BUILDING SIMULATION REPORT FOR GUILDFORD BOROUGH COUNCIL

A Mixed Use Scheme – Retail Unit(s)

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1. INTRODUCTION

This building simulation report summarises the findings of five simulations on two building energy models of a ‘warehouse style’ retail unit forming part of a scheme of similar units typical throughout the UK. These models are based on an adapted proposed development by a major retail developer that EVORA EDGE has worked on behalf of on a different project.

The simulations study the performance of two different but common building services solutions for mechanically ventilated retail premises, which we refer to throughout this report as System 1 and System 2. In both building models the building fabric, lighting and domestic hot water are the same. However, the heating, ventilation and air conditioning (HVAC) strategy varies in each building. Low and Zero Carbon (LZC) technologies are incorporated to augment or replace conventional non-LZC technologies.

The modelled simulations calculate a building’s Built Emission Rate (BER) as a result of the energy it is predicted to consume. Templates around occupancy and occupational parameters, such as hours of operation and temperature set points, are provided in a National Calculation Method (NCM) which was developed by the Building Research Establishment (BRE) for government. To comply with Part L2A *Conservation of fuel and power in buildings other than dwellings* of Building Regulations (Part L2A), a Target Emission Rate (TER) is set and the BER must achieve or better (≤) this target. The TER is based on the performance of the Notional Building which is also defined in the NCM.

In addition to building regulations, the TER is used in planning policy as a benchmark for sustainable development by setting out the maximum level of predicted CO_2 emissions that a building or development is permitted to emit. As part of an extant planning policy, Guildford Borough Council (GBC) requires the BER of a new building to be at least 10% lower than the TER, with any reduction achieved through the use of on-site LZC technologies.

GBC is currently in consultation to increase this target to either 15 or 20% and this document forms part of a series of reports to help determine if these targets are technically feasible, and if so, what the potential effect of revising this policy would be in terms of development costs to property developers.

1.1. The Simulations

Part L2A has five criterion and a requirement for any developer to analyse and take into account the technical, environmental and economic feasibility of using high-efficiency alternative systems in construction, if available[1]. For a building to pass the exacting requirements of Part L2A it must be designed and constructed to a standard that meets or betters the TER of a Notional Building (BER ≤ TER). A building that is constructed to the limiting parameters of Part L2A will fail Criterion 1, which is the Criterion that requires the BER ≤ TER.

Each model simulated is identical in every respect other than its building services, which may or may not include renewable energy systems. To ensure that the model is capable of passing Part L2A the building fabric is based upon the requirements of a Notional Building, and these remain unchanged throughout the various iterations of the model(s). By ensuring that the building construction and fabric remain as a constant, we can calculate a 'base building' construction cost. This in turn allows us to identify where additional expenditure is required to facilitate the CO_2 reduction targets of four benchmarks, detailed below. System 1 starts with the least number of LZC technologies possible for a typical services solution, and as the targets become

[1] These systems are to include decentralised energy supply systems based on energy from renewable sources, cogeneration, district or block heating / cooling, particularly where it is based entirely or partially on energy from renewable sources, and heat pumps.

more challenging, then more efficient conventional systems and/or LZC technologies are incorporated into the model(s) to augment or replace less efficient and/or non LZC technologies.

System 2 on the other hand starts with LZC technologies, for example primary fossil fuel heating is typically replaced with heat pumps. Simulations have been run against four benchmarks, these are:

1) The Building Emission Rate is equal to or lower than the Target Emission Rate (BER≤ TER). This is a requirement of Criterion 1 of Approved Document Part L2A of Building Regulations 2010 (Part L)
2) The BER must be 10% lower than the TER. This is the Extant Policy
3) The BER must be 15% lower than the TER. This is a proposed borough policy which we refer to as Proposed Policy A
4) The BER must be 20% lower than the TER. This is a proposed borough policy which we refer to as Proposed Policy B

1.2. Building Information Model (BIM)

To prepare this report we have used a building information model or BIM using IES engineering software - the Virtual Environment or VE. PDF drawings were provided to EVORA EDGE by GBC on a proposed development scheme in Guildford adapted for this study. These were converted into DWG files and scaled using AutoDesk AutoCad, and then in turn converted to DXF drawings so that they could be imported into the VE. We then imported additional models of commercial buildings from previous projects using gbXML and/or GEM files to create a 'virtual mixed use scheme'. This allowed us to model various types and numbers of buildings using a federated BIM which was shared between two principal energy modellers.

The BER and TER calculations and costs were all undertaken in the same model(s) and these are in turn available as IES Cabinet Files for future use. Nomenclature of itemised costs are based on the RICS New Rules of Measurement *Order of cost estimating and cost planning for capital building works.* A representation of the federated BIM is shown below.

1.3. Report Structure

This report has been arranged into the following sections. An executive summary, a more detailed tabulated section with basic technical information on our energy simulations, a summary of our costing methodology, and an extract from the BIMs showing our cost calculations and cost sources. Methodologies and sources of data have been clearly stated, however, it is important to note project limitations, which are expanded on in the section below.

1.4. Disclaimers

With any building, existing or proposed, there are almost an infinite number of design parameters for architects and engineers to consider including:

- Structure
- Orientation and Massing
- HVAC and Lighting Types
- Combination of HVAC and Fuel Types
- LZC Technologies

Whilst we have considered many scenarios, it is not possible to cover all potential design parameters. The aim of this research is to identify if it is possible to pass four benchmarks using the geometry and construction type of buildings which either already exist, or are proposed as part of a planning application; while assuming common design parameters and HVAC systems which are based upon a Notional Building or best (typical) market practice.

To do this we have looked at a number of building and system types adopting a hierarchical approach to favour the most efficient system(s). Where values or efficiencies are detailed in the Notional Building these are adopted. However where these values are not provided, or where they seem low when assessed against technologies readily available in the market, then these were replaced by values or efficiencies detailed in either Part L2A, or the Energy Technology List (ETL)[2], or other reputable or market sources.

Costs are indicative and for benchmarking purposes only. They exclude VAT and fees associated with design, professional services and project management. They do however include for preliminaries, profit and overheads for the services contractor. Build costs have typically been taken at the median of a range of costs detailed in SPONS 2017 unless indicated otherwise. Greater detail and information on our costing methodology has been provided in Section 4.7 of this report.

[2] The ETL (or Energy Technology Product List, ETPL) is a government-managed list of energy-efficient plant and machinery, such as boilers, electric motors, and air conditioning and refrigeration systems that qualify for full tax relief.

2. EXECUTIVE SUMMARY

Our findings over the following pages are summarised in the form of two schematics, one for each type of HVAC system including; a variable air volume system and a variable refrigerant flow or volume system. Each schematic shows the effect of each iterative simulation on the BER in order to meet or better a benchmark, the financial cost to the developer for each metre square (m^2) of building space to achieve this. Finally the schematic shows, expressed as a percentage increase, the cost of improving a building from Part L2A and the Extant Policy to a building that can comply with Proposed Policy B – the most stringent of the proposed policies, and Proposed Policy A.

2.1 System 1: Results

System 1 comprises a variable air volume (VAV) system. A VAV system supplies heated or cooled air at a constant temperature and regulates air supply by volume based on temperature demand. In an office, VAV heating is often replaced or augmented by perimeter heating through a low temperature hot water circuit (LTHW), but in a retail environment we have replaced LTHW with an electric air curtain. Photovoltaics (PV) is required in all cases to pass the relevant benchmark – increasing in capacity as the benchmarks becomes tougher. The results of the case studies are as follows:

- The cost of Proposed Policy B is up to 4.33% more expensive than constructing a building that complies with Criterion 1 of Part L2A.
- The difference in cost between Extant Policy construction costs and Policy B construction costs is up to 2.32%.
- The cost of Proposed Policy A is up to 2.76% more expensive than constructing a building that complies with Criterion 1 of Part L2A.
- The difference in cost between Extant Policy construction costs and Policy A construction costs is up to 0.77%.

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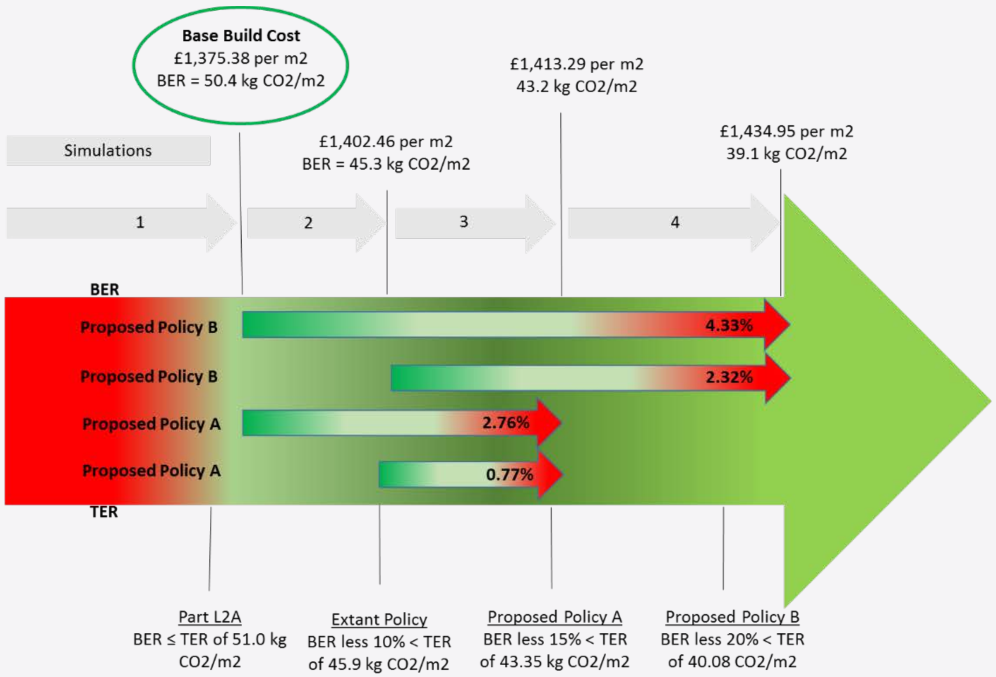
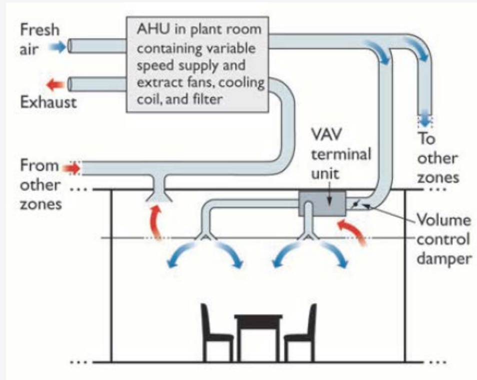
System 1: Results schematic



Shown below is a typical VAV system arrangement.



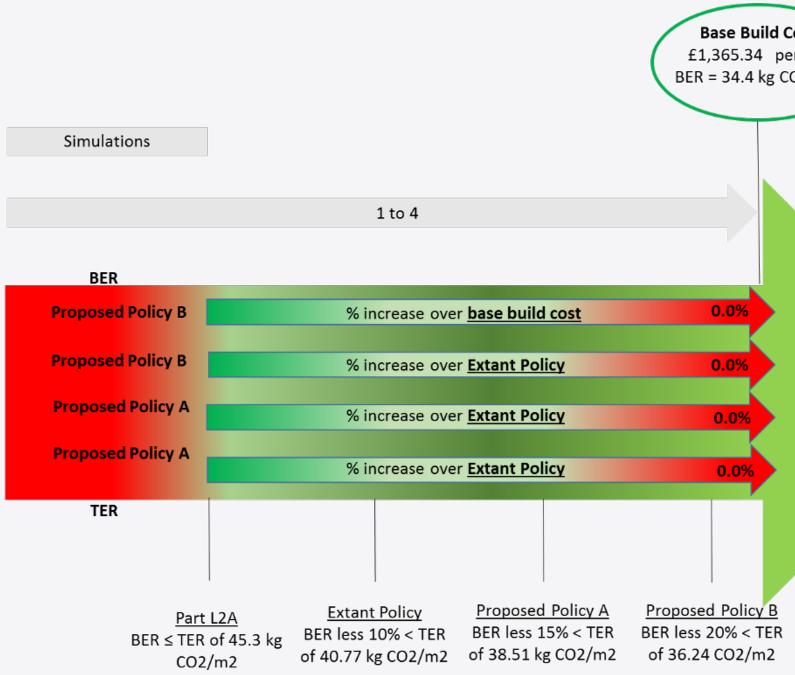
Source of picture, the BSRIA Illustrated Guide to Mechanical Building Services

2.2 System 2: Results

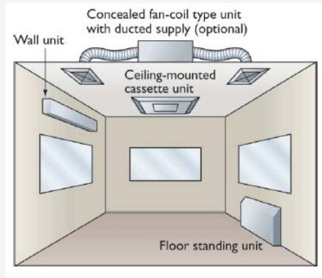
System 2 incorporates a variable refrigerant flow (VRF) or volume (VRV) system with mechanical ventilation and an electric air curtain. Based on Annex 2 of GBC's Sustainable Design and Construction Supplementary Planning Document, air source heat pumps (ASHP) are classified as an LZC technology. VRF/V is an ASHP technology, typically with additional heat recovery, and under the right conditions can be extremely efficient. Unlike other sources of heating, energy is not converted to heat or cooling, but is instead consumed by plant moving heat from point A to point B. The results of simulation 1 are interesting, as providing the building uses technologies at efficiencies that are available in the market, the base building can pass Proposed Policies A and B. Under these circumstances developers may look to reduce costs through so-called value engineering, but as in practice they are unlikely to be involved in the fit-out of a retail unit (typically this is undertaken by an occupier), then we would anticipate that they would base the proposed development at the 'as designed' stage on this type of specification to comply with planning policy - and then look to the first occupier as part of its first fit-out to issue the Buildings Regulations Part L2A (BRUKL) compliance certificate 'as built' once fitting out is complete. The results of the case studies are as follows:

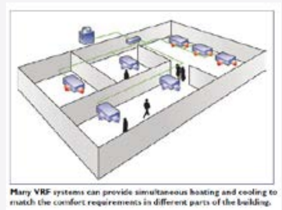
- In summary, unlike System 1 the base case building can comply with all four benchmarks and there is therefore no difference in costs between benchmarks.

System 2: Results schematic



Shown below is typical VRV/F arrangement.





Source of pictures, the BSRIA Illustrated Guide to Mechanical Building Services

2.3 A Comparison of System Performance

The table below compares the results of our simulations so that we can better understand cost-effectiveness alongside the impact on predicted CO_2 emissions. CO_2 emission are linked to energy consumption (kWh) and therefore, potentially, operational costs. System performance can be judged in two ways. The first, and in all probability, the most relevant to developers is establishing the most cost-effective way to reach Proposed Policy A or B. **This is highlighted in green**. In this case System 2, below, is the most cost-effective. Boxes that have been blacked out indicate that the previous simulation was capable of passing the target benchmark, and as a result it is not necessary to run additional simulations. For example, the simulation run to pass benchmark 1 for System 2 also passes benchmark 2, so this has been blacked out.

The second metric assesses the cost (£) of reducing CO_2 emissions. 0 = Zero operational carbon, the further away from zero the higher the cost (£) per Tonne (T) of CO_2 saved[3]. System 2 is not only the most effective to install but, in addition, for each £ invested per m^2 a greater amount of CO_2 savings are achieved. As a result, it is likely that operational running costs will also be the lowest of the two Systems.

[3] Calculated as: BER * system cost / 1,000 (= Tonnes of CO_2)

Benchmark	System 1 BER kg CO_2/m^2	System 2 BER kg CO_2/m^2	System 1 Cost per m^2 v carbon metric	System 2 Cost per m^2 v carbon metric
1. The BER ≤ TER. This is a requirement of Criterion 1 of Part L2A	50.4	34.4	£1,375.38/ m^2 £69.32 / Tm^2	£1,365.34/ m^2 £46.97 / TCO_2
2. The BER must be 10% lower than the TER. This is the Extant Policy	45.3		£1,402.46 / m^2 £63.53 / TCO_2	
3. The BER must be 15% lower than the TER. This is a proposed borough policy which we refer to as Proposed Policy A	43.2		£1,413.29/ m^2 £61.06 / TCO_2	
4. The BER must be 20% lower than the TER. This is a proposed borough policy which we refer to as Proposed Policy B	39		£1,434.95/ m^2 £55.96 / TCO_2	

3. SIMULATION RESULTS

The following two tables provide greater detail and granularity to the modelled buildings. The columns show the simulation number (1 to 4), the building type and target benchmark, the BER and TER, indicative costs and salient technical details.

3.1 System 1: Variable Air Volume (heating, cooling and fresh air)

Simulation	Building	BER kg CO_2/m^2	TER kg CO_2/m^2	Indicative costs of construction	Technical detail
1.	**Building type** Typical Retail Unit(s). **Benchmark** The BER ≤ TER. This is a requirement of Criterion 1 of Part L2A.	50.4 The BER is 1.18 % lower than the TER	51.0	£493,761.50[4] or £1,375.38 per functional unit (m2)	**Building fabric** Air permeability 5 at 50 Pa (m3/(h.m^2) = 5 Fabric U values, as per the notional building Glazing g values, as per the notional building **HVAC** <u>Heating</u>

[4] NB our simulations were initially run on a retail unit extending to 359 m^2. Cognisant that Action 4 of GBC's Sustainable Design and Construction Supplementary Planning Document (SPD) applies to non-domestic property >1000 m^2, we undertook a series of additional test simulations on an extended unit of 1059m^2 and found that the simulation results per functional unit, although nuanced, were directly transferable to the larger retail unit. These additional BIMs are available as part of the evidence pack.

Simulation Building		BER kg CO_2/m^2	TER kg CO_2/m^2	Indicative costs of construction	Technical detail
	Summary - pass In order to pass Criterion 1 of Part L2A a 4kWp PV system is required.				A ducted variable air volume system provided heating, cooling and fresh air. Dampers are adjusted based on temperature demand, reducing fan speed which saves energy. The boiler efficiency is taken at 91% gross and this together with wider system details and efficiencies are as per the notional building. 10% of the heating load has been assumed to be met by electric over door air curtains. Pumps are variable speed with multiple pressure sensors. Air conditioning Air-cooled chillers with a cooling SSEER of 3.6[5] as per the Notional Building.

[5] SSEER is a measure of cooling efficiency over a season. For every unit of energy input 3.6 units of cooling or coolth is transferred into the conditioned space.

Simulation Building		BER kg CO_2/m^2	TER kg CO_2/m^2	Indicative costs of construction	Technical detail
					<u>Ventilation</u> Ventilation is provided mechanically. The system SFP[6] is taken at 1.6 w/l/s as the Notional Building appears to also model SFP at 1.6 w/l/s, however, technically to adhere to the requirements of Part L2A 0.3 w/l/s should be added to this SFP to account for the heat exchangers. In other words the Notional Building SFP is better than required under Part L2A. Air exchange rates for WC/bathroom areas have been taken at 10 air changes per hour, and the SFP of local exhaust systems at 0.3 w/l/s as per the requirements of Part L2A, and it assumed that these will have an integral heat exchanger. **Domestic Hot Water**

[6] Specific Fan Power (SFP) is a parameter that quantifies the energy-efficiency of fan air movement systems. It is a measure of the electric power that is needed to drive a fan (or collection of fans), relative to the amount of air that is circulated through the fan(s)

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Simulation Building		BER kg CO_2/m^2	TER kg CO_2/m^2	Indicative costs of construction	Technical detail
					Provided at source through electric unvented water heaters with a combined storage capability of 50 litres. **Lighting** 60 lumens per circuit-watt, 200 lux – back of house/non-office or retail 60 lumens per circuit-watt, 500 lux office areas 60 lumens per circuit-watt, 600 lux for retail sales The light efficacy in the Notional Building is 60 lumens per circuit-watt. **Lighting controls** Photoelectric – typically yes Motion sensors – typically no, as this would be impractical for retail sales (PIR to common areas and office area only).

Simulation Building		BER kg CO_2/m^2	TER kg CO_2/m^2	Indicative costs of construction	Technical detail
					Renewable energy systems 4kWp mono crystalline PV system on roof mounts facing due south-east at a 30 degree incline. This will require around 48 m2 of flat roof space – the flat roof of the proposed property extends to about 359 m^2. **Design challenges/considerations** N/A
2.	**Building type** Typical Retail Unit(s). **Benchmark** The BER must be 10% lower than the TER. This is the Extant Policy. **Summary - pass** The BER of Simulation 2 is 11.18 % lower than the TER.	45.3 The BER is 11.18% less than the TER (the TER detailed in Simulation 1)	45.9 (this is the target under the Extant Policy. It is the TER less 10%)	£503,481.50 or £1,402,46 per functional unit (m^2) This represents an increase over the base build cost of £9,720.00 or 1.97%	As per Simulation 1 but with a 9kWp mono crystalline PV system on roof mounts facing due south-east at a 30 degree incline. This will require around 108 m^2 of flat roof space – the flat roof of the proposed property extends to about 359 m^2.

Simulation Building		BER kg CO_2/m^2	TER kg CO_2/m^2	Indicative costs of construction	Technical detail
	All of this reduction is a result of a 9 kWp PV system which saves 9.29 kg CO2 / m^2 reducing: 1) the BER without the benefit of any PV by over 18% (as noted in Simulation 1, it is not possible to pass Part L2A without any LZC) and 2) The BER against the TER under the Extant Policy by 11.18%.				
3.	**Building type** Typical Retail Unit(s). **Benchmark** The BER must be 15% lower than the TER. This is a proposed borough policy which we refer to as Proposed Policy A. **Summary - pass**	43.2 The BER is 15.29% less than the TER (the TER detailed in Simulation 1)	43.35 (this is the target under Proposed Policy A. It is the TER less 15%)	£507,369.50 or £1,413.29 per functional unit (m^2) This represents an increase over the base build cost of	As per Simulation 2, but with a PV system of increased capacity to 11 kWp requiring a flat roof area of 132 m2 - the flat roof of the proposed property extends to about 359 m2.

Simulation Building		BER kg CO_2/m^2	TER kg CO_2/m^2	Indicative costs of construction	Technical detail
	To ensure a 15% reduction against the BER through LZC, the PV system needs to be extended to 11kWp resulting in a reduction of 11.36 kg CO2/m^2. This is a reduction of 22.54% against the BER without any PV, and is 15.29% lower than the TER.			£13,608.00 or 2.76%	
4.	**Building type** Typical Retail Unit(s). **Benchmark** The BER must be 20% lower than the TER. This is a proposed borough policy which we refer to as Proposed Policy B. **Summary - pass** To ensure a 20% reduction against the BER through LZC technologies,	39.1 The BER is 23.33% less than the TER (the TER detailed in Simulation 1)	40.08 (this is the target under Proposed Policy A. It is the TER less 20%)	£515,145.50 or £1,434.95 per functional unit (m^2) This represents an increase over the base build of £21,384.00 or 4.33%	As per Simulation 3, but with a PV system of increased capacity to 15 kWp requiring a flat roof area of 180 m^2 - the flat roof of the proposed property extends to about 359 m^2

Simulation Building		BER kg CO_2/m^2	TER kg CO_2/m^2	Indicative costs of construction	Technical detail
	the PV system needs to be extended to 15kWp resulting in a reduction of 15.50 kg CO2/m² and 23.33% against the TER.				

3.4 System 2: VRV/F with mechanical ventilation

Simulation Building		BER kg CO_2/m^2	TER kg CO_2/m^2	Indicative costs of construction	Technical detail
1.	**Building type** Typical Retail Unit(s). **Benchmark** The BER ≤ TER. This is a requirement of Criterion 1 of Part L2A. **Summary - pass** It is possible to (easily) comply with Part L2A using a modern VRV/F system and mechanical ventilation.	34.4 The BER is 24.06% lower than the TER (the TER detailed in Simulation 1)	45.3	£490,155.59 or £1,365.34 per functional unit (m^2)	**Building fabric** Air permeability 5 at 50 Pa (m3/(h.m2) = 5 Fabric U values, as per the notional building Glazing g values, as per the notional building **HVAC** <u>Heating</u> A VRV/F air-source-heat-pump (ASHP) system to all areas other than plant room.

Simulation Building		BER kg CO_2/m^2	TER kg CO_2/m^2	Indicative costs of construction	Technical detail
					The CoP of the ASHP is 3.9[7] which is a requirement of the Energy Technology List and is higher than the Notional Building. <u>Ventilation</u> Full mechanical ventilation with heat recovery at 70% efficiency, and a specific fan power (SFP) of 1.2 w/l/s as per the Notional Building (a technical anomaly of modelling against the NCM is that the SFP must be lower for system 2 than system 1, and this has been reflected in costs). Air handling unit (AHU) and ductwork leakage have been taken at CEN standards Class D and L1. <u>Air conditioning</u> The SSEER of the VRV/F system is 3.6 (requiring an SEER of 4.9) as per the Notional Building.

[7] For every unit of energy input 3.9 units of heat is delivered as an output under test conditions

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Simulation Building		BER kg CO_2/m^2	TER kg CO_2/m^2	Indicative costs of construction	Technical detail
					NB this is higher than the requirements of the ETL, but several such systems are readily available on the open market. **Domestic Hot Water** Provided at source through electric unvented water heaters with a combined storage capability of 50 litres. **Lighting** 60 lumens per circuit-watt, 200 lux – back of house/non-office or retail 60 lumens per circuit-watt, 500 lux office areas 60 lumens per circuit-watt, 600 lux for retail sales The light efficacy in the Notional Building is 60 lumens per circuit-watt.

Simulation Building		BER kg CO_2/m^2	TER kg CO_2/m^2	Indicative costs of construction	Technical detail
					Lighting controls Photoelectric – typically yes Motion sensors – typically no, as this would be impractical for retail sales (PIR to common areas and office area only) **Design challenges/considerations** N/A
2 to 4.	**Building type** Typical Retail Unit(s). **Benchmark** The BER must be 10% lower than the TER. This is the Extant Policy. The BER must be 15% lower than the TER. This is a proposed borough policy which we refer to as Proposed Policy A.	34.4 The BER is 24.06 % lower than the TER, of this 20.33% is from LZC (the TER detailed in	40.77 (this is the target under the Extant Policy. It is the TER less 10%)	£473,268.28 or £1,318.30 per functional unit (m^2)	As per Simulation 1.

Simulation Building		BER kg CO_2/m^2	TER kg CO_2/m^2	Indicative costs of construction	Technical detail
	The BER must be 20% lower than the TER. This is a proposed borough policy which we refer to as Proposed Policy B. **Summary – pass (all benchmarks)** The BER is 24.06 % less than the TER. To calculate the percentage of energy consumed by an LZC, we are guided by the approach used the BRE for its EN 01 credit *Reduction of Energy Use and Carbon.* The methodology involves looking at the following metrics: • Building floor area (m^2) • Notional building heating and cooling energy demand (mJ/m^2)	Simulation 1)			

Simulation Building		BER kg CO_2/m^2	TER kg CO_2/m^2	Indicative costs of construction	Technical detail
	• Actual building heating and cooling energy demand (mJ/m^2) • Notional building primary energy consumption (kWh/m^2) • Actual building primary energy consumption (kWh/m^2) • Target Emission Rate (TER) (kgCO2/m^2) • Building Emission Rate (BER) (kgCO2/m^2) The heating and cooling source is an LZC and this is responsible for 9.21 kg CO2 / m2[8]. An alternative heating or cooling source of equal efficiency would therefore emit at least this much CO2 – meaning that the				

[8] Electrical emissions taken at 0.519 kg CO2 per kWh (SAP 2012)

Simulation Building		BER kg CO_2/m^2	TER kg CO_2/m^2	Indicative costs of construction	Technical detail
	reduction in emissions is 20.33% against the TER.				

4. COSTS

The costs detailed over the following pages have been taken from the BIMs which are available as cabinet files (CAB files). The headings include an ID, a code which defines the basis of the cost multiplier, a rate (£), quantity, weight, base cost, cost £, and cost £ /. Explanations are provided below:

4.1 ID

The ID is based on the nomenclature of the RICS New Rules of Measurement.

4.2 Code

The code is assigned through the VE and informs the quantity. Code 11, as an example, is the code for multiplying the rate by the quantity which is based on the Gross Internal Floor Area (GIFA), while Code 1 measures the quantity by item. For example, 1 or 2 No. boilers etc.

4.3 Rate

This is the rate (£) to be multiplied by the quantity.

4.4 Quantity

This is the basis of the cost multiplier.

4.5 Weight

This applies a weighted value to the quantity, a weight of 1 = 100% as a multiplier against the quantity. In the costs below a rate of £1,420.00 per m^2 has been adopted as the build cost, however this sum includes building services. Using BSRIA Rules of thumb as a guide, we have applied a discount rate to allow us to extract typical building services costs from the inclusive development cost. This is so that we can analyse the impact of different building services (on costs). For example, an adjusted weighting of 0.18 results in a weighting of 0.82 (1 – 0.18 = 0.82). The purpose of the exercise is to provide a consistent ‘base build cost’ across the simulations with the final project inclusive cost (i.e. with building services) reassessed against the range of costs provided in SPONS 2017[9]. The following weighting rules have been adopted throughout the project:

Property type	HVAC system type	Unadjusted BSRIA weighting	Less allowance for lifts[10] etc.	Adjusted weighting
Commercial (Offices)	Natural ventilation and no air conditioning	0.30	0.05	0.25
Commercial (Offices)	Mechanical ventilation and air conditioning	0.34	0.05	0.29

[9] In other words we would expect the project Cost per m2 to be within the range provided by SPONS 2017 after an adjustment for location.
[10] Items included in the BSRIA weighting have been added in our cost modelling as separate line items using the RICS NRM and therefore an allowance needs to be made (discounted) to avoid double counting.

Property type	HVAC system type	Unadjusted BSRIA weighting	Less allowance for lifts[10] etc.	Adjusted weighting
Commercial (Retail)	Mechanical ventilation and air conditioning	0.21	N/A	0.21
Commercial (Care Homes etc.)	Natural ventilation and no air conditioning	0.23	0.05	0.18
Commercial (Care Homes etc.)	Mechanical ventilation and air conditioning	0.33	0.05	0.28
Residential	Natural ventilation and no air conditioning	0.23	0.025	0.205

4.6 Base Cost

The base cost is an unadjusted cost (rate x quantity).

4.7 Cost

This is the adjusted cost. It is the cost multiplied by a location adjustment factor, a quality factor, and a complexity factor. In SPONS 2017 the location adjustment factor for the south east is 0.96, while a quality and complexity factor of unity (1) has been applied in the BIM representing a medium quality, medium complexity development for the type of building modelled.

4.8 Cost £ /

This is the cost per functional unit. In this case the functional unit is taken as m^2.

5. SYSTEM 1, SIMULATION 1

ID	Description	Code	Rate	Quantity	Weight	Base cost	Cost £	Cost £ /
6	**Complete buildings and building units - Retail Unit(s) - VAV system**							
6.1.1	Complete buildings	5						
6.1.1	Complete buildings (SPONS A&B 2017 - median cost, small / simple store fitted out)	11	1,420.00	359	0.79	402,726.19	386,617.16	1,076.93
5	Services (BES)	11	0.00	0	1.00	0.00	0.00	0.00
5.1	Sanitary installations (SA) (SPONS M&E 2017 - median cost)	11	8.05	359	1.00	2,889.95	2,774.35	7.73
5.3	Disposal installation (DI) (SPONS M&E 2017 - median cost)	11	12.40	359	1.00	4,451.60	4,273.54	11.90
5.4	Water installations (WI) (SPONS M&E 2017 - median cost)	11	13.63	359	1.00	4,891.38	4,695.72	13.08
5.5	Heat source (HS) - boilers (SPONS M&E 2017 - median cost)	11	6.90	359	1.00	2,477.10	2,378.02	6.62
5.6	LTHW heating, plantroom and risers (SPONS M&E 2017 - median cost)	11	13.80	359	1.00	4,954.20	4,756.03	13.25
5.6	CHW plant room and risers (SPONS M&E 2017 - median cost)	11	33.00	359	1.00	11,847.00	11,373.12	31.68
5.6	Ductwork plant room and risers (SPONS M&E 2017 - median cost)	11	63.50	359	1.00	22,796.50	21,884.64	60.96
5.6	Air curtains (SPONS M&E 2017 - median cost)	11	1.05	359	1.00	376.95	361.87	1.01
5.7	Ventilation systems WC & Misc. (VS) (SPONS M&E 2017 - median cost)	11	13.80	359	1.00	4,954.20	4,756.03	13.25
5.8	Electrical installations (EI) (SPONS M&E 2017 - median cost)	11	56.30	359	1.00	20,211.70	19,403.23	54.05
5.8.5	Local electricity generation systems (SPONS M&E 2017 - median cost)	11	2,025.00	4	1.00	8,100.00	7,776.00	21.66
5.9	Fuel installations / systems (FI) (SPONS M&E 2017 - median cost)	11	2.00	359	1.00	718.00	689.28	1.92
5.11	Fire and lightning protection (FLP) (SPONS M&E 2017 - median cost)	11	8.00	359	1.00	2,872.00	2,757.12	7.68
5.12	Communication, security and cntrol systems (CSC) (SPONS M&E 2017 - median cost)	11	35.90	359	1.00	12,888.10	12,372.58	34.46
2.3.1	Roof (ROO) - additional roof reinforcement for PV only (SPONS A&B 2017 - cost models)	11	20.00	359	1.00	7,180.00	6,892.80	19.20
							493,761.50	**1,375.38**
	CAPITAL COST						**493,761.50**	**1,375.38**

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6. SYSTEM 1, SIMULATION 2

ID	Description	Code	Rate	Quantity	Weight	Base cost	Cost £	Cost £ /
6	**Complete buildings and building units - Retail Unit(s) - VAV system**							
6.1.1	Complete buildings	5						
6.1.1	Complete buildings (SPONS A&B 2017 - median cost, small / simple store fitted out)	11	1,420.00	359	0.79	402,726.19	386,617.16	1,076.93
5	Services (BES)	11	0.00	0	1.00	0.00	0.00	0.00
5.1	Sanitary installations (SA) (SPONS M&E 2017 - median cost)	11	8.05	359	1.00	2,889.95	2,774.35	7.73
5.3	Disposal installation (DI) (SPONS M&E 2017 - median cost)	11	12.40	359	1.00	4,451.60	4,273.54	11.90
5.4	Water installations (WI) (SPONS M&E 2017 - median cost)	11	13.63	359	1.00	4,891.38	4,695.72	13.08
5.5	Heat source (HS) - boilers (SPONS M&E 2017 - median cost)	11	6.90	359	1.00	2,477.10	2,378.02	6.62
5.6	LTHW heating, plantroom and risers (SPONS M&E 2017 - median cost)	11	13.80	359	1.00	4,954.20	4,756.03	13.25
5.6	CHW plant room and risers (SPONS M&E 2017 - median cost)	11	33.00	359	1.00	11,847.00	11,373.12	31.68
5.6	Ductwork plant room and risers (SPONS M&E 2017 - median cost)	11	63.50	359	1.00	22,796.50	21,884.64	60.96
5.6	Air curtains (SPONS M&E 2017 - median cost)	11	1.05	359	1.00	376.95	361.87	1.01
5.7	Ventilation systems WC & Misc. (VS) (SPONS M&E 2017 - median cost)	11	13.80	359	1.00	4,954.20	4,756.03	13.25
5.8	Electrical installations (EI) (SPONS M&E 2017 - median cost)	11	56.30	359	1.00	20,211.70	19,403.23	54.05
5.8.5	Local electricity generation systems (SPONS M&E 2017 - median cost)	11	2,025.00	9	1.00	18,225.00	17,496.00	48.74
5.9	Fuel installations / systems (FI) (SPONS M&E 2017 - median cost)	11	2.00	359	1.00	718.00	689.28	1.92
5.11	Fire and lightning protection (FLP) (SPONS M&E 2017 - median cost)	11	8.00	359	1.00	2,872.00	2,757.12	7.68
5.12	Communication, security and cntrol systems (CSC) (SPONS M&E 2017 - median cost)	11	35.90	359	1.00	12,888.10	12,372.58	34.46
2.3.1	Roof (ROO) - additional roof reinforcement for PV only (SPONS A&B 2017 - cost models)	11	20.00	359	1.00	7,180.00	6,892.80	19.20
							503,481.50	**1,402.46**
	CAPITAL COST						**503,481.50**	**1,402.46**

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7. SYSTEM 1, SIMULATION 3

ID	Description	Code	Rate	Quantity	Weight	Base cost	Cost £	Cost £ /
6	**Complete buildings and building units - Retail Unit(s) - VAV system**							
6.1.1	Complete buildings	5						
6.1.1	Complete buildings (SPONS A&B 2017 - median cost, small / simple store fitted out)	11	1,420.00	359	0.79	402,726.19	386,617.16	1,076.93
5	Services (BES)	11	0.00	0	1.00	0.00	0.00	0.00
5.1	Sanitary installations (SA) (SPONS M&E 2017 - median cost)	11	8.05	359	1.00	2,889.95	2,774.35	7.73
5.3	Disposal installation (DI) (SPONS M&E 2017 - median cost)	11	12.40	359	1.00	4,451.60	4,273.54	11.90
5.4	Water installations (WI) (SPONS M&E 2017 - median cost)	11	13.63	359	1.00	4,891.38	4,695.72	13.08
5.5	Heat source (HS) - boilers (SPONS M&E 2017 - median cost)	11	6.90	359	1.00	2,477.10	2,378.02	6.62
5.6	LTHW heating, plantroom and risers (SPONS M&E 2017 - median cost)	11	13.80	359	1.00	4,954.20	4,756.03	13.25
5.6	CHW plant room and risers (SPONS M&E 2017 - median cost)	11	33.00	359	1.00	11,847.00	11,373.12	31.68
5.6	Ductwork plant room and risers (SPONS M&E 2017 - median cost)	11	63.50	359	1.00	22,796.50	21,884.64	60.96
5.6	Air curtains (SPONS M&E 2017 - median cost)	11	1.05	359	1.00	376.95	361.87	1.01
5.7	Ventilation systems WC & Misc. (VS) (SPONS M&E 2017 - median cost)	11	13.80	359	1.00	4,954.20	4,756.03	13.25
5.8	Electrical installations (EI) (SPONS M&E 2017 - median cost)	11	56.30	359	1.00	20,211.70	19,403.23	54.05
5.8.5	Local electricity generation systems (SPONS M&E 2017 - median cost)	11	2,025.00	11	1.00	22,275.00	21,384.00	59.57
5.9	Fuel installations / systems (FI) (SPONS M&E 2017 - median cost)	11	2.00	359	1.00	718.00	689.28	1.92
5.11	Fire and lightning protection (FLP) (SPONS M&E 2017 - median cost)	11	8.00	359	1.00	2,872.00	2,757.12	7.68
5.12	Communication, security and cntrol systems (CSC) (SPONS M&E 2017 - median cost)	11	35.90	359	1.00	12,888.10	12,372.58	34.46
2.3.1	Roof (ROO) - additional roof reinforcement for PV only (SPONS A&B 2017 - cost models)	11	20.00	359	1.00	7,180.00	6,892.80	19.20
							507,369.50	**1,413.29**
	CAPITAL COST						**507,369.50**	**1,413.29**

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8. SYSTEM 1, SIMULATION 4

ID	Description	Code	Rate	Quantity	Weight	Base cost	Cost £	Cost £ /
6	**Complete buildings and building units - Retail Unit(s) - VAV system**							
6.1.1	Complete buildings	5						
6.1.1	Complete buildings (SPONS A&B 2017 - median cost, small / simple store fitted out)	11	1,420.00	359	0.79	402,726.19	386,617.16	1,076.93
5	Services (BES)	11	0.00	0	1.00	0.00	0.00	0.00
5.1	Sanitary installations (SA) (SPONS M&E 2017 - median cost)	11	8.05	359	1.00	2,889.95	2,774.35	7.73
5.3	Disposal installation (DI) (SPONS M&E 2017 - median cost)	11	12.40	359	1.00	4,451.60	4,273.54	11.90
5.4	Water installations (WI) (SPONS M&E 2017 - median cost)	11	13.63	359	1.00	4,891.38	4,695.72	13.08
5.5	Heat source (HS) - boilers (SPONS M&E 2017 - median cost)	11	6.90	359	1.00	2,477.10	2,378.02	6.62
5.6	LTHW heating, plantroom and risers (SPONS M&E 2017 - median cost)	11	13.80	359	1.00	4,954.20	4,756.03	13.25
5.6	CHW plant room and risers (SPONS M&E 2017 - median cost)	11	33.00	359	1.00	11,847.00	11,373.12	31.68
5.6	Ductwork plant room and risers (SPONS M&E 2017 - median cost)	11	63.50	359	1.00	22,796.50	21,884.64	60.96
5.6	Air curtains (SPONS M&E 2017 - median cost)	11	1.05	359	1.00	376.95	361.87	1.01
5.7	Ventilation systems WC & Misc. (VS) (SPONS M&E 2017 - median cost)	11	13.80	359	1.00	4,954.20	4,756.03	13.25
5.8	Electrical installations (EI) (SPONS M&E 2017 - median cost)	11	56.30	359	1.00	20,211.70	19,403.23	54.05
5.8.5	Local electricity generation systems (SPONS M&E 2017 - median cost)	11	2,025.00	15	1.00	30,375.00	29,160.00	81.23
5.9	Fuel installations / systems (FI) (SPONS M&E 2017 - median cost)	11	2.00	359	1.00	718.00	689.28	1.92
5.11	Fire and lightning protection (FLP) (SPONS M&E 2017 - median cost)	11	8.00	359	1.00	2,872.00	2,757.12	7.68
5.12	Communication, security and cntrol systems (CSC) (SPONS M&E 2017 - median cost)	11	35.90	359	1.00	12,888.10	12,372.58	34.46
2.3.1	Roof (ROO) - additional roof reinforcement for PV only (SPONS A&B 2017 - cost models)	11	20.00	359	1.00	7,180.00	6,892.80	19.20
							515,145.50	**1,434.95**
	CAPITAL COST						**515,145.50**	**1,434.95**

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9. SYSTEM 2, SIMULATION 1 TO 4

ID	Description	Code	Rate	Quantity	Weight	Base cost	Cost £	Cost £ /
6	**Complete buildings and building units - Retail Unit(s) - VAV system**							
6.1.1	Complete buildings	5						
6.1.1	Complete buildings (SPONS A&B 2017 - median cost, small / simple store fitted out)	11	1,420.00	359	0.79	402,726.19	386,617.16	1,076.93
5	Services (BES)	11	0.00	0	1.00	0.00	0.00	0.00
5.1	Sanitary installations (SA) (SPONS M&E 2017 - median cost)	11	8.05	359	1.00	2,889.95	2,774.35	7.73
5.3	Disposal installation (DI) (SPONS M&E 2017 - median cost)	11	12.40	359	1.00	4,451.60	4,273.54	11.90
5.4	Water installations (WI) (SPONS M&E 2017 - median cost)	11	13.63	359	1.00	4,891.38	4,695.72	13.08
5.5	Heat source (HS) - heat pumps at £600 per kW (GIFA x 140 (cooling) / 1000) * 500 (Source CIBSE £5...	1	30,156.00	1	1.00	30,156.00	28,949.76	80.64
5.6	Ductwork plant room and risers (SPONS M&E 2017 - median cost)	11	63.50	359	1.00	22,796.50	21,884.64	60.96
5.6	Air curtains (SPONS M&E 2017 - median cost)	11	1.05	359	1.00	376.95	361.87	1.01
5.7	Ventilation systems WC & Misc. (VS) (SPONS M&E 2017 - upper end cost to account for reduced SFP)	11	15.60	359	1.00	5,600.40	5,376.38	14.98
5.8	Electrical installations (EI) (SPONS M&E 2017 - median cost)	11	56.30	359	1.00	20,211.70	19,403.23	54.05
5.9	Fuel installations / systems (FI) (SPONS M&E 2017 - median cost)	11	2.00	359	1.00	718.00	689.28	1.92
5.11	Fire and lightning protection (FLP) (SPONS M&E 2017 - median cost)	11	8.00	359	1.00	2,872.00	2,757.12	7.68
5.12	Communication, security and cntrol systems (CSC) (SPONS M&E 2017 - median cost)	11	35.90	359	1.00	12,888.10	12,372.58	34.46
							490,155.59	**1,365.34**
	CAPITAL COST						**490,155.59**	**1,365.34**

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