housing	Housing	Housing
-	Indicative distribution of development	Target	Remaining Target	Indicative distribution of development	Target	Remaining Target	Indicative distribution of development	Target	Remaining Target
Unit/KAOC	%	m^2	m^2	%	units/rooms	m^2	%	units	m^2
Smithfield and Barbican	10%	13230	13230	20%	598	352	40%	1051	1035
Fleet Street and Ludgate	5%	6615	6615	10%	299	147	10%	263	263
Liverpool Street	35%	46305	46305	0%	0	0	0%	0	0
Aldgate, Tower and Portsoken	5%	6615	6615	20%	598	598	20%	526	526
City Cluster	10%	13230	13230	10%	299	293	0%	0	0
Pool of London	5%	6615	6615	0%	0	0	0%	0	0
Blackfriars	0%	0	0	0%	0	0	0%	0	0
Rest of city	30%	39690	39690	40%	1195	599	40%	1051	940
TOTAL	100%	132300	132300	100%	2988	2000	110%	2891	2750

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Appendix E

Waste heat sources

E. Waste heat sources

Table E.1: Waste heat sources data and estimated heat offtake (1/4)

Waste heat type	Source	Address	Name	X-coord	Y-coord	Estimated heat offtake (MWh per annum)
Office - servers	WSP report	81 Newgate St	Orion Capital Managers (old BT building)	-0.0979	51.5154	274
Office - servers	WSP report	30 Old Bailey, London EC4M 7AU	Mizuho Bank	-0.1026	51.5152	250
Office - servers	WSP report	2 King Edward St, London EC1A 1HQ	Bank of America Merrill Lynch International Designated Activity Company	-0.1002	51.516	2121
Office - servers	WSP report	200 Aldersgate Street	200 Aldersgate Street	-0.0795	51.5177	190
Office - servers	WSP report	10-15 Newgate Street	Sudbury House	-0.101	51.5162	163
Office - servers	WSP report	65 Gresham Place	65 Gresham Place	-0.0934	51.5157	156
Office - servers	WSP report	20 Old Bailey	Barings Bank	-0.1042	51.5165	127
Office - servers	WSP report	Newgate St	London Stock Exchange	-0.099	51.5151	115
Office - servers	WSP report	10-12 Gresham St	Standard Life Investments	-0.0802	51.5144	623
Office - servers	WSP report	125 London Wall	Alban Gate	-0.0936	51.5175	424
Office - servers	WSP report	150 Cheapside	St Martins Property Co.	-0.0967	51.5148	256
Office - servers	WSP report	New Change	Landsec One New Change	-0.0955	51.5139	153
Office - servers	Public info	10 Fleet Pl, London EC4M 7QN	Level3 London (10 Fleet)	-0.1034	51.5153	2629
Office - servers	Public info	8-12 New Bridge Street	5 NINES Global HQ	-0.1045	51.5135	2016
TfL vent shaft	TfL		Bishopsgate	redacted	redacted	4285

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E. Waste heat sources

Table E.1: Waste heat sources data and estimated heat offtake (2/4)

Waste heat type	Source	Address	Name	X-coord	Y-coord	Estimated heat offtake (MWh per annum)
TfL vent shaft	TfL		Moorgate	redacted	redacted	5786
TfL vent shaft	TfL		Chancery Lane	redacted	redacted	2575
TfL vent shaft	TfL		Weston Rise	redacted	redacted	3254
Data centre	Online	260-266 Goswell Road	Lumen London 2	-0.1008	51.5288	5466
Data centre	Online	65 Clifton Street	Telehouse London (Metro)	-0.0835	51.5223	1367
Data centre	Online	80 Clifton Street	City Lifeline (Redcentric)	-0.083	51.523	2733
Data centre	Online	6 Braham Street	Level3 London (Braham)	-0.0725	51.5139	2050
Data centre	Online	55-71 City Rd	Oliver's Yard	-0.0872	51.5241	3416
Data centre	Online	11 Hanbury Street	LON1,2 & 3 Data Centre	-0.0731	51.5202	21865
Data centre	Online	Standard House, 16-22 Epworth Street	Iomart Central London Data Centre	-0.0849	51.5232	2733
Data centre	Online	Great Sutton Street	Volta	-0.1008	51.5236	8746
Potential sewer heat recovery site	WSP report	Queen Victoria Street	Potential sewer heat recovery site	-0.0971	51.5126	11000
Substation	UKPN	Back Hill Cap Ss Warner Street	Back Hill 33Kv	-0.1102	51.5228	941
Substation	UKPN	Back Hill Mss Warner Street	Back Hill A 11Kv	-0.1099	51.5229	694

E. Waste heat sources

Table E.1: Waste heat sources data and estimated heat offtake (3/4)

Waste heat type	Source	Address	Name	X-coord	Y-coord	Estimated heat offtake (MWh per annum)
Substation	UKPN	Bankside Mss Sumner Street	Bankside C 11Kv	-0.0988	51.5077	1,929
Substation	UKPN	Bankside D 20Kv	Bankside D 20Kv	-0.0985	51.5078	1,256
Substation	UKPN	Beech Street Mss Beech Street	Beech St A 00407	-0.0934	51.5207	149
Substation	UKPN	Beech Street A Mss Beech Street	Beech St B	-0.0933	51.5206	1,141
Substation	UKPN	City Road Mss City Road	City Rd B 11Kv	-0.0959	51.5304	1,720
Substation	UKPN	City Road Mss City Road	City Rd C 11Kv	-0.0961	51.5308	70
Substation	UKPN	Devonshire Sq Mss Devonshire Square	Devonshire Sq	-0.0798	51.5164	1,685
Substation	UKPN	Finsbury Mkt B C Ss Snowden Street	Finsbury Market B 33Kv	-0.0819	51.521	498
Substation	UKPN	Snowden Street	Finsbury Market F 33Kv	-0.0833	51.5214	402
Substation	UKPN	Finsbury Mkt A 11Kv	Finsbury Mkt A 11Kv	-0.0823	51.5211	257
Substation	UKPN	Finsbury Mkt D Css Snowden Street	Finsbury Mkt D 11Kv	-0.083	51.5213	1,589
Substation	UKPN	Finsbury Market	Finsbury Mkt E 11Kv	-0.0831	51.521	273
Substation	UKPN	Fisher Street	Fisher St B 11Kv	-0.1199	51.5184	733
Substation	UKPN	Hearn Street Mss Hearn Street	Hearn St	-0.0797	51.5224	390

E. Waste heat sources

Table E.1: Waste heat sources data and estimated heat offtake (4/4)

Waste heat type	Source	Address	Name	X-coord	Y-coord	Estimated heat offtake (MWh per annum)
Substation	UKPN	Kingsway Mss Kingsway	Kingsway 11Kv	-0.1196	51.5149	493
Substation	UKPN	Leicester Square Mss Leicester Square	Leicester Sq 11Kv	-0.13	51.5101	1,875
Substation	UKPN	Limeburner Lane Mss Limeburner Lane	Limeburner Ln 11Kv	-0.1031	51.5148	1,191
Substation	UKPN	Osborn St B 11Kv	Osborn St B 11Kv	-0.0709	51.5168	608
Substation	UKPN	Paternoster Row Mss Paternoster Row	Paternoster	-0.1005	51.5143	208
Substation	UKPN	Shorts Gardens Mss Shorts Gardens	Shorts Gdns 11Kv	-0.1238	51.5153	310
Substation	UKPN	South Bank Mss Belvedere Road	South Bank	-0.1145	51.5058	471
Substation	UKPN	Tooley Street	Tooley St 11Kv	-0.0828	51.5047	282

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Appendix F

Modelling assumptions

Deployment assumptions

Table F.1: Assumptions on deployment of technologies

Scenario	Technology	Assumption	Target	Reference
Optimised	Retrofit rollout	Varying shallow/deep	LAEP target	LAEP target
Optimised	Heat pump	Linear increase from now until 100% deployment in 2032	2022 - scrappage of boilers more than 10 years old (London) 2024 - mandate no new boilers (London)	Element energy[11]
Optimised	Hydrogen boilers	In hydrogen scenario, assume hydrogen roll out from 2026	2026 - Hydrogen decision	Hydrogen Strategy
Optimised	Heat networks	Accelerated by Heat Network Zoning	New networks accelerated by heat network zoning policy (2025)	Heat Network Zoning[19]
Optimised	Citigen decarbonisation	In line with current plans, accelerated from 2027 to 2040	LAEP target	LAEP target
Optimised	Solar PPA	PPA agreement extended to 2040	LAEP target	LAEP target
Optimised	Rooftop PV	As per London Solar Plan	2030 - 1 GW solar installed 2050 - 2 GW solar installed	London Solar Plan[10]
Optimised	EVs	Aligned to charger rollout based on ESC forecasts	-	ESC forecasts[6]
Business as Usual	Retrofit rollout	Shallow, only rolled out in existing buildings where a heat pump will be installed	Follows heat pump installation	-
Business as Usual	Heat pump	In line with national 2028 targets with and increase from 2035	2028 - 600,000 heat pump installations per year (UK) 2035 - no new gas boilers (UK)	UK Net Zero Strategy[12]
Business as Usual	Hydrogen boilers	None	-	-
Business as Usual	Heat networks	No new networks	-	-

Deployment assumptions (continued)

Table F.1 (continued): Assumptions on deployment of technologies

Scenario	Technology	Assumption	Target	Reference
Business as Usual	Citigen decarbonisation	In line with current City Corporation strategy	City Corporation targets	City Corporation
Business as Usual	Solar PPA	As existing 15 year agreement	2022-2037 - Solar PPA agreement	CAS Dashboard[1]
Business as Usual	Rooftop PV	Linear increase to 2040	Based on current growth	-
Business as Usual	EVs	Increase from 2035 due to petrol, diesel and hybrid ban	2035 - no new petrol, diesel or hybrid car sales	UK Net Zero Strategy[12]
Do Nothing	Retrofit rollout	None	-	-
Do Nothing	Heat pump and direct electric heating	In line with national 2028 targets with and increase from 2035	2028 - 600,000 heat pump installations per year (UK) 2035 - no new gas boilers (UK)	UK Net Zero Strategy[12]
Do Nothing	Hydrogen boilers	None	-	-
Do Nothing	Heat networks	No new networks	-	-
Do Nothing	Citigen decarbonisation	No further decarbonisation	-	-
Do Nothing	Solar PPA	As existing 15 year agreement	2022-2037 - Solar PPA agreement	CAS Dashboard[1]
Do Nothing	Rooftop PV	No additional rooftop PV	-	-
Do Nothing	EVs	Increase from 2035 due to petrol, diesel and hybrid ban	2035 - no new petrol, diesel or hybrid car sales	UK Net Zero Strategy[12]

Emission factors

Table F.2: Fixed carbon emissions.

Fuel type	Unit	Constant EF	Source
Natural gas - carbon factor	kgCO2e / kWh gas	0.1839	BEIS (2020). Greenhouse gas reporting: conversion factors 2020. https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020, Natural gas scope 1 emissions factor used. This will not change over the time period, because we are assuming natural gas stays the same, hydrogen and biogas are dealt with as separate carriers and can be blended into the natural gas.
Oil - carbon factor	kgCO2e / kWh oil	0.2467	Burning oil from: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020
Diesel/petrol - carbon factor	kgCO2e / kWh diesel/petrol	0.2349	Average of diesel and petrol from: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020

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Table F.3: Time variable carbon emissions.

Fuel type	Unit	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Grid electricity*	kgCO2e / kWh elec	0.122	0.149	0.118	0.102	0.078	0.065	0.062	0.040	0.034	0.028	0.026	0.021	0.017	0.016	0.013	0.013	0.012	0.012	0.011
Hydrogen grid**	kgCO2e / kWh hydrogen	-	-	-	-	0.184	0.181	0.178	0.175	0.171	0.155	0.138	0.122	0.105	0.088	0.072	0.055	0.039	0.022	0.006

* based on FES Leading the way (without BECCS) (national Grid forecast)
** assuming a hydrogen blend until 2030, with hydrogen emissions 20g/MJ as per the UK Low Carbon Hydrogen Standard

Table F.4: Assumed hydrogen grid blend.

Fuel type	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Gas	-	-	-	-	100%	98%	97%	95%	93%	84%	74%	65%	56%	47%	37%	28%	19%	9%	0%
Hydrogen	-	-	-	-	-	2%	4%	5%	7%	16%	26%	35%	44%	54%	63%	72%	81%	91%	100%

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Appendix G

2040 scenarios - End use electricity demand

G. 2040 scenarios - End use electricity demand

Figure G.1 shows the end use of electricity demand in 2040 across the five optimised scenario. It can be seen that electricity demand (which covers lighting, ventilation etc) makes up a significant proportion of the demand in all scenarios.

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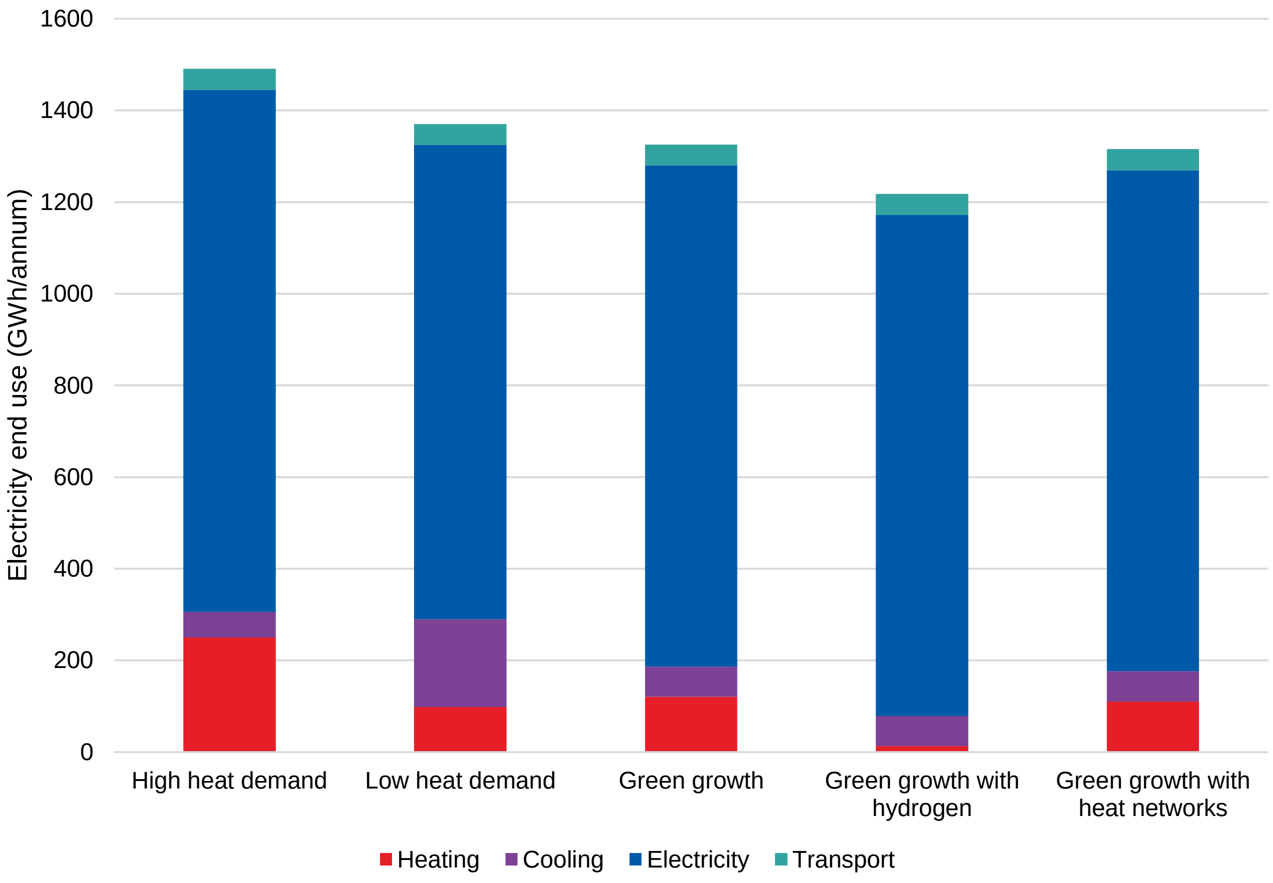

Figure G.1: End use electricity in 2040 for each optimised scenario

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Appendix H

SkenarioLabs baseline energy demand methodology

Skenario Labs

Energy Demand and CO_2 Emissions Methods

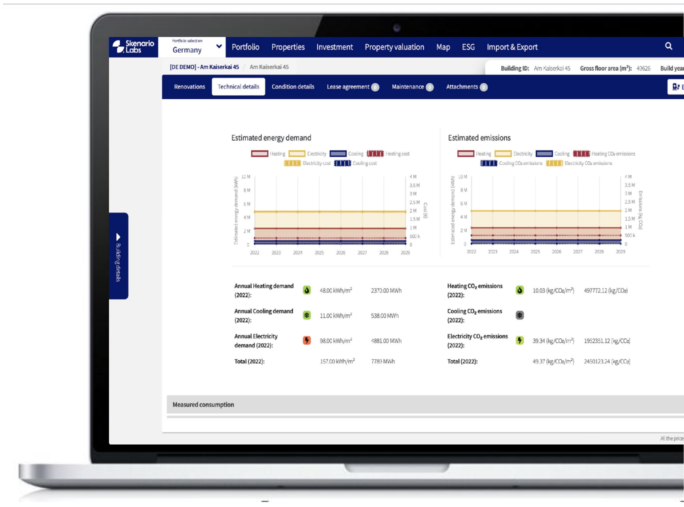
Background

The Skenarios model is intended to be used in estimating the energy demand, CO_2 emissions and saving potential of heterogeneous urban areas. The origins of the method date back to 2015. Currently the method is also utilized as a part of SkenarioLabs' offering in **ESG risk assessment** for banks and property analysis for asset managers. The system was developed from the beginning in a way that it makes the method **universally applicable** providing that localized data on building typologies, building codes and construction costs are readily available.

Methods

Energy Demand

Buildings are assigned **archetypes** based on their build year, main construction material and purpose. Each Archetype has custom parameter values e.g. U-values, electric appliance usages rates and domestic hot water demands. Projected area of building polygon, building floor area, number of floors and other features allow us to estimate the effective areas and shapes of individual buildings.



Calculation of heating and cooling demands is based on the **monthly method** of the ISO 52016-1:2017 standard. The heat or cooling demand of a space is calculated based on heat transfer through the building envelope, ventilation demand and air infiltration rate. Domestic hot water demand and the usage of electricity for appliances, HVAC and lighting is estimated based on the building usage type. Internal heat gains from electricity usage and occupancy and external heat gains from passive solar are calculated into the mix, and their effectiveness depends among others on the thermal mass of the property. Peak demands of heating/cooling are calculated as well, allowing for review of the effects of an intervention on the peak energy demand of a property.

Costs and Cost Effectiveness of Energy Efficiency interventions

The system has a number of **predefined energy efficiency interventions** which can be combined to retrofits. Also, interventions where a building part system (e.g. windows) are entirely replaced by a modern equivalent can be simulated. The **effect** of an intervention on energy demand and ergo energy cost is calculated dynamically by its effect for example on the efficiency of a HVAC system, U-value of a building part or utilization rate of a heat gain. Investment costs are reached by multiplying the unit cost in the database with the effective unit in the building.

Skenario Labs

Because the method considers the basic geometry of the property, the costs as well as effects of certain interventions can be more rigorously assessed. The system calculates the effects of a proposed intervention in a **dynamic method** on a fuel-by-fuel basis allowing for the assessment of net CO_2 emission and cost reduction estimates of interventions.

An optimization tool which would allow **automatically ranking and selecting interventions** in each individual property based on cost effectiveness and a predefined aspiration level is currently planned.

Data Sources

Our model has been taught with building data, weather and climate data, cost data, and more. The data is provided by our partners, customers, and open data sources. The main data points are listed below. The model might vary between countries due to availability of data.

Building Data

The model utilizes different country data sources to establish the locations, projected areas and typologies of buildings. These data is further supplemented by Open Street Map data, where it is available and usable in adding value to the analysis.

Energy Performance Certificates (EPC's) through OpenDataCommunities are used to assess individual properties – where such data is available – and to extrapolate and build a statistical model to supplement on the features of building archetypes and suggested interventions.

Building Characteristics

The current and past country building regulations, individual case studies and the open EPC register are used to establish building characteristics such as the U-values of different parts of the building envelope and air permissibility for average buildings of different types from different eras.

Weather and climate Data

Skenarios model utilizes NASA global temperature and solar insolation data to assess monthly average, max and min temperatures as well as monthly average direct and diffuse insolation. The data covers the world on a latitude / longitude deg grid.

Cost Data

The average costs of each are calculated per effective unit (e.g. roof or façade area). The unit cost data is reached by combining cost data from literature such as "Spon's Architects' and Builders' Price Book" with actual cost data accumulated by SkenarioLabs from customer cases.