RIBA Stage 2
Energy Assessment
Chalcot House

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About the Scheme

The project consists of the development of a 2–storey house in London. The scheme is located in the London Borough of Camden and has a total gross internal area of approximately 535 m^2.

Planning policy

The scheme has been developed in accordance with the London Plan 2021 "The Spatial Development Strategy for Greater London, March 2021" and with the Sustainable, Design and Construction SPG. According to the planning policies, the scheme should achieve:

- A minimum on–site CO_2 reduction of at least 35% beyond Building Regulations
- Residential development should achieve 10% CO_2 improvement through energy efficiency measures, 'Be Lean' stage
- As least 20% CO_2 improvement through renewable technologies, 'Be Green' stage

Summary

The scheme complies with the 2013 Building Regulations Part L and the minimum energy efficiency targets in the following documents have been followed:

- New build (Part L1A) – The actual dwelling CO_2 emissions rate (DER) is no greater than the notional building CO_2 target emissions rate.

In addition, the CO_2 emissions of the scheme have been calculated using the SAP 10.0 carbon emission factors, and the scheme can achieve:

- An on–site CO_2 reduction of 56.5% beyond Building Regulations through energy efficiency measures and maximised of renewable technologies (Air Source Heat Pumps and PV panels)
- Residential part of the development achieves 26.2% CO_2 improvement through energy efficiency measures, 'Be Lean' stage
- A further improvement of 30.3% CO_2 has been achieved through renewable technologies 'Be Green' stage (Air Source Heat Pumps and PV panels)

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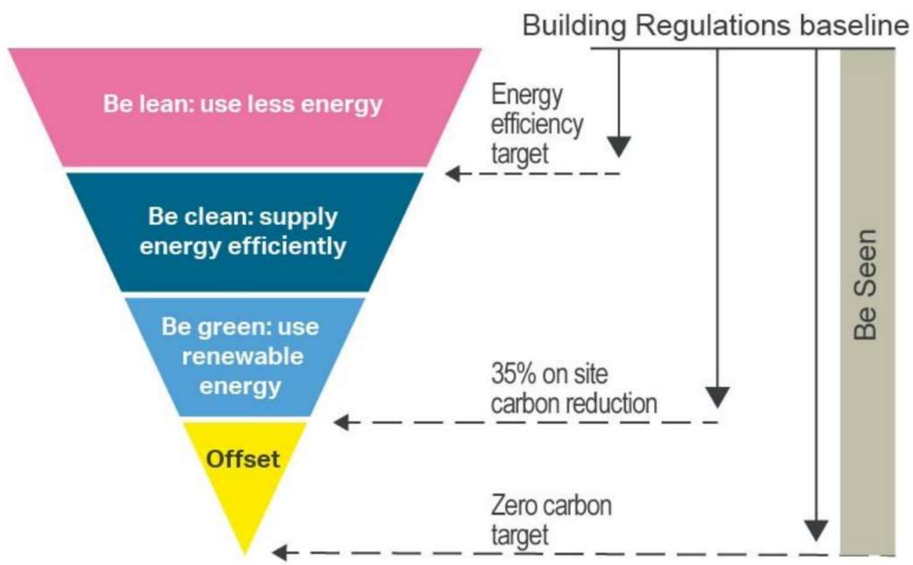
Energy hierarchy

The proposed scheme has followed the energy hierarchy that is illustrated below:



Source: Greater London Authority

Key measures

Key measures identified for each stage are shown below:

- Be Lean:
  - Low U–values for opaque elements and fenestration
  - Low g–value
  - Low air permeability
  - High efficiency lighting
  - Mechanical ventilation with heat recovery
  - Green roof
- Be Clean:
  - No measures were identified
- Be Green:
  - Air Source Heat Pumps to provide space heating and hot water
  - Photovoltaic panels

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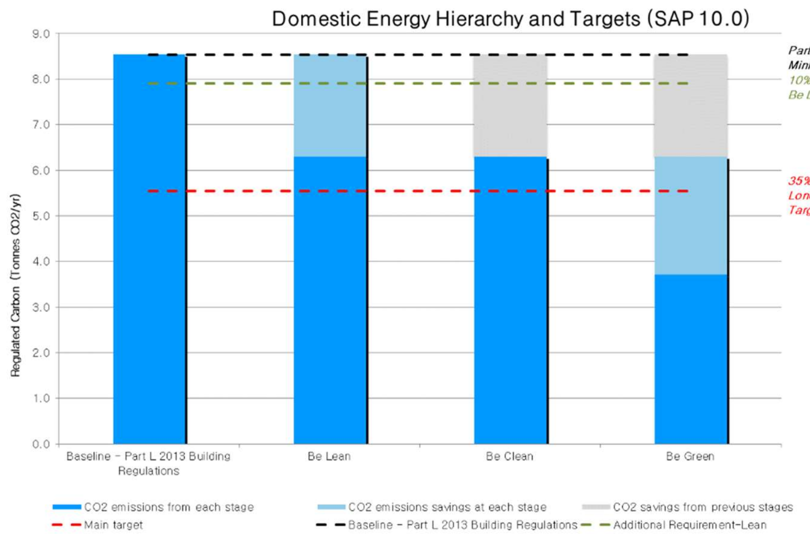
GLA's Energy Hierarchy: Regulated carbon emissions

The proposed scheme has followed the energy hierarchy. A graphical illustration of how the scheme performs in relation to Building Regulations and the Energy Hierarchy is shown below. Carbon dioxide emission factors for SAP 10.0 have been used for the calculation.

As demonstrated in the figure the proposed scheme will reduce carbon emissions by 26.2% from the fabric energy efficiency measures described in the 'Be Lean' section and will reduce the total carbon emissions by 56.5% over Building Regulations (using SAP 10.0 carbon dioxide emission factors) with the further inclusion of low and zero carbon technology (Air source heat pumps and photovoltaic panels).

Therefore, the scheme meets and exceeds the planning policy carbon reduction target and complies with London Plan 2021 Policy SI2.



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Regulated CO_2 emissions

GLA's Energy Hierarchy: Regulated CO_2 – Calculated using SAP 2012 CO_2 factors				
	Baseline:	Be lean:	Be clean:	Be green:
CO_2 emissions (tCO_2/yr)	9.08	7.44	–	3.89
CO_2 emissions saving (tCO_2/yr)	–	1.63	–	3.56
Saving from each stage (%)	–	18.0	–	39.2
Total CO_2 emissions saving (tCO_2/yr)	5.19			
57.2% total CO_2 savings over Building Regulations Part L 2013 achieved				
GLA's Energy Hierarchy: Regulated CO_2 – Calculated using SAP 10.0 CO_2 factors				
	Baseline:	Be lean:	Be clean:	Be green:
CO_2 emissions (tCO_2/yr)	8.53	6.30	–	3.71
CO_2 emissions saving (tCO_2/yr)	–	2.23	–	2.59
Saving from each stage (%)	–	26.2	–	30.3
Total CO_2 emissions saving (tCO_2/yr)	4.82			
56.5% total CO_2 savings over Building Regulations Part L 2013 achieved				

Carbon Emission Factors
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Emission factors:

The Greater London Authority (GLA) Guidance on Energy Assessments published in October 2018 highlights a critical development regarding carbon emission factors. Grid electricity has significantly decarbonised since the last update of Part L in April 2014 and in July 2018 the Government published updated carbon emission factors (SAP 10.0) demonstrating this. Although SAP 10.0 is not in use yet, the GLA Guidance encourages the use of SAP 10.0 carbon emission factors from January 2019 in areas where there are no opportunities to connect to existing or planned district heat networks. Any applicants proposing to use the SAP 2012 emissions factors is required to provide adequate justification.

SAP 2012 emission factors can be used where:

- The scheme is located within a Heat Network Priority area; and
- There is potential to connect to an existing network using gas-engine CHP or a new network using low-emission CHP; and
- The heat network operator has, or is in the process of developing, a strategy to decarbonise the network and has shared it with the GLA

While the proposed scheme is expected to comply with SAP 2012 for Building Regulation compliance, the assessment presents total emissions using SAP10.0 as it is required for demonstrating performance against planning policy targets. The revised factors are below:

Fuel Type	Carbon Factor (kg CO_2/kWh)	
	SAP 2012	SAP10.0
Natural Gas	0.216	0.210
Grid Electricity	0.519	0.233

The carbon emissions of the scheme have been calculated using Building Regulations methodology for estimating energy performance against Part L 2013 requirements, and the outputs have been manually converted for the SAP 10.0 emission factors using a spreadsheet.

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Methodology

The purpose of an energy assessment is to demonstrate that climate change mitigation measures comply with London Plan energy policies, including the energy hierarchy. It also ensures energy remains an integral part of the scheme's design and evolution.

The methodology followed in this report follows the guidance set out by the Greater London Authority (GLA) for developing energy strategies as detailed in the document. "Energy Assessment Guidance: Greater London Authority guidance on preparing energy assessments as part of planning applications (April 2020)". The scheme has been developed in accordance with the London Plan 2021.

This report has followed these documents and comprises the following components:

- Baseline: A calculation of the Part L 2013 Building Regulations compliant CO_2 emission baseline using approved software. The baseline assumes a gas boiler would provide heating.
- Be Lean: A calculation of the impact of demand reduction measures. For example, passive design measures, including optimising orientation and site layout, natural ventilation and lighting, thermal mass and solar shading, and active design measures such as high efficacy lighting and efficient mechanical ventilation with heat recovery.
- Cooling Hierarchy: In accordance with London Plan 2021Policy SI4, measures that are proposed to reduce the demand for cooling have been set out such as minimisation of solar and internal gains and night cooling strategies.
- Be Clean: In accordance with London Plan 2021 Policy SI3, this report has demonstrated how the scheme has selected heating, cooling, and power systems to minimise carbon emissions. This comprises an evaluation of the feasibility of connecting to existing low carbon heat networks, planned networks, site-wide and communal heat networks, and CHP.
- Be Green: In accordance with London Plan 2021 Policy SI2, this report has conducted a feasibility assessment of renewable energy technologies. This comprised a site-specific analysis of the technologies and, if applicable, how they would be integrated into the heating and cooling strategy for the scheme.

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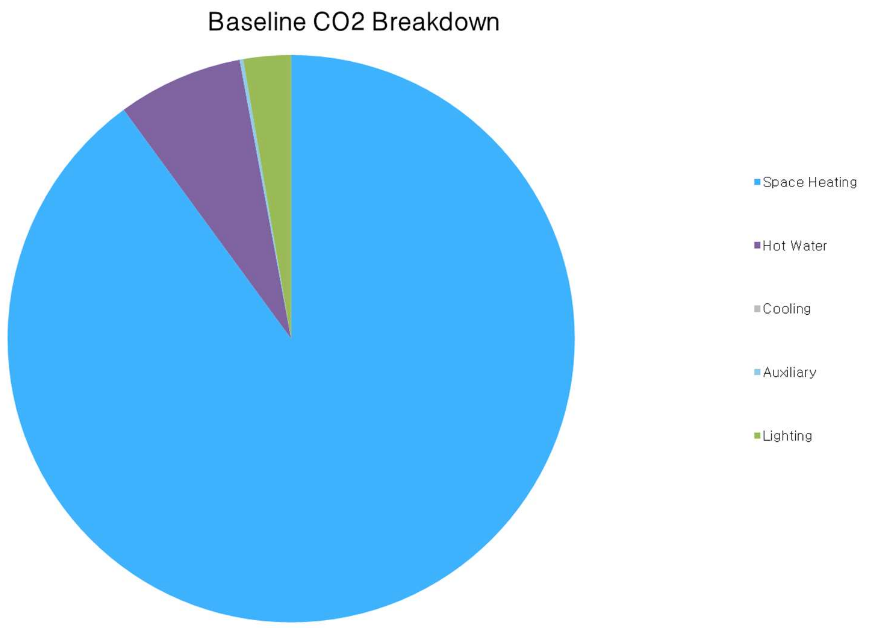
Building regulations Part L 2013 minimum compliance

The total baseline carbon emissions for the whole scheme is 8.53 tonnes CO_2/yr (using SAP 10.0 carbon dioxide emission factors).

The pie chart provides a breakdown of the specific carbon emissions by system over the course of one year. The chart shows that space heating is the primary source of carbon dioxide emissions, and hot water is the second largest.

Carbon Emissions in tonnes CO_2/yr.				
Heating	Hot Water	Cooling	Auxiliary	Lighting
7.68	0.61	0.00	0.02	0.23



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Be Lean: summary

Demand reduction measures have reduced the scheme's carbon emissions by 26.2% (using SAP 10.0 figures) over the minimum Part L 2013 Building Regulations baseline. In order to achieve that, an enhanced construction specification has been adopted as per table below:

U-values

Element	Minimum Building Regulations U-value W/m^{2}K	Proposed U-value W/m^{2}K
Flat roof	0.20	0.10
Wall	0.30	0.12
Ground floor	0.25	0.10
Swimming pool basin	0.25	0.10
Windows	2.00	0.90 (g-value 0.50)
Rooflights	2.00	1.00 (g-value 0.55)
Doors	2.00	1.20

Air permeability

A reduced air permeability has been targeted as per the table below:

Air permeability (m^3/hm^2 @50 Pa)	Minimum Building Regulations	Proposed
Domestic	10	3

This will require careful attention to two key areas:

- Structural leakage
- Services leakage

Structural leakage occurs at joints in the building fabric and around window and door openings, loft hatches and access openings. There will also be some diffusion through materials such and cracks in masonry walls typically caused by poor perpends in the blockwork or brickwork. Structural leakage is hard to remedy retrospectively therefore good detailing at the design stage is essential.

Services leakage occurs at penetrations from pipes and cables entering the building. These can be sewerage pipes, water pipes and heating pipes. As well as electricity cables there may also be telecommunication cables. Attention, therefore, needs to be paid to sealing all penetrations during construction.

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Thermal Bridging:

The new dwelling will be designed in line with the accredited construction details (ACD) and therefore it has been indicatively modelled with the accredited thermal bridge Psi-values for the following junctions:

- Lintels (E2)
- Sill (E3)
- Jambs (E4)
- Ground floor (E5)
- Intermediate floor within dwelling (E6)
- Corners (E16)
- Corners inverted (E17)

A bespoke thermal bridging calculation will be required for the following junctions to achieve the specified Psi-values:

- Flat Roof with Parapet (E15): 0.30 W/mK

The default psi-value has been used for the remaining junctions.

Thermal Mass:

Thermal mass of the scheme has been indicatively modelled as 250 kJ/m^{2}K (medium).

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Heating

For the 'Be Lean' scenario, the scheme has been modelled with a gas boiler with an efficiency of 89.5% (as required by the GLA). For the 'Be Green' final scenario, an air source heat pump with a minimum COP of 2.80 will be proposed providing 40% of the heating demand. The remaining 60%will be provided by a gas boiler with an efficiency of 90%. Heat will be provided via underfloor heating and will be controlled with a charging system linked to use of community with programmer and TRVs.

Hot Water

For the 'Be Lean', the hot water will be provided by the main gas heating system (gas boilers with an efficiency of 89.5%). For the 'Be Green' final scenario, hot water will be provided by the main heating system, gas boiler (60%) and air source heat pump (40%).

Ventilation

Balanced ventilation with heat recovery has been specified for the dwelling with an SFP of 0.96 W/l/s and a heat recovery efficiency of 91%.

Cooling

No cooling has been specified for the dwelling.

Lighting

High efficiency lighting has been specified for the development with a minimum efficacy of 75 lumens/W.

Energy demand following energy efficiency measures (MWh/year)

Space Heating	Hot water	Lighting	Auxiliary	Cooling	Unregulated gas	Unregulated electricity
23.3	2.8	1.0	2.5	0.0	0.0	7.5

Fabric energy efficiency

Target Fabric Energy Efficiency (MWh/year)	Design Fabric Energy Efficiency (MWh/year)	Improvement (%)
41.95	31.56	25%

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Overheating and cooling

The aim of this section is to reduce the impact of the urban heat island effect in London and encourage the design of spaces to avoid overheating and excessive heat generation, and to mitigate overheating due to the impact of climate change.

Where design measures and the use of natural and/or mechanical ventilation are not enough to guarantee the occupant's comfort, in line with the cooling hierarchy the development's cooling strategy must include details of the active cooling plant being proposed, including efficiencies, and the ability to take advantage of free cooling and/or renewable cooling sources.

Where appropriate, the cooling strategy should investigate the opportunities to improve cooling efficiencies using locally available sources such as ground cooling and river/dock water-cooling.

The Cooling Hierarchy in Policy SI4

Developments should reduce potential overheating and reliance on air conditioning systems and demonstrate this with the Cooling Hierarchy:

1. Reduce the amount of heat entering the building through orientation, shading, high albedo materials, fenestration, insulation, and the provision of green infrastructure
2. Minimise internal heat generation through energy efficient design
3. Manage the heat within the building through exposed internal thermal mass and high ceilings
4. Provide passive ventilation
5. Provide mechanical ventilation
6. Provide active cooling systems

Avoiding overheating: measures taken

The following measures have been taken in accordance with the cooling hierarchy to reduce overheating and the need for cooling:

1. Reduce the amount of heat entering the building through orientation, shading, high albedo materials, fenestration, insulation, and the provision of green infrastructure
    - Solar shading devices such as light-coloured curtain/roller blinds will be specified to limit solar gain. The shading has also been optimised to avoid substantially reducing daylighting or increasing the requirement for electric lighting.
    - High albedo materials: A high albedo (reflective) surface has been specified for the roof and vertical facades in order to minimise the heat absorbed by the roof, and significant thermal insulation has been specified to prevent any heat absorbed being transferred into the building.
    - Green roofs – a green roof has been specified for the scheme at the ground floor roof. This will act as an insulation barrier and the ecological processes will reduce the amount of solar energy absorbed by the roof membrane, so will reduce temperatures below the surface and cool the building areas directly below.
    - Insulation levels have been maximised and the resulting U-values are lower than required by Building Regulations. The build-ups therefore prevent the penetration of heat as much as practically possible. See the 'Be Lean' section of this report for target U-values.
    - A reduced air permeability rate has been targeted to minimise uncontrolled air infiltration. This will require attention to detailing and sealing. See 'Be Lean' section of this report for details of how this will be achieved.

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2. Minimise internal heat generation through energy efficient design
    - Internal heat gains have been minimised where possible. Energy efficient appliances will help reduce internal heat gain and reduce the cooling requirement.
    - Energy efficient lighting will also be specified as per the 'Be Lean' section.
    - Heat distribution infrastructure within building will be designed to minimise pipe lengths, particularly lateral pipework in corridors of the apartment block. Twin pipes configuration will be adopted to minimise heat loss.
3. Manage the heat within the building through exposed internal thermal mass and high ceilings
    - High thermal mass – exposed building fabric materials such as masonry or concrete have been utilised in the form of concrete floors. These materials act as 'thermal batteries'; they absorb heat gains during the day when the building is occupied and 'store' it for an extended period, thereby helping to stabilise daytime temperatures. At night this heat can be dissipated, which 'resets' the heating cycle. Ventilation will also be used at night to purge the stored heat within the structure. A 'ground coupled' system that uses the thermal storage capacity of the ground has not been specified as the passive ventilation option has been selected instead.
    - Room heights – high ceilings are traditionally used in hot climates to allow thermal stratification so that occupants can inhabit the lower cooler space, and to decrease the transfer of heat gain through the roof. The proposed building has floor to ceiling heights of more than 3m. As the roof will be well insulated, there will be minimal penetration of heat through the roof.
4. Provide passive ventilation
    - Openable windows are specified on all facades of the building.
    - Cross ventilation will be achieved by opening windows on two facades and ensuring there is a clear path for airflow.
    - Night time cooling will also be utilised. This will work in tandem with high thermal mass materials specified. The larger temperature differential that exists between internal and external temperatures at night will allow effective stack ventilation and purging of heat accumulated within the structure during the day.
5. Provide mechanical ventilation
    - Mechanical ventilation with summer by-pass will be used to make use of 'free cooling' where the outside air temperature is below that in the building during summer months.
    - The mechanical systems will comply with the Domestic Building Services Compliance Guide as it is demonstrated in the 'Be Lean' section.

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Overheating risk

The overheating risk considering all the above-described passive measures have been assessed for the scheme:

Areas	Overheating risk from SAP
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According to the GLA guidance on preparing energy assessments (April 2020) Section 8, a dynamic modelling in line with CIBSE TM59 should be carried out to assess the risk of overheating. A dynamic overheating analysis has been carried out by Eight Associates '5908-Energy Assessment-Chalcot House-2107-22vvyp', issued on the 22/07/2021, confirms that the scheme meets the CIBSE TM59 requirements.

Active cooling

Air conditioning has not been specified for the scheme, since the overheating analysis demonstrates the there is no significant risk of overheating and the passive design measured are enough to guarantee the occupant's comfort.

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Heating infrastructure including CHP

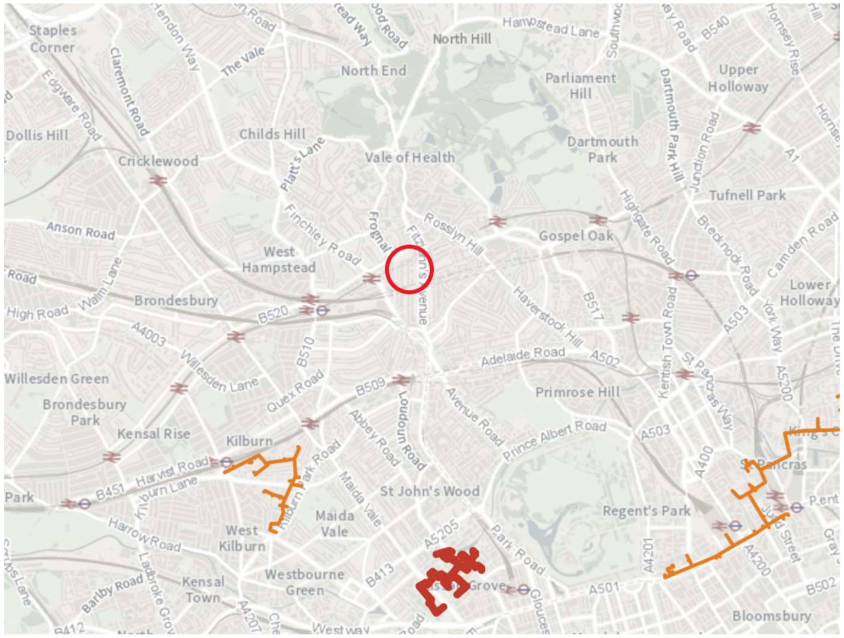
Once demand for energy has been minimised, schemes must demonstrate how their energy systems have been selected in accordance with the order of preference in Policy SI3 of London Plan 2021. This has involved a systematic appraisal of the potential to connect to existing or planned heating networks and on site communal and CHP systems.

To comply with London Plan 2021 Policy SI 3, developments in Heat Network Priority Areas (HNPAs) should have a communal low-temperature heating system and should select a heat source in accordance with the following heating hierarchy:

a) connect to local existing or planned heat networks
b) use zero-emission or local secondary heat sources (in conjunction with heat pump, if required)
c) use low-emission combined heat and power (only where there is a case for CHP to enable the delivery of an area-wide heat network, meet the development's electricity demand and provide demand response to the local electricity network)
d) use ultra-low NOx gas boilers

Connect to local existing or planned heat network

The illustration below shows the London heat map. Red lines are existing heat networks and orange lines are proposed heat networks. The red circle shows the location of the proposed scheme.



A review of the London Heat Map demonstrates that there are no existing networks present within connectable range of the scheme. Therefore, a connection is not possible.

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Use zero-emission and/or local secondary heat sources

According to the GLA and London Plan 2021 Policy SI3, the exploitation of local energy opportunities to maximise the use of locally available energy sources whilst minimising primary energy demand and carbon emissions is encouraged. Secondary heat includes environmental sources such as air, water and ground; and waste sources such as heat from the sewerage system, sewage treatment plants, the tube network, data centres and chiller systems.

There are no local available waste heat sources for the scheme.

Use low-emission combined heat and power (CHP)

In accordance with section 9 of the GLA guidance for Energy Planning where connection to an area wide heat network will not be available in the foreseeable future i.e., 5 years following completion, or the development is of such a scale that it could be the catalyst for an area wide heat network, applicants should evaluate the feasibility of on-site CHP

GLA guidance stipulates that small, or purely residential developments of less than 350 dwellings will not be expected to include on-site CHP. CHP systems are best utilised where there is a consistent and high demand for heat. Because of the small electricity supplies and demand of this scheme, a CHP installed to meet the base heat load would typically require the export of electricity to the grid. The administrative burden of managing CHP electricity sales at a small scale without an active energy service companies (ESCOs) is prohibitive for smaller operators of residential developments.

The heat demand profile of this residential scheme is not suitable to CHP. The implemented fabric improvements from the 'Be Lean' scenario have also reduced the energy demand from space heating to hot water. For CHP systems to be economically viable they need to run for at least 5,000 hours per year. Therefore, a CHP system would most likely be oversized, and as a result less efficient and economic.

Use ultra-low NOx gas boilers

Where it is clearly demonstrated that the above heating options (District heating, local secondary heat source and CHP) have been fully investigated and ruled out, then a site-wide heating strategy led by ultra-low NOx gas boilers can be considered. 60% of the space heating and hot water demand of the scheme will be provided by an Ultra-low NOx gas boiler.

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Renewable Energy Feasibility:

In line with Policy SI2 of the London Plan 2021 the feasibility of renewable energy technologies has been considered. A detailed site-specific analysis and associated carbon saving calculations has also been provided for renewable energy technologies considered feasible.

Each technology has been assessed under 3 broader categories. There are key criteria for each category on which the technology is evaluated. The key criteria have been given a weighting based on a tick-system, a graphical representation of this is shown below:

The weighting of each of the criteria within the categories is shown below:

- Local, site-specific impact: (Maximum score of 5)
  - Local planning criteria = ✓
  - Land used by all components = ✓
  - Noise impact from operation = ✓
  - Interaction on the current building design = ✓
  - Buildability of installation = ✓

- Economic viability: (Maximum score of 5)
  - Capital cost of all components = ✓
  - Grants and funding available = ✓
  - Payback periods (years) 3-5, 5-10, 10-15 = ✓
  - Servicing requirements (low or high) = ✓
  - Maintenance costs (low or high) = ✓

- CO2 and sustainability: (Maximum score of 10)
  - Carbon saving per year = ✓✓✓✓
  - Impact of future grid decarbonisation (gas vs. electric) = ✓✓
  - Local air quality/pollution = ✓✓
  - Resource use of installation = ✓✓

Key comments on each of the criteria and the corresponding score will be provided in a table for each of the technologies. The score for each of the criteria will be summed and each of the technologies will then be ranked. The assessment of each technology is undertaken on the following pages.

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Biomass & Biofuel – Rejected

Biomass is normally considered a carbon 'neutral' fuel, as the carbon dioxide emitted on burning has been recently absorbed from the atmosphere by photosynthesis. Although some form of fossil fuel derived inputs are required in the production and transportation of the fuel.

Wood is seen as a by-product of other industries and the small quantity of energy for drying, sawing, pelleting and delivery are typically discounted. Biomass from coppicing is likely to have external energy inputs from fertiliser, cutting, drying etc. and these may need to be considered. In this toolkit, all biomass fuels are considered to have zero net carbon emissions.

Biomass can be burnt directly to provide heat in buildings. Wood from forests, urban tree pruning, farmed coppices or farm and factory waste, is the most common fuel and is used commercially in the form of wood chips or pellets. Biomass boilers can also be designed to burn smokeless to comply with the Clean Air Acts.

Boilers can be fed automatically by screw drives from fuel hoppers. This typically involves daily addition of bagged fuels.

A biomass boiler could be installed on site for supplementary LTHW heating; however, a major factor influencing the suitability of a biomass boiler is the availability of the biomass fuel. A local and reliable fuel source would be essential for the biomass boiler to be an efficient replacement for a conventional boiler system. Therefore, a very comprehensive feasibility assessment needs to be undertaken to understand the practicalities of such a system.

It is estimated that the heating and hot water demand of the site is too large to meet the required CO_2 emissions reduction if a biomass boiler was a standalone system. Therefore, a biomass boiler would need to be combined with energy demand reduction measures and/or CHP. The likely installed cost would be circa £10,000. The additional cost of providing and storing the bio-fuel also needs to be accounted for. The site is likely to be unsuitable for biomass boilers due to site constraints such as limited transport/access issues, and storage of the biomass fuel. A detailed feasibility study will be required to investigate the suitability.

Local, site-specific impact (out of 5)	Economic viability (out of 5)	CO_2 and sustainability (out of 10)
✓	✓✓✓	✓✓✓✓✓
Local air quality impacts, increased transport usage, increased plant space, slightly increased buildability issues.	Increased capital costs of installation, typical payback of 8 years, Increased maintenance relative to gas boiler, resource use not significantly increased if well serviced.	Very low carbon intensity of feedstock if properly procured. Decarbonisation impact not applicable, air quality issues.

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Photovoltaic Panels (PV) – Accepted

Photovoltaic systems convert energy from the sun into electricity through semi–conductor cells. Systems consist of semi–conductor cells connected together and mounted into modules. Modules are connected to an inverter to turn the direct current (DC) output into alternating current (AC) electricity for use in buildings.

Photovoltaic panels supply electricity to the building and are attached to electricity gird or to any other electrical load. Excess electricity can be sold to the National Grid when the generated power exceeds the local need. PV systems require only daylight, not sunlight to generate electricity (although more electricity is produced with more sunlight), so energy can still be produced in overcast or cloudy conditions.

The cost of PV cells is heavily dependent on the size of the array. There are significant cost reductions available for larger installations.

The most suitable location for mounting photovoltaic panels is on roofs as they usually have the greatest exposure to the sun. The proposed site has a potential useable flat roof area of approximately 150 m^2.

Local, site–specific impact (out of 5)	Economic viability (out of 5)	CO_2 and sustainability (out of 10)
✓✓✓✓ No local air quality impacts, use of unutilised roof space, no noise issues, good orientation, and slightly increased buildability issues for wiring and metering.	✓✓ Increased capital costs of installation, typical payback of 10–15 years, Feed in Tariff available, limited servicing and maintenance i.e. 1 visit per year, inverter will require replacement.	✓✓✓✓✓ ✓✓✓ High carbon saving from electricity, uses minimal grid electricity, no local air impact, high embodied energy of panels.

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Solar Thermal – Rejected

Solar water heating systems use the energy from the sun to heat water for domestic hot water needs. The systems use a heat collector, generally mounted on the roof in which a fluid is heated by the sun. This fluid is used to heat up water that is stored in either a separate hot water cylinder or a twin coil hot water cylinder inside the building. The systems work very successfully in all parts of the UK, as they can work in diffuse light conditions.

Like photovoltaic panels the most suitable location for mounting solar hot water panels is on roofs as they usually have the greatest exposure to the sun. The proposed site has a potential useable flat roof area of approximately 150 m^2.

It is estimated that the CO_2 emissions reduction that would be produced by solar hot water as a standalone system would not be adequate to achieve the required CO_2 emissions reduction target. Therefore, a solar hot water system would need to be combined with more energy efficiency strategies, a CHP, or additional renewable technologies to achieve the carbon reduction target.

Local, site-specific impact (out of 5)	Economic viability (out of 5)	CO_2 and sustainability (out of 10)
✓✓✓✓	✓✓✓	✓✓✓✓✓✓
No local air quality impacts, use of unutilised roof space, no noise issues, good orientation, slightly increased buildability issues for piping and cylinders.	Increased capital costs of installation, typical payback of 8–10 years, Heat Incentive available, limited servicing and maintenance i.e., 1 visit per year, heat transfer fluid requires replacing every 10 years.	Lower carbon saving as primarily displacing gas, uses minimal grid electricity, no local air impact, medium embodied energy of panels.

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Wind Energy – Rejected

Wind energy is a cost-effective method of renewable power generation. Wind turbines can produce electricity without carbon dioxide emissions in ranges from watts to megawatt outputs. The most common design is for three blades mounted on a horizontal axis, which is free to rotate into the wind on a tall tower.

The blades drive a generator either directly or via a gearbox to produce electricity. The electricity can either be linked to the grid or charge batteries. An inverter is required to convert the electricity from direct current (DC) to alternating current (AC) for feeding into the grid.

Modern quiet wind turbines are becoming viable in low density areas where ease of maintenance and immediate connection to the grid or direct use of the electricity in a building, may make them cost effective, despite lower wind speeds than open areas.

Wind turbines are generally less suited to dense urban areas as their output will be affected by potentially lower and more disrupted wind speeds, and their use of much more cost-effective machines may be prohibited by their proximity to some building types. Small turbines can be used in inner city areas mounted on buildings, although there are relatively few installations.

A detailed wind resource evaluation would be required for the site to fully understand the generation potential and payback period. Also, it is likely that planning restrictions and resistance from groups within the local community could also affect the viability of wind energy for the project.

Local, site-specific impact (out of 5)	Economic viability (out of 5)	CO_2 and sustainability (out of 10)
✓	✓✓✓✓	✓✓✓✓✓
No local air quality impacts, use of unutilised roof space, medium noise issues, relatively limited wind speeds in local area, increased buildability issues for wiring and metering.	Medium capital costs of installation, typical payback of 5 years, Feed in Tariff available, limited servicing and maintenance, costs of 2-3% typical.	High carbon saving from electricity, output limited from urban installation, consumes little grid electricity, no local air impact, low embodied energy of panels

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Ground Source Heat Pump (GSHP) – Rejected

Geo-thermal energy is essentially heat collected from the ground. Heat obtained from the ground may be considered it as a source of heating and cooling within the UK by the use of a geo-thermal heat pump or ground source heat pumps.

A ground source heat pump is a device for converting energy in the form of low-level heat to heat at a usable temperature. The heat pump consists of five main parts: ground collector loop/or boreholes, heat exchanger, compressor, condenser heat exchanger and expansion valve.

At approximately 1.2-1.5 metres down below ground level the temperature is a constant 10 to 12°C. Any boreholes would need to be sunk to an effective depth of 50 – 120m and a ground feasibility report would be required to ascertain if this method of heat source were viable.

From the boreholes pre-insulated pipework is laid in the ground to the heat exchanger device. The system is filled with water and antifreeze. The cooled water is pumped around the loop / borehole gathering energy as it circulates. The water that has been heated to 10-12°C is returned to the ground source heat exchanger where the energy is transferred to the refrigerant gas. For every 1kW of energy used to compress the refrigerant, the process 'gives up' 4 kW of energy for use in the system being used to heat the building.

The installation cost for a Ground Source Heat pump is typically high compared to a gas-boiler installation.

Local, site-specific impact (out of 5)	Economic viability (out of 5)	CO_2 and sustainability (out of 10)
✓✓ No local air quality impacts, no visual impact, no noise issues, however the constrained site may prohibit its installation. Increased buildability issues for pipework and heating emitters internally.	✓ High capital costs of installation, typical payback >15 years where gas is displaced, Renewable Heat Incentive available, limited servicing and maintenance i.e., 1 visit per year, mechanical parts may require replacement over lifespan.	✓✓✓✓✓ ✓✓✓ Medium carbon saving from gas displacement, consumes some electricity so benefits from decarbonisation, no local air impact, high embodied energy of equipment.

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Air Source Heat Pump (ASHP) –Accepted

Air source heat pump systems work on the same principle as a ground source heat pump although they use the outside air as the heat source.

The coefficients of performance given by air source heat pump systems are inferior to that of ground source systems due to varying air temperatures. In the depth of winter, the energy efficiency of an air source system will be lower than that of a ground source system, and it is likely that more back-up heat will be required if an air source unit is fitted. This back-up heat often comes from a direct electric heater. They operate over a varying temperatures range of −15˚C to +25˚C, however, the performance will reduce to below the required 3 to 1 carbon saving ratio in winter, and they also require a defrosting mechanism to melt ice that forms on the air heat exchanger.

ASHPs are cheaper to install than ground source heat pumps but carbon dioxide emission savings will typically be less than that of a ground source heat pump.

Local, site-specific impact (out of 5)	Economic viability (out of 5)	CO_2 and sustainability (out of 10)
✓✓✓✓ No local air quality impacts, use of unutilised roof space, over visual impact, low noise issues, increased buildability issues for pipework and heating emitters internally.	✓✓ Medium– high capital costs of installation, typical payback >15 years where gas is displaced, Renewable Heat Incentive available Limited servicing and maintenance i.e., 1 visit per year, mechanical parts may require replacement over lifespan.	✓✓✓✓✓ ✓✓ Medium carbon saving from gas displacement, less efficient in winter, consumes electricity so benefits from decarbonisation, no local air impact, high embodied energy of equipment.

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Summary comparison matrix

An assessment of the feasibility of each of the technologies is shown below.

Renewable Technology	Comments	Local, site–specific impact (out of 5)	Economic viability (out of 5)	CO_2 and sustainability (out of 10)	Total Score
Biomass Boiler	High air quality impact	✓	✓✓✓	✓✓✓✓✓	9
Photovoltaic	High CO_2 savings and have low visual impact	✓✓✓✓	✓✓	✓✓✓✓✓ ✓✓✓	14
Solar Thermal	Low CO_2 savings compared to PV panels	✓✓✓✓	✓✓✓	✓✓✓✓✓ ✓	13
Wind Energy	High visual and noise impact	✓	✓✓✓✓	✓✓✓✓✓	10
GSHP	High capital cost	✓✓	✓	✓✓✓✓✓ ✓✓✓	11
ASHP	Can provide carbon savings with minimal site impact	✓✓✓✓	✓✓	✓✓✓✓✓ ✓✓	13

Photovoltaic panels, solar thermal panels and ASHPs have scored the best.

Due to the limited roof space, photovoltaic panels and ASHPs have been specified as they can provide higher CO_2 savings compared to the solar thermal panels.

In order to achieve the required temperatures, a combination of ASHP and gas boiler has been proposed for this site. The dwelling can meet 40% of its hot water/space heating consumption via air source heat pumps, with the remaining 60% demand being met by the gas boiler.

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Air Source Het Pump (ASHP) – Performance

The lifecycle of the proposed system is 25 years. To calculate the lifecycle cost of the ASHP, the maintenance of the system and cost of electricity to run the pumps will be included.

The ASHP has been estimated to have a CoP of 2.8 and it will cover 40% of the space and hot water demand. The remaining 60% of the space and hot water demand will be covered by a gas boiler.

The following table summarise the reduction in carbon emissions and the life cycle cost of the ASHP system compared to a gas boiler.

	Gas Boiler	Air Source Heat Pump
	Heating and hot water	Heating and hot water
Installation cost (£)	2,000	7,000
Maintenance and replacement cost (£)	3,000	2,000
Total (£)	5,000	9,000
Energy demand (kWh)	10468	3124
Cost of gas/electricity (p/kWh)	5	12.5
Annual operational cost (£)	523	391

It should be noted that the figures above are based on SAP modelling for CO_2 compliance. Compliance models are not well suited to investment appraisals because they do not accurately estimate energy consumption. It is estimated that the lifecycle saving for ASHP will be greater than boiler under 'real-life' operating conditions and consumption.

Moreover, the servicing strategy has been proposed based on sustainability aspirations and compliance with GLA requirements, which is intended to supersede simple economic payback appraisals for purposes of energy strategies.

Cost Performance Criteria	Value
Extra Cost Over Life Cycle (£)	4,000
Predicted Annual Savings (£)	133
Payback Period (years)	30.1
Energy and Carbon Performance Criteria	Value
Predicted Annual Energy Saved (kWh/yr)	7,344
Annual Carbon Emissions Reductions (kg CO_2/year) using SAP10.0 carbon factors	1,067
CO_2 Emissions Reduction (%) with SAP10.0	12.5%

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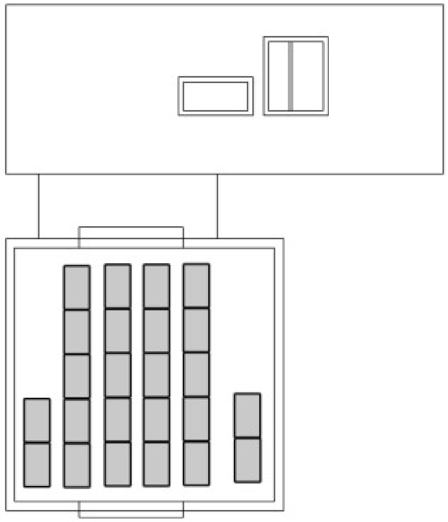
Photovoltaic panels (PV) – Performance

A photovoltaic panel system of 7.92 kWp (24 panels of 330W each) has been specified for the whole development, a detailed summary of the lifecycle cost, revenue and payback for the photovoltaic panels is presented in this section.

The following drawing shows that there are 150m^2 of available roof that could be used to install photovoltaic modules and lack of shading. PV panels will be placed with 30° tilt, oriented southeast, covering around 50m^2 of the roof.



The lifecycle of the proposed high efficiency panels is 25 years. To calculate the lifecycle cost of the panels, the maintenance of the system and replacement cost will be included. The total costs for the proposed system's lifetime are shown in the table below.

Capital cost (£)	10,300
Maintenance cost (£)	1,800
Operational cost (£)	900
Total (£)	13,000
Cost of electricity (p/kWh)	12.5
Electricity generation (kWh/yr)	6,521
% of energy used on site	50%
Savings (£)	583
Summary	
Cost Performance Criteria	Value
Extra Cost Over Life Cycle (£)	13,000
Predicted Annual Savings (£)	583
Payback Period (years)	22.3
Energy and Carbon Performance Criteria	Value
Predicted Annual Energy Saved (kWh/yr)	6,521
Annual Carbon Emissions Reductions (kg CO_2/year) using SAP10.0 carbon factors	1,519
CO_2 Emissions Reduction (%) with SAP10.0	17.8%

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Summary

The project consists of the development of a 2-storey house in London. The scheme is located in the London Borough of Camden and has a total gross internal area of approximately 535 m^2.

The CO_2 emissions of the scheme have been calculated using the SAP 10.0 carbon emission factors, and the scheme can achieve:

- An on-site CO_2 reduction of 56.5% beyond Building Regulations through energy efficiency measures and maximised of renewable technologies (Air Source Heat Pumps and PV panels)
- The development achieves 26.2% CO_2 improvement through energy efficiency measures, 'Be Lean' stage
- 30.3% CO_2 improvement has been achieved through renewable technologies 'Be Green' stage (Air Source Heat Pumps and PV panels)

Appendix A
Energy Assessment
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SAP and BRUKL files

The emission figures and details of the calculations and methodology used to determine the figures provided within the report can be found in the following pages:

- Baseline – TER from the TER SAP worksheet
- Be Lean – DER from the Be Lean scenario DER SAP worksheet
- Be Green – DER from the Be Green scenario DER SAP worksheet

Appendix A
Energy Assessment
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Baseline – TER from the TER SAP worksheet

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Be Lean – DER from the Be Lean scenario DER SAP worksheet

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Be Green – DER from the Be Green scenario DER SAP worksheet