Energy Statement

44 Gloucester Avenue

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XCO2 energy

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About us:
XCO2 Energy are a low-carbon consultancy working in the built environment. We are a multi-disciplinary company consisting of both architects and engineers, with specialists including CIBSE low carbon consultants, Code for Sustainable Homes, EcoHomes and BREEAM assessors and LEED accredited professionals.

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Executive Summary

This report assesses the predicted energy performance and carbon dioxide emissions of the proposed mixed-use development at 44 Gloucester Avenue. The development is located to the north of Gloucester Avenue and is bounded by a railway along the south-western site boundary. The development is located within the London Borough of Camden.

The proposed mixed-use development at 44 Gloucester Avenue comprises the refurbishment, extension and conversion of the existing non-domestic buildings on the site. The proposal will comprise:

- 40 nos. 1 to 3 bedroom residential units, of which 22 units will be located in the newly constructed buildings; and
- approximately 698m^2 of commercial space.

The methodology used to determine the carbon dioxide emissions is in accordance with the London Plan's three-step Energy Hierarchy (Policy 5.2A) outlined below. It should be noted that due to the nature of the proposed development, the baseline conditions for the refurbished portions of the development are based on the existing fabric and services of the retained building. The baseline carbon dioxide emissions for the new-build portions are based on the notional building built to current Part L 2013 standards.

1. Be Lean - use less energy

The first step addresses reduction in energy use, through the adoption of sustainable design and construction measures.

In accordance with this strategy, the proposed development will incorporate a range of energy efficiency measures including insulation of existing thermal elements, insulation levels exceeding current Building Regulations (2013) requirements for new build thermal elements, installation of high performance glazing, energy efficient lighting and energy efficient local extraction fans for the toilets and kitchens.

The implementation of these measures will reduce regulated carbon dioxide emissions by 42.5%, when compared to the baseline buildings.

2. Be Clean - supply energy efficiently

The second strategy takes into account the efficient supply of energy, by prioritising decentralised energy generation.

The London Heat Map indicates that there is no existing and proposed District Heat Network in close proximity to the site. Additionally, it is not considered economically or technically feasible to incorporate a communal heat system with a CHP for a relatively small scale development such as the one at 44 Gloucester Avenue. It is therefore recommended that space heating and hot water for the residential units be provided by high efficiency individual gas boilers. The shell and core non-domestic units shall be heated separately by high efficiency gas boilers.

3. Be Green - use renewable energy

The third strategy covers the use of renewable technologies. A feasibility study was carried out for the development and a range of renewable technologies were analysed. The analysis included a biomass heating system, ground-source heat pumps, air-source heat pumps, photovoltaics, solar thermal and wind turbines.

The analysis identified photovoltaics as the most suitable technology for this development. The installation of 78m^2 of 15% efficient of PV panels on the new buildings will reduce the regulated carbon dioxide emissions by 1.7% compared to the baseline buildings. Further reductions in CO_2 emissions from renewables are not deemed to be achievable, due to the scheme's location within the Primrose Hill Conservation area, and the importance of maintaining the characteristics of the existing facades and pitched roofs of the retained buildings on site.

Conclusion

The graph below provides a summary of the regulated carbon dioxide savings at each stage of the London Plan Energy Hierarchy.

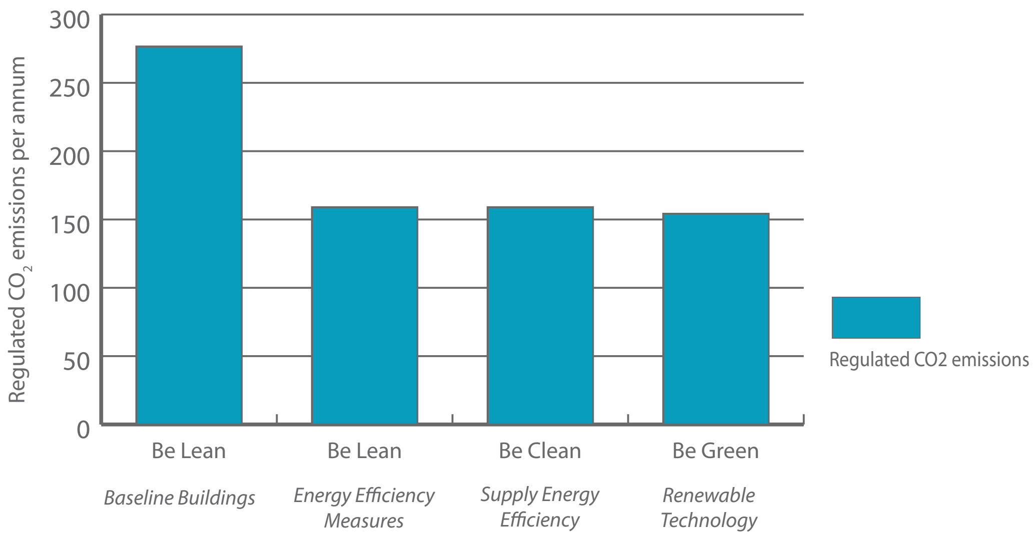
It can be seen on the graph below that the development at 44 Gloucester Avenue achieves a significant reduction in regulated carbon dioxide emissions through energy efficiency, with further reductions made through the installation of renewables.

The development will achieve a saving of 44.3% over the baseline performance through energy efficiency measures and maximising renewable provision with the given site constraints.

The energy performance will enable the development to achieve the energy targets as required to achieve BREEAM Domestic Refurbishment 'Very Good' and BREEAM Refurbishment and Fit-Out 'Very Good' for the non-domestic spaces. This is deemed to be a notable achievement for a scheme of this scale and with a predominantly refurbishment nature.

The table below demonstrates the regulated and unregulated emissions.

The Energy Hierarchy for 44 Gloucester Avenue



Carbon Dioxide Emissions After Each Stage of the Energy Hierarchy

	Carbon dioxide emissions (tonnes CO_2 per annum)	
	Regulated	Total
Baseline building	276.6	368.9
After energy demand reduction	159.0	251.3
After CHP	159.0	251.3
After renewables	154.2	246.4

Regulated Carbon Dioxide Savings From Each Stage of the Energy Hierarchy

	Regulated Carbon Dioxide Savings	
	Tonnes CO_2 per annum	%
Savings from energy demand reduction	117.6	42.5%
Savings from CHP	0.0	0.0%
Savings from renewable energy	4.8	1.7%
Total Cumulative Savings	122.4	44.3%

Introduction

The proposed mixed-use development at 44 Gloucester Avenue comprises the refurbishment, extension and conversion of the existing non-domestic buildings on the site, which include:

- 40 nos. 1 to 3 bedroom residential units, of which 22 units will be located in the newly constructed buildings; and
- approximately 698m^2 of commercial space at the basement and ground floor levels.

This document demonstrates how the development follows the recommendations of relevant policies of the London Plan and the requirements of London Borough of Camden, as outlined in their Core Strategy. It outlines the expected energy performance and design features of the development that will be employed to reduce the energy consumption and carbon dioxide emissions.

In particular this report responds to the energy policies of section 5 in the London Plan, including:

- Policy 5.2 Minimising Carbon Dioxide Emissions
- Policy 5.3 Sustainable Design and Construction
- Policy 5.5 Decentralised Energy Networks
- Policy 5.6 Decentralised Energy in Development proposals
- Policy 5.7 Renewable Energy where feasible.

The methodology employed to determine the potential carbon dioxide savings for this development, is in accordance with the three step Energy Hierarchy outlined in the London Plan:

- Be Lean - Improve the energy efficiency of the scheme.
- Be Clean - Supply as much of the remaining energy requirement with low-carbon technologies such as combined heat and power (CHP).
- Be Green - Offset a proportion of the remaining carbon dioxide emissions by using renewable technologies.

Energy calculations were carried out using the FSAP 2012 methodology for the residential units and SBEM for the non-domestic units. This is in line with Building Regulations Part L 2013.

It should be noted that due to the nature of the proposed development, the baseline conditions for the refurbished portions of the development are based on the existing fabric and services of the retained building. The baseline carbon dioxide emissions for the new-build portions are based on the notional building built to current Part L 2013 standards.

The design aims to comply with the policies mentioned above where possible, through the adoption of BREEAM assessment schemes as indicated below:

- The 5 nos. shell and core refurbished non-domestic units are assessed under the BREEAM Refurbishment and Fit-Out 2014 scheme.
- The 18 nos. refurbished and change of use dwellings are assessed under the BREEAM Domestic Refurbishment scheme.
- Code for Sustainable Homes has been abolished by the government in April 2015, therefore, it will no longer be possible to assess the new build dwellings under Code. However, the site wide sustainability measures applied to the refurbished dwellings and non-domestic units will also be implemented to the new build portions of the scheme.

For further details on the non-energy related policies and how assessment standards are met please refer to the supplementary Sustainability Statement.

Demand Reduction (Be Lean)

Our analysis of the energy demand and CO_2 emission of the development uses the methodology set in Part L 2013 of the building regulations, by performing a preliminary SAP and SBEM assessment on the proposed scheme.

In order to compare the energy demand and CO_2 emissions of the development prior to the relevant baselines, the following conditions were modelled:

- For the refurbishment and change of use part of the scheme, SAP and SBEM assessments were carried out with existing building fabric and system properties to inform the baseline condition, and subsequently with the proposed 'Be Lean' measures to allow a comparison of the energy demand of the scheme pre and post refurbishment.
- The new build portions of the scheme have been compared to a notional building constructed to current Part L 2013 Building Regulations

The energy demand reduction measures to be implemented at the proposed development are described in more detail under the headings which follow:

Passive Design Measures

Enhanced Building Fabric

The heat loss of different building elements is dependent upon their U-value. A building with low U-values provides better levels of insulation and reduced heating demand during the cooler months.

The existing thermal elements in the refurbished residential and non-domestic parts will be upgraded to meet Part L1B and L2B fabric standards where possible. An appropriate level of internal insulation will be added to existing external elements of the building during the refurbishment to reduce fabric heat loss and demand for space heating. Conservation Area consent requirements mean that it would not be possible to insulate externally.

The insulation to all retained external walls will comprise 60mm of insulated plasterboard. The roofs and ground/basement floors will be insulated to meet minimum Part L1B targets. The windows on the retained facade will also be upgraded.

U-Values (W/m²K) - Retained and upgraded elements

Element	Existing value	Upgraded value	Improvement
Walls	2.10	0.50	76%
Ground Floor	0.70	0.25	64%
Windows/ Doors	4.80	2.00	58%
Roof	2.30	0.18	92%

The new parts of the development will incorporate high levels of insulation and high-performance glazing on all of the facades to significantly reduce the demand for space heating to exceed the minimum fabric Part L1A and L2A 2013 standards.

U-Values (W/m²K) - New elements (Part L1A)

Element	Building Regulations	Proposed	Improvement
Walls	0.30	0.15	50%
Floor	0.25	0.10	60%
Roof	0.20	0.10	50%
Windows	2.00	1.20	40%

Air Tightness
Heat loss may also occur due to air infiltration. Although this cannot be eliminated altogether, good construction detailing and the use of best practice construction techniques can minimise the amount of air infiltration.

Current Part L1A Building Regulations (2013) sets a maximum air permeability rate of $10m^3/m^2$ at 50Pa. The new build residential part of the development is likely to improve upon this to achieve of $5m^3/m^2$ at 50Pa through the application of best practice techniques.

Air permeability rate within the refurbished parts of the development, across both residential and non-domestic units will be improved to $10m^3/m^2$ at 50Pa through draught proofing and best practice refurbishment techniques.

Thermal Bridging
The dwellings will also reduce heat loss through minimising thermal bridging. All thermal junctions in the new-build dwellings will be in line with Accredited Construction Details, to achieve a thermal bridging y-value of less than 0.08 W/m^2K.

Orientation & Site Layout
The dwellings have been designed to benefit from passive solar gains. Where possible, areas of glazing have been incorporated on south elevations for the main habitable rooms to benefit from passive solar gains and to reduce the need for space heating. Solar control glazing will be installed to minimise the risk of overheating, and reduce cooling energy consumption in the non-domestic units.

Lighting
The development has been designed to improve daylighting in all habitable spaces, as a way of improving the health and wellbeing of its occupants. The majority of the habitable rooms in the new-build residential portions, such as living rooms, will benefit from full height windows to increase the amount of daylight within the internal spaces. The dwellings within the refurbished buildings will also receive good daylight as a result of the narrow plans of the units.

Natural Ventilation
The dwellings will rely on natural ventilation where possible, through the use of openable windows in each room. Extract fans will be provided in bathrooms and kitchens, and mechanical ventilation will be provided to spaces with no access to external windows. Mechanical ventilation with heat recovery (MVHR) systems will be installed in the non-domestic units where necessary.

Active Design Measures

High Efficacy Lighting
The development intends to incorporate low energy lighting fittings throughout the building. All light fittings will be specified as low energy lighting, and will accommodate LED, compact fluorescent (CFLs) or fluorescent luminaries. Internal areas of the non-domestic space which are not frequently used will be fitted with occupant sensors.

Energy Demand

The table below shows a breakdown of the energy consumption and CO_2 emissions associated with the building's heating and electricity demand. The figures provide a comparison between the baseline condition and the proposed development once energy efficiency measures (Lean) have been taken into account. The breakdown shows the CO_2 savings made to the hot water, space heating, cooling, auxiliary and lighting demands once the energy efficiency measures have been incorporated into the building fabric.

Breakdown of Energy Consumption and CO_2 Emissions

	Baseline Building		Lean		
	Energy (kWh/year)	CO_2 emissions ($kgCO_2$/year)	Energy (kWh/year)	CO_2 emissions ($kgCO_2$/year)	CO_2 ($kgCO_2/m^2$)
Hot Water	159,450	35,480	96,970	21,980	4.7
Space Heating	804,090	212,820	360,200	109,530	23.6
Cooling	0	0	6,700	3,390	0.7
Auxiliary	11,890	6,080	8,670	4,400	0.9
Lighting	43,380	22,200	38,500	19,670	4.2
Equipment (excluded from Part L)	177,820	92,290	177,820	92,290	19.9
Total Part L	1,018,820	276,580	511,040	158,970	34.3
Total (incl. Equip)	1,196,640	368,870	688,860	251,260	54.2

CO_2 Emissions

The table below shows the regulated and unregulated CO_2 emissions for the baseline scheme and the emissions after the 'be lean' measures have been implemented.

In summary, regulated CO_2 emission are reduced by 42.5% compared to the baseline building once Lean measures are adopted.

CO_2 Emissions Breakdown

	Carbon Dioxide emissions (tonnes CO_2 per annum)		
	Regulated	Unregulated	Total
Baseline building	276.6	92.3	368.9
After energy demand reduction (Lean)	159.0	92.3	251.3

	Carbon dioxide savings (Tonnes CO_2 per annum)		Carbon dioxide savings from baseline (%)	
	Regulated	Total	Regulated	Total
Savings from energy demand reduction	117.6	117.6	42.5%	31.9%

Heating and Cooling Infrastructure (Be Clean)

Energy System Hierarchy

Local heat and power sources minimise distribution losses and achieve greater efficiencies when compared to separate energy systems, thus reducing carbon dioxide emissions.

In accordance with Policy 5.6 of the London Plan, the energy systems for 44 Gloucester Avenue have been determined in accordance with the following hierarchy:

1. Connection to existing heating and cooling networks
2. Site wide CHP network
3. Communal heating and cooling

In a communal energy system, energy in the form of heat, cooling, and/or electricity is generated from a central source and distributed via a network of insulated pipes to surrounding residences and commercial units.

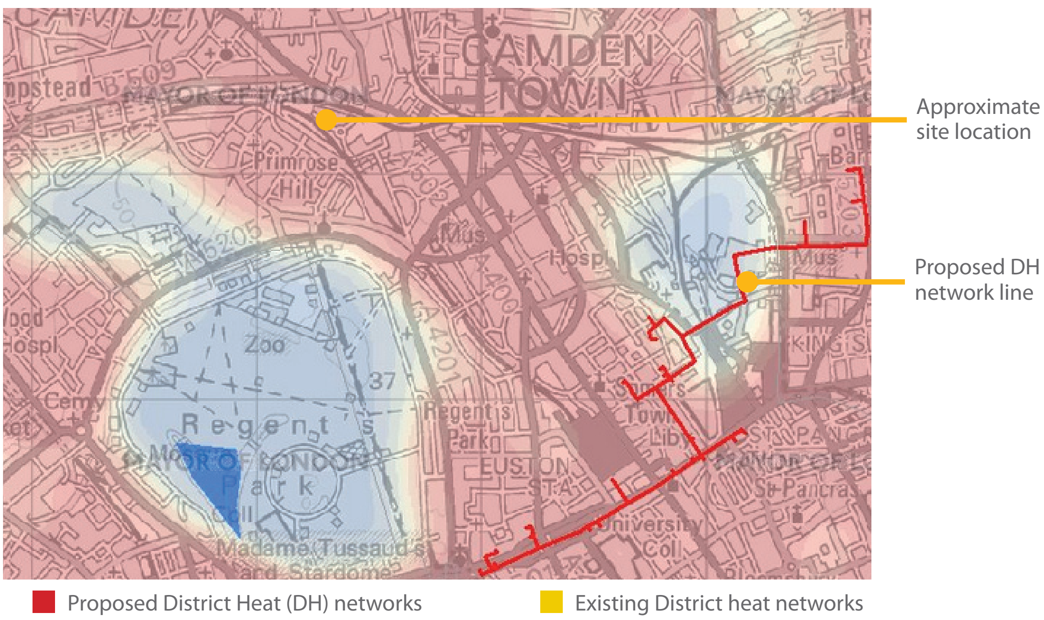
Connection to Existing Low Carbon Heat Distribution Networks

The London Heat Map identifies existing and potential opportunities for decentralised energy projects in London. It builds on the 2005 London Community Heating Development Study. An excerpt from the London Heat Map below shows the energy demand for different areas. Darker shades of red signify areas where energy demand is high. The map also highlights any existing and proposed district heating systems within the vicinity of the development.

A review of the London Heat Map indicates that the nearest District Heating supply network is the Euston Road network, situated about 2 km to the southeast. Additionally, it is not considered economically or technically feasible to incorporate a communal heat system with a CHP for a predominantly refurbishment based and relatively small scale development such as that at 44 Gloucester Avenue.

Hence, no connection to an existing or proposed district heat network is recommended for the proposed development. It is proposed that space heating and hot water for the residential units be provided by high efficiency gas boilers, whilst the non-domestic units be heated separately by high efficiency gas boilers.

London Heat Map



CO_2 Emissions

The table below shows the regulated and unregulated CO_2 emissions for the baseline scheme as well as the reduced emissions once Lean (energy efficiency) and Clean (CHP/communal heating system) measures have been implemented.

The table illustrates that there is no further reduction in regulated CO_2 at the Clean stage.

CO_2 Emissions Breakdown

	Carbon Dioxide emissions (tonnes CO_2 per annum)		
	Regulated	Unregulated	Total
Baseline building	276.6	92.3	368.9
After energy demand reduction (Lean)	159.0	92.3	251.3
After CHP (Clean)	159.0	92.3	251.3

	Carbon dioxide savings (Tonnes CO_2 per annum)		Carbon dioxide savings from baseline (%)	
	Regulated	Total	Regulated	Total
Savings from energy demand reduction	117.6	117.6	42.5%	31.9%
Savings from CHP	0.0	0.0	0.0%	0.0%

Renewable Energy (Be Green)

Methods of generating on-site renewable energy (Green) were assessed, once Lean and Clean measures were taken into account.

The development at 44 Gloucester Avenue will benefit from an energy efficient building fabric which will reduce the energy consumption of the proposed development in the first instance. A range of renewable technologies were subsequently considered including:

- Biomass
- Ground/water source heat pumps
- Air source heat pump
- Wind energy
- Photovoltaic panels
- Solar thermal panels

In determining the appropriate renewable technology for the site, the following factors were considered:

- CO_2 savings achieved
- the site constraints
- payback and maintenance costs
- any potential visual or noise impacts

The following pages discuss in detail each of the renewable technologies listed above.

It should be noted that the proposed development is located within the Primrose Hill Conservation Area, which constraints the potential for roof mounted renewable technologies on the existing facades and pitched roofs of the retained buildings facing the railway to the north-east and Gloucester Avenue to the south west of the site.

Biomass - Not Adopted

A biomass system designed for this development would be fuelled by wood pellets due to their high energy content. Wood pellets also require less volume of storage than other biomass fuels, require less maintenance and produce considerably less ash residue. The potential options for this development include the use of biomass in the communal boiler as an alternative to gas, or a biomass CHP in place of the gas boiler.

Biomass boiler

A communal biomass boiler could be installed for the proposed development. However, a biomass system, would not be an appropriate low-carbon technology for the site for the following reasons:

- a communal heating system is not considered to be suitable for a small scale, part refurbishment and change of use scheme of this nature
- the burning of wood pellets releases substantially more NOx emissions than gas boiler equivalents. This would significantly reduce the air quality of the site which is located in an urban environment
- storage and delivery of wood pellets would be difficult due to the site constraints and the lack of local biomass suppliers. Pellets would have to be transported from elsewhere in the UK

Biomass CHP

For the size of system required for this development, a biomass CHP is still in its infancy and brings a number of financial and technological risks. Therefore this option is not considered feasible.

For the reasons listed above, biomass is not considered feasible for this development. Site specific analysis for biomass can be found in appendix A.

Wind Energy - Not Adopted

Due to the limited space on site, building-integrated turbines would be most suited to the development, as opposed to stand alone turbines. This results in very low CO_2 savings. In addition, a roof-mounted wind turbine would have a significant visual impact.

For these reasons, wind turbines would not be feasible for this project. Site specific analysis for Wind turbines can be found in appendix A.

Ground Source Heat Pumps (GSHP) - Not Adopted

A ground source heat pump system for the site would include a closed ground loop where a liquid passes through the system, absorbing heat from the ground and relaying this heat via an electrically run heat pump within the building.

A ground source heat pump system would deliver space heating through a low temperature efficient distribution network such as underfloor heating. The installation of ground source loops significantly increases the construction time at the beginning of the project and adds to the capital cost of the project which makes this technologically and financially infeasible.

Site specific analysis for GSHPs can be found in appendix A.

Air Source Heat Pumps (ASHP) - Not Adopted

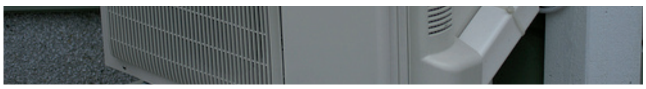
Air source heat pumps (ASHPs) employ the same technology as ground source heat pump (GSHPs). However, instead of using heat exchangers buried in the ground, heat is extracted from the external ambient air.

The following issues are of concern when considering the installation of ASHP for the development:

- ASHP evaporators are required to be located externally, and roof spaces are commonly used. This could reduce the amount of roof space required for other purposes.
- Any noise associated with the units could potentially be an issue due to the proximity of the neighbouring buildings and residential spaces.

In addition, ASHPs are considered efficient for developments with significant heating and cooling demands, and low hot water demands. ASHPs are therefore not suitable for the residential portion of the development. Due to the unconfirmed nature of the commercial portion, a cooling demand has not been speculated. The non-domestic portion of the development will therefore not be able to benefit from the efficiency and potential savings from ASHPs at this stage.

Based on the reasons stated above, ASHPs are not considered suitable for this development. Site specific analysis for ASHPs can be found in appendix A.



Photovoltaic Panels - Adopted

Four types of solar cells are available on the market at present and these are mono-crystalline, poly-crystalline, thin film and hybrid panels. Although mono-crystalline and hybrid cells are the most expensive, they are also the most efficient with an efficiency rate of 12-20%. Poly-crystalline cells are cheaper but they are less efficient (9-15%). Thin film cells are only 5-8% efficient but can be produced as thin and flexible sheets.

Photovoltaics are considered a suitable technology for this development for the following reasons:

- the development provides sufficient amount of roof space for the installation of PV panels
- PV arrays are relatively easy to install when compared to other renewable systems
- PV panels provide a significant amount of CO_2 savings

Photovoltaic Panels are recommended for residential part of the development at 44 Gloucester Avenue. Details of the system are included in Page 17.

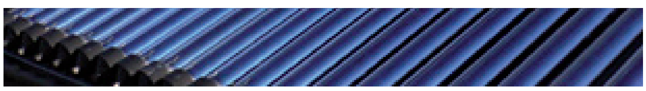
Solar Thermal Panels - Not Adopted

Solar thermal arrays include evacuated tubes and flat plate collectors. Evacuated tubes are more efficient, produce higher temperatures and are more suited to the UK climate when compared to flat plate collectors. Evacuated tubes tend to be more costly than flat plate collectors.

The use of solar thermal for this development would be limited to domestic hot water only. The use of solar thermal for space heating would not be practical as it is not required when solar thermal is most effective (during the summer months).

Solar thermal arrays would require additional plumbing which is likely to incur additional financial costs.

For these reasons, solar thermal technology would not be the most feasible option for the proposed development. Site specific analysis for solar thermal can be found in appendix A.



Renewable Energy Summary

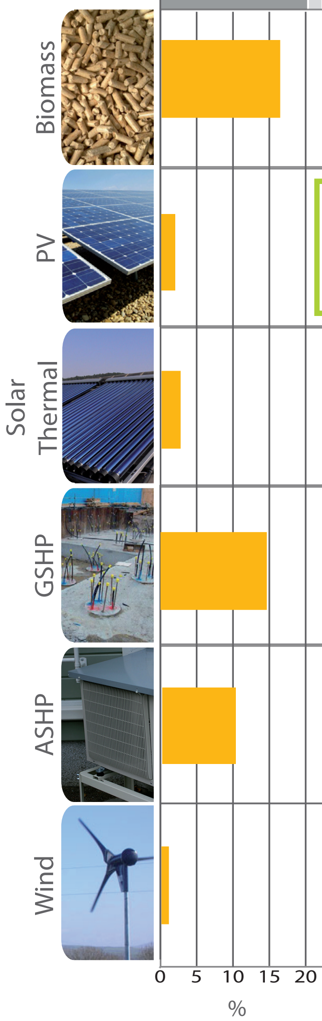
The table below summarises the factors taken into account in determining the appropriate renewable technology for this project. This includes estimated carbon savings, lifetime, level of maintenance and level of impact on external appearance.

The final column indicates the feasibility of the technology in relation to the site conditions (10 being the most feasible and 0 being infeasible).

It is important to note that the information provided is indicative and based upon initial estimates.

The feasibility study demonstrates that photovoltaics would be the most feasible renewable technology for the proposed development at 44 Gloucester Avenue.

44 Gloucester Avenue



	% Total CO_2 Reduced	Tonnes CO_2 per year	Lifetime	Maintenance	Impact on External Appearance	Site Feasibility
Biomass		40.5	20yrs	High	High	3
PV		4.8	25yrs	Low	Med	9
Solar Thermal		6.1	25yrs	Low	Med	3
GSHP		36.1	20yrs	Med	Low	3
ASHP		25.4	20yrs	Med	Med	5
Wind		2.11	25yrs	Med	High	2

Adopted technology

Detailed Assessment of Photovoltaic Panels

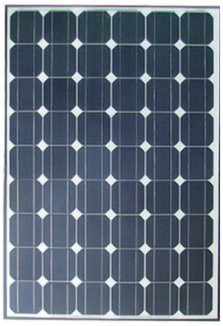
The feasibility study for 44 Gloucester Avenue shows that photovoltaics are the most suitable renewable technology for the residential units for the following reasons:

- there is sufficient roof space to install enough PV modules to have a significant impact on CO_2 emissions
- the installation of photovoltaics is much simpler when compared to other renewable technologies
- photovoltaics sited on the roof are less visually intrusive when compared to wind turbines for generation of electricity.

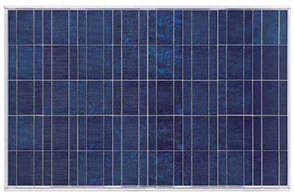
In order to maximise carbon dioxide reductions, it is proposed that PV panels are installed on the roofs of the development. The panels will be installed on the south (or southwest) facing unshaded areas of the roof on the new buildings to maximise array area.

In total, 78.4m^2 of 15% efficiency PV panels, rated at 11.8 kWp, would produce regulated carbon dioxide savings of 1.7% for the development at 44 Gloucester Avenue when compared against the baseline. The following page shows an indicative PV roof layout for the scheme.

Photovoltaic Panels		
Module Efficiency	15	%
Tilt of collectors	In line with roof pitch	
Predicted site solar energy	990	kWh/m^2/yr
System losses	20	%
System peak power	11.8	kWp
Array area	78.4	m^2
Primary electricity offset by PV array	9,310	kWh/yr
Total CO_2 savings	4.8	t/yr
Regulated Clean CO_2 emissions	159.0	t/yr
Total clean CO_2 emissions	251.3	t/yr
Regulated CO_2 reduction from Clean Stage	3.0	%
Total CO_2 reduction from Clean Stage	1.9	%
Regulated CO_2 reduction from baseline	1.7	%
Total CO_2 reduction from baseline	1.3	%



A monocrystalline PV Panel



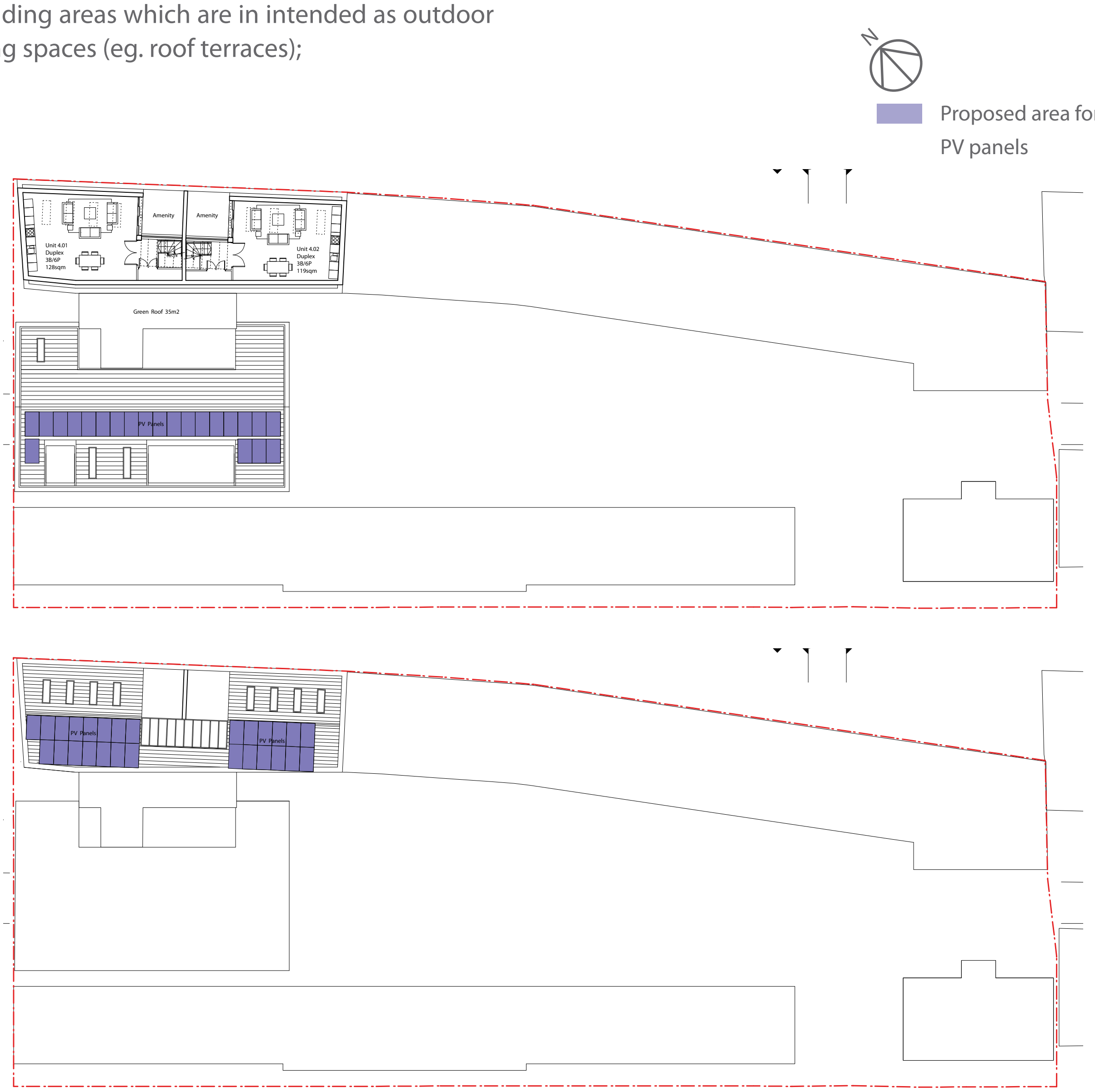
A polycrystalline PV Panel

Layout of Photovoltaic Panels

An appropriate location for the proposed photovoltaic panels was identified once the site constraints were taken into account. The factors taken into consideration included:

- avoiding any potential overshadowing from adjacent PV panels;
- space required for maintenance including all health and safety requirements for roof access;
- avoiding areas which are in intended as outdoor living spaces (eg. roof terraces);

A 78.4m² array of 15% efficiency PV modules, with a rated output of 11.8 kWp would offset 1.7% of regulated CO_2 emissions in comparison to the baseline buildings. An indicative PV layout is presented in the figure below.



Proposed area for PV panels for 44 Gloucester Avenue

CO_2 Emissions

The table below lists the regulated and unregulated CO_2 emissions for the baseline scheme and the emissions once the lean, clean and green measures have been implemented.

The figures show a CO_2 reduction of 1.7% in emissions through implementation of PV after the 'Be Clean' stage. The overall reduction in regulated CO_2 emissions amounts to 44.3%, when compared to the baseline building. The area of photovoltaics installation has been maximised for the proposed development, considering the constraints of the site and its location within a Conservation Area.

CO_2 Emissions Breakdown

	Carbon Dioxide emissions (tonnes CO_2 per annum)		
	Regulated	Unregulated	Total
Baseline building	276.6	92.3	368.9
After energy demand reduction (Lean)	159.0	92.3	251.3
After CHP (Clean)	159.0	92.3	251.3
After PV (Green)	154.2	92.3	246.4

	Carbon dioxide savings (Tonnes CO_2 per annum)		Carbon dioxide savings from baseline (%)	
	Regulated	Total	Regulated	Total
Savings from energy demand reduction	117.6	117.6	42.5%	31.9%
Savings from CHP	0.0	0.0	0.0%	0.0%
Savings from Renewables	4.8	4.8	1.7%	1.3%
Cumulative savings	122.4	122.4	44.3%	33.2%

Conclusion

In line with the London Plan three step energy hierarchy, the carbon dioxide emissions for this development have been reduced by 44.3% in comparison to the baseline buildings, once energy efficiency measures and renewables are taken into account. The details below show the savings made at each stage of the energy hierarchy.

1. Be Lean - use less energy
In accordance with this strategy, the proposed development will incorporate a range of energy efficiency measures including insulation of existing thermal elements, levels of insulation exceeding current Building Regulations (2013) requirements for new build thermal elements, the installation of high performance glazing, energy efficient lighting and energy efficient local extraction fans for the toilets and kitchens. The implementation of these measures will reduce regulated carbon dioxide emissions by 42.5%, when compared to the baseline building.

2. Be Clean - supply energy efficiently
The feasibility study showed that no district heating networks currently exist within close proximity of the site. Also, it is not considered economically or technically feasible to incorporate a communal heat system with a CHP for a relatively small scale development such as that at 44 Gloucester Avenue. Space heating and hot water for the residential units will be provided by high efficiency gas boilers. The non-domestic units will be heated separately.

3. Be Green - use renewable energy
The feasibility study analysed a number of renewable technologies for their suitability for the site. The analysis included a biomass heating system, ground-source heat pumps, air-source heat pumps, photovoltaics, solar thermal and wind turbines.

The analysis identified photovoltaics to be the most suitable renewable technology for this development. The installation of 78.4m^2 of PV panels with a rated output of 11.8 kWp will reduce regulated carbon dioxide emissions by 1.7% in comparison to the baseline buildings.

Further reductions in CO_2 emissions from renewables are not deemed to be achievable, due to the scheme's location within the Primrose Hill Conservation area, and the importance of maintaining the characteristics of the existing facades and pitched roofs of the retained buildings on site.

The overall reduction of regulated carbon dioxide emissions is 44.3% over the baseline building. The reductions will enable the refurbished domestic part of the development to achieve BREEAM Domestic Refurbishment 'Very Good' rating, and the non-domestic part of the development to achieve BREEAM Refurbishment and Fit-out 'Very Good' rating. The CO_2 reduction achieved by the proposed development is significant for a scheme of this nature and scale.

Regulated Carbon Dioxide Savings From Each Stage of the Energy Hierarchy

	Regulated Carbon Dioxide Savings	
	Tonnes CO_2 per annum	%
Savings from energy demand reduction	117.6	42.5%
Savings from CHP	0.0	0.0%
Savings from renewable energy	4.8	1.7%
Total Cumulative Savings	122.4	44.3%

Appendix A

Biomass Heating

A biomass system designed for this development would be fuelled by wood pellets which have a high energy content. Wood pellets require less volume of storage than other biomass fuels. Pellet boilers also require less maintenance and produce considerably less ash residue.

A biomass boiler could supply 50% of the space heating and hot water demand to the communal heating scheme. This would be equivalent to a regulated carbon dioxide saving of 25.4%.

A biomass system, however, would not be an appropriate low-carbon technology for the site for the following reasons:

- the burning of wood pellets releases substantially more NOx emissions when compared to similar gas boilers. As the development is situated within an urban area, the installation of a biomass boiler would further reduce the air quality in this area.
- pellets would need to be transported from other sites within the UK due to the lack of local pellet suppliers.

Example of pellet boiler and pellet storage room. Source: Energy Crops Limited

Biomass		
% of heating load supplied by biomass	50	%
Biomass System Efficiency	90	%
Carbon Intensity of Biomass	0.039	$kgCO_2$/kWh
Backup System Efficiency	90	%
Carbon Intensity of Backup	0.216	$kgCO_2$/kWh
Heating Demand Met	205,730	kWh/yr
Total CO_2 savings	40.5	t/yr
Regulated Clean CO_2 emissions	159.0	t/yr
Total Clean CO_2 emissions	251.3	t/yr
Regulated CO_2 reduction from Clean Stage	25.4	%
Total CO_2 reduction from Clean Stage	16.1	%
Regulated CO_2 reduction from baseline	14.6	%
Total CO_2 reduction from baseline	11.0	%

Solar Thermal

Solar thermal arrays have similar requirements as PV arrays, in terms of their orientation and inclination. The most efficient use of solar thermal arrays would be to orientate them to the south at an inclination of about 30°.

Solar thermal arrays are available as evacuated tubes and flat plate collectors. Evacuated tubes are more efficient, produce higher temperatures and are more suited to the UK climate in general when compared to flat plate collectors.

For this development solar thermal would be used for domestic hot water only. The use of solar thermal for space heating would not be practical as it is not required when solar thermal is at its most effective during the summer months.

If solar thermal were to be considered for this development, based on a solar fraction of approximately 32%, 70m² solar thermal arrays would produce a regulated carbon dioxide saving of 3.8%.

The installation of solar thermal would require additional plumbing and space for hot water storage which would incur additional financial costs. Therefore photovoltaics would be a more appropriate solution for this development.

Solar Thermal		
Collector Type	Evacuated Tube	
System Efficiency	40	%
Orientation/inclination	South/30°	
Predicted site solar energy	1,100	kWh/m²/yr
Solar fraction	32	%
Total collector area	70	m²
Primary gas energy offset by Solar Thermal system	30,800	kWh/yr
Total CO_2 savings	6.1	t/yr
Regulated Clean CO_2 emissions	159.0	t/yr
Total Clean CO_2 emissions	251.3	t/yr
Regulated CO_2 reduction from Clean Stage	3.8	%
Total CO_2 reduction from Clean Stage	2.4	%
Regulated CO_2 reduction from baseline	2.2	%
Total CO_2 reduction from baseline	1.6	%

Air Source Heat Pumps

Air source heat pumps (ASHPs) employ the same technology as ground source heat pump (GSHPs). However, instead of using heat exchangers buried in the ground, heat is extracted from the external ambient air.

The efficiency of heat pumps is very much dependent on the temperature difference between the heat source and the space required to be heated. As a result ASHPs tend to have a lower COP than GSHPs. This is due to the varying levels of air temperature throughout the year when compared to the relatively stable ground temperature. The lower the difference between internal and external air temperature, the more efficient the system.

ASHP		
COP Heating	3.2	
COP Cooling	3.2	
Carbon Intensity of Electricity	0.519	$kgCO_2$/ kWh
Proportion of Space Heating met by ASHP	90	%
Proportion of Hot Water met by ASHP	25	%
Energy met by ASHP	328,650	kWh/yr
Energy used by ASHP	102,710	kWh/yr
Total CO_2 savings	25.4	t/yr
Regulated Clean CO_2 emissions	159.0	t/yr
Total Clean CO_2 emissions	251.3	t/yr
Regulated CO_2 reduction from Clean Stage	16.1	%
Total CO_2 reduction from Clean Stage	10.1	%
Regulated CO_2 reduction from baseline	9.2%	%
Total CO_2 reduction from baseline	6.9	%

The use of ASHPs for this development would result in regulated CO_2 savings of 16.1%.

The following issues are of concern when considering the installation of ASHP for the development:

- ASHP evaporators are required to be located externally, and roof spaces are commonly used. This could reduce the amount of roof space required for other purposes.
- Any noise associated with the units could potentially be an issue due to the proximity of the neighbouring buildings and residential spaces.

ASHPs are considered efficient for developments with significant heating and cooling demands, and low hot water demands. ASHPs are therefore not suitable for the residential portion of the development. Due to the unconfirmed nature of the commercial portion, a cooling demand has not been speculated. The non-domestic portion of the development will therefore not be able to benefit

Ground Source Heat Pumps

The footprint of the development occupies a significant portion of the site. For this reason, a ground source loop would need to be incorporated within the foundations of the building.

A suitable ground source heat pump system for the site would include a number of closed ground boreholes, where a liquid passes through the system, absorbing heat from the ground and relaying this heat via an electrically run heat pump into the building.

Studies have shown that ground source boreholes located within close proximity of structural foundations may result in a reduction of the life span of the loops. Thermal testing would need to be carried out on the foundations to determine the implications to the ground boreholes over time.

Ground source heat pumps would deliver space heating through a low temperature efficient distribution network such as underfloor heating.

Approximately 90% of the annual space heating demand would be supplied by a system sized to meet approximately 50% of the peak load. The number of ground boreholes required would require a significant amount of space on site and result in additional time at the beginning of the construction process. In addition, the capital cost of installing these boreholes would be very high. For these reasons, ground source heat pumps were not considered to be an appropriate renewable technology for the site.

Energy piles within foundations of construction. Source: Geothermal International Italia

GSHP		
COP Heat	4.0	
COP Cooling	4.0	
Carbon Intensity of Electricity	0.519	$kgCO_2$/ kWh
Proportion of Space Heating met by GSHP	90	%
Proportion of Hot Water met by GSHP	25	%
Energy met by GSHP	328,655	kWh/yr
Energy used by GSHP	82,164	kWh/yr
Total CO_2 savings	36.1	t/yr
Regulated Clean CO_2 emissions	159.0	t/yr
Total Clean CO_2 emissions	251.3	t/yr
Regulated CO_2 reduction from Clean Stage	22.7	%
Total CO_2 reduction from Clean Stage	14.4	%
Regulated CO_2 reduction from baseline	13.1	%
Total CO_2 reduction from baseline	9.8	%

Wind Turbines

Building-integrated turbines would be most suited to this site due to the limited amount of roof space, as opposed to stand alone turbines.

Carbon dioxide savings from wind turbine technologies take into account their mounting height, the turbine wind curve and wind data. This information was obtained from the BERR web site and used in the Carbon Trust Wind Yield Estimation Tool. The average annual wind speed at a mounting height of 10m above the building canopy is estimated to be 3.5m/s.

The two tables below outline carbon dioxide savings for a 2.5kW and 6kW roof-mounted wind turbines.

The results show that the carbon dioxide savings are minimal for each option, offering 0.5% and 1.3% savings over regulated carbon dioxide emissions for the 2.5kW and 6kW turbines respectively.

This technology is not considered appropriate for this development due to the low carbon dioxide savings achieved, limited roof space and varied building heights. The installation of wind turbines also has a significant visual impact on the building.

A building-mounted 6kW Proven wind turbine

Wind Power - 2.5kW		
Average wind speed at site	3.5	m/s
Number of Turbines	1	
Electricity offset by turbine	1,580	kWh/yr
Carbon intensity of offset electricity	0.529	$kgCO_2$/ kWh
Total CO_2 savings	0.84	t/yr
Regulated Clean CO_2 emissions	159.0	t/yr
Total Clean CO_2 emissions	251.3	t/yr
Regulated CO_2 reduction from Clean Stage	0.5	%
Total CO_2 reduction from Clean Stage	0.3	%
Regulated CO_2 reduction from baseline	0.3	%
Total CO_2 reduction from baseline	0.2	%

Wind Power - 6kW		
Average wind speed at site	3.5	m/s
Number of Turbines	1	
Electricity offset by turbine	3,990	kWh/yr
Carbon intensity of offset electricity	0.529	$kgCO_2$/ kWh
Total CO_2 savings	2.11	t/yr
Regulated Clean CO_2 emissions	159.0	t/yr
Total Clean CO_2 emissions	251.3	t/yr
Regulated CO_2 reduction from Clean Stage	1.3	%
Total CO_2 reduction from Clean Stage	0.8	%
Regulated CO_2 reduction from baseline	0.7	%
Total CO_2 reduction from baseline	0.5	%