create
CONSULTING
ENGINEERS LTD

# 51 CALTHORPE STREET, LONDON

## Energy Statement

# 51 CALTHORPE STREET, LONDON

# Energy Statement

**Client:** Mr Simon Firth

**Engineer:** Create Consulting Engineers Limited
15 Princes Street
Norwich
Norfolk
NR3 1AF

Tel: 0845 450 7908
Email: enquiries@createconsultingengineers.co.uk
Web: www.createconsultingengineers.co.uk

**Report By:** Alicja Kreglewska, MSc, GradEI

**Checked By:** Fiona Keysell, BSc (Hons), AIEMA

**Reference:** AK/GL/P12-385/09

**Date:** August 2013

51 CALTHORPE STREET, LONDON
Energy Statement

# 51 CALTHORPE STREET, LONDON

# Energy Statement

## Contents



## Appendices



### Registration of Amendments

| Revision and Date | Amendment Details | Revision Prepared By | Revision Approved By |
|---|---|---|---|
| | | | |
| | | | |

## EXECUTIVE SUMMARY

This Energy Statement looks at options for energy efficiency measures, cleaner energy and renewable energy generation for the proposed development at 51 Calthorpe Street. The options are examined in the context of the local policy requirements for this site as detailed in the London Plan (adopted July 2011), Camden Core Strategy Policy CS13 - *Tackling climate change through promoting higher environmental standards* and Camden Supplementary Planning Document CPG 3 *Sustainability*.

The statement concludes that given the constraints of this site, a gas powered CHP system meeting the development base heat load and a 70m² polycrystalline roof mounted photovoltaic array are the most feasible options for meeting the requirements.

This combination would result in a 30.63% reduction in $CO_2$ emissions over the 2010 Building Regulations (Part L1A and L1B) and a 5.8% reduction in site wide $CO_2$ emissions from renewable energy generation alone.

The table below summarises the energy and $CO_2$ emission reductions for the stages of the energy hierarchy for the proposed development of the Calthorpe Street site.

<table>
<tr><th></th><th>Regulated kgCO<sub>2</sub>/year (% reduction)</th><th>Unregulated kgCO<sub>2</sub>/year</th><th>Regulated Energy kWh/year</th><th>Unregulated Energy kWh/year</th></tr>
<tr><td>Baseline emissions</td><td>26,999</td><td rowspan="4">27,867</td><td>141,585</td><td rowspan="4">58,657</td></tr>
<tr><td>Savings from energy efficiency (Lean)</td><td>23,263 (13.84%)</td><td>103,629</td></tr>
<tr><td>Savings from CHP (Clean)</td><td>21,596 (20.01%)</td><td>108,134</td></tr>
<tr><td>Savings from PV panels (Green)</td><td>18,729 (30.63%)</td><td>102,353</td></tr>
</table>

Please note, the unregulated energy and $CO_2$ emissions have been calculated in accordance with the formulas provided within the SAP 2009 Appendix L guidance and CIBSE Guide D. The unregulated values are for cooking and appliances, lift and communal lights, and are unaffected by building energy efficiency improvements or renewable energy generation as they are a function of occupant lifestyle rather than building design.

## 1.0 INTRODUCTION

1.1 Create Consulting Engineers Ltd has been commissioned by Mr Simon Firth to provide an Energy Statement in support of the planning application for the proposed development at 51 Calthorpe Street, London. The Energy Statement will demonstrate how the development will comply with the $CO_2$ emission and energy related sustainability requirements of the London Plan, July 2011, and the London Borough of Camden policies and guidance.

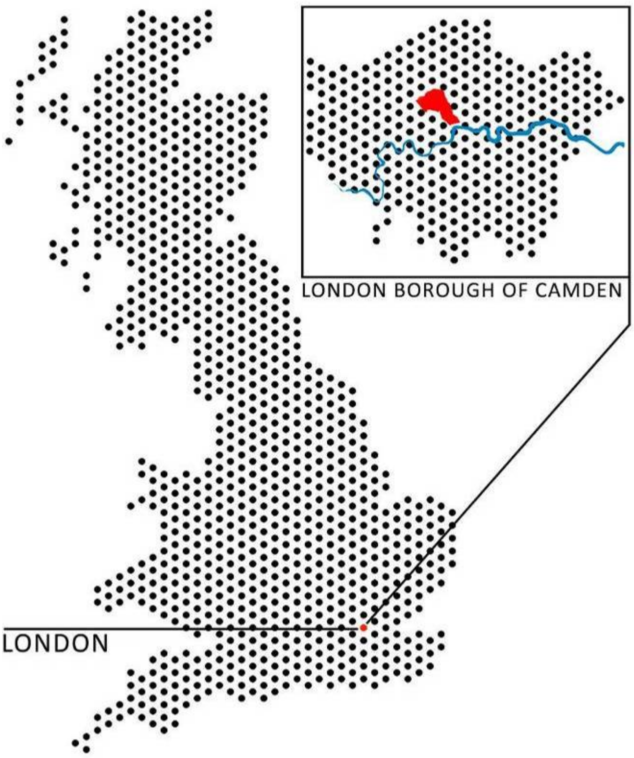


**Figure 1: London Borough of Camden, Location Map**

**Current Site Use**

1.2 The Site is located at 51 Calthorpe Street, London, WC1, and comprises an existing three storey Victorian-era building that is currently used as offices and storage space. The building's eastern side is located adjacent to the Holiday Inn Hotel and the western side abuts other residential buildings on Calthorpe Street while also facing the rear elevations and gardens of dwellings on Packenham Street. The front of the existing development faces south-east over Calthorpe Street and is opposite the Mount Pleasant Royal Mail sorting centre. The rear north-west facing of the development faces the Cubitt Street play centre. The Site is accessed via Calthorpe Street.


**Figure 2: Site Location Plan, 51 Calthorpe Street, London**

**Development Description**

1.3 The proposal includes the reconstruction of an existing 3 storey building (including basement) to create a residential use six storey building. The proposed development consists of 16 residential apartments, comprising studio-flats and 1, 2 and 3 bedroom flats, two of which are 2-storey apartments. A total of 12 of the proposed 16 flats will be created within the existing building envelope and the remaining 4 flats will be constructed on the newly-created second and third floor.

1.4 The proposed development is north/south facing in orientation with the main entrance to the building on the south side. The east elevation is facing onto the existing Holiday Inn hotel which limits natural daylight access to the rooms with openings on the east elevation. Five flats are located on the basement level with access to private gardens.

1.5 The assessment has been based on drawings prepared by Brooks/Murray Architects. Please refer to the following drawings, issued in July 2013, which accompany the planning submission and on which this report has been based.

| | |
|---|---|
| X939.P2.108 | Basement Plan |
| X939.P2.109 | Mezzanine Plan |
| X939.P2.110 | Ground Floor Plan |
| X939.P2.111 | First Floor Plan |
| X939.P2.112 | Second Floor Plan |

| | |
|---|---|
| X939.P2.113 | Third Floor Plan |
| X939.P2.115 | Roof Plan |
| X939.P2.300 | Elevations |
| X939.P2.200 | Sections |

## 2.0 PLANNING POLICIES AND PROJECT REQUIREMENTS

2.1 This Energy Statement outlines how the proposed development will meet the energy requirements as specified by the London Borough of Camden and the requirements of Part L1A and L1B of the 2010 Building Regulations.

2.2 Camden Core Strategy 2010 – 2025 sets out the key elements of the Council's planning vision and strategy for the borough. The strategy forms the central part of the Local Development Framework; a group of documents setting out their planning strategies and policies. The Core Strategy is supported by a number of development policy documents and supplementary planning documents, which provide detailed guidance on how the council's planning strategy and policies will be implemented.

2.3 Camden Core Strategy Policy CS13 - *Tackling climate change through promoting higher environmental standards* provides the overarching policy requirements with respect to minimising the effects of climate change, adaptation measures and improved environmental standards during construction and occupation. The requirements of Policy CS13 are supported by Camden Supplementary Planning Document CPG 3 *Sustainability*.

2.4 CPG 3 *Sustainability* outlines the specific targets and policy requirements relating to the energy performance and sustainable design and construction of new and existing buildings, and provides detailed information on how the requirements of the Core Strategy Policy CS13 are to be implemented along with preferred calculations methodologies for inclusion within the Energy Statement.

2.5 Camden Policy CPG 3 *Sustainability* requires developments of 5 or more dwellings and/or 500 $m^2$ (gross internal floor space) to demonstrate how the development's carbon dioxide emissions are to be reduced in accordance with the London Plan 'Energy Hierarchy'.

2.6 Camden Policy CPG 3 *Sustainability* requires development proposals to be supported by an energy statement to demonstrate how the targets for carbon dioxide emissions reduction are to be met within the framework of the energy hierarchy of Be Lean, Be Clean and Be Green. The Energy Statement will provide calculations for the carbon dioxide emissions covered by Part L Conservation of Fuel and Power of the 2010 Building Regulations, referred to as regulated energy, and separate calculations covering the carbon dioxide emissions not covered by the Building Regulations, referred to as unregulated energy at each stage of the energy hierarchy.

2.7 Within the framework of the energy hierarchy the following opportunities will be explored and their feasibility assessed concluding in a final recommendation for how the proposed development will meet the energy requirements outlined within Camden Core Strategy Policy CS13.

2.8 Be Lean: use less energy: The energy demand of the proposed residential development will be reduced by improving the building fabric performance, through the incorporation of energy efficiency measures.

2.9 The proposed development will be designed and constructed to achieve BREEAM Domestic Refurbishment 'Excellent' rating demonstrating a high standard of sustainable design and construction in accordance with Development Policy DP22 – *Promoting Sustainable Design and Construction.*

2.10 In accordance with Camden Planning Guidance CPG 3 *Sustainability*, Camden strongly encourage development proposals to achieve a minimum of 60 per cent of the available credits under the energy section. This requirement will be taken into consideration within this Energy Statement.

2.11 Further details on the BREEAM Domestic Refurbishment assessment and an appraisal of the wider sustainability issues can be found within the Sustainability Statement (Report Ref AK/GL/P12-385/08) prepared by Create Consulting Engineers Ltd in support of the planning application.

2.12 Be Clean: supply energy efficiently: Opportunities for linking into an existing or planned decentralised energy network will be explored using the London Heat Map tool. Where an existing decentralised energy network is not present, an assessment of the feasibility of establishing a decentralised energy system for the proposed development will be undertaken; including an assessment of the feasibility of a Combined Heat and Power (CHP) communal heating system, and whether the system could be extended beyond the site boundary into adjacent sites. The feasibility of a Combined Heat and Power system will be assessed in accordance with the hierarchy detailed within Camden guidance document CPG 3 *Sustainability*.

2.13 Where it is unfeasible to connect to a decentralised energy network or include a Combined Heat and Power (CHP) system within the development designs, the London Borough of Camden request a financial contribution towards the expansion of the current decentralised energy network and future connection of the proposed development to the network.

2.14 Be Green: use renewable energy: A percentage reduction in the carbon emissions of the proposed development will be achieved through the use of on site renewable energy generation in accordance with Camden Core Strategy Policy CS13. The policy states 'the Council will expect developments to achieve a reduction in carbon dioxide emissions of 20% from on-site renewable energy generation unless it can be demonstrated that such provision is not feasible.' The policy requirement is for a reduction in site wide carbon emissions, and therefore includes the emissions from both regulated and unregulated energy. A feasibility study will be undertaken and the most economically viable renewable technology providing the highest overall reduction in carbon dioxide emissions within the proposed development will be recommended.

## 3.0 CALCULATION METHODOLOGY

**Baseline Energy and Carbon Dioxide Emissions**

3.1 A total baseline energy demand and carbon dioxide emissions of the entire development, including the energy demand of the 16 apartments, will be established prior to the inclusion of any measures to reduce carbon dioxide emissions. Camden's guidance document CPG 3 *Sustainability* confirms that the baseline energy demand should include both the regulated energy associated with lighting, heating and hot water systems, covered by the Building Regulations, and unregulated energy sources not covered by the Building Regulations such as cooking and appliances. In addition to the regulated and unregulated energy sources, the baseline calculations will also consider the energy consumption associated with the communal lighting and lift.

3.2 In accordance with the London Plan 2011 and document CPG 3 the baseline for the calculations will be a 2010 Building Regulations compliant development.

3.3 The estimated annual energy demand and carbon dioxide emissions for the apartments within the proposed development have been calculated using the Standard Assessment Procedure (SAP) methodology. SAP is the national calculation methodology accepted for the energy rating of domestic buildings, and it is the preferred method accepted by the London Borough of Camden.

**Calculation and Site Constraints**

3.4 This development is at the pre planning stage and as such this report has made several assumptions. The assumptions made and their impacts are detailed below.

3.5 Building geometric information has been based upon the drawings provided by Brooks/Murray Architects. At the time of writing no specific construction methods had been determined. This report assumes a medium level thermal mass structure for flats within the refurbished building envelope and low thermal mass for the newly constructed flats on the second and third floor.

3.6 This report has used a representative number of apartments to determine the overall site wide $CO_2$ emissions and energy requirements. The representative apartments used were those judged to be an average to worst case with higher than average areas of exposed wall or roof areas. This selection is intended to give a robust calculation of the energy requirements and associated $CO_2$ emissions.

3.7 All circulation spaces have been assumed to be unheated. No lighting scheme was available at the time of writing. This report assumes that lighting in communal spaces will have a design illuminance of 150 lux and an efficacy of 60 lumens per circuit Watt. A control system based on occupancy sensing (PIR sensors) has been assumed.

3.8 At the time of writing no details were available for the proposed lift system to be fitted. The energy consumption and guidance given in CIBSE Guide D 'Transport systems in buildings' has been used to inform the calculations.

3.9 The air permeability for of the new flats has been based upon a presumed value of $3m^3/m^2$@50PA/hr. This meets the requirements detailed within Camden guidance document CPG 3. Low levels of air permeability reduce space heating energy demand but also result in a corresponding requirement for mechanical ventilation to provide adequate fresh air to ensure occupiers' comfort. The energy saved with a lower level of air permeability must be weighed against the energy required to operate a mechanical ventilation system and the added complexity and cost of installing such a system. The flats constructed within the refurbished part of the building have no minimum air permeability requirement and therefore will utilise natural ventilation throughout.

3.10 The base case development is assumed to use individual gas combination boilers with interlock, delayed start thermostat and load compensator for newly constructed flats and gas combination boilers with minimum acceptable efficiencies and controls as described in 'Domestic Heating Services Compliance Guide'.

**Baseline Emissions and Energy Consumption**

3.11 The baseline development $CO_2$ emissions and energy requirements have been determined and detailed within the following table. Please refer to Appendix A for a full breakdown of the calculation methodology used to establish the baseline carbon dioxide emissions and energy consumption.

3.12 The base case $CO_2$ emissions and energy demand values for new flats, constructed on the second and third floor, were taken from the TER worksheets for these flats. These values represent Building Regulations compliant dwellings. The base case $CO_2$ emissions and energy demand figures for the refurbished units cannot be calculated the same way. The DER/TER target does not apply to refurbished dwellings; therefore the reconstructed flats were modelled with the minimum acceptable values required by the Building Regulations Part L1B for building fabric and services. $CO_2$ emissions and energy demand values were then extracted from the DER Worksheets available for these plots.

| | $CO_2$ Emissions $kgCO_2$/year | | Energy Requirement kWh/year | |
|---|---|---|---|---|
| | Refurbished flats | New flats | Refurbished flats | New flats |
| Regulated (Heating, lighting, pumps and fans) | 20,421 | 6,578 | 94,125 | 47,460 |
| Unregulated (Cooking and appliances) | 27,867 | | 58,657 | |
| Lighting systems in communal areas | 184 | | 356 | |
| Lift Systems | 1,736 | | 3,358 | |
| **Total site wide value** | **54,866** | | **200,242** | |

**Table 1: Baseline Development $CO_2$ Emissions and Energy Requirements**

## 4.0 ENERGY HIERARCHY

4.1 The energy hierarchy as detailed by the London Plan, 2011 and Camden Core Strategy CS13 outlines a series of sequential steps that should be assessed in order for any new development. The steps and the order in which they are to be assessed are as follows:

1. Be Lean: use less energy
2. Be Clean: supply energy more efficiently
3. Be Green: use renewable energy

4.2 These steps are examined in the context of this development below.

## 5.0 BE LEAN: USE LESS ENERGY

5.1 Minimising the requirement for energy is the first step that should be considered. The rate at which heat energy is lost from a building greatly influences the annual heat load, and therefore the $CO_2$ emissions and energy requirements of that building. Energy requirements for hot water applications are essentially independent of improvements to the building's fabric efficiency as these are functions of occupancy and usage rather than rate of heat loss. The main areas where the efficiency of a building can be improved are detailed below.

**Building Fabric's Thermal Transmittance**

5.2 Building fabric thermal transmittance is measured by the U-value of each building element in Watts/m²/K. The U-value is a measure of the rate at which energy is lost through a building element; the greater the U-value, the higher the rate of energy loss.

5.3 The building fabric performance will be much improved compared to the values recommended by Camden within their guidance document CPG 3.

5.4 Table 2 shows the fabric performance levels assumed in relation to the values stated in guidance document CPG 3 and the minimum requirements of the 2010 Building Regulations.

| Building Element/Characteristic | Proposed Development New Flats | Camden Document CPG 3 | Proposed Development Refurbished Flats | Building Regulations Part L1B Requirements |
|---|---|---|---|---|
| Exterior Wall U values (Dwellings) | **0.14** W/m²K | 0.2 W/m²K | **0.25** W/m²K | 0.30 W/m²K (for refurbished element) |
| Floor U value | **0.1** W/m²K | 0.2 W/m²K | **0.1** W/m²K | 0.25 W/m²K (for refurbished element) |
| Roof U value | **0.1** W/m²K | 0.13 W/m²K | n/a | 0.18 W/m²K (for refurbished element) |
| Window U value (Dwellings) | **1.3** W/m²K | 1.5 W/m²K | **1.3** W/m²K | 1.6 W/m²K (for provision of new elements) |
| Door U value (solid) | **0.85** W/m²K | 1.0 W/m²K | **0.85** W/m²K | 1.8 W/m²K (for provision of new elements) |
| Design Air Permeability | **3** m³/hr/m² @50Pa | 3 m³/hr/m² @50Pa | n/a | n/a |

**Table 2: Proposed Fabric Efficiency Standards Versus Part L1A and L1B Acceptable Standards**

**Air Permeability**

5.5 Air permeability is a measure of infiltration. It indicates how often the entire air quantity in a building is exchanged with outside air within 1 hour without any ventilation in place. Any air exchanged with outside air is carrying heat energy away from the building, resulting in a higher heating load. From an efficiency perspective lower air permeability levels are desirable, however reduced air permeability, usually below 4 $m^3h/m^2$ @50Pa, can make natural ventilation ineffective, necessitating the use of mechanical ventilation.

5.6 As detailed in Section 3 Calculation Methodology, the air permeability of the new flats within the proposed development has been assumed to be $3m^3/m^2$@50PA/hr. This is to ensure that a well sealed building, with minimal air infiltration through the gaps in building fabric, provides a comfortable environment to its occupants. The low air permeability will necessitate the use of mechanical ventilation with heat recovery. The flats constructed within the refurbished part of the building have no minimum air permeability requirement; they will however be dry-lined on the inside ensuring any gaps in the building envelope are sealed.

**Thermal Bridging**

5.7 Thermal bridging of junctions is the loss of heat energy through the junction between different building elements (such as a wall and window) or where a building element changes direction (such as a corner). Such areas can result in breaks in the continuity of insulation that can form 'bridges' for heat energy to escape from the building.

5.8 The proposed development will use existing front and side elevation walls and upgrade them internally to minimise heat loss through the walls. The existing basement will be converted into flats with part of the front walls submerged and acting as retaining walls. For this reason it is not possible to assume that Accredited Construction Details (ACD) could be applied to all the elements' junctions. The flats on the second and third floor however, can adopt the ACD junctions as they will be newly constructed without incorporating the existing structure into their design. For the purpose of the energy calculations a default thermal bridging value has been used for the refurbished flats and ACD have been assumed for the new flats.

**Thermal Mass and Solar Gain**

5.9 Thermal mass and passive solar gains are two related aspects of efficient building design. Thermal mass is the ability of the fabric of the building to absorb excess heat. If effectively utilised, it can reduce heating and cooling loads and, in some cases, remove the requirement to provide air conditioning. Timber frame is typically a lightweight construction with low thermal mass whereas a building with external, party and internal walls made from dense blocks and with concrete lower and upper floors typically has a high thermal mass. Buildings with a high thermal mass and high level of insulation generally make better use of solar gains in the day by absorbing them and radiating the warmth later on as the level of solar radiation drops.

5.10 The proposed development does contain a significant area of south facing elevation and could potentially take advantage of passive solar gain and thermally massive building materials; however the interaction of passive solar gain, building thermal mass and the risk of overheating is a complex one beyond the scope of an initial energy assessment. At this stage it can only be determined that the development is potentially suitable; a precise determination will be reliant on more comprehensive dynamic thermal simulation of the development undertaken at the detailed design stage.

**Lighting and Appliances**

5.11 High efficiency low energy lighting and controls would be specified throughout. All residential spaces will utilise 100% low energy lighting. All communal spaces will utilise automatic lighting controls. The communal circulation spaces will utilise occupancy sensors.

5.12 The residential spaces will be fitted with energy display devices to allow the occupants to accurately monitor their energy consumption and to inform them of areas of high consumption to allow for effective adjustment of their usage patterns. Energy display devices will be required as part of the BREEAM Domestic Refurbishment strategy.

**Limiting the Risk of Overheating**

5.13 The design of the development will contribute to reducing the risk of overheating. The balconies and large windows facing west will be shaded by means of external vertical shutters. The courtyard at the back of the building will be transformed into private gardens reducing the urban heat island effect during the summer months. Also, the third floor terraces will incorporate brown and/or green roofs to limit the risk of overheating associated with flat roof finishes, such as bitumen and/or felt.

**Lean Case $CO_2$ Emissions and Energy Requirements**

5.14 The overall effect on the energy demand and associated $CO_2$ emissions of incorporating the energy efficiency measures detailed above into the proposed development would be as follows:

| | $CO_2$ Emissions $kgCO_2$/year | | Energy Requirement kWh/year | |
|---|---|---|---|---|
| | Refurbished flats | New flats | Refurbished flats | New flats |
| Regulated with efficiency improvements LEAN CASE | 17,607 | 5,656 | 79,915 | 23,714 |
| Unregulated (Cooking and appliances) | 27,867 | | 58,657 | |
| Lighting systems in communal areas | 184 | | 356 | |
| Lift Systems | 1,736 | | 3,358 | |
| **Total site wide value** | **51,130** | | **162,286** | |

**Table 3: 'Lean Case' development $CO_2$ emissions and energy requirements**

5.15 The use of energy efficiency measures would reduce the regulated $CO_2$ emissions in comparison to the 2010 Building Regulations Compliant case by 13.84%.

## 6.0 BE CLEAN: SUPPLY ENERGY EFFICIENTLY

6.1 Connection to a decentralised energy network and the use of combined heat and power is a recognised method of generating energy more efficiently. The London Borough of Camden Core Strategy Policy CS13 and guidance document CPG 3 *Sustainability* requires development proposals to explore the opportunities to link into an existing or planned decentralised energy network using the London Heat Map tool. Where an existing decentralised energy network is not present, an assessment of the feasibility of establishing a decentralised energy system for the proposed development should be undertaken; including an assessment of the feasibility of a Combined Heat and Power (CHP) communal heating system.

6.2 Where it is unfeasible to connect to a decentralised energy network or include a Combined Heat and Power (CHP) system within the development designs, the London Borough of Camden request a financial contribution towards the expansion of the current decentralised energy network and future connection of the proposed development to the network.

6.3 The feasibility of connecting to an existing network and specification of a Combined Heat and Power system has been assessed within the following section.

**Decentralised Energy Networks**

6.4 The London Heat Map tool is operated by the London Development Agency, and details the existing and proposed major heat loads and supplies within London as well as existing and proposed heat distribution networks. The London Heat Map was consulted during the writing of this report. The output from the London Heat Map indicating the location of the proposed development in relation to existing and proposed energy networks can be found in figure 3 below.

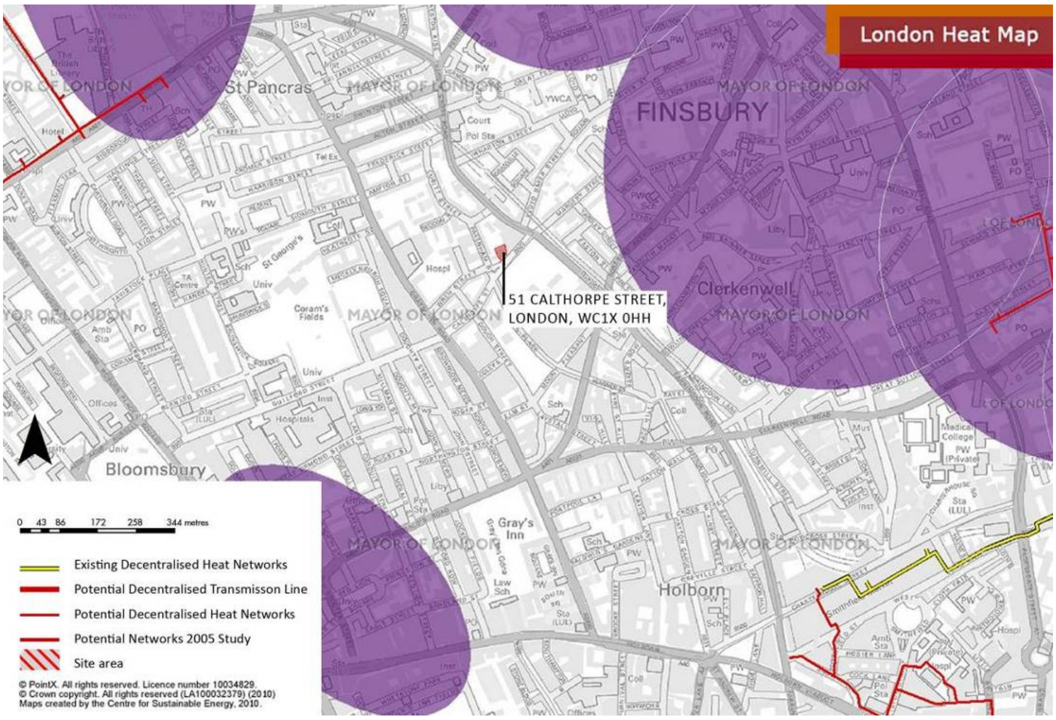


**Figure 3: London Heat Map Tool**

6.5 Based on the information given by the London Heat Map and the maps contained in Section 5 of Camden's guidance document CPG 3 there are no existing or proposed heat networks, or suitable heat sources or heat loads within 1200m of the proposed development location. As this distance is further than the 1km recommended in guidance document CPG 3 for assessing viability, connection to a decentralised heat network has not been explored further for this development.

**Combined Heat and Power System**

6.6 The incorporation of a Combined Heat and Power (CHP) system would be feasible. Sizing a CHP system can be a complex undertaking depending upon a developments heat usage profile. Typically a CHP system would be sized to the base heat load (the heat load present all year round) in order to maximise the running time, and therefore the efficiency of the system. For a residential development the base heat load would typically be the hot water demand.

6.7 Integration of a CHP system requires that the proposed system is compatible with the expected heat and pressure parameters of the building's heating system. This report assumes a micro CHP system suitable for integration within conventional low pressure heating circuits and for connection in sequence with conventional gas boiler systems. The model assumed for calculation purposes is the BAXI DACHS mini CHP system, although detailed system design and client preference may alter the model selected at the detailed design stage.

6.8 The incorporation of a gas powered mini CHP system as the lead heat generator within the sequenced communal gas boiler system would allow the CHP system to achieve maximum run time and therefore efficiency. The calculations that support this report have assumed that a gas CHP system would meet 20% of the overall heat load of the development. This level has been assumed as a robust (conservative) value approximately equivalent to around 35% of the developments total hot water heating requirement. More detailed design analysis may increase this percentage.

**Communal Heating**

6.9 The development will utilise a central communal heating system, distributing a heating flow to the residential units. The heat source would utilise sequenced high efficiency gas boilers. The use of sequenced gas boilers would allow the heating system to more efficiently match the heat load at any one time as only those boilers required would operate.

6.10 The use of a communal heating system would be a pre-requisite for the incorporation of a CHP system and for the possible connection of the building's heating system to a decentralised energy network at a later date.

6.11 The design and layout of the building's plant room will be such that it will facilitate the possible future connection of the development to an energy network. Space will be allowed for the possible inclusion of heat exchange equipment and the building heating circuit will be designed to incorporate connection points suitable for future connection to a decentralised energy network.

**Clean Case $CO_2$ Emissions and Energy Requirements**

6.12 The effect on $CO_2$ emissions and energy requirements of incorporating a CHP system and the energy efficiency measures noted above would be as follows:

| | $CO_2$ Emissions $kgCO_2$/year | | Energy Requirement kWh/year | |
|---|---|---|---|---|
| | Refurbished flats | New flats | Refurbished flats | New flats |
| Regulated with efficiency improvements and gas CHP CLEAN CASE | 16,386 | 5,210 | 83,612 | 24,522 |
| Unregulated (Cooking and appliances) | 27,867 | | 58,657 | |
| Lighting systems in communal areas | 184 | | 356 | |
| Lift Systems | 1,736 | | 3,358 | |
| **Total site wide value** | **49,463** | | **166,791** | |

**Table 4: 'Clean Case' Development $CO_2$ Emissions and Energy Requirements**

6.13 The use of a CHP system along with the energy efficiency measures would reduce the regulated $CO_2$ emissions in comparison to the 2010 Building Regulations compliant case by 20.01%

6.14 The $CO_2$ emissions for the Clean, Lean and Base case are shown on the graph below:

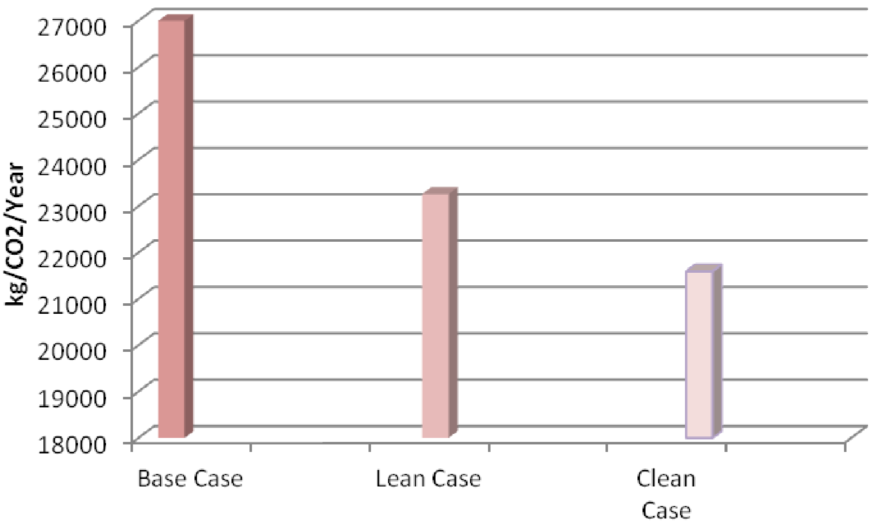


**Figure 4: Base Case, Be Lean Case and Be Clean Case Reductions in Carbon Dioxide Emissions**

## 7.0 BE GREEN: USE RENEWABLE ENERGY

7.1 The final step in the energy hierarchy requires the clean generation of energy by renewable energy technologies be examined. Camden Core Strategy Policy CS13 requires the incorporation of on site renewable energy generation to provide a percentage reduction in the carbon emissions from the proposed development. The London Borough of Camden require all developments to achieve a 'reduction in carbon dioxide emissions of 20% from on-site renewable energy generation unless it can be demonstrated that such provision is not feasible'.

7.2 A feasibility study has been undertaken to establish the most economically viable renewable technology which provides the highest overall reduction in carbon dioxide emissions for the proposed development to meet Camden's policy requirements. The feasibility study has also explored the possibility of reducing carbon dioxide emissions by 20 per cent through the sole use of on site renewable technologies in accordance with Camden Core Strategy Policy CS13 and London Plan Policy 5.7 'Renewable Energy'. The following renewable technologies are identified in Camden planning guidance document CPG 3:

- Biomass heating, cooling and electricity
- Photovoltaic panels
- Solar water heating
- Wind turbines
- Heat pumps

7.3 The following chapter of this report assesses the suitability of the renewable energy technologies listed above in the context of this development.

**Renewable Technology Feasibility Study**

Photovoltaic Panels: Suitability – **VIABLE**

7.4 PV panels would be a viable option for meeting the requirements outlined within Camden's guidance document CPG 3. Over shading from the neighbouring high rise hotel will affect the panels' performance. This has been taken into account when determining the system's size and energy generated. The over shading would however compromise the ability of the proposed development to achieve the 20% site wide reduction in carbon dioxide emissions. Photovoltaic panels would be suitable for gaining the required energy credits under the BREEAM Domestic Refurbishment to contribute towards achieving 60% of the un-weighted energy credits.

7.5 Photovoltaic panels are typically straight forward to integrate into a buildings services strategy. As PV panels supplement grid supplied electricity production and its associated high $CO_2$ emissions per kWh, they are typically far more effective at reducing site wide carbon dioxide emissions than a heat producing technology.

Solar Thermal Hot Water Panels: Suitability – **VIABLE**

7.6 Solar thermal systems supplement the water heating load which in this development is powered by mains gas. The carbon emissions from mains gas are far lower than those of electricity (0.198kg$CO_2$/kWh against 0.517kg$CO_2$/kWh for electricity: source SAP 2009 Table 12), therefore a solar thermal system will result in proportionally lower $CO_2$ reductions than a technology producing renewable electricity. The SAP calculations are heavily influenced by $CO_2$ emissions reductions and a solar thermal system would have a comparatively small effect on them. Solar thermal panels are a viable, however not a recommended option, due to lower $CO_2$ emissions reduction than PV panels and more complicated installation process.

Heat Pumps: Suitability – **NOT VIABLE**

7.7 The efficiency or Coefficient of Performance (CoP) of a heat pump at any one time is dependant on the temperature that needs to be supplied and the thermal energy available from the heat source. If the heat source has high levels of thermal energy the system will have a higher CoP. By example, on a hot day the ambient air temperature is relatively high and so any given volume of air contains a relatively large amount of thermal energy for an air source heat pump to extract, and therefore the system will have a high CoP. However hot days are when you are least likely to require heating. Conversely on a cold day the system has to work proportionally harder to extract thermal energy and so has a far lower CoP.

7.8 The viability of a heat pump system depends on the heat load and usage profile of the building to be served. Heat pumps can generally offer efficient space heating but are less efficient for domestic hot water heating typically requiring either immersion heaters or a separate dedicated hot water heating system. For domestic applications the method for calculating a domestic TER value for a heat pump powered dwelling can give a misleading representation of the actual carbon emissions. The Building Regulations incorporate a fuel factor into the TER calculation for domestic heat pumps that results in a TER that is proportionally higher than that for an equivalent gas powered dwelling. This high TER value offers more favourable improvements in the DER/TER ratio meaning a heat pump powered dwelling can have a significant DER over TER reduction yet have $CO_2$ emissions comparable to a conventional gas boiler. Camden Borough Council requires that any calculation for the contribution of electric heating (which includes heat pumps) be compared to a gas fuelled heating system and not an electric one.

7.9 Using this methodology ASHP's would not offer any improvement over the use of conventional gas powered heating systems. Depending upon the efficiency of the system installed, a GSHP installation would offer a reduction in $CO_2$ emissions when compared to gas installations; they are however more costly to install and require a detailed ground and neighbouring buildings' structure survey to establish the site's suitability for deep bore holes required for GSHP piling.

7.10 The London Borough of Camden require the coefficient of performance (CoP) for both air and ground source heat pumps to be at least 4:1 before they can be considered a renewable technology.

7.11 Calculation methodologies such as SAP use an approximated seasonal coefficient of performance (SCoP) which measures the energy in versus the energy out over one complete season, and as such gives a more realistic interpretation of heat pump performance. The default respective SCoPs used by SAP is 2.5:1 and 3.2:1 for air and ground source, neither of which would meet the 4:1 minimum required by the London Borough of Camden. For this reason heat pumps are considered unviable for this development and have not been considered further in this assessment.

Biomass Heating, Suitability – **NOT VIABLE**

7.12 A biomass boiler system would not be viable for this development. A biomass system would result in significant reductions in development carbon emissions; however such a system would have significant technical and planning policy issues.

7.13 The primary issue would be air quality impact. The London Plan states that planning submissions proposing biomass systems will require an air quality assessment to demonstrate the system will not have an adverse effect on air quality. Given the dense residential nature of the area surrounding the proposed development it can be reasonably assumed that air quality would suffer to some extent. This could be mitigated by flue design and the use of filtration equipment, but will not be capable of completely eliminating the effects on air quality.

7.14 A second major concern would be fuel supply. A secure fuel storage facility of sufficient size to provide at least several weeks fuel would be required and a reliable long term fuel source would need to be secured. This would result in an additional large number of vehicle movements into and out of the development for refuelling operations. Biomass systems for developments of this size are typically sized to meet a proportion of the heat load with faster responding gas boilers being used to meet peak demand. This dual system would be relatively complex and require a disproportionately large plant room for a development of this size.

7.15 Biomass CHP systems are available that can produce both heat and electricity from the same biomass process; however they will still have the same issues as a normal biomass installation.

Wind Turbines: Suitability – **NOT VIABLE**

7.16 Whilst a wind turbine could be sized to meet the requirements of this development there are numerous factors that would discount its suitability in this setting. Typically wind turbines perform poorly in urban environments as surrounding buildings and features dissipate much of the useful energy of the wind before it can be extracted by the turbine. To be clear of the disturbance created by surrounding buildings, it would be necessary to provide a mounting tower in excess of 25m tall, which would also require a large amount of free space for the erecting and periodic maintenance of the turbine. This is likely to be an issue with this site.

7.17 Environmental concerns such as noise and shadow flicker are also problematic in populated areas. While modern turbines have low levels of noise generation, even at high rotational speeds, the noise generated may still be an issue for local residents particularly given the close proximity of the turbine. Given the dense urban setting of this development, shadow flicker is likely to be a problem for the residents of the proposed development and the adjacent hotel. A wind turbine would not be a viable option for this development.

**Recommended Renewable Technology – PV panels**

7.18 Photovoltaic panels have been identified as the only feasible technology for incorporation into this development. This system is examined in greater detail in relation to this development in the following section. The system has been evaluated against the following criteria:

- System size;
- $CO_2$ emissions from renewables;
- Capital and life cycle costs, payback and grants;
- Environmental and visual impact;
- Site suitability;
- Security and availability of fuel supply;
- Installation and maintenance issues.

7.19 The following section details the technology that is considered potentially suitable to meet the requirements of this development.

| Photo Voltaic Panels | |
|---|---|
| PV panels would offer a relatively inexpensive option with low technical risk. | |
| *System Size:* | The development would utilise a 9.4kWp photovoltaic panel array mounted upon the flat roof. The panels would be mounted in a horizontal formation. Horizontal mounting does carry a small performance penalty for the PV system; however this is more than made up for by the greater density of panels that can be horizontally mounted.<br>A 9.4kWp PV system would comprise approximately 47 PV panels and would have a total panel area of approximately 70m² (assuming panel dimensions of 1.5m x 0.95m).<br>PV is inherently flexible and the system size can be adjusted with relative ease to accommodate changes in building design. |
| *$CO_2$ Emissions from renewables:* | The combined improvement over the base case, incorporating the Lean, and Green measures would be:<br>**((26,999 – 18,729)/26,999 x 100 = 30.63%**<br>Site wide $CO_2$ emissions reduction from PV, including unregulated energy use, would be:<br>**((49,463 – 46,596)/49,463 x 100 = 5.8%** |
| *Capital and Life Cycle Cost, Payback and Grants.* | The cost of a 9.4kWp PV system would be approximately £28,000 although a bulk purchase may reduce this estimate. PV systems do not require any notable additional power input to operate resulting in negligible running costs. Feed in Tariffs, introduced in April 2010, offer a guaranteed price per kWh significantly above the market rate for energy generated. The tariff levels are subject to periodic review but at the time of writing the rate for a 9.4kWp system would be 13.99 pence per kWh. The feed in tariff is allocated based upon the registered meter location. If the array is distributed and registered to individual dwellings the feed in tariff will be 15.44 pence per kWh. This is a function of the tariff mechanism which gives the highest rate to the smaller arrays. Electricity displaced from the grid has emissions per kWh of 0.529kg$CO_2$/kWh (source SAP 2009 Table 12).<br>For a 9.4kWp array this would give a tariff rate of:<br>**2,867kg$CO_2$/year / 0.529 = 5,420kWh/year**<br>**5,420 x 0.1399 = £758/year for 25 years**<br>A Feed in Tariff of this level would give a payback period of approximately 37 years. |
| *Environmental and Visual Impact:* | The PV systems will be flat mounted on the roof of the building and so will have a minimal visual impact and no noise impact on the development. |
| *Site Suitability:* | This site is suitable for PV panels, providing that over shading from the adjacent hotel is considered. A full sun cast model has been carried out to determine the suitability of the system. The results prove that the flat roof will be over shaded throughout the year by the adjacent Holiday Inn hotel in the early morning hours. The roof will be fully exposed to the sun light from 9.30am onwards. Given that the modelling tool estimates that the sun rises at 6.30am and sets at 3.45pm in the winter and 6pm in the summer, the performance of PV panels will drop for 3 hrs each day which equals to 26% to 32% of the day time hours. This translates to 'modest' over shading in the SAP calculation tool. |

| | |
|---|---|
| | The proposed system sizing takes the shade cast by the adjacent hotel into account as shown in figures 1 – 6 in Appendix B.<br>Please refer to Daylight/Sunlight Report (Ref. PS/CS/P12-385/10) for a detailed study of the daylight availability. |
| *Security and Availability of Fuel Supply* | PV panels generate electricity from solar radiation, an inexhaustible resource. All UK sites are suitable. |
| *Maintenance and installation Issues:* | PV systems have no moving parts and minimal maintenance requirements. Maintenance is generally restricted to periodic visual inspection and cleaning. PV panels only require electric cabling to connect multiple panels making them relatively simple and quick to install. |

## 8.0 CONCLUSION AND SUMMARY

8.1 This Energy Statement outlines how the proposed re-development of 51 Calthorpe Street, Camden will meet the energy requirements as specified by Core Strategy Policy CS13 *Tackling Climate Change through promoting high environmental standards*. The requirements of Policy CS13 are supported by Camden Supplementary Planning Document CPG 3 *Sustainability*.

8.2 This Energy Statement has been prepared following the principles of the London Plan Energy Hierarchy: Be Lean, Be Clean and Be Green. The overriding objective in the formulation of the Energy Statement has been to maximise the viable reductions in total carbon dioxide emissions from the development within the framework of the energy hierarchy.

8.3 In addition to the Energy Hierarchy the Energy Statement takes into consideration decentralised energy in development proposals and supply of renewable energy detailed within Camden planning guidance document CPG 3 *Sustainability.*

8.4 Be Lean: Energy efficiency measures will be applied to the development. The development will meet and exceed all of the building fabric performance standards suggested within Camden guidance document CPG 3 and exceed the minimum requirements of Part L1A and L1B for fabric efficiency standards.

8.5 The opportunity for the proposed development to link into an existing or planned decentralized energy network has been explored using the London Heat Map tool. In the absence of an existing heat network within a reasonable distance of the proposed development site, the report assessed the feasibility of incorporating a CHP communal heating system within the development. The installation of the CHP system in combination with the 'Be Lean' measures will reduce the regulated carbon dioxide emissions in comparison to the 2010 Building Regulations compliant case by 20.01 per cent.

8.6 A feasibility study has been undertaken to establish the most suitable renewable technology for integration at the proposed development. Solar photovoltaic panels are the recommended renewable technology within the constraints of the site and provide the most cost effective carbon dioxide emission saving for the proposed development.

8.7 A 70m² 9.4kWp photovoltaic system mounted horizontally on the flat roof areas, combined with the 'Be Lean': energy conservation measures and 'Be Clean' CHP system will provide a 30.63% reduction in the $CO_2$ emissions over the Building Regulations compliant case.

8.8 The specified photovoltaic system will provide a reduction in carbon dioxide emissions of 5.8%. The proximity of the existing building to the adjacent Holiday Inn hotel restricts the use of PV panels and reduces their performance due to the partial over shading of the flat roof. The available roof area is also reduced by incorporation of large rooflights, providing daylight to the top floor penthouse apartment. Other renewable technologies have been explored as part of the renewable technology feasibility study, none of which would perform better than the PV panels in terms of carbon dioxide emissions reduction given the physical constraints of the site. To maximise the electricity generation, and therefore $CO_2$ reduction from renewable technologies, the available roof area will be fully utilised for the proposed PV system. The recommended renewable technology will provide a reasonable contribution towards meeting the 20% reduction in carbon dioxide emissions as detailed within the London Plan Policy 5.7 Renewable Energy, and Camden Core Strategy Policy CS13. The 20% reduction in carbon dioxide emissions is required 'unless it can be demonstrated that such provision is not feasible'.

## 9.0 DISCLAIMER

9.1 Create Consulting disclaims any responsibility to the Client and others in respect of any matters outside the scope of this report.

9.2 The copyright of this report is vested in Create Consulting Engineers Ltd and Mr Simon Firth. The Client, or his appointed representatives, may copy the report for purposes in connection with the development described herein. It shall not be copied by any other party or used for any other purposes without the written consent of Create Consulting Engineers Ltd or Mr Simon Firth.

9.3 Create Consulting Engineers Ltd accepts no responsibility whatsoever to other parties to whom this report, or any part thereof, is made known. Any such other parties rely upon the report at their own risk.

# APPENDICES

# APPENDIX A

## $CO_2$ Calculations Methodology

The $CO_2$ and energy calculations for the proposed development at 51 Calthorpe Street have been determined based upon calculations for selected dwellings; some of them are unique in their design and some repeat throughout the development and can be multiplied to achieve results that will represent the whole of the development.

The dwellings selected have been chosen as they represent the average to worst case for energy consumption with higher than average areas of heat loss wall/floor or roof.

All areas and dimensions have been determined based upon AutoCAD drawings supplied by Brooks/Murray Architects.

The proportional sizing has been determined as follows based on the plots modelled:

| Plot Modelled | Floor Area [$M^2$] | Total Floor Area for Plot Type | Multiplier for Assessed Plots |
|---|---|---|---|
| Refurbished flats | | | |
| Flat 4 | 78.3 | 410.80 (5 flats total) | 5.25 |
| Flat 10 | 100 | 496.9 (7 flats total) | 4.97 |
| New flats | | | |
| Flat 15 | 81.3 | 241.9 (3 flats total) | 2.98 |
| Flat 16 | 165.8 | 165.8 | 1 |
| TOTAL | | 16 flats | |

## Unregulated Emissions

- **Cooking and Appliances**

The energy associated with cooking and appliances is not accounted for in the DER and TER calculations used to confirm compliance with the Building Regulations. Section D of London Plan Policy 5.2 requires that these demands be accounted for. Section 16 and Appendix L of the SAP 2009 guidance detail procedures for calculating the unregulated $CO_2$ and energy associated with cooking and appliances.

The calculations for the assessed dwellings are given below; all $CO_2$ is in kg/year all energy is in kWh/year:

| Plot | Cooking | | Appliances | |
|---|---|---|---|---|
| | $CO_2$ | Energy* | $CO_2$ | Energy |
| Refurbished plots | 2,263 | 7,903 | 15,710 | 30,387 |
| New plots | 788 | 2,753 | 7,186 | 13,900 |
| TOTAL | **3,051** | **10,656** | **22,896** | **44,287** |

*Energy from cooking was calculated based on the assumption that 50% of cooking is powered by gas and 50% by electricity (BRE guidance)

**Total unregulated $CO_2$ emissions and energy from cooking and appliances will be:**

**$CO_2$: 25,947 kg/$CO_2$/year**

**Energy: 54,943 kWh/year**

- **Communal Lighting**

It has been assumed, based on industry standards, that a design lighting level of 150Lux will be utilised for the corridors and stair wells.

1 Lux = 1 Lumen/m²

The floor area of communal corridors and stairwells is 97.50m²

97.50 x 150 = 14,625 Lumens

A high efficacy lighting system capable of at least 60Lumens/Circuit Watt is assumed (equivalent to a modern compact fluorescent lamp system)

14,625/60 = 243.75 Watts

PIR occupancy sensing is assumed. The daily hours of operation are assumed to be 4.

4 x 365 x 243.75 = 355,875 Watt/hours per year or 356kWh/year

The emissions factor for grid supplied electricity is 0.517kgCO2/kWh

0.517 X 356 = 184 kgCO2/year

**$CO_2$ emissions: 184 kg/year**

**Energy: 356 kWh/year**

- **Lift Energy**

The lift calculation assumes a 9.2kW motor operating for a total duration of 1 hour a day.

**Energy:** 9.2 x 365 = **3,358 kWh/year**

**$CO_2$ emissions:** 3,385 x 0.517 = **1,736 kgCO2/year**

**Total Unregulated emissions and energy**

**$CO_2$ emissions:** 25,947 +184 + 1,736kg = **27,867 kgCO2/year**

**Energy:** 54,943kWh + 356kWh + 3,358kWh = **58,657 kWh/year**

## Base Case

### $CO_2$ emissions and energy requirements

The base case $CO_2$ emissions and energy requirements for refurbished flats have been determined from the DER Worksheet for flats that just meet the requirements of Part L1B of the Building Regulations. The base case data for new build flats have been obtained from TER worksheets.

| Plot modelled | $CO_2$ [kg/y] | Multiplier for assessed plots | Total [kg/y] |
|---|---|---|---|
| **Refurbished flats** | | | |
| Flat 4 | 1,949 | 5.25 | 10,232 |
| Flat 10 | 2,050 | 4.97 | 10,189 |
| **New flats** | | | |
| Flat 15 | 1,336 | 2.98 | 3,981 |
| Flat 16 | 2,597 | 1 | 2,597 |
| | | **TOTAL REGULATED** | **26,999** |
| | | **UNREGULATED** | **27,867** |
| | | **TOTAL ALL** | **54,866** |

| Plot modelled | Energy [kWh/y] | Multiplier for assessed plots | Total [kWh/y] |
|---|---|---|---|
| **Refurbished flats** | | | |
| Flat 4 | 9,012 | 5.25 | 47,313 |
| Flat 10 | 9,419 | 4.97 | 46,812 |
| **New flats** | | | |
| Flat 15 | 9,592 | 2.98 | 28,584 |
| Flat 16 | 18,876 | 1 | 18,876 |
| | | **TOTAL REGULATED** | **141,585** |
| | | **UNREGULATED** | **58,657** |
| | | **TOTAL ALL** | **200,242** |

## Be Lean – Efficiency Measures Only

### $CO_2$ Emissions and Energy Requirements

| Plot modelled | $CO_2$ [kg/y] | Multiplier for assessed plots | Total [kg/y] |
|---|---|---|---|
| **Refurbished flats** | | | |
| Flat 4 | 1,642 | 5.25 | 8,621 |
| Flat 10 | 1,808 | 4.97 | 8,986 |
| **New flats** | | | |
| Flat 15 | 1,222 | 2.98 | 3,642 |
| Flat 16 | 2,014 | 1 | 2,014 |
| | | **TOTAL REGULATED** | **23,263** |
| | | **UNREGULATED** | **27,867** |
| | | **TOTAL ALL** | **51,130** |

| Plot modelled | Energy [kWh/y] | Multiplier for assessed plots | Total [kWh/y] |
|---|---|---|---|
| **Refurbished flats** | | | |
| Flat 4 | 7,464 | 5.25 | 39,186 |
| Flat 10 | 8,195 | 4.97 | 40,729 |
| **New flats** | | | |
| Flat 15 | 5,094 | 2.98 | 15,180 |
| Flat 16 | 8,534 | 1 | 8,534 |
| | | **TOTAL REGULATED** | **103,629** |
| | | **UNREGULATED** | **58,657** |
| | | **TOTAL ALL** | **162,286** |

Percentage $CO_2$ Reduction over the Base Case:

**((26,999–23,263)/26,999x100 = 13.84%**

## Be Clean – Generating energy efficiently using CHP (and efficiency measures)

### $CO_2$ Emissions and Energy Requirements

Calculations assume a BAXI –DACHS Mini CHP (non condensing) unit provides 20% of development heat load (very conservative assumption).

| Plot modelled | $CO_2$ [kg/y] | Multiplier for assessed plots | Total [kg/y] |
|---|---|---|---|
| **Refurbished flats** | | | |
| Flat 4 | 1,526 | 5.25 | 8,012 |
| Flat 10 | 1,685 | 4.97 | 8,374 |
| **New flats** | | | |
| Flat 15 | 1,105 | 2.98 | 3,293 |
| Flat 16 | 1,917 | 1 | 1,917 |
| | | **TOTAL REGULATED** | **21,596** |
| | | **UNREGULATED** | **27,867** |
| | | **TOTAL ALL** | **49,463** |

| Plot modelled | Energy [kWh/y] | Multiplier for assessed plots | Total [kWh/y] |
|---|---|---|---|
| **Refurbished flats** | | | |
| Flat 4 | 7,814 | 5.25 | 41,024 |
| Flat 10 | 8,569 | 4.97 | 42,588 |
| **New flats** | | | |
| Flat 15 | 5,194 | 2.98 | 15,478 |
| Flat 16 | 9,044 | 1 | 9,044 |
| | | **TOTAL REGULATED** | **108,134** |
| | | **UNREGULATED** | **58,657** |
| | | **TOTAL ALL** | **166,791** |

Percentage $CO_2$ Reduction over the Base Case:

**((26,999–21,596)/26,999x100 = 20.01%**

## Be Green – Generating energy from renewable energy sources

### $CO_2$ Emissions and Energy Requirements

**PHOTOVOLTAICS**

Calculations assume 70m² of available roof area for PV panels. They are assumed to be mounted horizontally. Each panel is assumed to have a power output of 0.2kWp and area of 1.5m².

70m$^2$ of roof space will allow for approximately 47 panels, i.e. 9.4kWp system.

1kWp of horizontally mounted panels with modest overshading will save approximately 325kg $CO_2$ per year, therefore:

**9.4kWp x 305kg $CO_2$ = 2,867kg $CO_2$/year**

**Site wide $CO_2$ emissions-regulated (LEAN+CLEAN) = 49,463kg $CO_2$/year**

**$CO_2$ reduction from renewables = 5.8%**

PV system is the only feasible option for the proposed development due to the site constraints. Calculations assume that whole of the available roof area will be covered with PV panels. The proposed system size is not sufficient to meet the requirements of the London Plan Policy 5.7 of 20% of the site wide $CO_2$ emissions to be reduced by renewable sources; however the policy states that this requirement should be met where feasible.

# APPENDIX B

**SUN CAST MODELLING IMAGES**

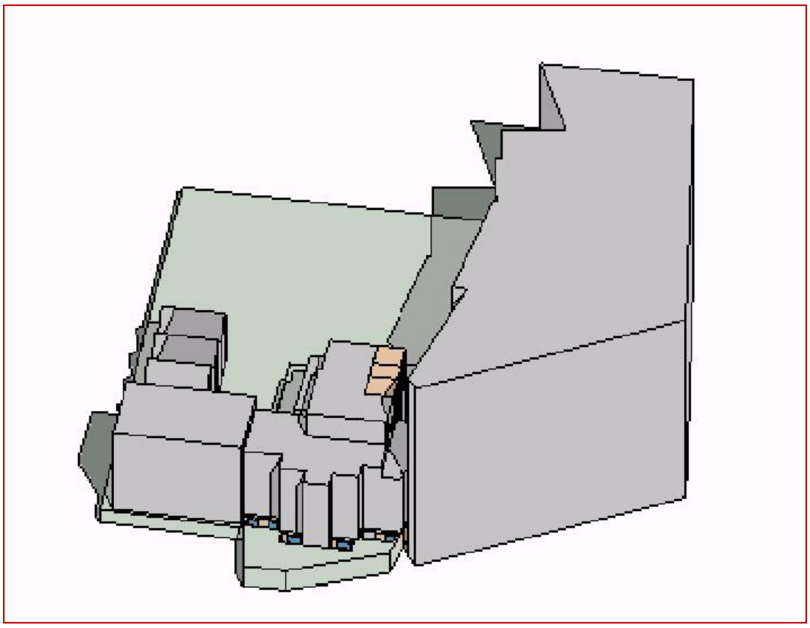

**Figure 1: Sun cast model for 21 June, 9:30**

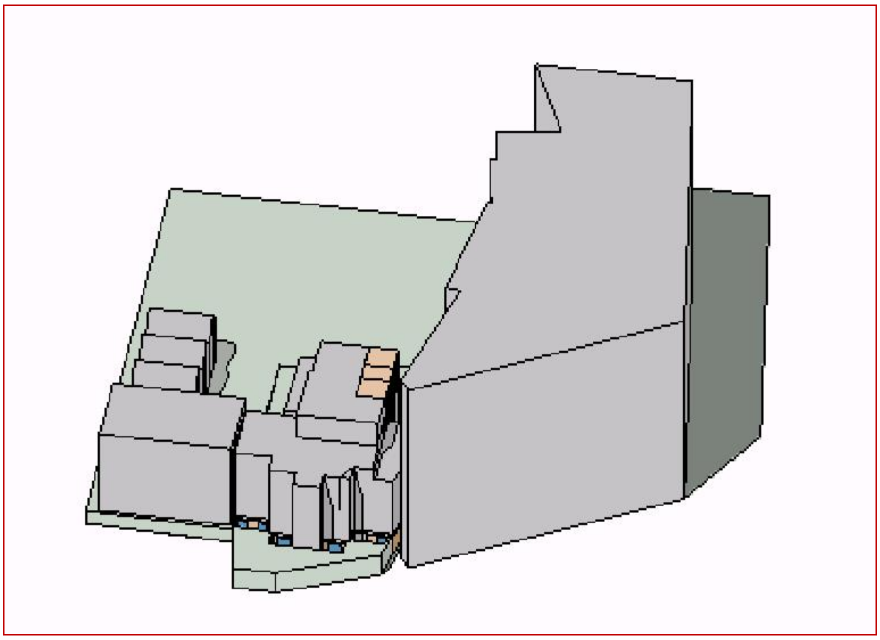

**Figure 2: Sun cast model for 21 June, 12:00**

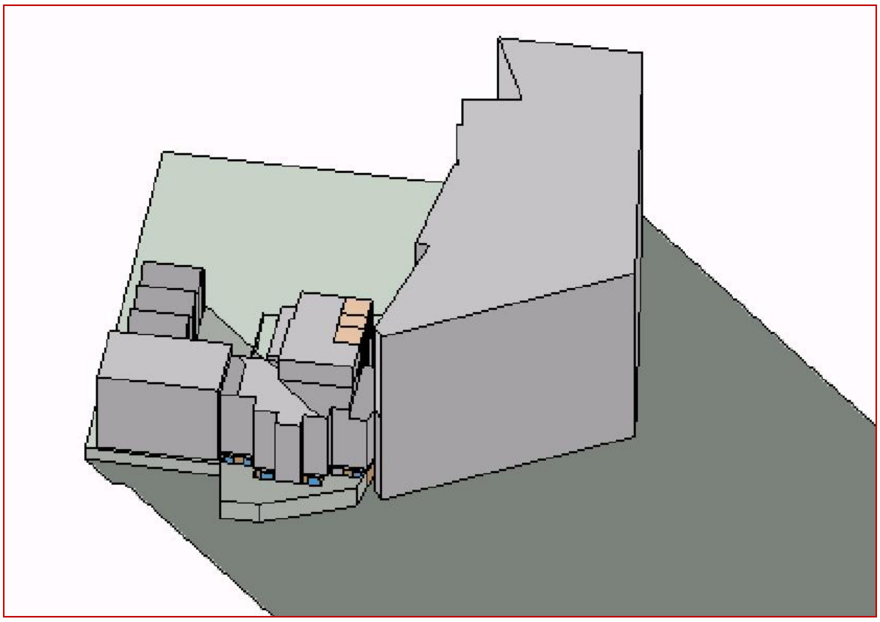

**Figure 3: Sun cast model for 21 June, 18:00**

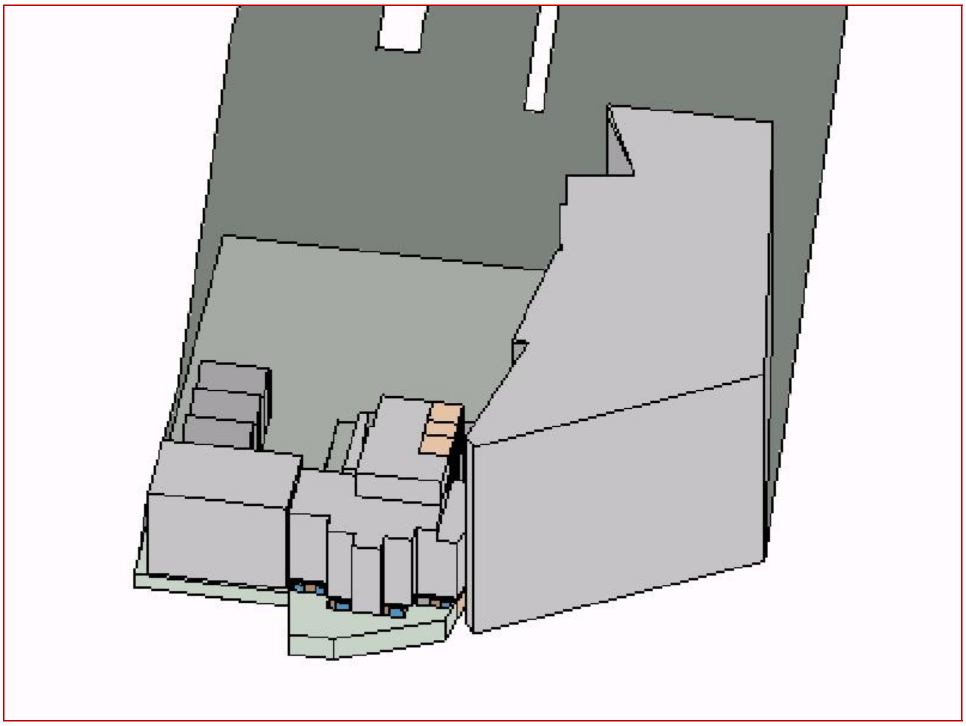

**Figure 4: Sun cast model for 21 December, 09:30**

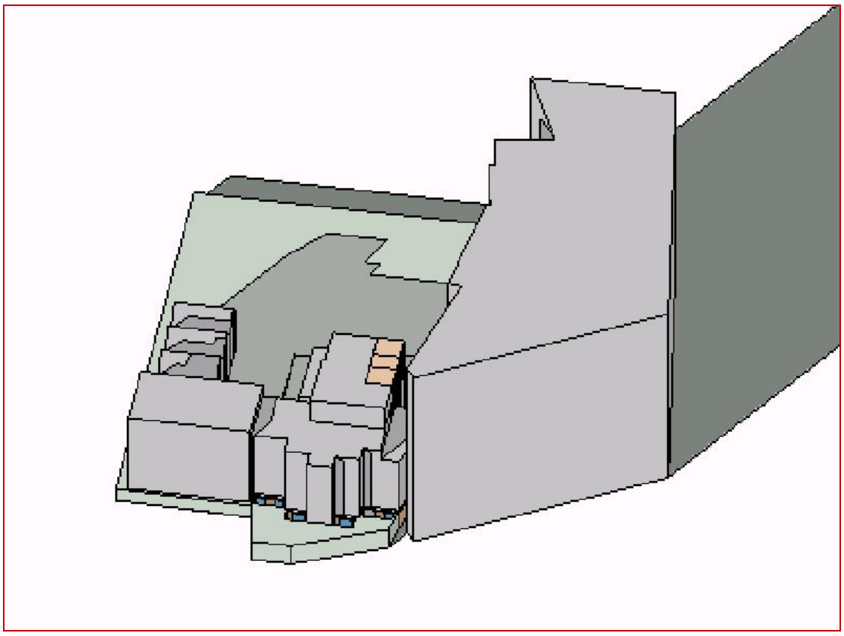

**Figure 5: Sun cast model for 21 December, 12:00**

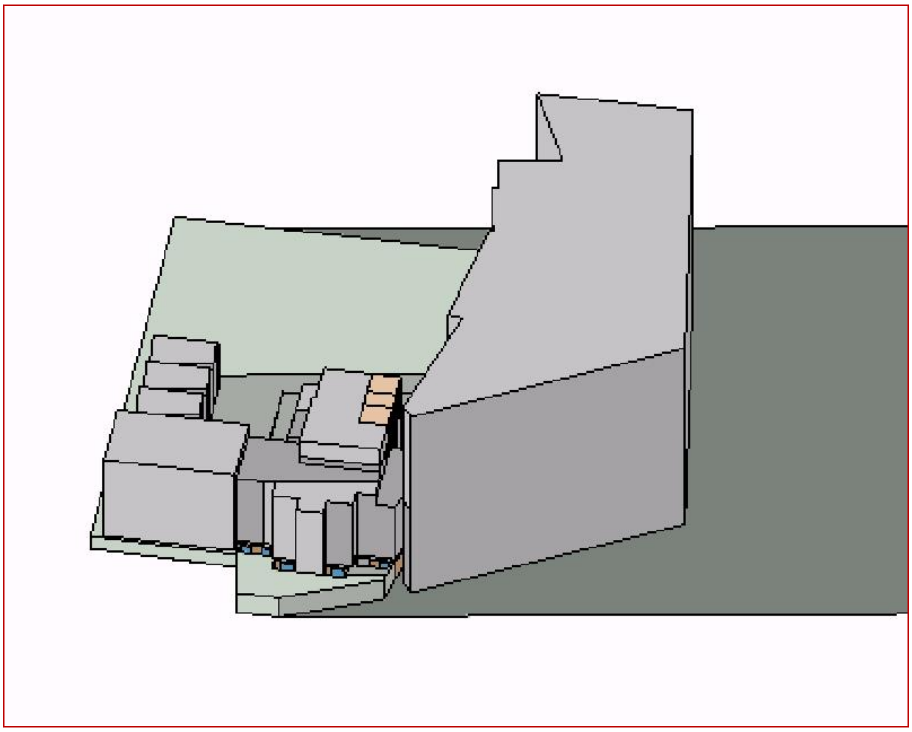

**Figure 6: Sun cast model for 21 December, 15:45**