BUROHAPPOLD ENGINEERING

UCL Institute of Education

Interim Sustainability Statement – Phase 1

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Revision 01

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00	UCL IOE – Interim sustainability statement – Phase 1	MD	12 Apr 17	NW
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Contents

1 Executive summary

This report sets out the interim sustainability statement for planning for Phase 1 of the UCL Institute of Education refurbishment, covering the level 3 ISD offices and the level 2 and 3 wing. Studies contained include a summary of the baseline building performance, the Phase 1 energy strategy, the BREEAM pre-assessment and responses to Camden planning criteria.

The UCL Institute of Education is a Grade II* listed building, however despite this limiting factor significant efforts are being made by the design team to enhance the sustainability of the building. Key measures include:

- Improving the thermal performance of the building fabric in line with heritage constraints, through the addition of secondary glazing and internal insulation to cladding panels.
- Upgrading all major MEP systems and lighting. To comply with Building Regulations, all performance values are better or equal to Part L2B 2010 (including 2016 amendments) and Non-Domestic Building Services Compliance Guide 2013.
- Retaining connection to the Bloomsbury Heat and Power network, which includes boiler and combined heat and power plant, enabling up to 80% of the building's electricity to come from low carbon sources.
- BREEAM 'Excellent' strategy – this includes a wide variety of sustainability measures including a 40% improvement in potable water use, responsible sourcing of construction materials, measures to enhance site ecology, security studies, acoustic measures and stringent sustainability criteria for the Contractor.

In terms of total CO_2 reduction for the Phase 1 areas, preliminary modelling following the BREEAM refurbishment and fit out calculation methodology shows a 28.4% in regulated CO_2 emissions compared to the existing building, meeting the BREEAM Excellent minimum requirements (at least 6 credits in Ene01). During RIBA Stage 4, further coordination with the Contractor, Building Control and heritage specialist shall be conducted to develop the final design strategy, adhering to the project sustainability targets.

It is currently estimated that for Phase 1, 19.8% of the project budget will be spent on energy efficiency improvements (including fabric improvement measures, new HVAC plant, lighting, controls and metering. This is in line with the "Camden Council Planning Guidance – Sustainability CGP3" for guidelines existing buildings which requires 10% of project cost to be spent on energy efficiency. Appendix A contains a schedule of the costing information. Section 2 of this report contains further responses to the planning guidance criteria.

In terms of renewable energy, there is a Camden Planning requirement to target at least a 20% reduction in carbon dioxide emissions through the installation of on-site renewable energy technologies. For UCL IOE, the only applicable on-site form of renewable energy would be solar photovoltaics (which are estimated to saved 2.3% of CO2 across Phases 1-3), however these are potentially contentious according to the heritage consultant. If PV panels are to be considered, these will be brought forward in future refurbishment phases in discussion with Camden and Historic England. It should be noted that the site is served by the Bloomsbury Combined Heat and Power (CHP) district network, which according the Display Energy Certificate allows the UCL IOE building to obtain up to 80% of its electricity from low carbon sources.

In summary, there is good potential to undertake an extensive and sustainable refurbishment for the UCL Institute of Education, which achieves BREEAM Excellent and enhances thermal comfort. The works undertaken in Phase 1 have investigated many of the opportunities for the UCL IOE refurbishment applicable to later phases and setting a positive ethos for the project.

2 Planning checklist

2.1 Camden Planning Guidance – Sustainability CGP3

The table below outlines the Camden Council planning requirements in relation to sustainability for existing buildings. Preliminary comments in relation to the UCL IOE Phases 1-3 are given.

Table 1 Camden council planning requirements on sustainability relevant for IOE.

<table>
<tr><th>Requirement</th><th>Initial commentary</th></tr>
<tr><td>Sustainability assessment tools (BREEAM)

Submission of a pre-assessment report at the planning application stage. The report should summarise the design strategy for achieving your chosen level of BREEAM and/or Code for Sustainable Homes and include details of the credits proposed to be achieved.
Pre-assessment report is to be carried out by a licensed assessor. The name of the assessor and their licence number should be clearly stated on the report.
You are strongly encouraged to meet the following standards in accordance with Development Policy DP22 - Promoting sustainable design and construction:

<table>
<tr><th>Time period</th><th>Minimum rating</th><th>Minimum standard for categories (% of un-weighted credits)</th></tr>
<tr><td>2010-2012</td><td>‘very good’</td><td rowspan="2">Energy 60%
Water 60%
Materials 40%</td></tr>
<tr><td>2013+</td><td>‘excellent’</td></tr>
</table>
</td><td>The project is targeting a BREEAM Excellent rating with a single assessment across Phases 1-3.
The current strategy is targeting 65% of credits in the energy category.
66% of water credits are currently targeted.
69% of materials credits are currently targeted.
The licenced BREEAM assessor is Adonis Charalambous (AC61). The licenced BREEAM AP is Mark Dowson (1000124).</td></tr>
<tr><td>Energy efficiency: existing buildings

All buildings, whether being updated or refurbished, are expected to reduce their carbon emissions by making improvements to the existing building. Work involving a change of use or an extension to an existing property is included. As a guide, at least 10% of the project cost should be spent on the improvements.
Where retro-fitting measures are not identified at application stage we will most likely secure the implementation of environmental improvements by way of condition.
Development involving a change of use or a conversion of more than 500sq m of any floorspace, will be expected to achieve 60% of the un-weighted credits in the Energy category in their BREEAM assessment.
Special consideration will be given to buildings that are protected e.g. listed buildings
</td><td>Substantial works are planned to improve the energy efficiency of this Grade II* listed building. Based on the interim cost check report, it is estimated that 19.8% of project costs are being spent on energy efficiency for Phase 1. See Appendix A for details of the calculation. As stated, 65% of energy credits are targeted for BREEAM,</td></tr>
<tr><td>Renewable energy

All developments are to target at least a 20% reduction in carbon dioxide emissions through the installation of on-site renewable energy technologies. Special consideration will be given to heritage buildings and features to ensure that their historic and architectural features are preserved.
</td><td>See Appendix B. Solar PV is the only feasible “on-site renewable technology”. This provides up to 2.3% CO2 savings, however the heritage consultant has confirmed this is potentially contentious. If PV panels are considered, these will be brought forward in future refurbishment phases in discussion with Camden & Historic England.</td></tr>
<tr><td>Decentralised energy

Where feasible and viable your development will be required to connect to a decentralised energy network or include CHP.
</td><td>IOE is connected to the Bloomsbury Heat & Power (BHP) combined heat & power network</td></tr>
</table>

Water efficiency • The Council expects all developments to be designed to be water efficient by minimising water use and maximising the re-use of water. This includes new and existing buildings. • The Council will require developments over 1000sq m to include a grey water harvesting system, unless the applicant demonstrates to the Council's satisfaction that this is not feasible.	*Low flow fittings will be targeted to achieve a 40% reduction in potable water use for BREEAM Wat 01. Rainwater/Grey water recycling is not feasible for the project given existing building constraints.*
Sustainable use of materials • All developments should aim for at least 10% of the total value of materials used to be derived from recycled and reused sources. This should relate to the WRAP Quick Wins assessments or equivalent. Special consideration will be given to heritage buildings and features to ensure that their historic and architectural features are preserved. • Major developments are anticipated to be able to achieve 15-20% of the total value of materials used to be derived from recycled and reused sources.	*A pre-refurbishment waste audit has been carried out. This has identified that 35% of materials can be re-used or recycled. All materials sourcing will be in line with BREEAM responsible sourcing requirements.*
Adapting to climate change • All development is expected to consider the impact of climate change and be designed to cope with the anticipated conditions.	*A climate change risk assessment was conducted for BREEAM credit Wst05. During RIBA Stage 1 and 2 a detailed natural ventilation study was carried out. Due to the high occupancy requirements an artificial cooling solution is required. Supporting passive design measures have been incorporated to reduce loads.*
Brown roofs, green roofs and green walls • The Council will expect all developments to incorporate brown roofs, green roofs and green walls unless it is demonstrated this is not possible or appropriate. This includes new and existing buildings. Special consideration will be given to historic buildings to ensure historic and architectural features are preserved.	*An ecology study has been completed, recommending planting of native species on external terrace areas.*
Flooding • Developments must not increase the risk of flooding, and are required to put in place mitigation measures where there is known to be a risk of flooding. Within the areas shown on Core Strategy Map 5 (Development Policies Map 2) we will expect water infrastructure to be designed to cope with a 1 in 100 year storm event in order to limit the flooding of, and damage to, property.	*The site is located in flood risk zone 1 (low risk of flooding). The proposed Phase 1-3 refurbishment works will not increase surface water run off.*
External lighting • Lighting can have particular negative impacts on biodiversity. Unnecessary lighting should be avoided. Where lighting may harm biodiversity timers or specific coloured lighting will be required to minimise any disturbance.	*BREEAM requirements for external lighting have been embedded into the electrical performance specifications.*
Local food growing • We encourage food to be grown wherever possible and suitable. Rooftops and shared spaces such as gardens and parks provide opportunities.	*Local food growing is not incorporated into the scheme, but shall be raised to the ecologist.*
Biodiversity • Proposals should demonstrate how biodiversity considerations have been incorporated into the development; if any mitigation measures will be included; and what positive measures for enhancing biodiversity are planned.	*An ecology study has been completed, recommending planting of native species on external terrace areas.*

3 Baseline performance

3.1 Overview

This chapter gives an overview of the baseline performance of the UCL Institute of Education, covering running costs, energy use, CO_2 emissions and fabric performance. The study covers the whole IOE building.

3.2 Running costs

The UCL Institute of Education building is an expensive asset to run, spending over half a million pounds on energy every year. This is not sustainable and represents a key area to be considered as part of refurbishment works.

District heating costs (Aug-14 to Jul-15)	£185,000/year
Electricity costs (Aug-14 to Jul-15)	£330,000/year
Total annual running costs	**£515,000/year**

3.3 Energy use

Based on historic energy surveys, it is estimated that approximately 45% of the buildings energy use is for heating and hot water via a district heat network. The remaining 55% of energy use can be attributed to electricity consumption, with lighting being the main source of electrical energy use. 5% of total building energy use can also be attributed to electric heating, indicating that the building is currently not meeting thermal comfort standards. Measures to improve fabric performance, where appropriate and unregulated electricity consumption should therefore be prioritised.

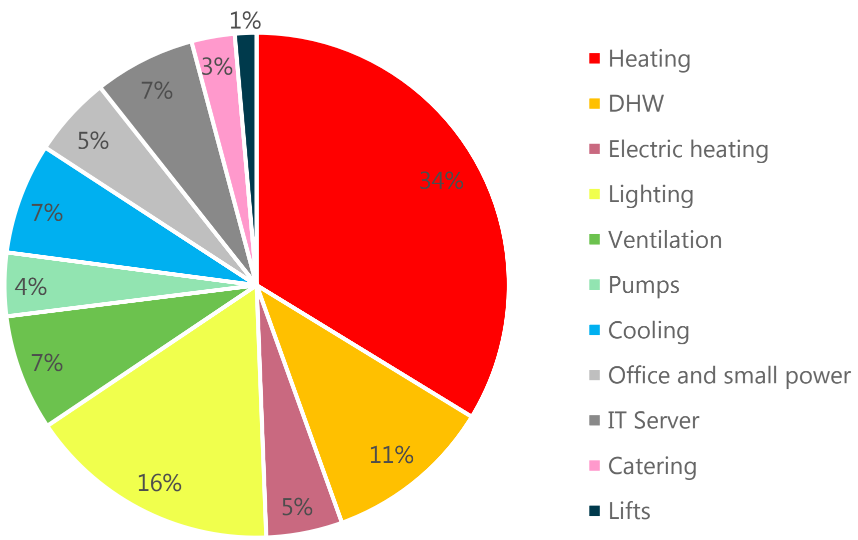


Figure 1 Energy consumption by end-use for 20 Bedford Way (UCL IOE carbon management plan, 2014)

3.4 CO_2 emissions

In terms of CO_2 emissions, the UCL Institute of Education building actually performs very well. This is because the building is connected to the existing Bloomsbury Heat and Power (BHP) district heating network, which provides low-carbon heat as well as renewable electricity generated simultaneously via a CHP (combined heat and power) engine. According to the building's display energy certificate, 78.8% of the building's electricity is supplied from this renewable source. This gives the building an operational performance rating of a "B". By reducing the initial energy consumption, this can improve the operational performance further.

For Phase 1, domestic hot water will be provided from the district heating network and heating will be provided from an air source heat pump solution (which will be replaced with district heating once a new plate heat exchanger is installed when the Phases 2 and 3 refurbishments occur.

Figure 2 District heating illustration (left) and operational performance rating (middle/right) **(DEC number 0650-0313-7079-7509-006)**

3.5 Fabric performance

Despite the good CO_2 performance, a key consideration for the UCL IOE refurbishment relates to thermal comfort for users and the building fabric performance. This is because the 1970s building has a significant amount of single glazing, large areas of original cladding panels, as well as un-insulated concrete walls. In addition, according to the facilities manager many users complain periodically about the building being too hot in summer and too cold in winter. A thermal imaging assessment has been undertaken by BuroHappold sustainability to investigate these issues.

The key findings from the study were:

- Heat loss from the IOE is much higher than that of adjacent buildings of older construction.
- Heat losses through the windows and window frames at IOE is significant; the seals on window frames could also be improved throughout the building to avoid air leakage when windows are not closed properly.
- The cladding panels perform marginally better than the glazing. Cladding joints show moderate heat loss.
- In the undercroft of the building, there are noticeable thermal bridges around beams and columns
- Heat loss at the entrance level is significant due to large expanses of single glazing
- The thermal performance of glazing on the wing (by Core A) is poor
- The new library extension shows less air leakage, but generally also performs poorly
- Some windows were open during the survey. This may suggest poor heating/ventilation control.

The main recommendations (which have all now taken place) were:

- Upgrade the thermal performance of the façade, prioritising new glazing.
- Develop internal insulation strategy to treat cladding panels and thermal bridging.
- Façade engineer to be appointed to carry out investigation on improvement options / solutions to treating thermal bridging in consultation with heritage specialist.

A selection of images from the thermal imaging study, including an image of the Phase 1 wing are given below. As a result of this exercise, a façade condition survey was carried out giving 3 improvement options in correspondence with the project heritage consultant. This is described alongside the overall energy strategy in the next chapter.

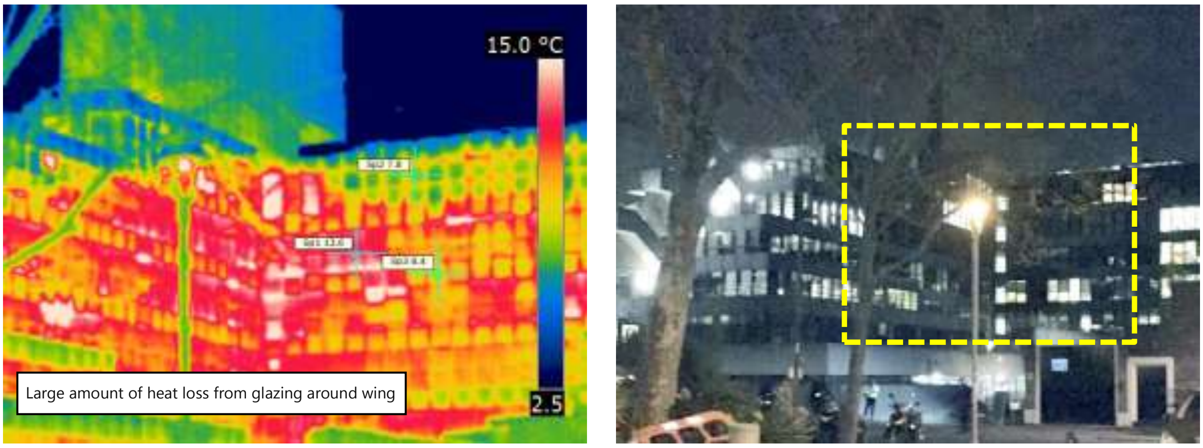


Figure 3 – Thermal image showing large sources of heat loss through the curtain walling

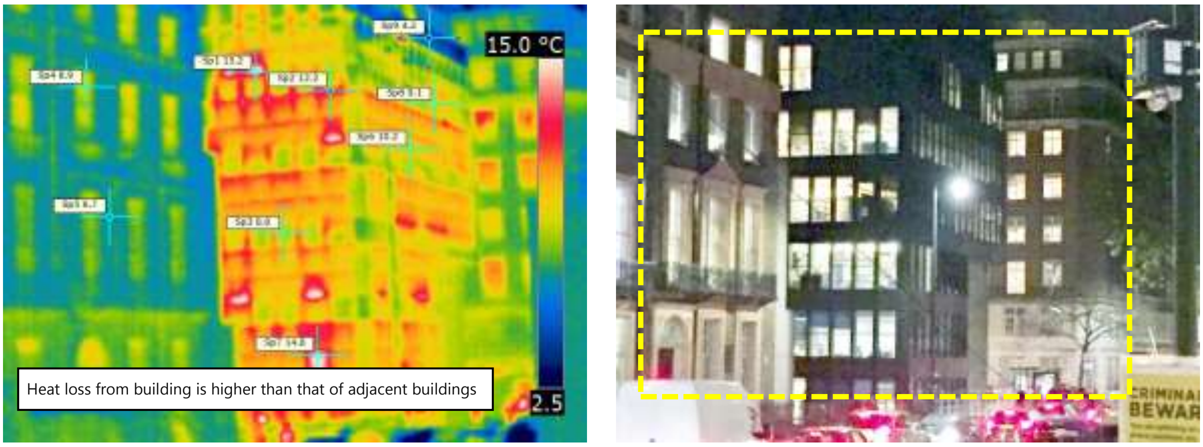


Figure 4 – Thermal image showing the end of the IOE building compared to adjacent buildings

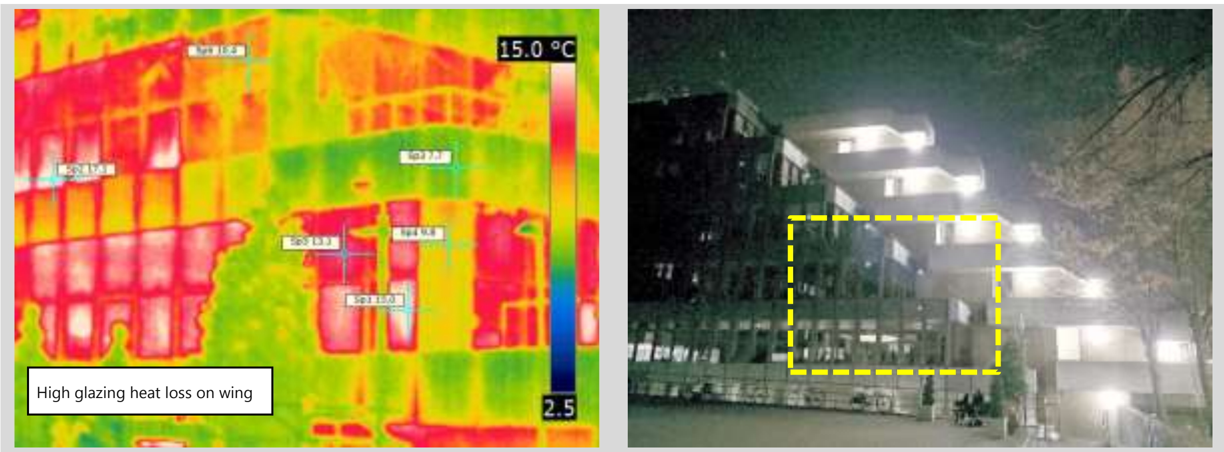


Figure 5 – Thermal image of the Phase 1 wing

4 Energy strategy

4.1 Overview

This section of the report describes the energy strategy for the Phase 1 areas of the UCL IOE refurbishment.

In order to demonstrate compliance with BREEAM, energy modelling is required comparing the existing building performance to the refurbished case. The minimum standard for the 'Excellent' rating under BREEAM credit "Ene01 – reduction of energy use and CO_2 emissions" is 6 credits (out of a possible 15).

For Building Regulations Part L2B, as an "elemental compliance" route is being followed, which does not require modelling. The relevant version of the Building Regulations are Part L2B 2010, incorporating 2016 amendments. Draft proposals and mark-ups for this Building Control submission have been prepared for review by the Contractor. This includes details of fabric performance levels (currently in development) and system efficiencies.

4.2 BREEAM energy modelling method

The BREEAM RFO Ene01 calculation method aims to assess the existing building performance to the proposed refurbishment. The two key steps in this calculation are as follows:

- Step 1- the existing building performance is modelled (old fabric and old systems) with the proposed model geometry, space use and NCM occupancy profiles. This model is used to generate the Actual (existing) and Reference data for the EPR rating tool.
- Step 2- the proposed building is modelled (new fabric and new systems) with the proposed model geometry, space use and NCM occupancy profiles. This model is used to generate the Actual (proposed) data for the EPR rating tool.

The energy modelling conducted covers the Phase 1 wing and ISD areas (layouts received from Hawkins Brown 03.04.17). The model is shown in Figure 6 below.

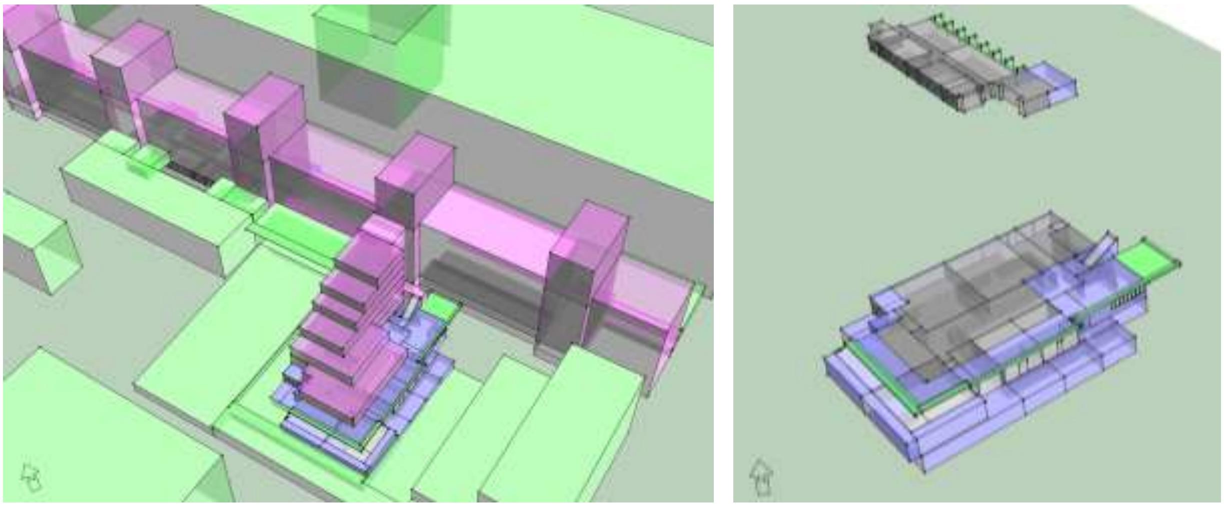


Figure 6 Phase 1 Wing and ISD areas (including adjacent buildings and local shading)

4.2.1 Building fabric improvement options

Following the thermal imaging study, the Burohappold facades team proposed three options to upgrade the performance of the cladding and glazing at IOE as follows:

- **Option A:** Minimum intervention – repair works.
- **Option B:** Medium intervention – secondary glazing with insulation to curtain walling.
- **Option C:** High intervention – façade replacement.

Further to input from the heritage consultant Option B was deemed to be the most appropriate solution balancing heritage and energy efficiency. This approach includes secondary glazing and insulation to the curtain walling panel, as illustrated in Figure 7. Option C was not appropriate as this would be harmful to the significance of the heritage assets.

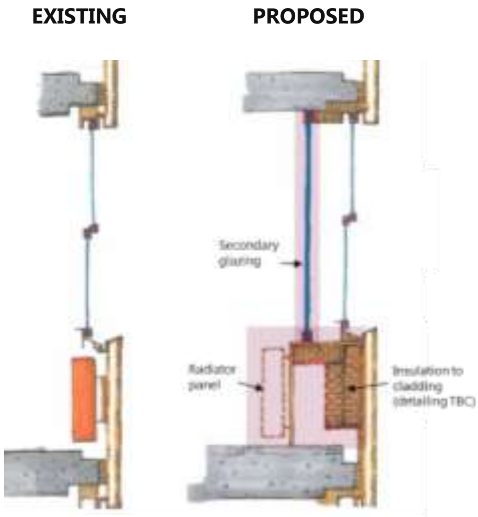
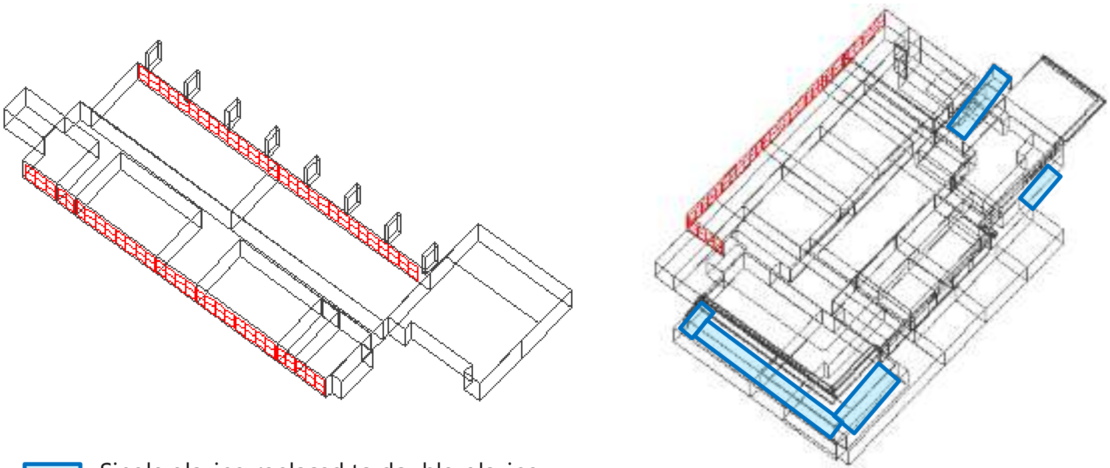


Figure 7 – Existing fabric & proposed approach (Option B)

4.2.2 Building fabric modelling inputs

Figure 8 highlights areas that are currently agreed by UCL to be upgraded with secondary glazing and fitted with new double glazed units (in place of single glazed skylights and windows). The BuroHappold façade team have initially estimated that the effective curtain walling U-value achievable would be between 2.5 and 3.1 W/m^{2}K, due to the physical limitations from the existing structure and its cold bridging. This figure shall be confirmed by the Contractor in correspondence with Building Control and the façade engineer, together with further detailing of insulation.

Note that further strategies to insulate the exposed roof and parts of the internal concrete walls in line with Part L2B requirements are also under consideration, but those results are not yet included in this BREEAM energy analysis.



Single glazing replaced to double-glazing.

Low-e secondary glazing + insulation to curtain walling panel.

Figure 8 Building fabric mark-up for Phase 1 (note that roof insulation and internal wall insulation also currently under review)

Table 2 summarises the existing building and medium intervention model inputs, as well as listing Part L2B threshold and replacement U-values.

Table 2 Modelling inputs tested (building fabric parameters) and Part L2B

		1. Existing Model (assumed based on review of available information)	Improved case: (Includes curtain wall upgrade and single glazed skylights replaced)	Part L2B 2013		
				Threshold of retained Element	Value of replacement element	New thermal elements and controlled fittings
Fabric U-values (W/m2K)	Curtain wall panel	Average curtain wall value assumed to be 5.8 Panel 3.2: 13mm aluminium, 23mm asbestos insulation, 8mm aluminium Glazing at 5.7 : single glazing metal frame + 15% psy value allowance	Average curtain wall; 3.1 with insulation at back of panel and secondary glazing *	Not greater than the better of 1.8 or: $U_{limit} = 0.8 + \{(1.2 + (FOL \times 0.5)) \times GF\}$ where FOL is the fraction of opening lights and GF is the glazed fraction.		
	Solid wall	2.5 (300mm cast dense concrete, membrane)	2.5 existing & 0.28 for new thermal element on L2 Wing *	0.7	0.28	
	Roof	2.3 (400mm concrete deck & membrane, concrete tile 100mm)	2.3 (400mm concrete deck & membrane, concrete tile 100mm) *	0.35	0.18 flat roof	
	Internal wall	2.5 (200mm cast concrete medium)	1 (lightweight plaster)	-	-	-
	Internal floor/ceiling	2.6 (300 reinf concrete, 20mm screed)	2.6 (300 reinf concrete, 20mm screed)	-	-	-
	Ground floor	0.2 (400mm reinf. Concrete & 30mm screed + adjustment)	0.2	-	-	0.22
Curtain wall glazing	G-value	0.73	0.4	-		
Glazing-Wing L3 terrace	U-value	2 (double glazed, air)	2	-	1.8 W/m^{2}K Or heritage constraint does not allow to achieve 1.8 the centre pane U value should achieve 1.2 W/m^{2}K , or single glazing should have weather-stripped low-e secondary glazing	
	G-value	0.57	0.57	-		
Glazing-Wing L3 skylights (stairs and teaching)	U-value	6 (single glazing metal frame)	1.8 (double glazing) *	-		
	G-value	0.73	0.25 (stage 2 overheating study recommendation)	-		
Air tightness	50 pa (m3/h.m2 @ 50 Pa)	19 (to be tested by contractor)	6.5 (target to be tested by contractor)	-		

* Figures / strategies to be confirmed in RIBA Stage 4

Systems model inputs

Table 3 summarises the HVAC and lighting systems modelling inputs for existing and phase 1 model based on Stage 3 information. To comply with Building Regulations, all performance values are greater or equal to Part L2B 2016 and Non-Domestic Building Services Compliance Guide 2013.

Table 3 System modelling inputs. Figures marked with * are assumed performance levels for contractor to confirm in Stage 4.

		1. Existing Model (assumed based on review of available information)	2. Phase 1 Wing and ISD systems upgrade	Part L2B limiting efficiencies for new systems
Lighting	Efficacy lm/W	40	60 to 80	>60 lm/W
	Controls	Switch	Dimming/PIR/Time	-
	Parasitic power W/m2	0.1 W/m2	0.3 W/m2	-
Wing Systems	Description	Radiator and mech vent (DX in canteen)	Split or multi split	-
	Central SFP (W/l/s)	3 at room level for canteen *	AHU set at room level 2.6	<2.2 for central balanced, +0.1 for return filter to heat recovery, +0.3 for thermal wheels.
	Room SFP (W/l/s)			
	SCOP	0.89	3	Heat pump COP >2.5 space heating
	Cooling SEER/EER	2/2.5 (DX default)*	3/2.6	Multi split >12W & VRF; EER >2.6
	Heat recovery %	0%	70%	Thermal wheel > 65%
	Demand control	none	CO_2	-
	Pump type	Constant speed	Variable speed differential sensors across pump	Refer to the non domestic building servicers compliance guide
	Extract fan SFP (W/(l/s)	0.8 @ 10ACH *	0.4 @ 10ACH	<0.4 for existing buildings
ISD Systems	Description	FCU	FCU	
	Central SFP (W/l/s)	3 *	2.2	As above
	Room SFP (W/l/s)	1.5 (default) *	0.5	
	Cooling SEER/EER	3.2/3	3.2/3	Water cooled chiller <750W: EER>3.9 & Air cooler <750W: EER>2.55
	SCOP	0.92	0.92	
	Heat recovery %	0%	70%	Thermal wheel > 65%
	Demand control	none	CO_2	-
	Pump type	Variable speed differential sensors across pump	Variable speed differential sensors across pump	Refer to the non domestic building servicers compliance guide
	Extract fan SFP (W/(l/s)	0.8 @10ACH*	0.4 @10ACH	<0.4 for existing buildings
Ventilation	Duct air leakage standard	Not tested	Comply with Part L2B >>	Either of B&ES DW/144, BS EN1507:2066, BS EN 12237:2003, BS EN 13403:2003
	AHU air leakage standard	Class worse than L3 or not tested	Comply with Part L2B >>	AHU to comply as a minimum with Class L2
Heating system controls	Central time control	no	yes	To comply with as a minimum with the Non-Domestic Building Services Compliance Guide
	Optimum start and stop	no	yes	
	Local temperature control	no	yes	
	Local time control	no	yes	
	Weather compensation	no*	Contractor to confirm	
Metering	System metering	no	yes	
	Metering warn "out of range" values	no*	Contractor to confirm	
DHW	Storage volume	600 L each	600 L each	
	Storage losses (kWh/(l.day))	0.0063 *	0.0063	
	Circulation losses (W/m)	30 *	7	
	Pump power	0.2	0.2	
District heating	DH carbon factor (kgCO2/kWh)	0.25	0.25	-

4.2.3 Energy modelling results (preliminary)

The BREEAM energy modelling results are given below. As shown, 7 credits for BREEAM RFO Ene01 are achieved in the Stage 3 modelling, which exceeds the minimum requirement for BREEAM excellent (at least 6 credits in Ene01). Total CO_2 savings are estimated at 28.4% for the measures tested over the baseline.

Table 4 Stage 3 Ene01 modelling results for Phase 1

		1. Existing Phase 1	2. Phase 1 refurbishment with improved fabric and systems
Building emission rate ($kgCO_2/m^2$)		65	46
Carbon savings (%)		-	28.4%
Preliminary Ene01 score		-	7
BREEAM minimum requirements*		**Very Good**	**Excellent**
Energy kWh/m^2	Heating	107	63
	Cooling	1	2
	Auxiliary	19	19
	Lighting	28	11
	Domestic hot water	38	34
$kgCO_2/m^2$	Heating	28	20
	Cooling	1	1
	Auxiliary	10	10
	Lighting	15	6
	Domestic hot water	10	8

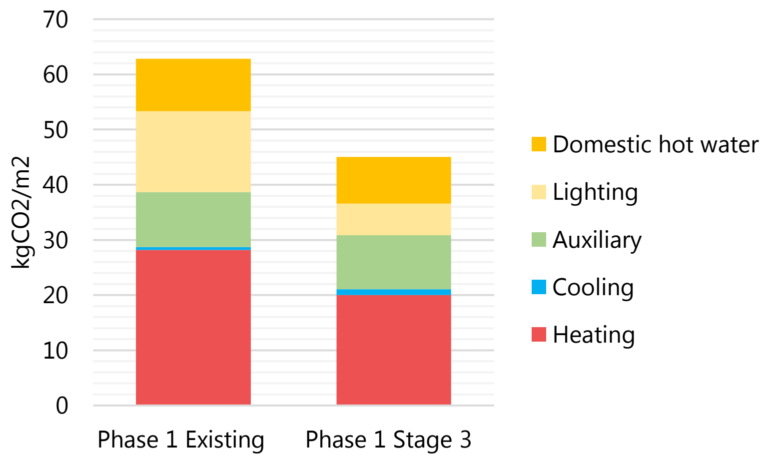


Figure 9 RIBA Stage 3 regulated CO2 emission reduction from existing building baseline for BREEAM RFO calculation.

The analysis presented in this section is to be updated by the contractor as the design and underlying assumptions progress. The contractor is to ensure compliance with Part L2B, the Non-Domestic Building Services Compliance Guide recommendations and to ensure a minimum of 7 credits are achieved under BREEAM RFO Ene 01 for Phase 1, with an aspiration to exceed this subject to further implementation of Part L compliant measures where feasible.

In terms of the overall BREEAM assessment score, note that Phases 1-3 will all eventually be assessed together as one to confirm the Ene01 modelling score. In terms of the Part L2B compliance strategy, further correspondence shall be undertaken by the Contractor with Building Control.

5 Wider Sustainability (BREEAM)

5.1 Overview

BREEAM (which stands for the "Building Research Establishment Environmental Assessment Methodology") sets the standard for best practice in sustainable building design, construction and operation and has become one of the most comprehensive and widely recognised measures of a building's environmental performance.

Phases 1-3 of the UCL IOE refurbishment will be submitted together under one BREEAM 2014 (RFO) refurbishment and fit out assessment 2014. The "UCL Sustainable Building Standard" states that all refurbishment projects with building services or building fabric upgrades must achieve a **BREEAM Excellent** rating.

5.2 Impact on capital costs

In order to achieve the BREEAM Excellent rating, the following measures impacting on capital costs would ideally need to be incorporated into the project:

- Investment in passive design (e.g. fabric improvement)
- Investment in improved HVAC system efficiencies
- LED lighting and zoning of lighting
- Electrical and heat metering by end use
- Electrical and heat metering by functional area
- Demand control for mechanical ventilation
- CO_2 sensor alerts for natural ventilation
- Thermal zoning and accessible controls
- Low flow water fittings
- Water metering and leak detection
- Refrigerant leak detection
- Energy efficient lifts
- Acoustic improvements
- Glare control (e.g. blinds)
- Security provisions (e.g. CCTV)
- Low refrigerant charge cooling systems
- Ecological improvements (e.g. new habitats)
- Responsibly sourced materials
- Materials with a high green guide rating
- Materials with low volatile organic compound

5.3 Minimum standards for BREEAM Excellent

BREEAM excellent would require a score of 70% as well as all of the following minimum standards be achieved:

Table 5 Minimum standards for BREEAM 'Excellent' rating

BREEAM credit	Minimum standards for 'Excellent'
Man 03: Responsible construction practices	One credit - Score of at least 25 in the Considerate Construction
Man 04: Commissioning and handover	Criteria 10 - Building user developed prior to handover
Man 5: Aftercare	One credit - Seasonal commissioning for 12 months after occupation
Ene 01: Reduction of energy use and carbon emissions	Five credits - Equivalent Performance ratio EPR>0.375
Ene 02: Energy monitoring	One credit - Sub metering of major energy consuming systems
Wat 01: Water Consumption	One credit - 12.5% improvement in water usage over baseline
Wat 02: Water monitoring	Criteria 1 - specification of water meter on mains supply
Mat 03: Responsible sourcing of materials	Criteria 1 - All timber used is 'legally harvested and traded timber'
Wst 03: Operational waste	One credit - Dedicated space for recycling and segregating waste
LE 03: Minimising impact on existing site ecology	One credit – No negative change in ecology of the existing site

5.3.1 BREEAM pre-assessment

The graphics and table below summarise the targeted BREEAM score for the UCL Institute of Education Phase 1-3 refurbishment. As shown, a pre-assessment score of 72.7% (Excellent) is targeted. To date, evidence has been gathered and requirements have been included in the Contractor's Employers Requirements for Phase 1 areas as if it were a single BREEAM assessment in its own right.

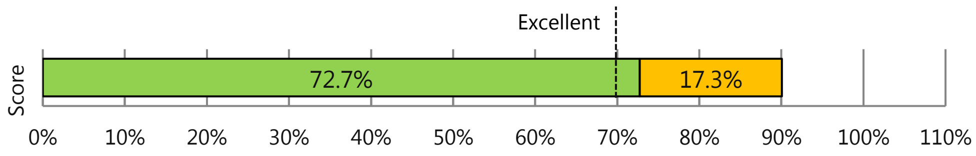


Figure 10 Summary of BREEAM pre-assessment strategy

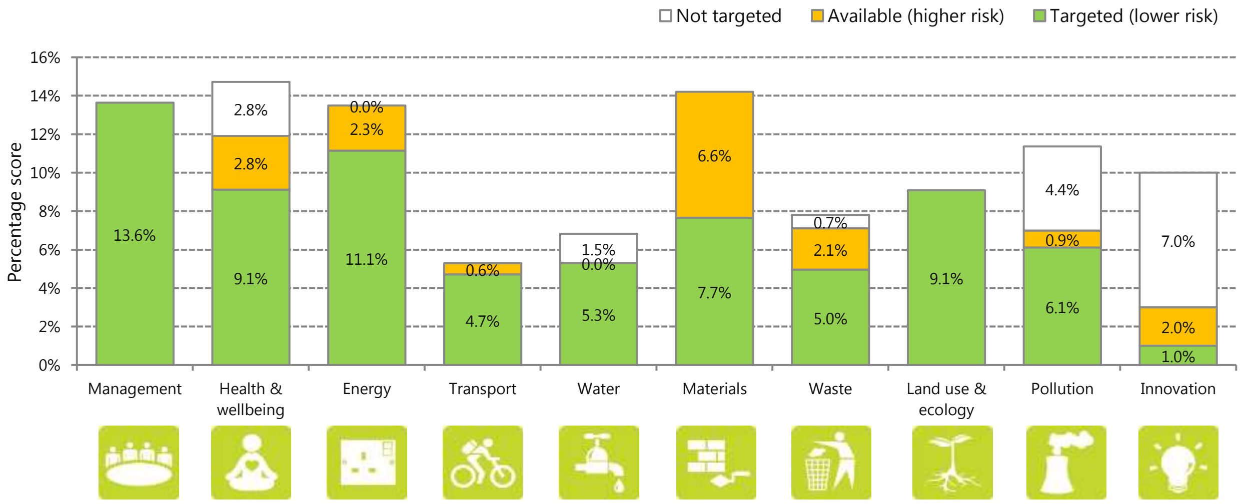


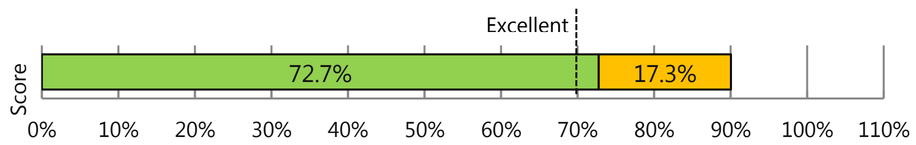
Figure 11 Summary of BREEAM pre-assessment strategy by category

Table 6 Detailed scoring

BREEAM Refurbishment & Fit Out 2014	Credits available			Credits			% Score		
	Section Weighting	**Total credits**	**Credit value**	**Target low risk**	**Target High risk**	**Not targeted**	**Target low risk**	**Target High risk**	**Not targeted**
Management	13.64%	21	0.65%	21	0	0	13.64%	13.64%	0.00%
Health & Wellbeing	14.72%	21	0.70%	13	3	5	9.11%	11.22%	3.50%
Energy	17.01%	29	0.59%	19	4	0	11.14%	13.49%	0.00%
Transport	5.30%	9	0.59%	9	0	0	5.30%	5.30%	0.00%
Water	6.82%	9	0.76%	7	0	2	5.30%	5.30%	1.52%
Materials	14.21%	13	1.09%	7	6	0	7.65%	14.21%	0.00%
Waste	7.81%	11	0.71%	7	3	1	4.97%	7.10%	0.71%
Land Use & Ecology	9.09%	4	2.27%	4	0	0	9.09%	9.09%	0.00%
Pollution	11.36%	13	0.87%	7	1	5	6.12%	6.99%	4.37%
Innovation	10.00%	10	1.00%	1	2	7	1.00%	3.00%	7.00%
TOTALS	**110%**	**140**	**-**	**95**	**19**	**20**	**73.33%**	**89.3%**	**17.1%**

5.3.2 Overview of targeted credits

This page contains a pre-assessment checklist for the BREEAM strategy, providing further detail of which credits have been targeted and which party is responsible for providing evidence. The strategy aims to target cost effective credits, but will require full commitment from the design and project team in order to achieve.



= Targeted credit (green) = Not targeted (white)
= Possible credit (orange) = Not applicable to building type (grey)

		Excellent
Low risk score		72.7%
High risk score*		90.00%

MANAGEMENT — Credit weighting 0.65%

Credit	Targeted	Possible	Not targeted	Not applicable	Responsibility
Man 01 - Project brief and design	4				Project Manager, Architect
Man 02 - Life cycle cost & service life planning	4				Cost consultant
Man 03 - Responsible construction practices	6				Contractor
Man 04 - Commissioning and handover	4				Comm. manager, Client
Man 05 - Aftercare	3				-

HEALTH & WELLBEING — Credit weighting 0.70%

Credit	Targeted	Possible	Not targeted	Not applicable	Responsibility
Hea 01 - Visual comfort	2	2	3		Architect, Physics, MEP
Hea 02 - Indoor Air Quality	3	1	1		MEP
Hea 03 - Safe containment in laboratories	1	1			-
Hea 04 - Thermal comfort	3				Physics
Hea 05 - Acoustic performance	3				Acoustician
Hea 06 - Safety and security	1				Architect, Security consultant

ENERGY — Credit weighting 0.59%

Credit	Targeted	Possible	Not targeted	Not applicable	Responsibility
Ene 01 - Reduction of energy use & carbon emissions	9		3		Physics
Ene 02 - Energy monitoring	2				MEP
Ene 02 - External lighting	1				MEP
Ene 04 - Low carbon design	3				Physics
Ene 05 - Energy efficient cold storage				2	-
Ene 06 - Energy efficient transportation systems	3				Lift consultant
Ene 07 - Energy efficient laboratory systems	1	2			-
Ene 08 - Energy efficient equipment		2			-
Ene 09 - Drying space				1	-

TRANSPORT — Credit weighting 0.59%

Credit	Targeted	Possible	Not targeted	Not applicable	Responsibility
Tra 01 - Public Transport accessibility	5				Sustainability
Tra 02 - Proximity to amenities	1				Sustainability
Tra 03 - Cyclist facilities	1	1			Architect
Tra 04 - Maximum car park capacity					Architect
Tra 05 - Travel plan	1				Transport consultant

WATER — Credit weighting 0.76%

Credit	Targeted	Possible	Not targeted	Not applicable	Responsibility
Wat 01 - Water consumption	3		2		Architect, MEP
Wat 02 - Water monitoring	1				MEP
Wat 03 - Water leak detection	2				MEP
Wat 04 - Water efficient equipment	1				Landscape consultant

MATERIALS — Credit weighting 1.09%

Credit	Targeted	Possible	Not targeted	Not applicable	Responsibility
Mat 01 - Life cycle impacts	3	3			Architect
Mat 02 - Hard landscaping & boundary protection					Architect
Mat 03 - Responsible sourcing	2	2			Architect, MEP
Mat 04 - Insulation	1				Architect, MEP
Mat 05 - Design for durability & resilience	1				Architect, Structures
Mat 06 - Material efficiency		1			Full design and project team

WASTE — Credit weighting 0.71%

Credit	Targeted	Possible	Not targeted	Not applicable	Responsibility
Wst 01 - Construction waste management	4	3			Contractor
Wst 02 - Recycled aggregates			1		Structures
Wst 03 - Operational waste	1				Architect
Wst 04 - Speculative floor & ceiling finishes					Client, Project Manager
Wst 05 - Adaptation to climate change	1				Full design and project team
Wst 06 - Functional adaptability	1				Architect

LAND USE & ECOLOGY — Credit weighting 2.27%

Credit	Targeted	Possible	Not targeted	Not applicable	Responsibility
LE 01 - Site selection					Project manager
LE 02 - Ecological value of site & protection of features	1				Ecologist
LE 03 - Minimising impact on existing site ecology					Ecologist
LE 04 - Enhancing site ecology	1				Ecologist
LE 05 - Long term impact on biodiversity	2				Ecologist, Contractor

POLLUTION — Credit weighting 0.87%

Credit	Targeted	Possible	Not targeted	Not applicable	Responsibility
Pol 01 - Impact of refrigerants	2	1			MEP
Pol 02 - NOx emissions			3		MEP
Pol 03 - Surface water run-off	3	1	1		Flood risk consultant, Ramboll
Pol 04 - Reduction of night time pollution	1				MEP
Pol 05 - Noise pollution	1				Acoustician

INNOVATION — Credit weighting 1.00%

Credit	Targeted	Possible	Not targeted	Not applicable	Responsibility
Inn 01 - Exemplary performance credits	1	2	5		Contractor, Sustainability

Very Good = 55% **Excellent = 75%** **Outstanding = 85%**

* All minimum standards must be achieved at each level.

6 Summary and vision

6.1 Summary

This report has covered an analysis of the baseline performance for the UCL Institute of Education, the Phase 1 energy strategy, BREEAM pre-assessment and responses to Camden planning criteria.

In summary, there is good potential to undertake an extensive and sustainable refurbishment for the UCL Institute of Education, which achieves BREEAM Excellent and provides comfortable internal environments. Works undertaken to date for Phase 1 have shown that this will require investment in passive design and fabric improvements, for which an appropriate strategy has been developed in line with the heritage consultant advice.

6.2 Investing in sustainability

The IOE currently spends approximately £515,000/year on energy, which is obviously a very significant amount. Based on energy modelling conducted to date it is estimated that if the proposed fabric renovation works were applied to the whole building, the cost saving over 25 years including expected fuel price rises would be in the order of £2.2 million. Over a 60 year period the cost saving comes to an estimated £5 million, as illustrated below.

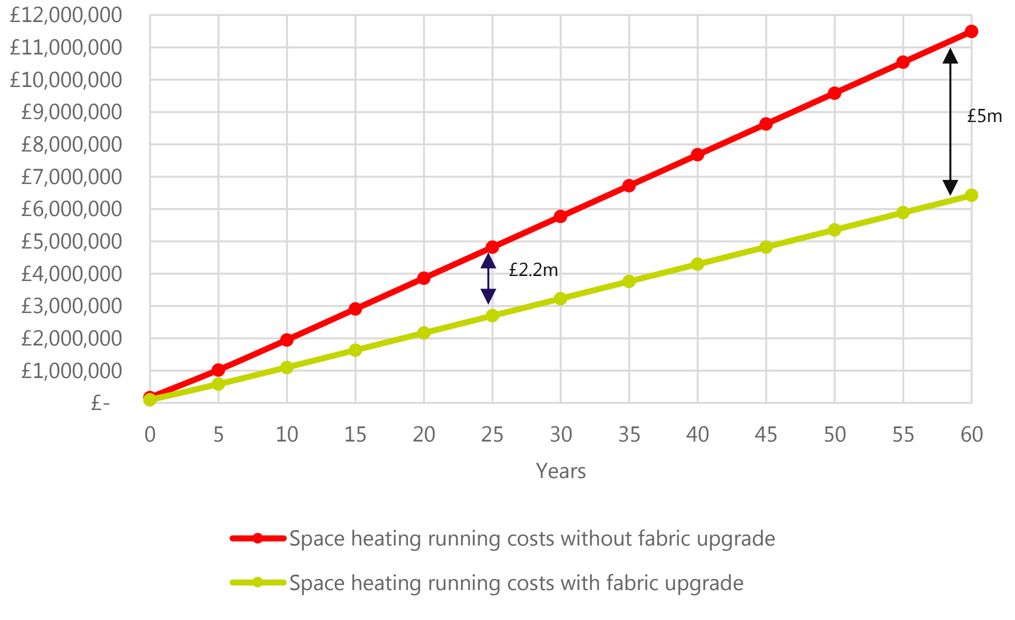


Figure 12 Space heating running cost comparison with and without façade upgrade

6.3 Wider socio-economic benefits

Throughout this project, a case has been built to UCL that the investment in the façade should not be considered solely on a CapX vs. OpX model. Instead it should be appreciated that improvements to the façade will improve thermal comfort and noise, as well as light and air quality. This in turn improves health, well-being and productivity for occupants and ultimately provides wide economic savings.

In terms of quantifying this indirect productivity saving, there is a large body of research linking the internal built environment with improvements in health, well-being and productivity.

Example research papers include:

- 3% gain in productivity achieved by improved personal control over workspace temperature (Loftness et al, 2013).
- Better air quality can result in an 8-11% improvement in overall productivity (Loftness et al, 2013).
- Noise reduction in the workplace can increase productivity by up to 28% (Oseland and Burton, 2012)

In terms of quantifying this indirect cost benefit, according to published records on the 'Research Excellence Framework (REF)' portal, from 2008 and 2013 the average research income at the UCL Institute of Education was £15.5 million/year. If it was considered that the fabric refurbishment could improve overall productivity by 2% then over a 25 year period the total economic benefit could be up to £10 million. Over a 60 year period the total economic benefit could be up to £25 million.

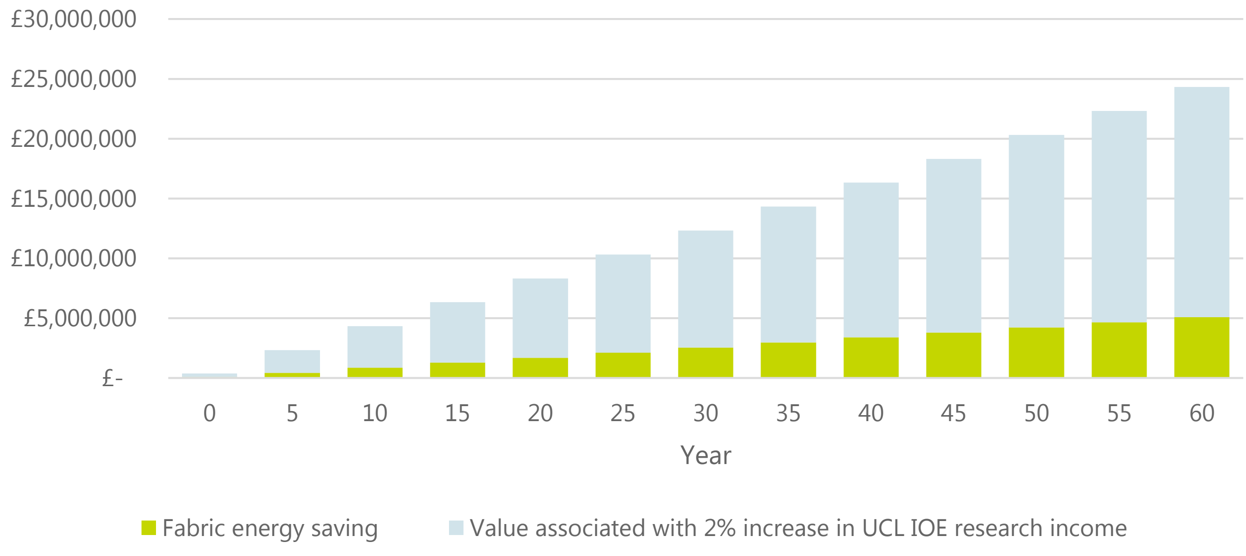


Figure 13 Potential cost benefit from fabric upgrade including additional 2% productivity gain on research income

6.4 Next steps

Moving forward into RIBA Stage 4 for the Phase 1 refurbishment, further work will be undertaken to establish a set of baseline data for the IOE on metric such as thermal comfort, health, well-being and perceived productivity in the building. This will inform the concept design stages for Phases 2 and 3 (and beyond), then also be available for benchmarking during a post occupancy evaluation as part of the client's commitment to long term sustainability.

Despite the constraints of this existing listed building, significant efforts have been made to date to improve the energy performance of the asset. As the design progresses, further work shall be carried out to develop detailed strategies for all IOE phases in line with the BREEAM Excellent requirements, the UCL Sustainable Building Standard, Building Regulations Part L2B and the Camden Planning requirements for existing buildings.

Appendix A Cost assessment

The following schedule has been prepared in line with the Camden Council Planning Guidance – Sustainability CGP3, guideline requirement that for existing buildings at least 10% of project cost should be spent on energy efficiency.

The information presented is based upon the AECOM Interim Cost Check report issued 05/April/2017. The selection of energy efficiency measures was undertaken by Burohappold Sustainability. Adjustments to costs and confirmation of total % impact was then undertaken by AECOM.

In summary, it is shown that 24.1% of total construction costs are planned to be spent on energy efficiency measures. This is equivalent to 19.8% of total project cost.

Table 7 Analysis of energy efficiency costs for Phase 1 as a function of total construction and total project costs.

Phase 1 area	Efficiency measures	Cost	***Details***
Wing L2-L3	External envelope	£ 137,866	*New secondary glazing, insulation, making good, external doors, new roof lights*
	Blinds	£ 22,600	*Anti-glare and roller blinds*
	Heating controls	£ 12,700	*New TRV valves*
	New efficient HVAC plant	£ 247,000	*New AHU plant with heat recovery, new VAV boxes, chilled water to ASHP*
	New lighting	£ 158,200	*New LED lighting installation*
	Lighting controls	£ 37,000	*New lighting controls*
	Energy efficient lift	£ 88,000	*New lift (meeting BREEAM energy efficiency requirements)*
	BMS controls	£ 110,900	*New building management system*
ISD L3	External envelope	£ 124,201	*New secondary glazing, insulation, making good*
	Blinds	£ 13,800	*Anti-glare and roller blinds*
	Heating controls	£ 21,600	*New TRV valves*
	New efficient HVAC plant	£ 82,300	*New AHU plant with heat recovery, new VAV boxes, chilled water to ASHP, FCUs*
	New lighting	£ 39,700	*New LED lighting installation*
	Lighting controls	£ 9,600	*New lighting controls*
	Energy efficient lift	£ -	*n/a*
	BMS controls	£ 28,900	*New building management system for new teaching areas*
	Sum of energy efficiency measures	**£ 1,134,000**	
	Adjustment to generate 'construction cost'	**£ 1,835,900**	*Includes Main Contractor Preliminaries, OH&P, Inflation, Design Reserves*
	Adjustment to generate 'project cost'	**£ 2,953,000**	*Includes Professional fees, Project contingency and VAT*
	Total % construction cost	**24.1%**	*Construction cost = £7,623,800 (Interim cost check 05.Apr.2017)*
	Total % project cost	**19.8%**	*Project cost = £14,908,400 (Interim cost check 05.Apr.2017)*

Appendix B Renewable energy study

6.5 Overview

This section contains a low and zero carbon renewable energy analysis conducted during RIBA Stage 2 of Phase 1, but covering Phases 1-3 of the UCL Institute of Education refurbishment. The aim of this study is to find cost effective ways to reduce reliance on fossil fuels such as natural gas or grid electricity. The study has been prepared in accordance with BREEAM credit Ene04 criteria 7-8 below.

One credit – Low zero carbon feasibility study

3. *A feasibility study has been carried out by the completion of the Concept Design stage (RIBA Stage 2 or equivalent) by an energy specialist to establish the most appropriate recognised local (on-site or near-site) low or zero carbon (LZC) energy source(s) for the building/development. The study should cover:*
    - *Energy generated and CO_2 savings from LZC energy source per year*
    - *Life cycle cost of the potential specification, accounting for payback*
    - *Local planning criteria, including land use and noise*
    - *Feasibility of exporting heat/electricity from the system*
    - *Any available grants*
    - *All technologies appropriate to the site and energy demand of the development.*
    - *Reasons for excluding other technologies*
    - *Where appropriate to the building type, connecting the proposed building to an existing local community CHP system or source of waste heat or power OR specifying a building/site CHP system or source of waste heat or power with the potential to export excess heat or power via a local community energy scheme.*
4. *A local LZC technology/technologies has/have been specified for the building/development in line with the recommendations of this feasibility study and this method of supply results in a meaningful reduction in regulated carbon dioxide (CO_2) emissions.*

As a guide, the BRE recommend that the installation should contribute at least 5% of overall building energy demand and/or CO_2 emissions. For Camden Planning requirements, there is a guideline figure to target a "20% reduction in carbon dioxide emissions from on-site renewable energy technologies".

6.6 Feasibility assessment

A low and zero carbon feasibility assessment is given in Table 8 highlighting pros and cons of various technologies, including remarks on planning and spatial requirements. As shown, the three most viable technologies for the site are deemed to be connection to the existing district heating network (DHN), low profile solar photovoltaics (PV) and air source heat pumps (ASHP). The main planning issues to consider with these options are the visual impact of the PV panels from ground level, due to the building's listed status. This may limit the placement of PV panels to areas away from the roof edge.

Technologies not deemed feasible for the project include biomass heating due to challenges associated with fuel deliveries and local air quality. Ground source heating/cooling is not viable due to the disruption which ground works would cause to the existing site. Stand-alone or roof mounted wind turbines are not deemed viable due to planning and heritage reasons. The district heat network connection already uses combined heat and power (CHP) engines to supply the baseload to several buildings on the campus; an on-site independent CHP is therefore not practicable, as it would reduce the network baseload, potentially increasing the carbon factor of heat on the network.

Table 8 Low carbon and renewable feasibility study

Approach	Description	Advantages	Disadvantages	Spatial requirements	Project viability
District heating connection	Low-carbon baseload heat is generated by CHP engines at an off-site centralised source and supplied via a pipe network, with gas and oil boilers providing top-up. Building interfaces with network via heat exchangers.	Carbon savings over supply via conventional methods, e.g. gas/oil boilers only.	Some heat generation on the DHN is from oil boilers, which is undesirable from a carbon perspective. These are being phased out in the coming years to be replaced with gas-fired boilers.	Heat exchanger plant room space ~ equivalent size to local boiler spatial requirements. Connection pipework below ground.	Building is currently connected to Bloomsbury DHN (which includes CHP-generated heat). Existing heat exchangers require upgrading.
Combined heat and power	CHP engine providing electricity and useable heat simultaneously.	Carbon savings when compared to conventional grid electricity and local boiler only case.	Noise, space requirements and vibration. Operation and maintenance costs increased.	Plant room space required, together with flue.	No benefit from a carbon or cost perspective over connecting to the DHN, which has CHPs to cover baseload.
Photovoltaic cells	Roof or façade mounted photovoltaic cells. Generate electricity.	Roof mounted systems are simple and integrate well.	High cost in relation to carbon savings. Outputs vary with weather.	South facing roof, or possible façade integration.	Potentially contentious in terms of heritage. If PV panels are to be considered, these will be brought forward in future refurbishment phases in discussion with Camden and Historic England
Solar thermal hot water	Roof mounted tubes through which water is pumped and heated by solar radiation. Generates hot water.	Simple and easily integrated into building systems. Small area required to meet small hot water demand.	Upper floor integration. Hot water unlikely to make significant impact on building energy demand.	South facing roof/façade. Location close to hot water cylinders is preferable.	Due to DHN connection, solar PV preferential use of roof space.
Air source heat pump	System that transfers heat from outside to inside building, or vice versa, with high efficiency. Includes electric heat exchange coil to boost temperatures.	High coefficient of performance (COP) can be achieved on heating and cooling side. Reasonably well tested technology in market.	Only the heat generated can be claimed as renewable. Peak heating demand can be challenging to fully meet with ASHP.	No additional requirements above and beyond typical fan coil units.	Client driver that building Phase 1 is temporarily served by ASHP independently of other phases to minimise disruption from DHN
Ground source heating/cooling	Fluid is pumped below ground, absorbing or low-grade heat or coolth. Generates heat /cooling.	Utilises low grade heat from the ground.	Large accessible ground area required for borehole field.	Plant room space plus large accessible ground area for borehole field.	Unviable due to disruption of existing site.
Biomass	Boiler fuelled by wood chips or wood pellets. Generates heat.	Carbon neutral heat and hot water supply on a large scale.	Local air quality. Plant room and storage space required, plus delivery access.	Plant room space and flue, plus considerable biomass storage volume.	Fuel delivery likely to be a challenge.
Stand-alone wind turbine	Ground based, medium scale wind turbine. Generates electricity.	High yield. Visible symbol.	Scale and site - large wind turbine would not fit. Also planning and wind speeds. Potentially loud.	Clear area radius of turbine height.	Visually obtrusive for planning
Roof mounted wind turbine	Small scale wind turbine mounted at high level. Generates electricity.	Clearer winds at height. Visible symbol.	Vibration, upper floor integration. Low urban wind speeds.	Roof top area plus area for construction and maintenance.	Visually obtrusive for planning

6.7 Renewable energy tariffs

A key driver for renewable technologies is the additional finance generated through the Feed-in-Tariff (FIT) and Renewable Heat Incentive (RHI). Tariffs are payable per kWh of electricity or heat produced. The level of the generation tariff is dependent on the technology and the system size and type. The latest rates relevant to this study are given in Table 9 and Table 10 respectively.

For FITs, the 'medium rate' is payable where the system owner has a total of 25 FIT-registered PV installations. The 'higher rate' prevails if this condition does not apply. For the RHI, each year the Tier 1 tariff is paid until the system has operated up to 15% of the annual rated output (i.e. the equivalent of 1,314 hours at the rated capacity of the installation). All installations would need to be provided with certified bodies.

Table 9 Feed-in tariff rates for solar PV (current for 1 January 2017 – 31 March 2017)

Energy source	Scale	Rate	Rates - p/kWh
Solar PV	>10 - 50kW	Higher rate	3.78
	>10 - 50kW	Middle rate	3.40
	>10 - 50kW	Lower rate	0.14
	>50 - 250kW	Higher rate	1.58
	>50 - 250kW	Middle rate	1.42
	>50 - 250kW	Lower rate	0.14

If the client were to apply for finance under the RHI, the metering strategy for the ASHP would need to be reviewed as additional meters may be required to meet the RHI requirement. The tariff for ASHP is received for all eligible heat produced, which is then used (i.e. cooling energy is not included).

Table 10 Renewable heat incentive tariff rates for ASHP

Tariff name	Eligible technology	Eligible sizes	Rates - p/kWh
Air-source heat pumps (commissioned on or after 4 December 2013)	Air-source heat pumps	All capacities	2.57

6.8 Renewable energy grants

Additional financing for renewable energy will be limited. Potential mechanisms to explore include the Renewables Obligation (RO), Enhanced Capital Allowance Scheme, the Green Deal or local borough financing.

The RO, operated by Ofgem is the main support mechanism for renewable electricity projects in the UK. It places an obligation on UK electricity suppliers to source an increasing proportion of electricity they supply to customers from renewable sources.

Enhanced Capital Allowances (ECAs) enable a business to claim 100% first-year capital allowances on their spending on qualifying plant and machinery. There are three schemes for ECAs, one of which includes energy-saving plant. The

Green Deal establishes a framework to enable private firms to offer energy efficiency improvements to businesses at no upfront cost; however, the future of this scheme is currently attracting low investor interest.

6.9 Energy saving and payback calculations

Solar photovoltaic (PV) panels

Taking a 'whole building' approach, (the potential for rooftop PV on the UCL IOE building was analysed with two layouts tested based a solar exposure analysis. The two layouts produced were:

- "Layout A" having 150m^2 of PV panels on top of Cores A-C (20 kW).
- "Layout B" having 320m^2 of PV panels on the roof areas between the three cores (42 kW).

Roof space is limited and will be required, in part, for rooftop plant. The building is also Grade II* listed which may limit the applicability detrimentally. To minimise visual impact, low profile PV panels (5 degree tilt) were modelled. These were aligned with the building, rather than directly due South, both to minimise visual impact and because has a lower impact on the energy output of low angle panels.

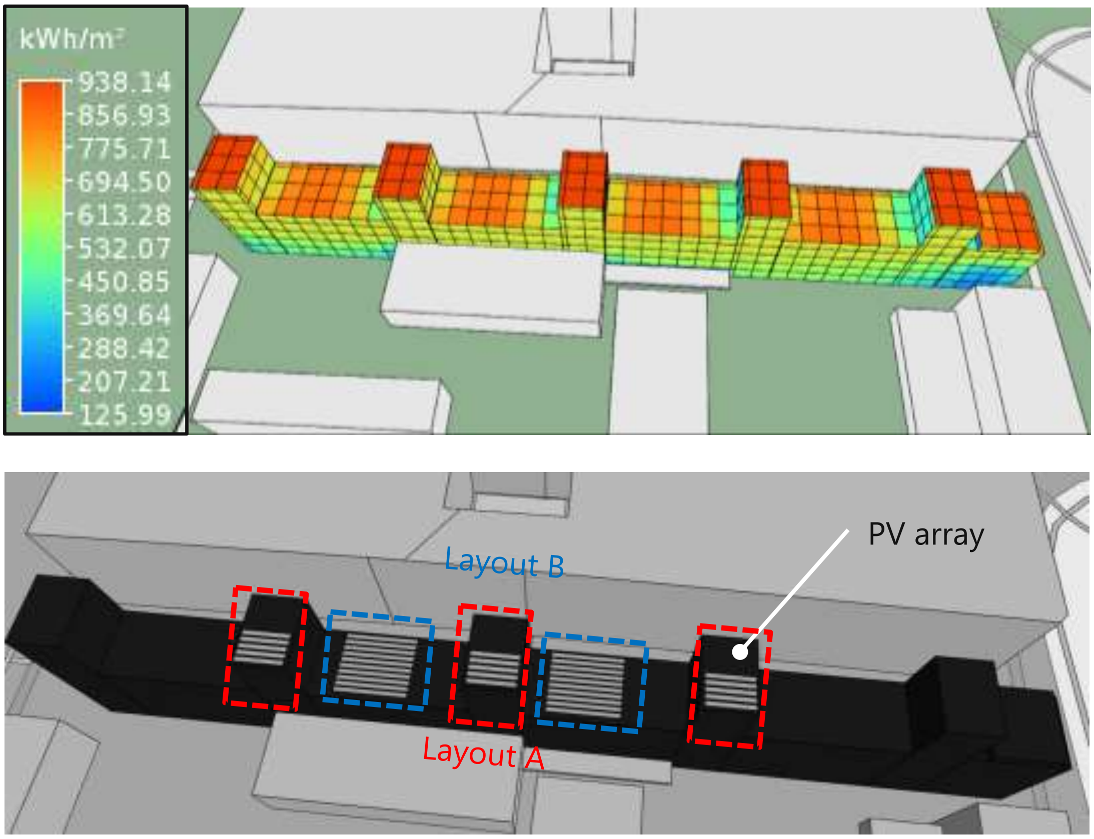


Figure 14 Annual solar irradiance of IOE building to inform PV placement (top). Two PV layout options, positioned for maximum solar exposure (bottom). Note that further to correspondence with the heritage consultant, solar PV is potentially contentious but the heritage consultant would be open to review should the client/council require this strategy. If PV panels are to be considered, these will be brought forward in future refurbishment phases in discussion with Camden and Historic England.

The renewable electricity generated over the course of a year for both PV layouts can be seen in Figure 6. For layout A, the generation is estimated to be approximately 14,000 kWh/year. For layout B, it is estimated to be approximately 27,000 kWh/year.

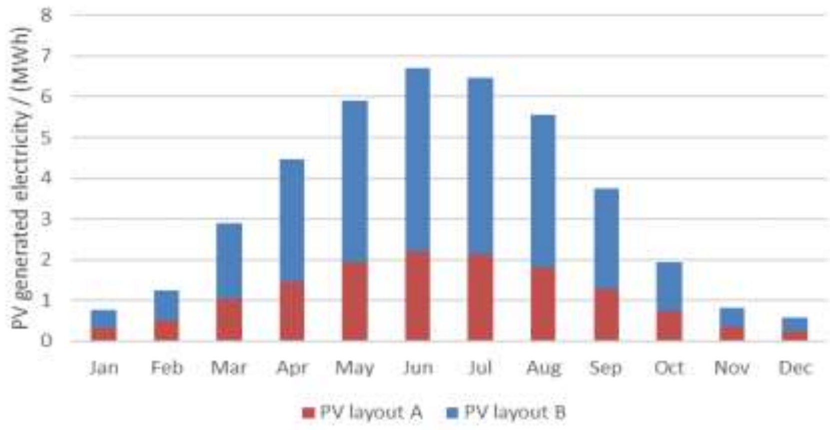


Figure 15 PV generated electricity for layouts A and B (13% cell efficiency)

The payback period of both layouts is shown in Table 11 along with CO_2 saving and capital cost (taken to be £1,250 per kW – DECC small scale generation costs). The combined CO_2 saving of installing layout A and B together is calculated to be 2.3% per year. This is based upon the Part-L modelling results (medium impact façade works) for Phase 1A wing applied to the floor area of Phases 1-3 on a pro-rata basis.

For the PV system it was assumed that a lower feed-in tariff rate of 0.14 p/kWh applies; this is based upon the medium impact fabric upgrade scenario, which has an indicative EPC rating of E. If the high-impact fabric upgrade scenario were taken forward, then the indicative EPC rating of a C would allow a feed-in tariff rate of 3.78 p/kWh for an installation smaller than 50 kW (either layout A or B individually). In this scenario, an installation between 50 and 250 kW (layouts A and B combined) would be eligible for a feed-in tariff rate of 1.58 p/kWh.

Table 11 Energy and carbon savings and payback calculations for PV

	Renewable energy provided	**Renewable energy %**	**CO_2 saving**	**CO_2 saving%**	**Capital cost**	**Annual cost saving with FITs**	**Payback with FITs**	**Annual cost saving no FITS**	**Payback no FITS**
	kWh/year	%	kg/year	%	£	£/year	Years	£/year	Years
A	13,964	0.5	5,753	0.8%	24,375	1,300	19	1,281	19
B	27,103	1.0	11,166	1.5%	52,000	2,523	21	2,485	21

<u>Air source heat pumps (ASHP)</u>

There is a client driven desire to provide heating for building Phase 1 independently of the district heat network connection via ASHP. This is in order to reduce the risk of disruption to the users of Phase 1 as a result of planned maintenance works to the DHN connection on Phases 2 and 3. If air source heat pumps (ASHP) were installed to meet the heating demand of Phase 1, this would result in 3.5% annual CO_2 saving for the building, when compared with a gas-boiler counterfactual case.

Energy saving and payback calculations for ASHP are given in Table 12 specific to Phase 1 areas. Assuming a renewable heat incentive of 2.57 p/kWh, the payback period for a 175 kW ASHP is 11.6 years (at a benchmark Capex cost of £500 per kW). ASHPs have been sized based upon preliminary loads modelling.

Table 12 Energy and carbon savings and payback calculations for ASHP in Phase 1.

Renewable energy provided	Renewable energy %	CO_2 saving	CO_2 saving %	Capital cost	Annual cost saving with FITs	Payback with FITs	Annual cost saving no FITS	Payback no FITS
kWh/year	%	kg/year	%	£	£/year	Years	£/year	Years
206,682	7.5	25,877	3.4%	320.2	7,542	11.6	687	127.4

District heating network (DHN) connection

The existing Bloomsbury Heat and Power (BHP) district heating network (DHN) provides low-carbon heat to connected buildings by generating thermal and electrical energy simultaneously via a CHP engine, displacing the use of grid electricity and thus reducing carbon emissions. The DHN currently serves the IOE and is expected to provide heating and domestic hot water for refurbished areas in Phases 1-3 once the masterplan is complete.

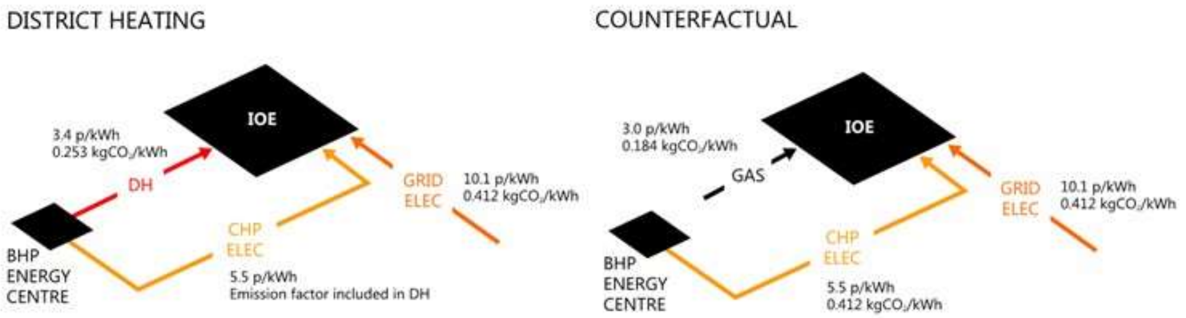


Figure 16 District heating costs and carbon factor compared to case with heat from gas boilers

The CO_2 emission factor of the delivered heat from the DHN has been calculated as 0.253 $kgCO_2/kWh_{th}$, based on a review of information provided by the network operator by the BuroHappold Energy team. This emissions factor takes into account the electricity displaced by the CHP engine, i.e. the CHP-generated electricity that is consumed by the IOE. While the CHP engine provides the DHN baseload heat, top-up heat is provided by gas and oil boilers. The estimated carbon factor is relatively high for heat networks; the CIBSE Heat Network Code of Practice (2015) recommends a maximum value of 0.150 $kgCO_2/kWh_{th}$, although typically this would be expected of new networks.

Carbon savings and simple payback from a DHN connection are calculated against a counterfactual case of heat generation from local gas boilers, as per Figure 7 Fuel prices and carbon emission factor inputs to the calculations are also provided based on the following inputs:

- The gas price is assumed based on BEIS (formerly DECC) figures for 2016,
- District heating and CHP electricity unit prices are estimated from unit charge rates for IOE (Aug-15 to Jul-16),
- Electrical imports are assumed based on UCL bill data for IOE (August 2014-2015),
- Carbon emission factors are based on BEIS figures for 2015/16.

Results for the analysis are provided in Table 13. Annual cost savings for DHN against the counterfactual are not achieved with the current financial inputs, as defined in Figure 16. This is because rates for DH and gas are similar, with gas being marginally cheaper. To provide more details on financial performance of the DHN connection more information is required from UCL on rates paid for energy.

Table 13 Energy and carbon savings and payback calculations for district heating in Phases 2 and 3.

Renewable energy provided	Renewable energy %	CO_2 saving	CO_2 saving %	Capital cost	Annual cost savings	Simple payback
kWh/year	%	kg/year	%	£	£/year	Years
639,702	34%	147,986	24%	£ 72,157	-783	n/a

In terms of capital costs, information on costs has not yet been prepared by AECOM – an example cost for plate heat exchangers for hydraulic separation of the primary network from any secondary building-side heating systems are included to drive through the calculation. It should be noted that connecting to the existing DHN avoids capital costs associated with local gas boilers and CHP engines, which are significantly higher than the plate heat exchangers.

Preliminary carbon savings over the counterfactual are shown to be 24% when connecting to the DHN, which is broadly in line with what is expected of heat networks versus a counterfactual case. Note that this calculation represents a preliminary figure to be updated when further information on Phases 2 and 3 becomes available.

6.10 LZC study summary

Based on the results from this study, if all low and zero carbon technologies (PV, ASHP and DHN) measures are implemented, an estimated carbon saving of up to 30% is currently estimated. In relation to the Camden target to provide 20% carbon reduction from on-site "renewable generation", only the PV panels would satisfy this requirement, however the maximum CO_2 saving is 2.3%.

Table 14 Summary of all renewable energy calculations. Only solar photovoltaic energy is strictly "on-site renewable generation"

	Low carbon / renewable energy provided	Low carbon / renewable energy %	CO_2 saving	CO_2 saving %	Capital cost	Annual cost saving with tariffs	Payback with tariffs	Annual cost saving no tariffs	Payback no tariffs
	kWh/year	%	kg/year	%	£	£/year	Years	£/year	Years
PV-a	13,964	0.5%	5,753	0.8%	24,375	1,300	19	1,281	19
PV-b	27,103	1.0%	11,166	1.5%	52,000	2,523	21	2,485	21
ASHP	206,682	7.5%	25,877	3.4%	320.2	7,542	11.6	687	127.4
DHN	639,702	34%	147,986	24%	72,157	-	-	-783	n/a

It should be noted that the % saving figures are generated from a Phase 1-3 energy and carbon baseline, developed for the Phase 1A wing Part L model. This baseline will therefore change as further areas of the building are modelled to give more accurate figures. It should also be noted that the baseline is not a measure of actual energy use (i.e. regulated + unregulated); this will be explored further across all 3 phases as the project progresses and CIBSE TM54 modelling is carried out. Note that further to correspondence with the heritage consultant, solar PV is potentially contentious but the heritage consultant would be open to review should the client/council require this strategy. As the project progresses and building energy demand and peak loads are refined it is recommended that detailed sizing calculations are undertaken to inform decisions, particularly if PV is to go ahead. Costings and payback analysis are based upon benchmark information and require further detailed calculation by a quantity surveyor in future design stages. If PV panels to be considered, these will be brought forward in future refurbishment phases in discussion with Camden and Historic England.

Appendix C BREEAM pre-assessment

A full version of the live BREEAM tracker is available upon request.

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