510121.000 WOKING FOOTBAL CLUB, WOKING
ENERGY STRATEGY REPORT
NOVEMBER 2019

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# 1    EXECUTIVE SUMMARY

Elementa Consulting have been appointed to prepare the Energy Strategy in support of the Planning Application for the Woking Football Club, Woking development.  The project includes the delivery of a new stadium for Woking Football Club, 1,032 residential units with related car parking and, a concierge building.

The targets for the development are to:
- Meet the requirements of Part L2A of the Building Regulations for the non-residential sections of the development.
- Meet the requirements of Part L1A of the Building Regulations for the residential sections of the development.
- Satisfy local planning policy requirements stipulated by Woking Borough Council and in particular:
  - Achieve a minimum of 19% carbon emissions reduction against minimum building regulation Compliance for the residential section of this development
  - Achieve a BREEAM 2014 *'Very Good'* rating for the non-residential section of this development
  - Achieve a 10% Carbon saving using Low-zero carbon (LZC) technologies

The following energy hierarchy was adopted to help guide decisions about which energy measures are appropriate, and in order to optimise design solutions to maximise carbon reductions:

**Be Lean:**     using less energy and utilising passive sustainable design measures
**Be Clean:**    using Combined Heat and Power (CHP) system and district heating networks
**Be Green:**    using renewable energy where possible, to further reduce carbon emissions

The measures listed in this report will ensure the proposed development:

- Complies with part L1A and Part L2A approved documents of Building Regulations
- Achieves an overall 25.8% carbon emissions reduction against the building regulation minimum requirements
- Achieves a 26.4% carbon emissions reduction for the residential section of the development
- Achieves a 20.2% carbon emissions reduction for the non-residential section of the development
- Achieves a 11.6% carbon emissions reduction due to renewable energy for the non-residential section of the development
- Achieves BREEAM *'Very Good'* rating for the non-residential section of the development
- Achieves a minimum of 2 Ene 01 credits against BREEAM NC 2018 rating system for the non-residential section of the development

The updated SAP 10 carbon emission factors have been used as part of the energy calculations: 0.233 kgCO$_2$/kWh for electricity and 0.210 kgCO$_2$/kWh for mains gas.  Further details on the reason of this choice are provided in *Section 1.2* of this report.

## 1.1 SUMMARY OF SYSTEMS INSTALLED

Four-pipes Air Source Heat Pumps (ASHP) will provide domestic hot water and space cooling to occupied spaces for the Stadium. The Air Source Heat Pumps will have an efficiency of at least 290% for Domestic Hot Water production, at least 315% (SCOP) for space heating and at least 475% (SEER) for space cooling.

A communal heating system fed by Gas Boilers and ASHP will provide domestic hot water and space heating for the residential part of development. The ASHP will heat up the water from 35°C to 45°C, with an efficiency of at least 350%, the Gas Boilers will then heat up the water from 45°C to 65°C, with an efficiency of at least 92%.

During the next stages of the design evolution, further improvements to the residential systems will be investigated to provide further carbon emissions reductions.

## 1.2 SAP 10 CARBON EMISSION FACTORS

Calculations for Part L of Building Regulation require the use of certain carbon factors, as outlined below. The latest best practice and guidance on preparing energy assessments, has recommended that SAP 10 carbon factors be used in these calculations. Although these are not yet reflected regulatory and planning policy in Woking, Elementa Consulting believes that decision making should be based on SAP 10 carbon factors rather than historic and outdated carbon factors.

Table 1: Carbon Factor

| Carbon Factor | Gas (kg CO2/kWh) | Electricity (kg CO2/kWh) |
|---|---|---|
| Current Part L of Bulding Regulations | 0.216 | 0.519 |
| SAP 10 | 0.210 | 0.233 |

The carbon emissions of the electricity grid are projected to continue to decrease over the next 20 years, as illustrated in the figure below.
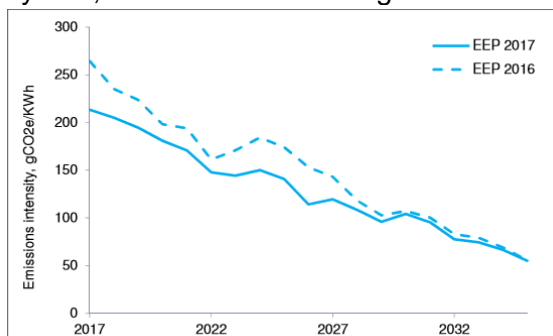


Source: BEIS (2018)[1]

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[1]
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/671187/Updated_energy_and_emissions_projections_2017.pdf

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## 1.3    PROPOSED DEVELOPMENT SITE-WIDE RESULTS

The following table and graph summarise the carbon emissions calculations for site-wide development.

Table 2: Carbon Dioxide emissions and carbon saving after each stage of the Energy Hierarchy for site-wide development

| Site-wide SAP10 carbon emissions (Tonnes $CO_2$ per annum) | | |
|---|---|---|
| | Regulated | Unregulated |
| Part L 2013 of the Building Regulations compliant development | 1353.20 | N/A |
| After energy efficient measures | 1236.55 | N/A |
| After renewable energy | 1003.58 | N/A |
| Regulated carbon dioxide savings | | |
| | Tonnes $CO_2$ per annum | % Improvement |
| Saving through passive design and energy efficient measures | 116.6 | 8.6% |
| Savings through use of renewable energy | 233.0 | 17.2% |
| **Total cumulative savings** | 349.6 | 25.8% |
| | | |
| Total target savings* | 233.01 | |

*The total target savings refers to CO2 emissions reduction target for residential. For non-residential, there is no CO2 emissions target beyond building regulation compliance. For more details refer to Section 3.1.

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## Figure 1: Site Wide I Energy Hierarchy



Site Wide - SAP10
Annual tonnes of Carbon emissions

Chart data:
- Minimum Part L (kgCO2): Total 1353.20
- Be Lean (kgCO2/m2): Total 1236.55, Carbon Savings 116.649
- Be Clean (kgCO2): Total 1236.55, Carbon Savings 116.649
- Be Green with PVs (kgCO2): Total 1003.58, Carbon Savings 349.622

Y-axis: Tonnes of CO2 per annum (0 to 1600)

Legend:
- Carbon Savings
- Total
- Woking reduction target

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# 2    INTRODUCTION

## 2.1    PLANNING SUBMISSION DESCRIPTION

Elementa Consulting has been appointed by Goldev Ltd to prepare the Energy Strategy report in support of the planning submission for Woking Football Club, Woking development. The project includes the delivery of a new stadium for Woking Football Club, retail/restaurant/café use, with an integrated medical centre, a concierge/delivery building with cycle hub and 1,048 residential units with associated parking.

The Application Site is located approximately 1000m South of Woking Town Centre, following under the remit of Woking Borough Council.

The proposed residential development will deliver five residential blocks, comprising a total of 1,048 dwellings, concierge building, and 861 car parking slots, with a total Gross Internal Area of 77,198 m$^2$.

## 2.2    ENERGY STRATEGY DEVELOPMENT

In line with the Energy Hierarchy outlined within the Woking Core Strategy , the effects of passive design and energy efficiency measures were first analysed (such as low construction u-values and high air-tightness, the use of energy efficient services, etc.) to understand their effect on the development's annual energy consumption and carbon emissions, to ensure that the development has an energy efficient baseline. A summary of these measures is provided within Section 3 of this report.

The next stage of the process was to consider the development's suitability to connect to existing district heat and electricity networks, and to look at the viability of utilising a combined heat and power (CHP) installation. A summary of these assessment is provided within *Section 4* of this report.

The final stage of the analysis was to select viable Low Zero Carbon Technology Options in order to meet the project's carbon reductions targets. A summary of this assessment is provided within *Section 5* of this report.

This report is based on the drawings plan produced by LRW Architects dated 30-07-2019, and drawings produced by Holmes Miller dated 12-08-2019.

## 2.3    PROJECT AND SITE DESCRIPTION

The site is located just 1000m South of Woking Town Centre. It benefits from a high degree of connectivity, being only 25 minutes away from London Waterloo Station by train, 30 minutes away from London Heathrow Airport by car, and is easily accessed from the M3 and M25 motorways.

The stadium is located to the north east of the site, its access from Kingfield Road will be retained. The Stadium will be realigned for optimum North-South orientation, pedestrian and vehicle traffic

will be clearly delineated, approximately 70 car parking spaces will be provided together with better accessibility for disabled/elderly supporters.

The residential site offers an urban edge to the existing housing along Westfield Avenue. The scale of development reduces in height to the perimeter. The site is surrounded by a large buffer of existing green foliage which offers a great amount of privacy to surrounding buildings.

The ground floor residential units offer the creation of passive surveillance using entry points to the town houses along the newly formed pedestrianised streets.

Parking is provided to WBC standards with 861 spaces are provided within the residential site. All access to these parking facilities are from Westfield Avenue.

Figure 2: Proposed layout (from Design & Access Statement)

Figure 3: Aerial view (from Design & Access Statement)

## 2.4  PLANNING CONTEXT

### 2.4.1  Woking Core Strategy – Woking Borough Council (2012) + Climate Change Supplement Planning Document – Woking Borough Council (2013)

The following Core Strategies policies have been considered:

CS22 Sustainable Construction

- <span style="color:red">New residential developments required to achieve Code for Sustainable Homes level 5 requirements *(following the Housing Standard Review this requirement has been revised. See paragraph 2.4.2)*</span>
  - o New non-residential development of 1,000 m or more is required to comply with BREEAM very good standards
- CS23 Renewable and Low Carbon Energy Generation
  - o All schemes should implement the energy hierarchy including passive fabric based measures, energy efficiency measures and decentralised energy and renewable power
  - o The Council particularly encourages applications of community-based/owned projects
  - o Applicants should take appropriate steps to mitigate any adverse impact of proposed development through careful consideration of location, scale design, and other measures

### 2.4.2  Guidance note for the implementation of policies in the Core Strategy following the Housing Standard Review (2016)

This note explains how certain parts of Core Strategy will be applied in light of the Government's Housing Standard Review and the introduction of 'new national technical standard'.

- Policy CS22
  - o All new residential development will be required to achieve not less than a 19% improvement in the Dwelling Emission Rate (DER) over the Target Emission Rate (TER) as defined in Part L1A of the 2013 Building Regulation
  - o Non-residential development must still comply with BREEAM standards in the policy

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# 3 ENERGY EFFICIENT BUILDING

The first stage in reducing $CO_2$ emissions from the development is to reduce the energy required to service the building, through the implementation of passive design and active design measures.

To ensure that the development is inherently low in energy use, passive design measures were the initial point of focus.

- Efficient fabric to reduce heating and cooling demand, see *Table 3* for further information
- Appropriate glazing ratios to reduce solar gain during summer periods, limiting the risk of overheating in summer and reduce heat loss in winter
  - *At the next stage of the design, the design team should ensure that all rooms for the non-domestic section of the development will meet the part L2A solar criterion 3 requirements, reducing as required the glazing g-value or the glazing ratios*
- Enhanced fabric airtightness that reduces infiltration heat losses

Active design measures included in the proposed development are outlined below; see *Tables 4-7* for further details.

- Providing energy efficient heating cooling and mechanical ventilation plant
- Providing energy efficient lighting
- Providing adequate control of building services systems and lighting systems
- Providing training to building users to enable them to utilise the building efficiently

The following tables indicate how this development will reduce the baseline energy consumption required, through the implementation of passive design and energy efficient measures (i.e. Be Lean):

Table 3: Architectural 'Passive Design' Parameters for the development

| Element | Value Proposed for non-residential | Value Proposed for residential |
|---|---|---|
| Wall U-Value (W/m$^2$.K) | 0.13 | 0.13 |
| Ground Floor U-Value (W/m$^2$.K) | 0.13 | 0.13 |
| Roof U-Value (W/m$^2$.K) | 0.13 | 0.13 |
| External Door U-Value (W/m$^2$.K) | 1.6 | 1.6 |
| External glazed Door U-Value (W/m$^2$.K) | 1.6 | 1.6 |
| External glazed Door G-Value | 0.4* | 0.4 |
| Natural ventilation louver (W/m$^2$.K) | - | 1.4 |

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| | | |
|---|---|---|
| Window U-Value (W/m$^2$.K) | 1.4 | 1.4 |
| Glazing G-Value | 0.4* | 0.4 |
| Building Air Permeability (m$^3$/h.m$^2$) | 3 | 3 |

*The glazing g-value for the non-domestic section of the development should be specified for the development to comply to Part L2A solar criterion 3 of building regulation. Alternatively, a reduction a glazing area should be included for all the rooms to be compliant with Building Regulation.*

Table 4: Mechanical Services 'Energy Efficient' Measures

| Element | Description |
|---|---|
| Natural Ventilation | Natural ventilation option will be provided wherever feasible for resiliency |
| Mechanical Ventilation | For the non-domestic development, mechanical ventilation with enhanced heat recovery will serve the occupied spaces.<br>For the residential development, mechanical ventilation with enhanced heat recovery will serve all dwellings.<br>Duct sizes will be selected to reduce specific fan power and energy demand. |
| Mechanical Cooling | No mechanical cooling will be provided for the non-residential and residential development. |
| Pumps and Motors | Variable speed, variable frequency, variable voltage drives to be provided on all pumps and motors to reduce energy consumption to minimum on variable flow systems. |
| Metering and Sub-Metering | Use of water and energy metering and direct sub-metering, together with automatic controls to identify area of unusual energy use and optimum operating times and durations. Use of a smart meter. Out of range monitoring and alarms to be provided via automatic control system. |

Table 5: Mechanical Services 'Energy Efficient' Plant Design Parameters for non-residential development

| Element | Typical Value Proposed for non-residential | Typical Value Proposed for residential |
|---|---|---|
| Heat Generator Seasonal Efficiency: Gas boiler | 92%* (Be Lean only) | 89.5%* (Be Lean) 92% |
| Air Source heat Pump Efficiency (Domestic Hot Water) | 290% | N/A |

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| | | |
|---|---|---|
| Air Source heat Pump Efficiency (Cooling SEER/EER) | 475% / 320% | N/A |
| Heat Exchanger Efficiency | >85% | As per selected MVHR unit |
| AHU Combined Specific fan power | 1.2 W/l/s | N/A |
| Mechanical Ventilation with Heat Recovery | 1.0 W/l/s | As per selected MVHR unit |
| Zonal extract ventilation (toilers) | 0.40 W/l/s | N/A |

*So that improvements from energy efficiency alone can be understood as stipulated by the GLA guidance on preparing energy assessments the 'be lean' case assumes that heating is provided by gas boilers with an efficiency of 91% for the non-residential developments and 89.5% for residential development.

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Table 6:  Electrical Services 'Energy Efficient' System Design Parameters

| Element | Part L2A Minimum Requirements | Value Proposed for Development |
|---|---|---|
| LED Lighting | None | Provided throughout |
| Use of Natural Daylight | None | Average daylight factor to be maximised wherever possible |
| Daylight Dimming | None | Provided where possible |
| Lighting Efficiencies – General Lighting | 60 luminaire lumens per circuit Watt | 70 lm/cw (circulation, toilets, cupboards..) 80 lm/cw (occupied rooms) |
| Lighting Efficiencies – Display Lighting | 22 luminaire lumens per circuit Watt | $\geq$ 40 luminaire lumens per circuit Watt |
| Power Factor | None | 0.95 (to be achieved through use of power factor correction plant, if necessary) |
| Lifts | None | Lifts to incorporate energy efficient measures (including energy efficient motors, LED lighting and controls) |

For information, Table 9 below details the W/m$^2$ figures and lighting controls proposed, and therefore utilised within the thermal model.

Table 7: Assumed Lighting Power Density and Lighting Control Measures of non-residential development

| The Proposed Development | Lm/cw | Lighting Control Proposals |
|---|---|---|
| Accommodation | 80 | MAN-ON-AUTO-OFF + Daylight Dimming |
| Changing facilities | 70 | AUTO-ON-OFF |
| Circulation | 70 | AUTO-ON-OFF |
| Food Preparation | 80 | MAN-ON-AUTO-OFF + Daylight Dimming |
| Health/Specialist | 80 | MAN-ON-AUTO-OFF + Daylight Dimming |
| Hospitality/Food | 80 | AUTO-ON-OFF + Daylight Dimming |
| Offices/Meeting | 80 | MAN-ON-AUTO-OFF + Daylight Dimming |
| Press/TV | 80 | MAN-ON-AUTO-OFF |
| Retail | 80 | AUTO-ON-OFF + Daylight Dimming |
| Services | 70 | MAN-ON-AUTO-OFF |
| Store | 70 | MAN-ON-AUTO-OFF |
| Toilets | 70 | AUTO-ON-OFF |
| Workshop | 80 | MAN-ON-AUTO-OFF + Daylight Dimming |
| Circulation (Stands) | 70 | AUTO-ON-OFF |
| Concourse (Stands) | 70 | AUTO-ON-OFF |
| Kiosk (Stands) | 70 | AUTO-ON-OFF |
| Store (Stands) | 70 | MAN-ON-AUTO-OFF |
| Toilets (Stands) | 70 | AUTO-ON-OFF |

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### Other 'Energy Efficient' Design Measures:

In addition to the above energy efficient measures, a comprehensive commissioning programme shall be carried out, and full user training provided to ensure the building users understand how to utilise the building in an energy efficient manner, in accordance with the design intent.

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## 3.1 ENERGY EFFICIENT BUILDING RESULTS

The following tables summarise the percentage improvement from the Part L 2013 compliant development. Detailed calculations have been carried out for the non-residential and residential section of the development.

In following best practice methodology, Elementa Consulting have used the Energy Strategy Calculation spreadsheet, released by the Greater London Authority in October 2018, to calculate carbon emissions with the new representative carbon factors.

Table 8: **Non-residential development I** $CO_2$ emission reductions due to energy demand reduction measures (Be Lean)

| Non-residential development CO2 emissions (Tonnes $CO_2$ per annum) | | |
|---|---|---|
| | Regulated | Unregulated |
| Part L 2013 of the Building Regulations compliant development | 126.82 | 636.88 |
| After energy efficiency measures | 115.84 | |
| Regulated carbon dioxide savings | | |
| | Tonnes $CO_2$ per annum | % Improvement |
| Savings from energy efficiency measures | 10.98 | 8.7% |

Table 9: **Residential I** $CO_2$ emission reductions due to energy demand reduction measures (Be Lean)

| Residential carbon dioxide emissions (Tonnes $CO_2$ per annum) | | |
|---|---|---|
| | Regulated | Unregulated |
| Part L 2013 of the Building Regulations compliant development | 1,226 | N/A |
| After energy efficiency measures | 1,1121 | |
| Regulated carbon dioxide savings | | |
| | Tonnes $CO_2$ per annum | % |
| Savings from energy efficiency measures | 106 | 8.6% |

**Disclaimer:** The results are simulations of energy consumption and do not determine the consumption, emissions or costs of the proposed design after construction. Actual experience will differ from these calculations due to variations such as occupancy, building operation and maintenance, weather, energy use not covered by this standard, changes in carbon intensity of the electricity grid and precision of the calculation tool.

## 3.2   POTENTIAL FABRIC IMPROVEMENTS

The following actions should be considered at the next stage of design to improve the efficiency of the fabric envelope and related energy performance:

- Ensure that all rooms for the non-domestic section of the development will meet the part L2A solar criterion 3 requirements, reducing as required the glazing g-value or the glazing ratios
- Pressure testing for all dwellings
- Minimising heat losses related to thermal bridging, reducing dwelling thermal bridging (e.g. reducing global y-value from 0.1 to 0.07 or lower)
- Reducing windows u-value from 1.4 to 1.3 or lower if economically and technically viable
- Reducing door u-value from 1.6 to 1.4 or lower if economically and technically viable
- Reduce walls u-value adjacent to unheated corridors from 0.2 to 0.18 or lower for dwelling with higher wall area exposed to unheated corridors

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# 4    DISTRICT HEATING & CHP

## 4.1    DISTRICT HEATING NETWORKS

The proximity of existing, planned or potential District Heating networks has been investigated and no networks to derive heat from are available in the area.

A district heat network is currently active within Woking City Centre, but is around 1,500m from the proposed development. Due to the distance a connection to this network is not technically viable.
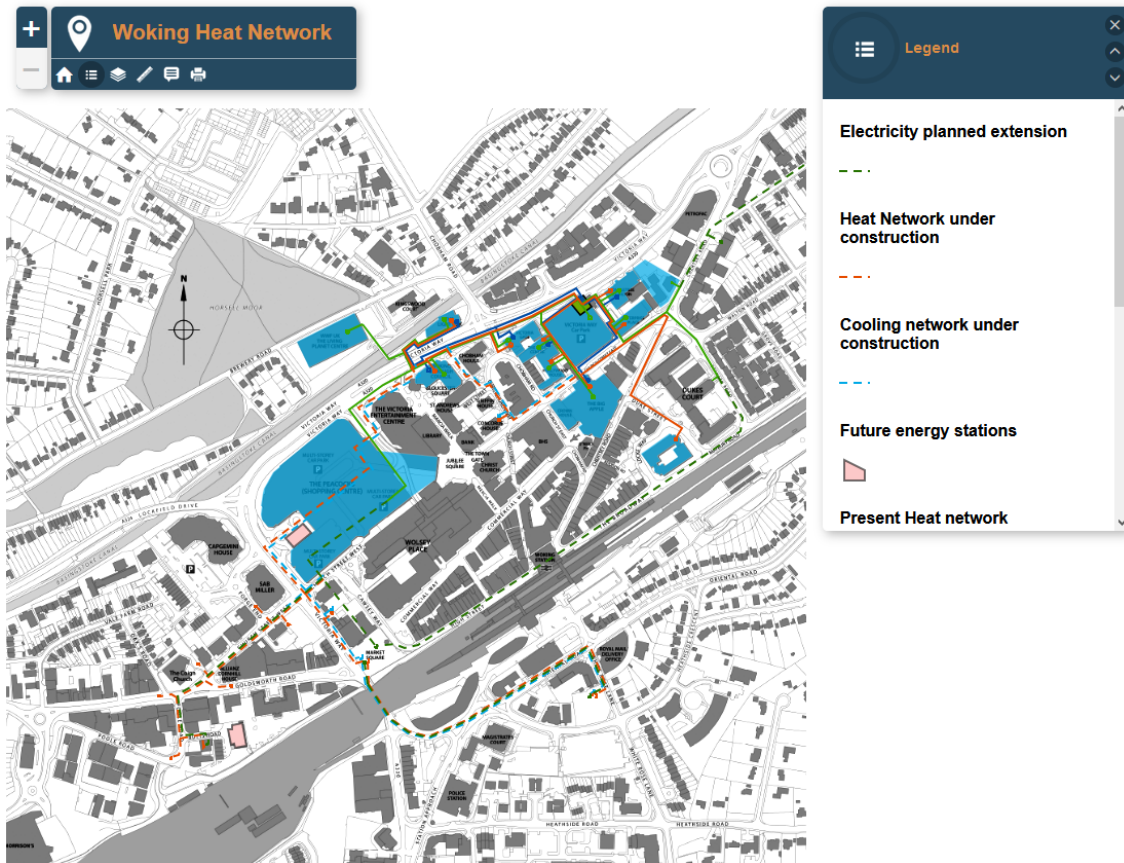


## 4.2    COMBINED HEAT AND POWER (CHP)

The CHP would produce heat with a lower thermal efficiency and higher actual carbon footprint, when compared to an ASHP and its carbon emissions offset, due to electricity production will decrease while the national grid decarbonises, therefore its related carbon emissions will constantly increase.

In addition, a CHP unit will have a detrimental impact on the neighbourhood's environment worsening the air quality of the area. Therefore, the option to use CHP unit to produce heat and power has been excluded.

# 5 RENAWABLE ENERGY

## 5.1 OVERVIEW

Low and Zero Carbon (LZC) technologies that could be used for this development were evaluated.

## 5.2 PHOTOVOLTAICS

The feasibility of Photovoltaics (PV's) has been assessed. PV panels could be potentially be installed on the roof area of the buildings.

Photovoltaics will be considered to further reduce carbon emissions of the development at the next stage of the design as the required carbon emissions saving will be achievable through ASHP technologies alone.

## 5.3 SOLAR THERMAL

Solar thermal technologies generate hot water from the sun's energy through the use of solar collectors. The sun's heat energy is accumulated by the solar cells and then water is pumped through these thus heating the water. The heated water is then stored or distributed for domestic use. These systems tend to be incorporated on to roof space so that they are clear of obstacles (obstructions on the roof can influence the solar array). Demand for domestic hot water from the non-domestic part will be minimal on the weekends, whereas there is a consistent demand for electricity.

Solar thermal will be considered to further reduce carbon emissions of the development at the next stage of the design as the required carbon emissions saving will be achievable through ASHP technologies alone.

## 5.4 GROUND SOURCE HEAT PUMP (GSHP)

Heat pumps use electricity to raise the temperature of water from a heat source, such as the ground, to a suitable level.  Ground source heat pumps extract heat from the heat source via plastic piping (ground loops) containing a mixture of water and antifreeze, which is connected to a pump. Ground loops absorb low-grade heat from the heat source, which is delivered to the heat pump.  Ground loops can either be horizontal pipes in trenches usually approximately 1.8m below ground (a slinky solution), or a series of boreholes, typically 100m to 150m deep. GSHP is not viable due to program and capacity issues.

GSHP will be considered to further reduce carbon emissions of the development at the next stage of the design as the required carbon emissions saving will be achievable through ASHP technologies alone.

## 5.5  AIR SOURCE HEAT PUMP

An air source heat pump (ASHP) works in a similar manner to a ground source heat pump, except the heat source is ambient air rather than the ground. In lieu of ground loops are fan-assisted heat exchangers, located in locations with a free air supply. Air is driven across the heat exchangers, and heat energy extracted.  Like GSHPs, ASHPs can be reversed to provide cooling during summer operation.

ASHP technology is recommended and has been proposed for this site.

The following

Table 10: Mechanical Services 'Energy Efficient' Plant Design Parameters for non-residential development

| Element | Typical Value Proposed for non-residential | Typical Value Proposed for residential |
|---|---|---|
| Air Source heat Pump Efficiency (Space heating) | 315% | 350% for 33% of heat load |
| Air Source heat Pump Efficiency (Domestic Hot Water) | 290% | 350% for 33% of heat load |
| Air Source Heat Pump Efficiency (Cooling SEER/EER) | 475% / 320% | N/A |

## 5.6  BIOMASS HEATING SYSTEM

Biomass is the burning of any plant-derived organic material (such as wood) that renews itself over a short period to generate energy. This fuel type is usually used for heating. Since the $CO_2$ released during the burning process is offset by the $CO_2$ absorbed during the life of the biomass source, biomass is considered to be close to carbon neutral.

Typically, a biomass system will burn wood in either a chip or pellet form instead of the conventional gas system.  Biomass can save large amounts of carbon at a relatively low capital cost.

The combustion of biomass will lead to a degradation of air quality, not appropriate to the location of the development. Furthermore, the delivery and storage of fuel may cause significant issues of access and storage on a constrained site, therefore biomass is deemed not feasible.

## 5.7  WIND TURBINES

Wind turbines convert the kinetic energy of the wind into rotational mechanical energy using an aerodynamic rotor.  This is then converted into electrical energy via a generator. There are two types of wind turbine available, smaller units which are roof mounted or fixed to the building, and larger free-standing turbines.

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Due to the urban nature of the site, wind speeds are relatively low, and the wind is turbulent reducing the efficiency of the turbines. Therefore, it is deemed that wind turbines are not suitable for this development.

## 5.8 LZC CONCLUSIONS

The results of the Low and Zero Carbon (LZC) technologies analysis show PV is the most appropriate low and zero carbon technology that can help targeting the development's carbon reduction targets.

Table 11: LZC Technology Feasibility

| LZC Technology | Technically Feasible | Recommended | Notes |
|---|---|---|---|
| Hydrogen Technology | No | No | Technology not yet economically viable |
| Tri-Generation | No | No | Structural limitations, height issues |
| CHP | Yes | No | No carbon savings due to decarbonisation of UK electricity Grid |
| ASHP | Yes | Yes | Recommended for this site |
| PV | Yes | No | To be considered to further reduce carbon emissions of the development. However, the required carbon emissions savings will be achieved through ASHP technologies |
| GSHP | Yes | No | To be considered to further reduce carbon emissions of the development. However, the required carbon emissions savings will be achieved through ASHP technologies |
| Wind Power | No | No | Not viable due to the urban nature of the development. |
| Solar thermal | Yes | No | To be considered to further reduce carbon emissions of the development. However, the required carbon emissions savings will be achieved through ASHP technologies |
| Biomass | No | No | Biomass heating will negatively impact air quality |

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## 5.9   RENEWABLE ENERGY RESULTS

The following carbon emission figures for the chosen combination of the LZC Technologies have been derived:

Table 12: Non-residential development carbon dioxide emission reductions due to energy efficiency measures and renewables

| Non-residential carbon dioxide emissions (Tonnes $CO_2$ per annum) | | |
|---|---|---|
| | Regulated | Unregulated |
| Part L 2013 of the Building Regulations compliant development | 126.82 | 636.88 |
| After energy efficiency measures | 115.84 | |
| After renewable energy | 101.15 | |
| Regulated carbon dioxide savings | | |
| | Tonnes $CO_2$ per annum | % Improvement |
| Savings from energy efficiency measures | 10.98 | 8.7% |
| Savings from renewable energy | 14.7 | 11.6% |
| Cumulative savings | 25.7 | 20.2% |

Table 13: Residential carbon dioxide emission reductions due to energy efficiency measures and renewables

| Residential carbon dioxide emissions (Tonnes $CO_2$ per annum) | | |
|---|---|---|
| | Regulated | Unregulated |
| Part L 2013 of the Building Regulations compliant development | 1,226 | N/A |
| After energy efficiency measures | 1,121 | |
| After renewable energy | 906 | |
| Regulated carbon dioxide savings | | |
| | Tonnes $CO_2$ per annum | % |
| Savings from energy efficiency measures | 106 | 8.6% |
| Savings from renewable energy | 218 | 17.8% |
| Total Cumulative savings | 324 | 26.4% |

*Calculation methodology from SAP Section 16

**Non- Domestic**
A 4-pipes Air Source heat pumps will provide domestic hot water and space cooling to occupied space heating for the Stadium. The Air Source Heat Pumps will have an efficiency of at least 290% for Domestic Hot Water production, at least 315% (SCOP) for space heating and at least 475% (SEER) for space cooling.

**Domestic**
A communal heating system fed by Gas boilers and Air Source Heat Pumps will provide domestic hot water and space heating for the residential part of development.

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The Air Source Heat Pumps will heat up the water from 35°C-to-45°C with an efficiency of at least 350%, the Gas Boilers will heat up the water from 45°C-to-65°C with an efficiency of at least 92%.

Further improvements to the system will investigated to minimise carbon emissions at next stage of design.

The results documented above demonstrate that through the implementation of passive design, energy efficiency measures, and through the provision of heating through ASHP the $CO_2$ reductions will enable the development to:

- Comply with Part L1A and Part L2A approved documents of Building Regulations
- Achieving an overall 25.8% carbon emissions reduction against the building regulation minimum requirements
- Achieve a 26.4% carbon emissions reduction for the residential section of the development
- Achieve a 20.2% carbon emissions reduction for the non-residential section of the development
- Achieve a 11.6% carbon emissions reduction due to renewable energy for the non-residential section of the development

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# 6 BREEAM UK 2018 CREDITS

## 6.1 ENE 01 – REDUCTION OF ENERGY USE AND CARBON

### 6.1.1 MODELLING ASSUMPTIONS

A whole building energy modelling with a National Calculation Methodology compliant software has been carried out.

See paragraph 3 and 5 for details about modelling inputs for proposed building.

### 6.1.2 RESULTS

The BREEAM 2018 online tool has been used to assess the proposed building performance against credit Ene 01 and it is estimated that 2 credits as an EPRnc of 0.231 could be achievable due to the passive and active measures described in this report.

A screenshot of the BREEAM 2018 Ene01 online calculation tool with generated outputs is provided below:

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**BREEAM UK**   **BREEAM New Construction 2018**   bre

Pre-assessment details    Initial details    Issues    Calculator tool upload    Reports

Pre-assessment details

Initial details

Issues

Management

Health and Wellbeing

►Energy

| Ene 01 | ✅ |
| Ene 02 | ✅ |
| Ene 03 | ✅ |
| Ene 04 | ✅ |
| Ene 05 | ✅ |
| Ene 06 | ✅ |
| Ene 07 | ✅ |
| Ene 08 | ✅ |

Transport

Water

Materials

Waste

Land use and ecology

Pollution

Innovation

Calculator tool upload

Reports

Pre-assessment : Design (Interim): test NC 2018 (test NC 2018)

Energy | Ene 01 Reduction of energy use and carbon emissions

To minimise operational energy demand, primary energy consumption and CO2 emissions.

More information Download calculator

**Credit targets**

Credits targeted

2                                                                                                      ⌄

Exemplary credits targeted

0                                                                                                      ⌄

**Assessment criteria**

Country

England                                                                                                ⌄

**Energy Production by Technology**

Photovoltaic systems (Actual)

| 0 | kWh/m² |

Photovoltaic systems (Notional)

| 0 | kWh/m² |

Wind turbines (Actual)

| 0 | kWh/m² |

Wind turbines (Notional)

| 0 | kWh/m² |

CHP generators (Actual)

| 0 | kWh/m² |

CHP generators (Notional)

| 0 | kWh/m² |

Solar thermal systems (Actual)

| 0 | kWh/m² |

Solar thermal systems (Notional)

| 0 | kWh/m² |

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## Energy & $CO_2$ Emissions Summary

**Actual building energy demand**

| 114.93 | MJ/m² yr |

**Notional building energy demand**

| 137.97 | MJ/m² yr |

**Actual building primary energy consumption**

| 261.07 | kWh/m² yr |

**Notional building primary energy consumption**

| 278.42 | kWh/m² yr |

**Actual building $CO_2$-eq emissions (BER)**

| 33.4 | KgCO₂-eq/m² yr |

**Notional building $CO_2$-eq emissions (TER)**

| 35.5 | KgCO₂-eq/m² yr |

## Building Score

**Total BREEAM credits achieved**

| 2.0 |

**Heating and cooling demand energy performance ratio (EPRdem)**

| 0.139 |

**Primary consumption energy performance ratio (EPRpc)**

| 0.046 |

**$CO_2$-eq energy performance ratio (EPRco2-eq)**

| 0.047 |

**Overall building energy performance ratio (EPRnc)**

| 0.231 |

**% improvement BER/TER**

| 5.9 | % |

Calculate score    Clear

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**Assessment criteria (exemplary credits)**

Maximum credits achieved in Ene 02 Energy monitoring?

> No ⌄

The client or building occupier commits funds to pay for the post-occupancy stage?

> Yes ⌄

The energy model is submitted to BRE and retained by the building owner?

> Yes ⌄

**Credits awarded**

Credits available : 13

Credits awarded : 2

## Exemplary credits

Exemplary credits available : 5

Exemplary credits awarded : 0

## Minimum Standard

Minimum Standard Achieved : Very Good

# 7 CONCLUSIONS

The measures listed in this report will ensure the proposed development to:

- Comply with part L1A and Part L2A approved documents of Building Regulations
- Achieve an overall 25.8% carbon emissions reduction against the building regulation minimum requirements
- Achieve a 26.4% carbon emissions reduction for the residential section of the development
- Achieve a 20.2% carbon emissions reduction for the non-residential section of the development
- Achieve a 11.6% carbon emissions reduction due to renewable energy for the non-residential section of the development
- Achieve BREEAM Very Good rating for the non-residential section of the development
- Achieve a minimum of 2 Ene 01 credits against BREEAM NC 2018 rating system for the non-residential section of the development

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# 8   APPENDICES

## 8.1   APPENDIX A – THERMAL MODELLING METHODOLOGY

### INTRODUCTION

A dynamic simulation of the non-domestic buildings was carried out using thermal modelling software (IES VE version 2019.0.1.0 and VE Compliance 7.0.12.0), with the building assessed as stipulated within the NCM Modelling Guide 2013.

SAP modelling of typical dwelling units – chosen among the most representative of the whole residential development - was carried out using JPA Designer 6.04a1 Build 026 approved software.

Appendix A has been provided to supplement this report in respect of the reduction of energy usage and carbon emissions through the use of passive design, energy efficiency measures and renewable energy measures, in line with methodology detailed within the London Plan.

For information, please find details relating to the accredited energy assessor and the dynamic simulation software utilised to generate this report:

| | | |
|---|---|---|
| Dynamic Simulation Software | - | IES Version 2019.0.1.0 |
| Energy Assessor | - | Adeel Ahmed of Elementa Consulting Ltd. |
| Energy Assessors Accreditation Body | - | CIBSE |
| Energy Assessors Accreditation Number | - | LCEA125791 |
| Energy Assessor Status | - | Level 3, Level 4 and Level 5 EPC and DEC |
| Energy Assessor Qualifications | - | BEng, MSc, CIBSE Low Carbon Consultant |

### METHODOLOGY

IES Virtual Environment software, provided by Integrated Environmental Solutions (IES) version 2019.0.1.0 has been used and is accredited for use in demonstrating compliance with Building Regulations L2A, and the production of Energy Performance Certificates in accordance with the National Calculation Method (NCM).  This software is accredited for level 3 to 5 assessments. The complexity of this project requires the use of Level 5.

The process of producing the thermal model and generating the required output is summarised below:

### BUILDING GEOMETRY

A three-dimensional computer model of the building is 'constructed' to represent the building geometry.  IES is able to represent complex room shapes, external shading features and shading from other buildings, correct orientation and geographical placement etc. It was used for the overheating strategy and for the non-domestic part of the development.

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*Non-Residential development*
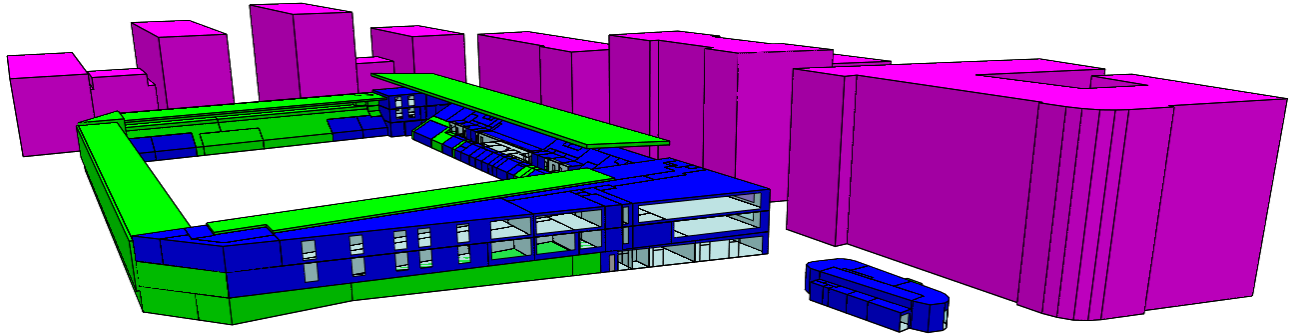


*Residential modelled typologies (exported into JPA Designer software for SAP calculations)*
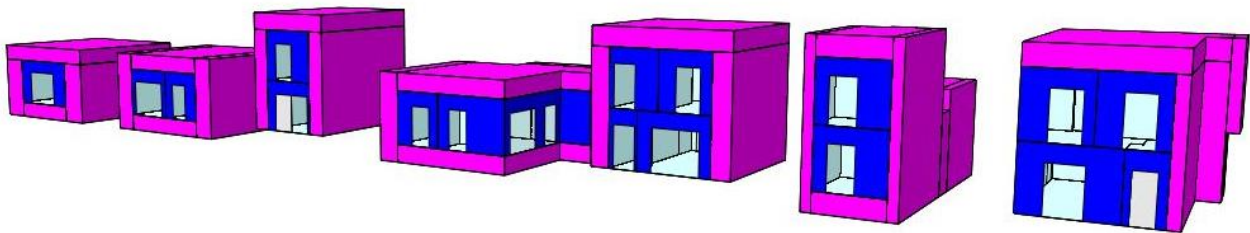


## CONSTRUCTION ELEMENTS

Thermal elements are defined in IES and are specified by inputting each layer of the construction as an element. IES is able to take account of thermal mass of buildings and calculates heating and cooling demands accordingly.

## NCM TEMPLATES (NON-RESIDENTIAL)

Each space defined within the model has an associated internal template. The space is firstly defined by type (e.g. occupied and heated, unoccupied and unheated, buffer space (e.g. an unheated garage), etc.). Occupied spaces are then assigned NCM templates which have the following fixed parameters:

- Patterns of heat gain from lighting, occupancy and other sources such as small power
- Heating, cooling and humidity control settings
- Domestic hot water usage rate
- Ventilation rate
- Lighting level

Lighting levels are inputted per zone, and lighting efficacy is input as luminaire lumens per circuit-watt in order for improvements in lighting efficacy to be taken into account. Controls such as PIRs and daylight compensation can also be taken into account.

## SYSTEM DESCRIPTION

- The user then specifies building specific data for the systems such as:
- Extent of servicing (heating only, heating with mechanical ventilation, etc.)
- The system efficiencies associated with the anticipated installations of heating, cooling and domestic hot water
- Controls for heating, cooling and domestic hot water
- Specific fan power and heat recovery efficiency of mechanical ventilation where appropriate

## OTHER INPUTS

IES requires other building data to be input, which includes:

- Air permeability. This relates to how well sealed the building is and is expressed in m3/m2/hour@50Pa
- The appropriate NCM weather data file. The nearest weather data file must be used and is known as the Test Reference Year (TRY). It contains data relating to a "typical" weather year for that location.
- Details of whether metering, sub-metering and out-of-range monitoring and alarms are to be installed
- Whether power factor correction is to be installed within the building.

## ACTUAL AND NOTIONAL / TARGET BUILDING MODELS

The user inputs all the above information into the model to produce the "actual" building model. From this, IES creates the notional/target building model which will be used to benchmark the actual building against. The building emission rate (BER) from the actual building must be lower than that of the target emission rate (TER) from the notional/target building, in order to satisfy Criterion 1 of Part L2A of the Building Regulations.

The notional/target building is the same size and shape as the actual building and contains the same rooms and servicing strategies (i.e. where rooms are "heated only" in the actual building, they are "heated only" in the notional/target building). User input parameters such as system efficiencies and controls, constructions, glazing parameters, air infiltration rates, etc. are set to standard defaults in order to calculate the TER.

## 8.2 APPENDIX B - LZC TECHNOLOGIES OVERVIEW

Appendix C provides an overview of the various low and zero carbon technologies that are currently available.

### GROUND SOURCE HEAT PUMPS (GSHP)

Heat pumps use electricity to raise the temperature of water from a heat source, such as the ground, to a suitable level.  Ground source heat pumps extract heat from the heat source via plastic piping (ground loops) containing a mixture of water and antifreeze, which is connected to a pump. Ground loops absorb low-grade heat from the heat source, which is delivered to the heat pump.  Ground loops can either be horizontal pipes in trenches usually approximately 1.8m below ground (a slinky solution), or a series of boreholes, typically 100m to 150m deep.  In both cases, the exact ground loop design depends on the soil/geological conditions and required plant duty.

This heat can then be utilised to heat the building.   A heat pump operates more efficiently with a higher heat source temperature. The ground is typically 10°C at 1 metre below the surface throughout the year, and so during the heating season acts as a better source of heat than air, where the heat source temperature in winter can drop to/below freezing.

The heating cycle can be reversed in summer to provide cooling via a low grade heat sink. Using GSHP's in this way is generally recommended in order to replenish the grounds heat store

GSHP systems can provide heat or coolth to either a wet secondary side (e.g. LTHW heating or chilled water circuit), or to a refrigerant based secondary side (i.e. a refrigerant-based VRF system, serving fan coil units).

For a GSHP serving an LTHW heating system, it is best utilised in conjunction with underfloor heating (UFH) coils, due to the relatively low temperatures that UFH systems operate at, therefore improving system efficiency.

The extraction of heat from the heat source requires electrical energy to drive the compressor and pumps of the GSHP equipment.  The ratio of electrical energy supplied to the heat energy delivered is known as the Coefficient of Performance (COP).  The seasonal COP of a GSHP system is dependent on a number of factors, but is generally in the region of 4.5.

A GSHP system can be designed to supply space heating only, or it can be designed to supply the space heating and to generate domestic hot water.

In the case of the domestic hot water generation, a GSHP system will only be able to provide a pre-heat to a conventional gas boiler system.  The COP of the GSHP drops below an acceptable level if temperatures of over 45ºC are required, thus it can heat the hot water to 45ºC but above this temperature it is more efficient to utilise gas.

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GSHP systems need to be sized carefully to work within the constraints of the site.

GSHP systems represent an unobtrusive technology, with no active external plant required. It should be noted that there is little noise associated with GSHP's systems, with the only source being from the heat pumps compressor, which can be minimised by taking appropriate attenuation measures (i.e. locating the plant within an indoor plantroom, on anti-vibration mountings).

GSHP installations are classified as a qualifying technology under the RHI scheme, which is a potential source of funding.

## AIR SOURCE HEAT PUMPS (ASHP)

An air source heat pump works in a similar manner to a ground source heat pump, except the heat source is ambient air rather than the ground. In lieu of ground loops are fan-assisted heat exchangers, located in locations with a free air supply. Air is driven across the heat exchangers, and heat energy extracted. Like GSHP's, ASHP's can be reversed to provide cooling during summer operation.

ASHP have a significant advantage over GSHP in that no ground loop is required. This leads to reduced capital costs and the "peace of mind" that no equipment is buried. It also removes the risk of unknown ground conditions at the time of design and installation. However, the performance of GSHP's is now well understood, whereas the performance of ASHP, particularly for large installations, is less certain.

The coefficient of performance (COP) of GSHP and ASHP systems is critical to the success of the installation. The COP is reduced as the difference between external temperature and delivered heat temperature increases. Therefore, during the coldest parts of the year, the efficiency of the ASHP will drop as air temperature falls.

In comparison, the COP of a GSHP will only fall slightly because the ground temperature remains more or less constant. In addition to this, the external heat exchangers will, during winter, frequently reduce the air temperature to sub-zero. This causes condensation in the air stream which freezes on to the heat exchanger; unless this is removed the system will cease to operate.

The solution to this is to pass heat back into the heat exchanger. This use of energy further reduces the ASHP COP. The extent of the effect of this problem will differ from situation to situation; the commonly quoted COP figure provided by manufacturers of ASHP equipment is generally approximately 3.5. However, with the provision of high efficiency plant, higher COP's are achievable.

The compressor/s and fan/s located within the external unit/s of an ASHP system generate some noise, so the location of the external plant compound therefore needs to be carefully considered during the early design stages, to ensure that the noise emitted does not create any issues. If necessary, attenuation measures can be applied to the external units, to ensure noise levels are kept at an acceptable level.

ASHP installations do not currently qualify for potential funding under the RHI. However, 'Enhanced Capital Allowances' can be claimed for air to air (e.g. variable refrigerant flow systems) and air to water systems. In order to qualify for ECA's, the ASHP plant needs to be present on the 'Energy Technology List'. This will enable the Client to claim 100% of first year capital gain allowances on their spending on qualifying plant and/or machinery.

## WIND TURBINES

Wind turbines convert the kinetic energy of the wind into rotational mechanical energy using an aerodynamic rotor. This is then converted into electrical energy via a generator. The UK is the windiest country in Europe, and therefore wind power is one of the UK's most promising technologies.

There are two types of wind turbine available, smaller units which are roof mounted or fixed to the building, and larger free-standing turbines.

The roof mounted units are limited in size due to wind induced stresses which are transmitted to the building structure. Most roof mounted turbines currently on the market are approximately 2m diameter and are capable of producing 1-1.5kW each and produce significant levels of noise locally. However, electrical output is dependent on the surrounding obstructions and local wind speed (wind turbines work best with laminar wind flows). In developed urban areas, outputs can be greatly reduced. Small scale wind turbines would not make any meaningful impact on a site such as this.

Large free-standing turbines are capable of producing hundreds of kilowatts of electrical energy which makes them a more attractive proposition in terms of energy generation. However, there are problems with noise, obtrusiveness and shadow flicker which means that generally large wind turbines need to be located at least 300m from any residential properties.

## PHOTOVOLTAIC (PV) SYSTEM

Photovoltaic cells, or solar cells as they are often referred to, are silicon semi-conductor devices that convert light energy emitted by the sun into direct current (DC) electricity.

Groups of PV cells are electrically configured into modules and arrays which form the building block of solar arrays. With the use of appropriate power conversion equipment (inverters), PV systems convert the generated DC current into alternating current (AC) compatible with conventional operating appliances and operate in parallel with the utility grid.

PV systems require only daylight to generate electricity (although more is produced with more sunlight); therefore, energy can be produced in overcast or cloudy conditions and are successfully utilised in all parts of the UK.

Arrays would normally be formed of panels mounted on the roof, and preferable face between South-East and South-West at an elevation of 20° to 40° to horizontal for maximum efficiency.

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PV's require minimal maintenance during the period of their life, normally estimated at 25 years, and carbon emissions associated with PV are considered to be zero.

From a noise perspective, PV's produce virtually no noise at all (only negligible sound from the inverter fan/s), and if roof-mounted require no additional land take.

Photovoltaics have traditionally represented a relatively expensive form of renewable technology, although installed costs have reduced significantly over the last couple of years.

## SOLAR THERMAL

Solar thermal technologies generate hot water from the sun's energy through the use of solar collectors. The sun's heat energy is accumulated by the solar cells and then water is pumped through these thus heating the water. The heated water is then stored or distributed for domestic use. These systems tend to be incorporated on to roof space so that they are clear of obstacles (obstructions on the roof can have an effect on the solar cell array). As with photovoltaic panels, the solar collectors are more effective if they are in a south-facing position.

There are two main types of solar thermal system; flat panel and thermal vacuum (evacuated) tubes. Flat panels consist of a flat "radiator" absorber, covered by glass and insulated. Their efficiency depends on the insulation properties and type of construction. More expensive double-glazed units have a better efficiency, so that a smaller area of solar thermal panels is required; a compromise would need to be made between efficiency and cost. Solar thermal panels are especially worth considering for new buildings, since they can be effectively built into roof structures during the construction stage.

Thermal vacuum tubes are a more recently developed technology designed for obtaining heat from the sun. These have been developed over the last thirty years into units that are now up to 90% efficient. Water is passed through an evacuated tube, which contains a black absorber plate. Vacuum tubes are more efficient and therefore a smaller area of collector is required. Solar vacuum tubes are capable of operating at higher working temperatures than flat plate collectors. Thermal losses for vacuum tubes also tend to be lower than those of flat plate collectors due to improved heat insulation. The vacuum provides insulation, and this allows the water to be heated to higher temperatures, and remain very effective even on cloudy days.

In the UK, solar thermal is most effective during the summer months, when space heating is not normally required, hence solar thermal systems are normally utilised to provide a heating source for domestic hot water.

From a noise perspective, solar thermal systems produce virtually no noise at all (only negligible sound from the associated water circulation pump), and if roof-mounted require no additional land take.

Solar thermal installations are classified as a qualifying technology under the RHI scheme, which is a potential source of funding.

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## BIOFUEL

Biomass is the burning of any plant-derived organic material (such as wood) that renews itself over a short period to generate energy. This fuel type is usually used for heating.

Since the $CO_2$ released during the burning process is offset by the $CO_2$ absorbed during the life of the biomass source, biomass is considered to be close to carbon neutral.

Typically, a biomass system will burn wood in either a chip or pellet form instead of the conventional gas system. Biomass can save large amounts of carbon at a relatively low capital cost.

Non-domestic biomass boilers mainly use either wood pellet or wood chip burners. Wood pellets are comprised of wood chips and sawdust that are compacted into smaller volumes.

This means that they have lower moisture content and they can be produced in a consistent size. However, wood pellet fuel is more expensive costing around 4.5p/kWh (price varies with required load). Wood chips are a cheaper source of fuel costing around 2.5p/kWh (price varies with required load).

Biomass boilers tend to be larger and more expensive than their gas equivalents. This is due to the higher temperatures required for efficient combustion which requires a larger fire box. Fuel storage and handling is less simple than for conventional oil or gas fuels. Fuel is typically delivered by truck and is generally stored in a bunker adjacent to the boiler room, or a silo within the respective boiler room. This has implications for delivery as lorries need to be able to draw up alongside the store to deliver the fuel. If fuel delivery from a reliable source within a reasonable distance of the site can be achieved and the logistics surrounding lorry deliveries can be overcome, then this can be a viable option to serve a proportion of the heating and hot water requirements of the site.

It is worth noting that in common with other types of combustion appliances, biomass boilers are potentially a source of air pollution. Pollutants associated with biomass combustion include particulate matter ($PM_{10}/PM_{2.5}$) and nitrogen oxides (NOx) emissions. These pollution emissions can have an impact on local air quality and affect human health.

The operation of a biomass boiler and its associated ancillary plant (e.g. fuel supply system) will generate noise, which will need to be carefully considered throughout all stages of the design process. Effective management of delivery schedules will help to minimise any potential noise issues associated with fuel supply.

The land take of a biomass boiler will be more than that of a comparable floor-mounted boiler providing a similar thermal duty. Additional space will also be required for the associated fuel storage and fuel distribution requirements.

Biomass installations are classified as a qualifying technology under the RHI scheme, which is a potential source of funding.

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## 8.3    APPENDIX C – SAP MODELLING METHODOLOGY

The following 8 typologies and additional variations have been modelled for a total of 58 units. A weighted average (based on area) TER and DER (for Be Lean and BE Green) has been calculated for each typology and projected for the whole development based on each typology dwellings total area within the development. The total carbon emissions have been derived based on the above methodology.
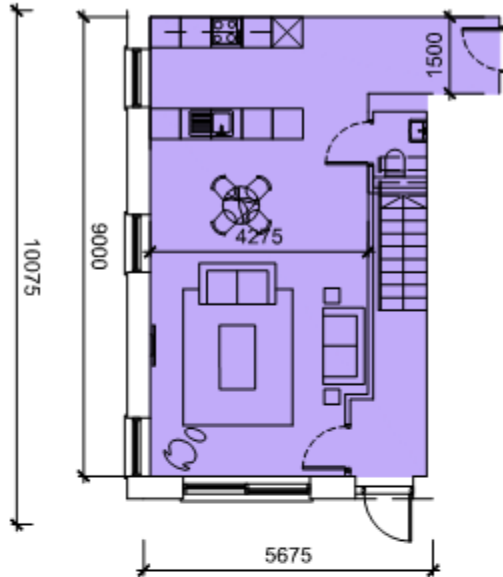


3 BED TOWNHOUSE - LOWER FLOOR PLAN



3 BED TOWNHOUSE - UPPER FLOOR PLAN



2 BED TOWNHOUSE - LOWER FLOOR PLAN



2 BED TOWNHOUSE - UPPER FLOOR PLAN

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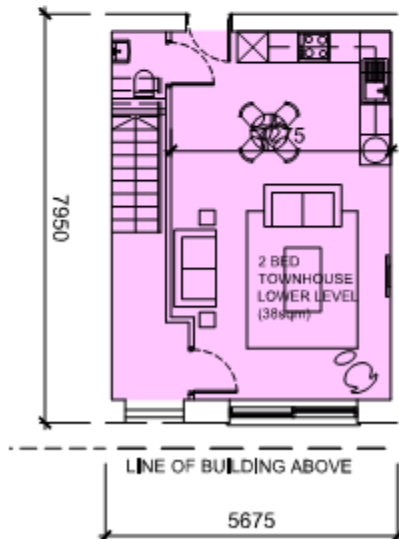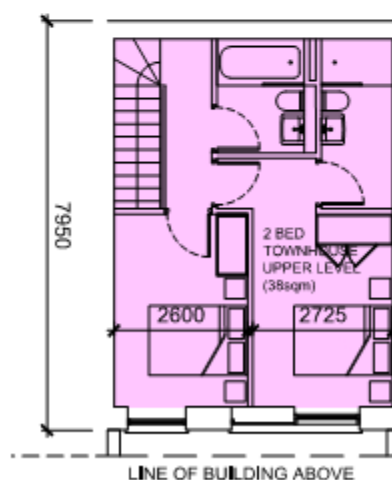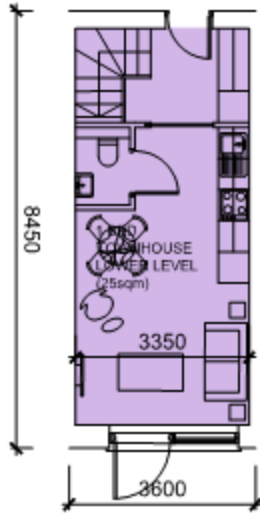
**1 BED TOWNHOUSE – LOWER FLOOR PLAN**
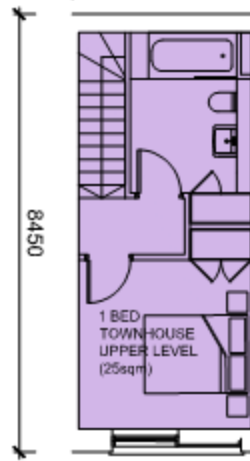
**1 BED TOWNHOUSE – UPPER FLOOR PLAN**
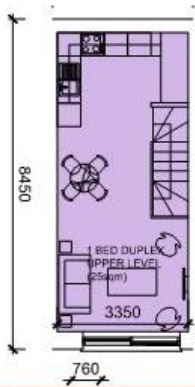
**1 BED DUPLEX – UPPER FLOOR PLAN**

**1 BED DUPLEX – LOWER FLOOR PLAN**

**2 BED DUPLEX – LOWER FLOOR PLAN**

**2 BED DUPLEX – MIDDLE FLOOR PLAN**

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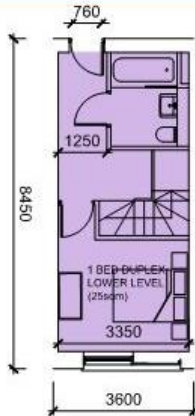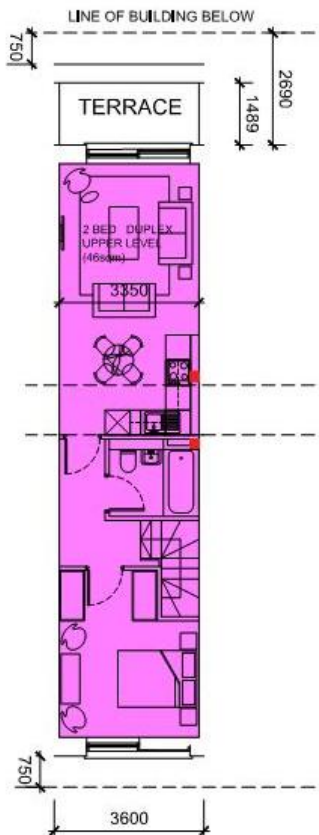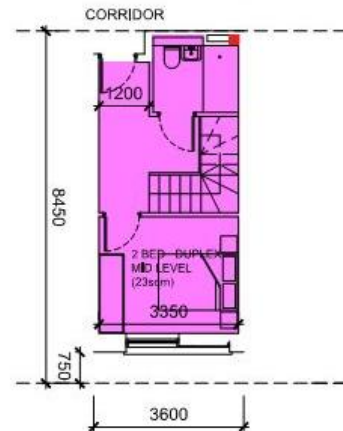Member of Integral Group

2 BED APARTMENT



STUDIO APARTMENT



1 BED APARTMENT

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The spreadsheet including the calculations methodology is attached below for reference:

| NAME | % of total | Area | Be Lean | | | | | | Be Green | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | SAP 2012 | | | SAP 10 | | | SAP 2012 | | SAP 10 | |
| | | | TER | DER | % | TER | DER | % | DER | % | DER | % |
| UNIT 1 | 9.0% | | 20.44 | 18.86 | -7.7% | 17.92 | 16.07 | -10.4% | 17.43 | -14.7% | 13.09 | -27.0% |
| STUDIO_E_MF | 2.2% | 37.62 | 20.23 | 18.59 | -8.1% | 17.7 | 15.80 | -10.7% | 17.17 | -15.1% | 12.90 | -27.1% |
| STUDIO_W_MF | 2.1% | 37.62 | 20.23 | 18.59 | -8.1% | 17.7 | 15.80 | -10.7% | 17.17 | -15.1% | 12.90 | -27.1% |
| STUDIO_N_MF | 2.1% | 37.62 | 20.9 | 18.91 | -9.5% | 18.4 | 16.10 | -12.5% | 17.47 | -16.4% | 13.10 | -28.8% |
| STUDIO_S_MF | 1.7% | 37.62 | 19.27 | 18.13 | -5.9% | 16.8 | 15.40 | -8.3% | 16.74 | -13.1% | 12.50 | -25.6% |
| STUDIO_E_GF | 0.1% | 37.62 | 22.54 | 21.30 | -5.5% | 20 | 18.40 | -8.0% | 19.74 | -12.4% | 15.00 | -25.0% |
| STUDIO_W_GF | 0.1% | 37.62 | 22.54 | 21.30 | -5.5% | 20 | 18.40 | -8.0% | 19.74 | -12.4% | 15.00 | -25.0% |
| STUDIO_E_TF | 0.1% | 37.62 | 22.54 | 21.30 | -5.5% | 20 | 18.40 | -8.0% | 19.74 | -12.4% | 15.00 | -25.0% |
| STUDIO_W_TF | 0.4% | 37.62 | 22.54 | 21.30 | -5.5% | 20 | 18.40 | -8.0% | 19.74 | -12.4% | 15.00 | -25.0% |
| STUDIO_N_TF | 0.1% | 37.62 | 23.3 | 21.70 | -6.9% | 20.7 | 18.80 | -9.2% | 20.10 | -13.7% | 15.30 | -26.1% |
| STUDIO_S_TF | 0.1% | 37.62 | 21.5 | 20.75 | -3.5% | 19 | 17.90 | -5.8% | 19.24 | -10.5% | 14.60 | -23.2% |
| UNIT 2 | 23.7% | | 18.65 | 17.39 | -6.8% | 16.41 | 14.77 | -10.0% | 16.11 | -13.6% | 12.04 | -26.6% |
| 1BEDA_W_MF | 6.6% | 47.32 | 18.51 | 17.10 | -7.6% | 16.3 | 14.50 | -11.0% | 15.84 | -14.4% | 11.80 | -27.6% |
| 1BEDA_E_MF | 5.2% | 47.32 | 18.51 | 17.10 | -7.6% | 16.3 | 14.50 | -11.0% | 15.84 | -14.4% | 11.80 | -27.6% |
| 1BEDA_N_MF | 3.4% | 47.32 | 19.33 | 17.51 | -9.4% | 17.1 | 14.90 | -12.9% | 16.22 | -16.1% | 12.10 | -29.2% |
| 1BEDA_S_MF | 5.2% | 47.32 | 17.36 | 16.53 | -4.8% | 15.1 | 13.90 | -7.9% | 15.31 | -11.8% | 11.40 | -24.5% |
| 1BEDA_W_GF | 0.4% | 47.32 | 20.85 | 19.87 | -4.7% | 18.5 | 17.20 | -7.0% | 18.44 | -11.6% | 14.00 | -24.3% |
| 1BEDA_E_GF | 0.4% | 47.32 | 20.85 | 19.87 | -4.7% | 18.5 | 17.20 | -7.0% | 18.44 | -11.6% | 14.00 | -24.3% |
| 1BEDA_N_GF | 0.1% | 47.32 | 21.76 | 20.36 | -6.4% | 19.4 | 17.60 | -9.3% | 18.89 | -13.2% | 14.40 | -25.8% |
| 1BEDA_S_GF | 0.7% | 47.32 | 19.61 | 19.20 | -2.1% | 17.3 | 16.50 | -4.6% | 17.84 | -9.0% | 13.50 | -22.0% |
| 1BEDA_W_TF | 0.7% | 47.32 | 20.85 | 19.87 | -4.7% | 18.5 | 17.20 | -7.0% | 18.44 | -11.6% | 14.00 | -24.3% |
| 1BEDA_E_TF | 0.5% | 47.32 | 20.85 | 19.87 | -4.7% | 18.5 | 17.20 | -7.0% | 18.44 | -11.6% | 14.00 | -24.3% |
| 1BEDA_N_TF | 0.1% | 47.32 | 21.76 | 20.36 | -6.4% | 19.4 | 17.60 | -9.3% | 18.89 | -13.2% | 14.40 | -25.8% |
| 1BEDA_S_TF | 0.4% | 47.32 | 19.61 | 19.20 | -2.1% | 17.3 | 16.50 | -4.6% | 17.84 | -9.0% | 13.50 | -22.0% |
| UNIT 3 | 8.1% | | 19.08 | 19.32 | 1.3% | 16.72 | 16.47 | -1.5% | 16.88 | -11.5% | 12.54 | -25.0% |
| 1BEDTH_W_GF | 2.0% | 51.56 | 19.48 | 19.79 | 1.6% | 17.10 | 16.90 | -1.2% | 17.30 | -11.2% | 12.90 | -24.6% |
| 1BEDTH_E_GF | 1.4% | 51.56 | 19.48 | 19.79 | 1.6% | 17.10 | 16.90 | -1.2% | 17.30 | -11.2% | 12.90 | -24.6% |
| 1BEDTH_N_GF | 0.9% | 51.56 | 20.09 | 20.14 | 0.2% | 17.70 | 17.30 | -2.3% | 17.50 | -12.9% | 13.10 | -26.0% |
| 1BEDTH_S_GF | 1.4% | 51.56 | 18.66 | 19.32 | 3.5% | 16.30 | 16.50 | 1.2% | 16.90 | -9.4% | 12.50 | -23.3% |
| 1BEDTH_W_MF | 1.1% | 51.56 | 18.32 | 18.31 | -0.1% | 16.00 | 15.50 | -3.1% | 16.00 | -12.7% | 11.80 | -26.3% |
| 1BEDTH_E_MF | 1.1% | 51.56 | 18.32 | 18.31 | -0.1% | 16.00 | 15.50 | -3.1% | 16.00 | -12.7% | 11.80 | -26.3% |
| 1BEDTH_N_MF | 0.2% | 51.56 | 18.90 | 18.62 | -1.5% | 16.50 | 15.80 | -4.2% | 16.30 | -13.8% | 12.00 | -27.3% |
| UNIT 4 | 13.9% | | 17.87 | 16.83 | -5.8% | 15.85 | 14.14 | -10.8% | 15.65 | -12.4% | 11.54 | -27.2% |
| 2BEDA_E_MF | 11.7% | 62.51 | 18.32 | 17.29 | -5.6% | 16.30 | 14.60 | -10.4% | 16.10 | -12.1% | 11.90 | -27.0% |
| 2BEDA_W_MF | 8.1% | 62.51 | 16.58 | 15.18 | -8.4% | 14.60 | 12.50 | -14.4% | 14.10 | -15.0% | 10.20 | -30.1% |
| 2BEDA_N_MF | 2.5% | 62.51 | 17.94 | 16.71 | -6.9% | 15.90 | 14.00 | -11.9% | 15.50 | -13.6% | 11.50 | -27.7% |
| 2BEDA_S_MF | 6.0% | 62.51 | 17.11 | 16.02 | -6.4% | 15.10 | 13.40 | -11.3% | 14.90 | -12.9% | 10.90 | -27.8% |
| 2BEDA_E_GF | 0.4% | 62.51 | 20.58 | 20.32 | -1.3% | 18.50 | 17.50 | -5.4% | 18.90 | -8.2% | 14.30 | -22.7% |
| 2BEDA_W_GF | 0.4% | 62.51 | 18.73 | 18.15 | -3.1% | 16.70 | 15.40 | -7.8% | 16.90 | -9.8% | 12.60 | -24.6% |
| 2BEDA_N_GF | 0.2% | 62.51 | 20.17 | 19.71 | -2.3% | 18.10 | 16.90 | -6.6% | 18.30 | -9.3% | 13.70 | -24.3% |
| 2BEDA_S_GF | 0.1% | 62.51 | 19.29 | 19.00 | -1.5% | 17.20 | 16.30 | -5.2% | 17.70 | -8.2% | 13.30 | -22.7% |
| 2BEDA_E_TF | 1.4% | 62.51 | 20.58 | 20.32 | -1.3% | 18.50 | 17.50 | -5.4% | 18.90 | -8.2% | 14.30 | -22.7% |
| 2BEDA_S_TF | 1.5% | 62.51 | 19.29 | 19.00 | -1.5% | 17.20 | 16.30 | -5.2% | 17.70 | -8.2% | 13.30 | -22.7% |
| 2BEDA_W_TF | 1.5% | 62.51 | 18.73 | 18.15 | -3.1% | 16.70 | 15.40 | -7.8% | 16.90 | -9.8% | 12.60 | -24.6% |
| UNIT 5 | 11.0% | | 17.17 | 16.41 | -4.4% | 15.19 | 13.77 | -9.3% | 15.29 | -10.9% | 11.26 | -25.8% |
| 2BEDTH_S_GF | 2.8% | 77.22 | 15.95 | 15.80 | -0.9% | 14.00 | 13.10 | -6.4% | 14.70 | -7.8% | 10.70 | -23.6% |
| 2BEDTH_W_GF | 2.8% | 77.22 | 17.27 | 16.21 | -6.1% | 15.30 | 13.80 | -9.8% | 15.30 | -11.4% | 11.30 | -26.1% |
| 2BEDTH_N_GF | 2.5% | 77.22 | 18.23 | 17.03 | -6.6% | 16.20 | 14.30 | -11.7% | 15.80 | -13.3% | 11.70 | -27.8% |
| 2BEDTH_E_GF | 2.6% | 77.22 | 17.27 | 16.51 | -4.4% | 15.30 | 13.80 | -9.8% | 15.30 | -11.4% | 11.30 | -26.1% |
| 2BEDTH_S_GTF | 0.3% | 77.22 | 17.07 | 17.16 | 0.5% | 15.10 | 14.50 | -4.0% | 15.90 | -6.9% | 11.80 | -21.9% |
| 2BEDTH_W_GTF | 0.1% | 77.22 | 18.41 | 17.90 | -2.8% | 16.40 | 15.20 | -7.3% | 16.60 | -9.8% | 12.30 | -25.0% |
| UNIT 6 | 11.7% | | 15.83 | 16.04 | 1.3% | 13.85 | 13.50 | -2.5% | 14.05 | -11.2% | 10.32 | -25.5% |
| 2BEDDUP_W_MF | 3.2% | 69.13 | 15.65 | 15.73 | 0.5% | 13.70 | 13.20 | -3.6% | 13.80 | -11.8% | 10.10 | -26.3% |
| 2BEDDUP_S_MF | 1.6% | 69.13 | 15.41 | 15.60 | 1.2% | 13.40 | 13.10 | -2.2% | 13.70 | -11.1% | 10.00 | -25.4% |
| 2BEDDUP_N_MF | 0.7% | 69.13 | 15.41 | 15.60 | 1.2% | 13.40 | 13.10 | -2.2% | 13.70 | -11.1% | 10.00 | -25.4% |
| 2BEDDUP_E_MF | 2.8% | 69.13 | 15.65 | 15.73 | 0.5% | 13.70 | 13.20 | -3.6% | 13.80 | -11.8% | 10.10 | -26.3% |
| 2BEDDUP_N_GF | 0.9% | 69.13 | 16.94 | 17.58 | 3.8% | 14.90 | 15.00 | 0.7% | 15.30 | -9.7% | 11.50 | -22.8% |
| 2BEDDUP_W_TF | 0.6% | 69.13 | 16.40 | 16.71 | 1.9% | 14.40 | 14.20 | -1.4% | 14.60 | -11.0% | 10.80 | -25.0% |
| 2BEDDUP_N_TF | 0.9% | 69.13 | 16.17 | 16.58 | 2.5% | 14.20 | 14.00 | -1.4% | 14.50 | -10.3% | 10.70 | -24.6% |
| 2BEDDUP_S_TF | 0.9% | 69.13 | 16.17 | 16.58 | 2.5% | 14.20 | 14.00 | -1.4% | 14.50 | -10.3% | 10.70 | -24.6% |
| UNIT 7 | 2.6% | | 16.47 | 16.41 | -0.4% | 14.77 | 13.89 | -6.0% | 15.13 | -8.1% | 11.21 | -24.1% |
| 3BED_S_GF | 1.2% | 103.54 | 15.98 | 16.01 | 0.2% | 14.30 | 13.50 | -5.6% | 14.90 | -6.8% | 11.00 | -23.1% |
| 3BED_N_GF | 0.2% | 103.54 | 17.11 | 16.64 | -2.7% | 15.40 | 14.10 | -8.4% | 15.40 | -10.0% | 11.50 | -25.3% |
| 3BED_W_GF | 0.9% | 103.54 | 17.34 | 16.83 | -2.9% | 15.60 | 14.30 | -8.3% | 15.60 | -10.0% | 11.60 | -25.6% |
| 3BED_E_GF | 0.3% | 103.54 | 15.67 | 16.65 | 6.3% | 14.00 | 14.10 | 0.7% | 14.64 | -6.6% | 10.80 | -22.9% |

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| | % of total | Area | TER BeLean | DER BeLean | DER BeGreen | TER BeLean | DER BeLean | DER BeGreen |
|---|---|---|---|---|---|---|---|---|
| UNIT 1 | 9.0% | 6957 | 20.44 | 18.86 | 17.43 | 17.92 | 16.07 | 13.09 |
| UNIT 2 | 23.7% | 18249 | 18.65 | 17.39 | 16.11 | 16.41 | 14.77 | 12.04 |
| UNIT 3 | 8.1% | 6209 | 19.08 | 19.32 | 16.88 | 16.72 | 16.47 | 12.54 |
| UNIT 4 | 33.9% | 26109 | 17.87 | 16.83 | 15.65 | 15.85 | 14.14 | 11.54 |
| UNIT 5 | 11.0% | 8484 | 17.17 | 16.41 | 15.29 | 15.19 | 13.77 | 11.26 |
| UNIT 6 | 11.7% | 9032 | 15.83 | 16.04 | 14.05 | 13.85 | 13.50 | 10.32 |
| UNIT 7 | 2.6% | 1990 | 16.47 | 16.41 | 15.13 | 14.77 | 13.89 | 11.21 |
| Weighted Average | | | 18.03 | 17.20 | 15.78 | 15.90 | 14.53 | 11.70 |

| SAP 2012 | | | |
|---|---|---|---|
| Total Target Emissions (kgCO2) | Total CO2 Emission Be Lean (kgCO2) | Total CO2 Emission excluding PV (kgCO2) | % reduction |
| 1390664 | 1326390 | 1217205 | -12.47% |
| SAP 10 | | | |
| Total Target Emissions (kgCO2) | Total CO2 Emission Be Lean (kgCO2) | Total CO2 Emission excluding PV (kgCO2) | % reduction |
| 1226712 | 1120712 | 902122 | -26.5% |

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## 8.4    APPENDIX D – SUPPORTING BRUKL AND SAP OUTPUT DOCUMENTS

Appended to this report the following output documents:
- x1 BRUKL output document for non-residential development (Be Lean)
- x1 BRUKL output document for non-residential development (Be Green)
- x39 SAP output documents for residential development (Be Lean)
- x39 SAP output documents for residential development (Be Green)

## DEEP GREEN ENGINEERING

Elementa

80 Cheapside
London
EC2V 6EE
T $^+$44(0)203 697 9300

–

99 Park Drive
Milton Park
Oxfordshire
OX14 4RY

T $^+$44(0)1235 820300

–

Contact
Marco Treglia
marco.treglia@elementaconsulting.com

Rob Harris
rob.harris@elementaconsulting.com.com

London, UK
Oxford, UK
San Francisco, CA
Oakland, CA
San Jose, CA
Los Angeles, CA
Seattle, WA
Washington, DC
Richmond, VA
Austin, TX
Atlanta, GA
Vancouver, BC
Calgary, AB
Toronto, ON
Kelowna, BC
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